RULES
FOR THE CLASSIFICATION AND CONSTRUCTION OF INLAND WATERWAYS VESSELS

PART VI
MACHINERY AND PIPING SYSTEMS

July
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GDAŃSK

RULES FOR CLASSIFICATION AND CONSTRUCTION OF INLAND WATERWAYS VESSELS developed and published by Polski Rejestr Statków S.A., hereinafter referred to as PRS, consist of the following Parts:

Part I – Classification Regulations
Part II – Hull
Part III – Hull Equipment
Part IV – Stability and Freeboard
Part V – Fire Protection
Part VI – Machinery and Piping Systems
Part VII – Electrical Equipment and Automatic Control

whereas the materials and welding shall fulfil the requirements specified in *Part IX – Materials and Welding* of the *Rules for Classification and Construction of Sea-Going Ships*.

Part VI – Machinery and Piping Systems 2019 was approved by PRS Executive Board on 14 June 2019 and comes into force on 1 July 2019.

As of the date of enforcement of this *Part VI*, the requirements contained herein apply, within the full scope, to the new vessels.

As for the existing vessels, the requirements contained in this *Part VI* apply in the scope resulting from the provisions of *Part I – Classification Regulations*.

The requirements of *Part VI – Machinery and Piping Systems* are extended and supplemented by the following publications:

Publication No. 4/P – I.C. Engines and Engine Components,
Publication No. 5/P – Requirements for Turbochargers,
Publication No. 7/P – Repair of Cast Copper Alloy Propellers,
Publication No. 8/P – Calculations of Crankshafts for I.C.Engine,
Publication No. 23/P – Pipelines Prefabrication,
Publication No. 27/P – Principles for Manoeuvrability Trials of Inland Waterways Vessels and Push Trains (available in Polish only),
Publication No. 28/P – Tests of I.C. Engines,
Publication No. 33/P – Air Pipe Closing Devices,
Publication No. 53/P – Plastic Pipelines on Ships,
Publication No. 57/P – Type Approval of Mechanical Joints,
Publication No.93/P – Emissions of gaseous and particulate pollutants from diesel engines
Publication No. 102/P – European Union Recognized Organizations Mutual Recognition Procedure for Type Approval,
Publication No. 121/P – Use of LNG as a fuel on inland waterways vessels
Publication No.122/P – Requirements for Baltic Ice Class Ships and Polar Class for Ships under PRS Supervision,
Publication No. 15/I – European Inland Waterways Zone Classification.

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CONTENTS

Page

1 GENERAL PROVISIONS

1.1 Application

1.1.1 This *Part VI – Machinery and Piping Systems* applies to the machinery spaces and their equipment, shafting, propellers, machinery and ship piping systems as well as to special piping systems related to the ship function.

1.1.2 The requirements relevant to the equipment apply to:
- **.1** internal combustion engines of the main propulsion system;
- **.2** internal combustion engines of power generating sets;
- **.3** gears, disengaging and flexible couplings;
- **.4** pumps used in the systems covered by the requirements contained in this *Part VI* and *Part V – Fire Protection*;
- **.5** air compressors;
- **.6** turbochargers;
- **.7** fans included into the systems covered by the provisions contained in this *Part VI*;
- **.8** steering gears;
- **.9** windlasses and towing winches;
- **.10** hydraulic drives;
- **.11** thrusters;
- **.12** pressure vessels and heat exchangers containing in working conditions entirely or in part gas or steam of working pressure 0.07 MPa or more, for which the volume is 25 dm^3 or more and the product of pressure [MPa] and volume [dm^3] amounts to 30 or more;
- **.13** coolers and heaters of oil and water for engines and gears.

1.1.3 The requirements concerning heating, galley and cooling arrangements as well as liquefied gas systems for domestic purposes are specified in Chapter 7 of *Part V – Fire Protection*.

1.1.4 This *Part VI* does not apply to steam boilers, steam generators, water heating boilers and thermal oil boilers including the systems where they are installed.

If they are provided on inland vessels, the construction and arrangement of the boilers as well as the design of the systems where they are installed are subject to PRS approval in each particular case.

1.1.5 The requirements specified in Chapters 1 to 27 are basic requirements for all types of ships to be assigned the main symbol of class of a ship constructed under PRS survey.

Chapters 28 to 36 specify additional requirements for the ships to be assigned an additional mark in the symbol of class mentioned in sub-chapter 3.7 of *Part I – Classification Regulations* and they also specify possible relaxation of the main requirements as provided thereto.

1.2 Definitions and Explanations

Definitions of the general terminology used in the *Rules for Classification and Construction of Inland Waterways Vessels* (hereinafter referred to as the *Rules*) are contained in *Part I – Classification Regulations*. Wherever, in *Part VI*, definitions given in other parts of the *Rules* are used, cross-reference to those parts is made.

For the purpose of *Part VI* the following additional definitions have been adopted:

Accommodation spaces – see *Part V – Fire Protection*.

ADN Rules – provisions of the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN).

Automatic control system – system intended to control the machinery without human interference in accordance with the specified control function.

Auxiliary machinery – machinery providing for the operation of main engines, supply of the ship with electric and other power, as well as for the operation of the shipboard systems and arrangements.

Auxiliary steering gear – equipment other than part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

Cargo area – see *ADN Rules*.

Control stations:

central – position fitted with the operating controls for steering of the main engines, auxiliary machinery and controllable propellers and thrusters, control devices, instrumentation, alarms giving warning of reaching the limits of the assumed permissible parameters, alarms announcing activation of the automatic protection devices, and means of communication;

local – position fitted with the operating controls, instrumentation and – where necessary – means of communication, located in close vicinity to or directly on the machine;

combined – position fitted with the operating controls for simultaneous steering of two or more main engines, control devices, instrumentation, warning alarms, and means of communication;

remote – position from which remote adjustment of working parameters, as well as possible remote starting and stopping of the engines and machinery is possible.

Dangerous goods –substances and articles whose international carriage by inland waterways is authorized only on certain conditions specified in ADN Rules.

Design pressure – pressure not lower than the opening pressure of safety valves or other protecting devices.

Engine room – machinery space containing main engines and auxiliary machinery.

Escape route – way from the lowermost level of the machinery space to the exit from that space.

ES-TRIN – European standard laying down technical requirements for inland navigation vessels contained in Annex II of Directive (EU) 2016/1629.

Exit – opening in a bulkhead deck or shell plating provided with means for closing and intended for the passage of persons.

Flame arrester – see *ADN Rules*.

Hold space – see *ADN Rules*.

IBC containers – see *ADN Rules*.

Machinery spaces – all machinery spaces containing main engines, internal combustion engines other than main engines, generators and major electrical machinery, refrigerating, ventilation and air-conditioning machinery, and other similar spaces and trunks to such spaces.

Main engines – machinery intended for the ship propulsion such as internal combustion engines, electric motors, etc.

Main steering gear – the steering arrangement provided for putting the rudder or the steering nozzle over and necessary for a ship under the normal service conditions. The main steering gear consists of an actuator enabling the rudder or the steering nozzle to be put over, a steering gear power units, if any, means of applying torque to the rudder stock (e.g. tiller or quadrant) and additional equipment.

Oil residues (sludge) – residues resulting from oil purification and oily bilge water treatment, as well as oil leakages and drains and any exhausted oil. This definition does not apply to the residues from cargo area in oil tankers.

Oily bilge water – oil contaminated bilge water, excluding water originating from cargo tanks, slop tanks and cargo pump rooms of oil tankers.

Protected area – see *ADN Rules*.

Rated power – the power, defined by the manufacturer, developed for unlimited time at the ambient conditions with mechanical and thermal load not exceeding the values defined by the manufacturer, taken for the calculations required by the *Rules*.

Rated speed – number of revolutions per minute corresponding to the rated power.

Sanitary drainage – drainage from galleys, messes, bathrooms (showers and washbasins) or laundries and human waste water.

Service spaces – see *Part V – Fire Protection*.

Steering gear power unit:

in the case of electric steering gear – electric motor and its associated electrical equipment;

in the case of electrohydraulic steering gear – electric motor with its associated electrical equipment and hydraulic pump;

in the case of hydraulic steering gear – driving engine and hydraulic pump.

Wheelhouse – a space or area containing all control and monitoring instruments necessary for manoeuvring the vessel.

Working pressure – the highest permissible pressure during normal course of long lasting operation.

1.3 Technical Documentation

1.3.1 General Requirements

Prior to commencement of the ship/equipment construction, the below listed technical documentation shall be submitted to PRS Head Office for approval (where required). The documentation shall be submitted in triplicate.

In the case of the vessels undergoing modifications, the documentation specified in sub-chapter 1.3.2 is subject to approval in the scope which covers the modifications.

1.3.2 Technical Documentation of Vessel

1.3.2.1 Documentation of Machinery Arrangements

.1 Arrangement plan of machinery and plants in machinery spaces and pump rooms as well as in the spaces of emergency power sources, including the means of escape;

.2 Characteristics of machinery including the data necessary for the required calculations;

.3 Diagram and specification of remote control of main machinery, including the data of remote control stations' fitting with control devices, instrumentation, warning devices, means of communication and other equipment;

.4 Drawings of seating the main engines on the foundation;

.5 Shafting:
- drawing of shafting assembly,
- drawings of stern tube and attached parts,
- drawings of shafts (propeller, intermediate and thrust), including the connections and couplings,
- calculation of torsional vibration of main engine – propeller set, for internal combustion engines in excess of 75 kW rated power and auxiliary engine – power receiver set, for internal combustion engines of 110 kW rated power and more. In case of electric-driven equipment, the necessity of submitting the torsional vibration calculations is subject to PRS acceptance in each particular case;

.6 Propeller:
- general drawing,
- drawings of blades, boss and fastening elements (for built-up propellers and c.p. propellers),
- diagrams and specifications of control systems for c.p. propellers,
- drawings of essential parts of pitch control gear in the boss of c.p. propeller;

.7 Thrusters: scope of required documentation is specified in 1.3.3.3.

1.3.2.2 Documentation of Piping Systems

.1 Diagram of bilge system;
.2 Diagram of oil residues system for collecting and discharge of oily bilge water and oil residues;
.3 Diagram of ballast system;
.4 Diagram of air, overflow and sounding pipes;
.5 Diagram of exhaust gas system;
.6 Diagrams of ventilation systems;
.7 Diagram of fuel oil systems;
.8 Diagram of lubricating oil system;
.9 Diagram of cooling water system;
.10 Diagram of compressed air system;
.11 Diagram of sanitary system;
.12 Diagram of drinking water system;
.13 Diagram of gravity drain pipes led overboard (or drainage) system (including the arrangement of watertight bulkheads and the distance from the waterline or freeboard deck to the specific discharge openings).

1.3.2.3 Documentation of Refrigerating Plant

Where a ship is provided with the refrigerating plant containing 150 kg or more refrigerant of group I or refrigerant of group II or III (irrespective of its amount), the following documentation is subject to PRS Head Office acceptance in each particular case:
.1 Arrangement plan of the ship's refrigerating plant;
.2 Basic diagrams of the refrigerating agent;
.3 Arrangement plan of the refrigerating machinery space.

1.3.3 Technical Documentation of Engines, Machinery and Equipment

1.3.3.1 Documentation for Approval of I.C. Engines:

.1 Data for crankshaft calculation in accordance with Publication No. 8/P – Calculation of Crankshafts for I.C. Engines **W**
.2 Engine transverse sectional drawing **W**
.3 Engine longitudinal section drawing **W**
.4 Drawing of bedplate and crankcase **W**
.5 Drawing of engine block [1), 2)] **W**
.6 Tie rod drawings **W**
.7 Drawing of cylinder head assembly **W**
.8 Drawing of cylinder jacket [2)] **W**
.9 Drawing of crankshaft with details **Z**
.10 Drawing of crankshaft assembly for each number of cylinders **Z**
.11 Drawing of counterweights with connecting bolts (unless integral with the crankshaft) **Z**
.12 Drawing of connecting rod **W**
.13 Drawing of connecting rod assembly [2)] **W**
.14 Drawing of piston assembly **W**
.15 Drawing of camshaft drive assembly **W**
.16 Material specifications of essential parts with detailed information on non-destructive and pressure tests **Z**
.17 Arrangement of foundation bolts (for main engines only) **Z**
.18 Schematic layout of the engine control system and safety systems **Z**
.19 Assembly drawing of shielding and insulation of exhaust pipes **W**
.20 Shielding of high pressure fuel pipes[3)] **Z**
.21 Crankcase safety devices and their arrangement **Z**
.22 Maintenance and service manuals[4), 5)] **W**
.23 Test programme **Z**

References:

1) For one cylinder only.
2) Required where the engine sections do not show all the details.
3) For engines installed in periodically unattended machinery spaces.
4) Single copy only.
5) Maintenance and service manuals shall contain the requirements for engine operation (repair and servicing), detailed information on special tools and control equipment (including their outfit and settings) as well as on the tests necessary after completion of the repair and maintenance.

Notes:

1. Documentation with code Z is subject to PRS approval in each particular case.
2. Documentation with code **W** shall be submitted for reference, although it may be subject to special requirements by PRS.
3. Technical documentation of the engines which has been approved in accordance with the Rules for Classification and Construction of Sea-going Ships is regarded as approved.

1.3.3.2 Documentation for Approval of Machinery

Documentation of machinery including turbochargers, gears, clutches and all auxiliary and deck machinery shall include:

.1 Technical description and basic technical specification **W**
.2 General arrangement with cross section and dimensional data **W**
.3 Drawings of foundations, crankcases, columns, as well as casings with all details and welding procedures **W/Z**

.4 Drawings of cylinder heads and cylinder liners **W**
.5 Drawings of piston rods, connecting rods assemblies and pistons **W**
.6 Drawings of rotors of turbochargers and compressors **W**
.7 Drawings of crankshafts and other torque transmitting shafts **Z**
.8 Drawings of pinions and toothed gear wheels (see also 5.2.1.2) **Z**
.9 Drawings of disengaging and flexible couplings (see also 5.3.1.2) **Z**
.10 Drawings of the main gear unit thrust bearing unless built-in **Z**
.11 Drawings of torsional vibration dampers **Z**
.12 Diagrams of control, alarm and safety systems within the machinery installation **Z**
.13 Diagrams of the fuel oil, lubricating oil, cooling water and hydraulic systems within the machine – including the information on flexible connections used **Z**
.14 Thermal insulation drawings including exhaust pipes **W**
.15 Drawings of foundations of the main machinery, gears, steering gears, windlasses, mooring and towing winches **Z**
.16 Material specification for essential parts including details concerning non-destructive tests, pressure tests and special manufacturing procedures **Z**
.17 Test programme **Z**

Notes:
1. Documentation with code **Z** is subject to PRS approval in each particular case.
2. Documentation with code **W** shall be submitted for reference, although it may be subject to special requirements by PRS.
3. In the case of documentation with code W/Z, the first letter applies to the cast structure, while the latter applies to the welded structure.
4. Technical documentation of the machinery which has been approved in accordance with the Rules for Classification and Construction of Sea-going Ships is regarded as approved.

1.3.3.3 Documentation for Approval of Thrusters

For approval of thrusters, the following documentation shall be submitted to PRS:

.1 Technical description and basic technical specification **Z**
.2 Assembly drawing in cross section with dimensions **Z**
.3 Drawings of casings, shafts and gears **Z**
.4 Drawings of the nozzle and screw propeller or other propulsion device **Z**
.5 Drawings of pitch control device or vanes of cycloidal type propellers **Z**
.6 Drawings of bearings, dynamic seals of the propeller shaft and rotating column **Z**
.7 Hydraulic, electrical, and pneumatic diagrams including specification of the components **Z**
.8 Diagrams of lubricating and cooling system, if applicable **Z**
.9 Diagram showing variation of the starting torque of the motor causing rotation of propeller column **W**
.10 Material specification for all essential parts specified in .3, .4 and .5 including the particulars concerning non-destructive tests, pressure tests as well as special manufacturing procedures
.11 Torsional vibrations calculations **Z**
.12 Calculations of gears and roller bearings **W**
.13 Operation and Service Manual **W**
.14 Test programme **Z**

Notes:
1. Documentation with code **Z** is subject to PRS approval in each particular case.
2. Documentation with code **W** shall be submitted for reference, although it may be subject to special requirements by PRS.

3. Technical documentation of the thrusters which has been approved in accordance with the Rules for Classification and Construction of Sea-going Ships is regarded as approved.

1.3.3.4 Documentation for Approval of Pressure Vessels and Heat Exchangers

.1 Design drawings of boiler drums as well as shells of heat exchangers and, pressure vessels including the data necessary for checking compliance of the dimensions with those specified in this *Part VI* and arrangement of the dimensioned welded joints;
.2 Drawings of other parts of boilers, pressure vessels and heat exchangers which are subject to approval except supercharging air coolers whose dimensions are specified in this *Part VI*;
.3 Arrangement of valves and fittings including their specification;
.4 Safety valves, their characteristics and data for calculation of their size;
.5 Material specification with the particulars concerning welding consumables;
.6 Welding and heat treatment procedures;
.7 Test programme.

1.4 Scope of Survey

1.4.1 General provisions concerning the survey of construction and shipboard installation of the engines, machinery, boilers, pressure vessels and heat exchangers as well as systems dealt with in *Part VI* are specified in *Part I – Classification Regulations*.

1.4.2 Subject to survey to be exercised by PRS in the process of construction or modification are those systems, machinery and equipment whose documentation is subject to approval.

1.4.3 Subject to the survey to be exercised by PRS in the process of manufacture are those products whose documentation is subject to approval (see paragraph 1.1.2), except for the fans which are not required to be explosion proof and for the hand-operated machinery.

Exempted from survey in the process of their manufacture are also compressed gas bottles produced in accordance with the relevant standards and under the survey of a competent technical inspection body recognised by PRS.

As regards coolers and heaters specified in 1.1.2.12, the survey is confined to the pressure tests.

1.4.4 The following essential parts of the products are subject to survey in the process of manufacture for compliance with the approved documentation:

.1 Internal combustion engines:
- crankshafts [M)];
- pistons;
- connecting rods with bearing covers [M)];
- cylinder blocks and liners [M1)];
- cylinder covers [M1)];
- tie rods [M)];
- steel gear wheels for camshaft drive.

.2 Shafts and shafting components:
- thrust, intermediate and propeller shafts;
- coupling flanges together with screws;
- tail-shaft liners;
- stern glands;
- separate thrust bearing casings.

.3 Propellers and their components:
- fixed propellers, vanes and bosses of and controllable propellers;
- propeller blade fastening parts, shaft nuts.

.4 Gears, disengaging and flexible couplings:
- casings;
- shafts M);
- pinions, gear wheels, toothed-wheel rims M);
- torque transmitting parts of couplings: rigid parts M), flexible parts;
- connecting bolts.

.5 Piston-type compressors and pumps:
- crankshafts M);
- connecting rods;
- pistons;
- cylinder blocks and cylinder liners;
- cylinder covers.

.6 Centrifugal pumps, fans, air blowers and turbochargers:
- shafts;
- rotors;
- casings.

.7 Steering gears:
- tillers of main and emergency gear M);
- rudder quadrant M);
- rudderstock yoke M);
- pistons with piston rods M);
- cylinders M);
- drive shafts M);
- gear wheels, toothed-wheel rims M).

.8 Windlasses and towing winches:
- drive, intermediate and output drive shafts M);
- gear wheels, toothed-wheel rims;
- sprockets;
- claw clutches;
- brake bands.

.9 Hydraulic drives, screw, gear and rotary pumps:
- shafts and screw rotors;
- rods;
- pistons;
- casings, cylinders, screw pump cases;
- gear wheels.

.10 Thrusters:
- movable and stationary casings M2);
- columns M2);
- propeller shaft and intermediate shafts M2);
- propellers M2);
- nozzles;
- fastening elements and keys;
- piping and fittings.

.11 Pressure vessels and heat exchangers:
- shells, distributors, end plates, headers and covers M1);
- tube plates M1);
- tubes M1);

- bodies of the valves for working pressure 0.7 MPa and more and of 50 mm and more in diameter M1);
- long and short stays and girders, fastenings M1).

Notes and index explanations:

M) – material shall be PRS approved.

M1) – material for parts of pressure vessels and heat exchangers of class I and II (see sub-chapter 14.1) shall be PRS approved.

M2) – material approved by PRS. Where the drive power of auxiliary thrusters is less than 200 kW, material manufacturer's certificate is acceptable. The material shall be examined by PRS surveyor and the hardness test shall be carried out in his presence.

1.4.5 The survey of mass production of internal combustion engines and turbochargers is performed in accordance with rules specified by PRS in *Publication No. 4/P – I.C. Engines and Engine Components* and *Publication No 5/P – Requirements for Turbochargers*.

1.4.6 Upon completion of assembly, adjustment and running in, each engine and piece of machinery shall be subjected to running tests at works, according to the test programme accepted by PRS.

The tests of internal combustion engines shall be carried out taking into account the requirements specified in *PRS Publication No. 28/P – Tests of I.C. Engines.*

1.4.7 Pipe tubes and fittings for piping of class I and II (see paragraph 15.1.2) as well as bottom and side valves and fittings intended to be installed on the collision bulkhead and remote-controlled fittings are subject to survey in the process of their manufacture.

1.4.8 Subject to PRS survey are fitting of mechanical equipment of the machinery spaces as well as assembly and operation tests of the machinery components listed below:

.1 main engines, their gears and couplings;
.2 auxiliary internal combustion engines;
.3 shafting and propellers;
.4 auxiliary machinery;
.5 hydraulic drive systems;
.6 thrusters;
.7 pressure vessels and heat exchangers;
.8 control and warning systems of machinery components;
.9 piping systems specified in 1.3.2.2.

1.5 Service Conditions

1.5.1 The main engines and auxiliary machinery as well as machinery installations required by the *Rules* to ensure the running and safety of the vessel shall be capable of operating under the conditions of:

- prolonged list 10°;
- prolonged trim 5°;
- ambient water temperature +20°C;
- air temperature in the machinery space +40°C.

The above given temperatures may be changed depending on the ambient temperatures in the vessel service region.

1.5.2 The steering gear shall be capable of operation in the conditions of prolonged list up to 15° and ambient air temperature ranging from –20°C to +50°C.

1.6 Pressure Tests

1.6.1 Tests of I.C. Engine Components

The parts of internal combustion engines shall be subjected to pressure tests in accordance with Table 1.6.1.

Table 1.6.1

Item	Part name		Test pressure [MPa]
1	Cooling space of the cylinder cover[1)]		0.7 MPa
2	Cylinder liner over the whole length of the cooled space		0.7 MPa
3	Cooling space of cylinder block		1.5*p*, however not less than 0.4 MPa
4	Exhaust valve cooling space		1.5*p*, however not less than 0.4 MPa
5	High pressure fuel injection system	Fuel injection pump body, pressure side	1.5*p* or *p*+30 whichever less
		Fuel injection valve	1.5*p* or *p*+30 whichever less
		Fuel injection pipes	1.5*p* or *p*+30 whichever less
6	Turbocharger, cooling space		1.5*p*, however not less than 0.4 MPa
7	Exhaust pipe, cooling space		1,5*p*, however not less than 0.4 MPa
8	Coolers, at both sides [2)]		1.5*p*, however not less than 0.4 MPa
9	Working spaces of engine driven pumps (lubricating oil, water, fuel and bilge pumps)		1.5*p*, however not less than 0.4 MPa

Notes:

1) For forged steel cylinder covers and forged steel piston crown, test methods other than pressure testing may be accepted, e.g. appropriate non-destructive testing and dimensional control properly recorded.
2) The supercharging air coolers may be upon PRS consent tested at the water side only.
3) *p* – maximum working pressure for the specific part.

1.6.2 Tests of Shafting Components and Propellers

1.6.2.1 The following components shall be subjected to pressure tests upon completion of machining:

.1 propeller shaft liners – with pressure equal to 0.1 MPa;
.2 stern tubes – with pressure equal to 0.2 MPa.

1.6.2.2 The seal of the propeller shaft, if lubricated with oil, shall be tested after assembly for tightness to a pressure equal to the head of working level of lubrication oil in the gravity tank. The propeller shaft shall be rotated during the test.

1.6.2.3 The complete boss of controllable pitch propeller, after assembly of the propeller, shall be tested for tightness to an internal pressure equal to the head of working level of lubricating oil in the gravity tank or the corresponding pressure induced by a pump.

The blades shall be put several times from one extreme position to another during the tests.

1.6.3 Tests of Machinery Components and Fittings

1.6.3.1 Upon completion of machining, but before application of protective coatings, parts of machinery and fittings working under pressure shall be tested with the hydraulic pressure determined using the following formula:

$$p_{pr} = (1.5 + 0.1K)p \quad [\text{MPa}] \qquad (1.6.3.1)$$

where:
p – working pressure [MPa];
K – coefficient determined in accordance with Table 1.6.3.1.

The test pressure, however, shall always be not less than:
- the pressure with the fully opened safety valve,
- 0.4 MPa for cooled spaces and their seals, and
- 0.2 MPa in other cases.

Where either working temperature or working pressure exceeds the values specified in Table 1.6.3.1, the test pressure shall be subject to PRS consent in each particular case.

Table 1.6.3.1

Material	Working temperature up to [°C]	120	200	250	300	350	400	430	450	475	500
Carbon and carbon-manganese steel	p [MPa], up to	no limit	20	20	20	20	10	10	–	–	–
	K	0	0	1	3	5	8	11	–	–	–
Molybdenum and molybdenum-chromium steel with molybdenum content 0.4% and more	p [MPa], up to	no limit				20	20	20	20	20	20
	K	0	0	0	0	0	1	2	3.5	6	11
Cast iron	p [MPa], up to	6	6	6	6	–	–	–	–	–	–
	K	0	2	3	4	–	–	–	–	–	–
Bronze, brass and copper	p [MPa], up to	20	3.1	3.1	–	–	–	–	–	–	–
	K	0	3.5	7	–	–	–	–	–	–	–

1.6.3.2 Pressure tests of machinery parts can be performed separately for each space, applying the test pressure determined according to the working pressure and temperature in the specific space.

1.6.3.3 Parts or assemblies of engines and machinery containing petrol products or their vapours (reduction gear casings, drip trays, etc) under hydrostatic or atmospheric pressure shall be tested for tightness applying the procedure accepted by PRS. In welded structures, only welded joints shall be tested for tightness.

1.6.4 Tests of Pressure Vessels and Heat Exchangers

1.6.4.1 Upon completion of construction and assembly, all parts of pressure vessels and heat exchangers shall be pressure tested in accordance with Table 1.6.4.1.

Table 1.6.4.1

Item	Specification	Test pressure, [MPa]	
		upon completion of construction or assembly of the strength members of shell elements, less mountings and fittings	upon completion of construction or assembly including mountings and fittings
1	Pressure vessels and heat exchangers [1)]	1.5 p_w , not less than p_w + 0.1 MPa	–
2	Mountings and fittings of pressure vessels and heat exchangers	in accordance with 1.6.3.1	closure tightness test for pressure equal to 1.25 p_w

Notes:
[1)] Pressure tests shall be performed for each side of the heat exchanger. For tests of IC engine coolers, see Table 1.6.1.
p_w –working pressure, [MPa].

1.6.4.2 Pressure tests shall be performed upon completion of all welding operations and prior to the application of insulation and protective coatings.

1.6.4.3 Where an all-round inspection of the surfaces to be tested is difficult or impossible to perform after assembling the individual components and units, the components and units in question shall be tested prior to assembling.

1.6.4.4 Compressed air vessels, after being installed on board the ship (with fittings and mountings), shall be tested with compressed air under the working pressure.

1.6.5 Tests of Valves, Fittings and Piping Systems

1.6.5.1 Valves and fittings installed on the piping systems of class I and II (see paragraph 15.1.2) shall be tested by hydraulic pressure in accordance with paragraph 1.6.3.1.

1.6.5.2 Valves and fittings designed for working pressures 0.1 MPa or less, as well as for underpressure shall be tested by hydraulic pressure equal to at least 0.2 MPa.

1.6.5.3 Valves and fittings installed on bottom and side sea chests as well as on external shell plating, below the load waterline, shall be tested by hydraulic pressure of not less than 0.5 MPa.

1.6.5.4 Completely assembled valves and fittings shall be tested for closing tightness by hydraulic pressure equal to the design pressure.

1.6.5.5 Piping systems of class I and II (see paragraph 15.1.2) as well as all feed water, compressed air, thermal oil and oil fuel piping of design pressure exceeding 0.35 MPa, irrespective of their class, shall be tested by hydraulic pressure, in the presence of PRS Surveyor upon completion of fabrication and final machining, but prior to their insulation. The test pressure p_{pr} shall be determined using the following formula:

$$p_{pr} = 1.5p \quad \text{[MPa]} \qquad (1.6.5.5)$$

where:

p – design pressure, [MPa]

In no case the stresses occurring during the pressure tests shall exceed 0.9 of the material yield point at the test temperature.

1.6.5.6 Where, for technical reasons, a complete pressure test of pipes cannot be performed prior to installing them on shipboard, the test programme for particular sections of piping, especially for assembly connections, shall be subject to PRS acceptance.

1.6.5.7 Upon PRS acceptance, the pressure test may be omitted for pipes of nominal diameter less than15 mm.

1.6.5.8 Tightness of piping shall be checked, in the presence of PRS Surveyor, during an operation test upon assembly on shipboard. This does not apply to oil fuel piping which shall be tested, in the presence of PRS Surveyor, by hydraulic pressure not less than the value determined using formula 1.6.5.5 and not less than 0.4 MPa.

1.6.5.9 Where, for technological reasons, the pipes have not been pressure tested in the workshop, the tests shall be performed upon completion of assembly on shipboard.

1.7 Materials and Welding

1.7.1 Intermediate, thrust and propeller shafts shall be made of forged steel with a tensile strength ranging from 400 MPa to 800 MPa.

1.7.2 Propellers shall be made of copper alloys or alloy cast steel with tensile strength not less than 440 MPa and verified fatigue bending strength.

Fatigue bending strength is regarded as verified if its value is not less than 20% of the minimum tensile strength of the propeller material, this being determined during 10^8 load cycles in 3% solution of sodium.

The use of grey cast iron for the manufacture of propeller screws is acceptable. The procedure of manufacturing of welded propellers is subject to PRS approval in each particular case.

1.7.3 Where alloy steel, including corrosion resistant and high tensile steels, is used for shafts, and alloy cast steel, including corrosion resistant and high tensile alloy cast steel, is used for propellers, the particulars concerning chemical composition, mechanical and other specific properties of the steel shall be submitted to PRS to confirm its suitability.

1.7.4 Materials intended for construction of parts of internal combustion engines, pieces of machinery and equipment covered by the requirements specified in this *Part VI* shall fulfil the relevant requirements of the *Rules for Classification and Construction of Sea-going Ships, Part IX – Materials and Welding.*

1.7.5 In general, butt joints shall be used. The structures with fillet joints or the joints affected by bending stress are subject to PRS approval in each particular case. The exemplary welded joints are presented in the Annex to this *Part VI*.

1.7.6 Arrangement of the longitudinal welds in single straight line in the structures composed of several sections is subject to PRS acceptance in each particular case.

1.7.7 Where high strength alloy steels (including creep resisting and heat resisting steels), cast steel or alloy cast iron are intended to be used for construction of the machinery parts, it is necessary to submit to PRS the particulars concerning chemical composition, mechanical and other special properties of the material to confirm its suitability for the production of the specific part.

1.7.8 Carbon and carbon-manganese steels may be used for parts of pressure vessels and heat exchangers with design temperatures not exceeding 400°C.

Components operating at higher temperatures may be made of the above-mentioned steels provided the values taken for strength calculation, creep strength $R_z/100\ 000$ inclusive, are guaranteed by the manufacturer and comply with the standards in force.

1.7.9 Upon PRS consent, hull steels complying with Chapter 3*, Part IX – Materials and Welding* of the *Rules for Classification and Construction of Sea-going Ships,* may be used in the construction of pressure vessels and heat exchangers operating at design temperatures below 250°C.

1.7.10 The use of alloy steels for the construction of boilers, pressure vessels and heat exchangers is subject to PRS approval in each particular case. The particulars concerning mechanical properties and creep strength of the steel and welded joints at the design temperature, technological properties, welding procedure and heat treatment shall be submitted for acceptance.

1.7.11 Parts and fittings of pressure vessels and heat exchangers of the shell diameter up to 1000 mm for working pressures up to 1.6 MPa may be manufactured of ferritic nodular cast iron in accordance with the requirements specified in Chapter 15, *Part IX – Materials and Welding* of the *Rules for Classification and Construction of Sea-going Ships*.

Other applications of cast iron are subject to PRS acceptance in each particular case.

1.7.12 Copper alloys may be used for parts and fittings of pressure vessels and heat exchangers operating at the working pressures up to 1.6 MPa and design temperatures up to 250°C.

Other applications of copper alloys are subject to PRS acceptance in each particular case.

1.7.13 In general, seamless pipes shall be used for parts being the subject of this *Part* of the *Rules*. Unless any special requirements have been provided, longitudinally or spiral welded pipes may be used upon PRS acceptance in each particular case, where their equivalence with seamless pipes has been demonstrated.

1.8 Heat Treatment

1.8.1 The components whose material structure may change as a result of welding or plastic forming shall be subjected to an appropriate heat treatment.

The heat treatment procedure of a welded structure shall take into account the requirements specified in *Chapter 23, Part IX – Materials and Welding* of the *Rules for Classification and Construction of Sea-going Ships*.

1.8.2 The following parts shall be subjected to normalising:

.1 cold formed parts with inner bend radius less than 9.5 times their thickness;
.2 cold formed: bottom plates of thickness exceeding 8 mm and other parts previously welded;
.3 hot formed parts when this operation was completed at the temperature lower than that required by the appropriate standard for plastic forming.

1.8.3 The following equipment shall be subjected to stress relief annealing after welding:

.1 welded structures of carbon steel with carbon content exceeding 0.25%;
.2 heat exchangers and pressure vessels belonging to Class I (see Table 8.1) made of steel with wall thickness exceeding 20 mm;
.3 heat exchangers and pressure vessels belonging to Class II (see Table 8.1) made of carbon or carbon-manganese steel with tensile strength more than 400 MPa and wall thickness exceeding 25 mm;
.4 heat exchangers and pressure vessels made of alloy steel where heat treatment is required by the appropriate standards;
.5 welded tube plates, the annealing being recommended to be performed prior to drilling of the holes.

1.9 Non-Destructive Testing

1.9.1 Propeller shafts shall be subjected to the ultrasonic tests in the process of their manufacture. After completion of machining, the following parts of the shafts:

- the aft end of the shaft cylindrical part and around 0.3 of the cone length from its big diameter where the propeller is fitted onto the propeller shaft cone, or
- the aft end of the propeller shaft and the place of its transition into flange where the propeller is fitted to the shaft flange,

– shall be subjected to the surface defect detecting tests by magnetic-particle inspection or liquid-penetrant inspection.

1.9.2 The following parts of engines and machinery shall be subjected to non-destructive tests in the process of their manufacture:

.1 crankshafts forged as a single piece;
.2 connecting rods;
.3 steel piston crowns;
.4 tie bolts;
.5 bolts subjected to direct variable loads (bolts of the main bearings, big end bearings, and cylinder covers);
.6 steel cylinder covers;
.7 steel gear wheels of the camshaft drive;
.8 shafts, rotors and rotor disks of turbines as well as the bolts connecting the high pressure turbine casings;
.9 shafts of main reduction gears and tillers of mass exceeding 100 kg;
.10 gear wheels and toothed rims of mass exceeding 250 kg.

1.9.3 Ultrasonic testing, with Maker's signed certificate, is required for the parts of internal combustion engines specified in .1, .3 and .5 under 1.9.2.

1.9.4 Surface defect detecting tests by magnetic-particle inspection or liquid-penetrant inspection shall be performed in the locations indicated by PRS surveyor for the internal combustion engines' parts specified in .1 and.2 under 1.9.2.

1.9.5 PRS may require the non-destructive tests to be performed also for the parts other than those mentioned above together with their welded joints where defects are suspected.

1.9.6 Non-destructive tests shall be performed in compliance with provisions of *Part IX – Materials and Welding* of the *Rules for Classification and Construction of Sea-going Ships*.

1.10 Main Propulsion Machinery and Equipment

1.10.1 In order to maintain sufficient manoeuvrability of a vessel in all normal circumstances, the main propulsion machinery shall be capable of ensuring the vessel going astern.

1.10.2 The main propulsion machinery shall be capable of maintaining at least 70% of the rated ahead revolutions for a period of at least 30 minutes in free route astern. The term 'rated ahead revolutions' is understood as the revolutions corresponding to the maximum continuous power of the main engine specified in the engine certificate. The reversing characteristics shall be demonstrated and measured during the inland waters trials.

For passenger vessels and special purpose vessels, PRS may require increased power in free route astern.

1.10.3 In the case of main propulsion systems with reversing gear, controllable pitch propeller or electric drive, running astern shall not lead to the overload of propulsion machinery. Where a disengaging clutch is applied in the propulsion system, engaging of the clutch must not create overload in the propulsion system (temporary, impact, dynamic) which may lead to the damage to the system elements.

1.10.4 The main engine of a single engine propulsion system shall fulfil requirements specified in Chapter 2.

1.10.5 The number, kind and arrangement of spare parts on the vessel is left to the discretion of the owner taking into account the construction and fitting of the engine room, intended service conditions, machinery manufacturers' recommendations as well as the necessity of fulfilment of the flag state requirements.

1.10.6 The spare parts regarded as essential ones are subject to PRS survey in the process of their manufacture similarly to their counterparts installed in the engines, machinery and equipment.

1.11 Machinery Spaces

1.11.1 The arrangement of engines and machinery in machinery spaces shall be such as to provide passages from the control stations and attendance positions to the means of escape. The width of passages over the whole length shall be at least 600 mm.

1.11.2 The width of passages along the switchboards shall fulfil the requirements specified in sub-chapter 4.5.7 of *Part VIII – Electrical Equipment and Automatic Control* of the *Rules for Classification and Construction of Sea-Going Ships*.

1.11.3 Machinery spaces and pipeline tunnels shall be provided with fire exits complying with the requirements specified in sub-chapter 2.2 of *Part V – Fire Protection*.

1.11.4 Doors and covers of companionways and skylights providing exit from the machinery spaces shall be capable of opening and closing from both outside and inside. The covers of companionways and skylights shall be marked with a clear inscription prohibiting placement of any objects on them.

The covers of skylights which do not constitute exits shall be fitted with the closing devices for locking the covers from outside.

1.11.5 Floor panels in the machinery spaces shall be made of metal and they shall have slip-free surface underfoot. The floor panels shall be sufficiently rigid and robustly fixed as well as easily removable.

1.11.6 Sound and heat insulation in the machinery spaces shall be made of incombustible materials. The outer surface of the insulation shall be impervious to oils, fuels and their vapours. The insulation type and fixing method shall be such that vibration shall not cause its cracking or loosening or deterioration of properties.

The insulation shall be also protected against mechanical damage.

1.11.7 Rotating machinery parts shall be properly shielded.

1.11.8 Machinery spaces and other spaces where combustible and toxic gases may spread shall be provided with ventilation complying with the requirements specified in Chapter 21.

1.11.9 The maximum allowable noise level in the machinery spaces is 110dB (A).

The noise level shall be measured mainly in such locations where the machinery is attended.

Near the entrances to the machinery spaces where the noise level exceeds 90 dB (A), warning noticeboards shall be provided.

1.11.10 The noise produced by a vessel under way, and in particular the engine air intake and exhaust noises, shall be damped by using appropriate means.

The noise generated by a vessel under way shall not exceed:
- 75 dB (A) at lateral distance of 25 m from the ship's side,
- 70 dB (A) measured at the level of the helmsman's head at the steering position.,
- apart from transhipment operations, the noise generated by a stationary vessel shall not exceed 65 dB(A) at a lateral distance of 25 m from the ship's side.

1.12 Arrangement of Engines, Machinery and Equipment

1.12.1 Engines, machinery, equipment, pipes, valves and fittings shall be so arranged as to provide free access to them for attendance, repairs in case of failure, and dismounting and removal from the ship.

Engines and machinery shall be so installed and fitted as to be adequately accessible for operation and maintenance and shall not endanger the persons assigned to those tasks. It shall be possible to make them secure against unintentional starting.

The requirements specified in paragraph 1.11.1 shall also be fulfilled.

1.12.2 Tanks for oil fuel, lubricating oil as well as oil used in power transmission systems, control, propulsion systems and heating systems and their pipework and other accessories shall be so laid out and arranged that neither such oil nor oil vapour may accidentally reach the inside of the vessel.

No such oil tanks may be located forward of the collision bulkhead.

Fuel oil or other oil tanks shall not be located directly above stairs, main engines, exhaust pipes, electrical equipment or main engine control stations.

Where location of fuel oil or other oil tanks in such places is necessary, drip trays shall be provided under the whole bottom surface of the tanks which do not constitute a part of the hull structure, whereas the tanks constituting a part of the hull structure shall be provided with the circumferential drip trays. The trays shall be provided with coamings of proper height.

1.12.3 The location of air compressors shall be such as to enable the least possible content of vapours of flammable liquids in the intake air.

1.13 Installation of Engines, Machinery and Equipment

1.13.1 Engines, machinery and equipment constituting the machinery installations shall be installed on robust and rigid foundations. The foundation design shall fulfil the requirements specified in sub-chapter 5.2.4 of *Part II – Hull*.

Small-size machinery and equipment may be installed on pads welded directly to the inner bottom plating or to the platform.

1.13.2 Machinery and other equipment may be installed on the inner bottom, watertight bulkheads, tank walls, provided they are fixed to foundations or supporting brackets welded to stiffeners, or to these parts of plating which are directly stiffened.

1.13.3 Where it is necessary to install engines or machinery on elastic pads, the pads shall be of a design approved by PRS.

The installation of engines on composite material pads is subject to PRS acceptance in each particular case. The composite material shall be approved by PRS.

1.13.4 Main engines and their gears as well as thrust bearings shall be fixed to the foundations, entirely or in part, with fitted bolts or special stops.

1.13.5 The bolts fixing main engines, auxiliary engines and machinery, and shaft bearings to their foundations as well as the bolts connecting particular segments of the shafting shall be secured against loosening.

1.13.6 Engines and machinery with horizontally arranged shafts shall be installed parallel to the ship centre line. Other orientation may be accepted, provided that the engine or machinery construction permits its operation in the conditions specified in sub-chapter 1.5, being so installed.

Classification of European inland waters' zones corresponding to zones **1**, **2**, **3** is contained *PRS Publication No. 15/I – European Inland Waterways Zone Classification*.

1.13.7 The generators' prime movers shall be installed on a common frame with the generators.

1.14 Main Engine Controls

1.14.1 Starting and reversing arrangements shall be so designed and situated that each engine can be started or reversed by one person.

It shall be possible to control and monitor the main engines and steering systems from the steering position. Main engines fitted with a clutch which can be actuated from the steering position, or driving a controllable pitch propeller which can be controlled from the steering position, need only to be capable of being started up and shut down from the engine room.

1.14.2 The direction of control levers movement shall be clearly indicated by an arrow and relevant inscription.

1.14.3 The control for each main engine shall take the form of a single lever which prescribes an arc within a vertical plane that is approximately parallel to the longitudinal axis of the vessel. Movement of that lever towards the bow of the vessel shall cause forward motion, whereas movement of the lever towards the stern shall cause the vessel to go astern. Clutch engagement and reversal of the direction of motion shall take place about the neutral position of that lever. The lever shall catch in the neutral position.

1.14.4 The design of main engine controls shall preclude the possibility of self- change of pre-set position.

1.14.5 The controls of main engines equipped with mechanical turning gear shall have interlocking system to preclude starting the main engine while the turning gear is engaged.

1.14.6 It is recommended that an interlocking system should be provided between the engine telegraph and the reversing and starting arrangements as to prevent the engine from running in the direction opposite direction.

1.14.7 Internal combustion engine controls shall enable it to stop the engine immediately.

1.15 Machinery Controlling and Control Stations

1.15.1 Main engines with remote control shall be also provided with local control stations.

1.15.2 The local control stations of the main engines shall be provided with:
- controls;

- instrumentation, as determined by the manufacturer, to monitor the operation of main propulsion machinery;
- tachometers and indicators of the direction of propeller shaft rotation, where the main engine power is 110 kW and more;
- indicators of blade position of controllable pitch propeller;
- means of communication;
- emergency alarm system (see paragraph 2.6.2).

1.15.3 In vessels equipped with several main engines, reversing gears or controllable pitch propellers, a combined control station shall be provided.

1.15.4 Where remote or remote-automatic control of the main propulsion machinery is provided, the relevant requirements specified in sub-chapter 15.5.1 of *Part VII – Electrical Equipment and Automatic Control*.

1.16 Means of Communication

1.16.1 Each control station of the main engines and propellers shall be provided with at least two independent means of two-way communication with the wheelhouse. One of these shall be an engine room telegraph, which provides visual identification of the orders and responses both in the machinery spaces and on the navigation bridge, fitted with clearly audible signal device well distinct in tone from any other signals which may resound in the room. The second means of communication shall be independent of the engine room telegraph and provide for verification of engine orders and responses.

1.16.2 Where a means of oral communication is provided, measures shall be taken to ensure clear audibility when the machinery is running.

1.17 Instrumentation

1.17.1 Instruments, with the exception of liquid thermometers, shall be checked and accepted by a competent administration body in accordance with the state rules in force.

1.17.2 Accuracy of tachometer indication shall be within ±2.5% of the measuring range. Where barred speed ranges for main engines are specified (see sub-chapter 4.4), they shall be clearly and durably marked on the indicating dials of all tachometers.

1.17.3 Piping systems shall be fitted with instruments necessary for monitoring their proper operation. When choosing the type and number of the instruments guidance provided by manufacturers of the machinery and equipment employed in particular installation shall be taken into consideration.

1.17.4 Instruments in the oil fuel, lubricating oil and other readily ignitable oil piping systems shall be fitted with valves or cocks for cutting the instruments off the medium. Temperature sensors shall be fitted in tight pockets.

1.17.5 Engines and machinery shall be equipped with the instrumentation necessary for monitoring of their proper operation. The number instrumentation pieces shall be in accordance with the manufacturer guidance whereas the instrumentation shall fulfil the requirements specified in this sub-chapter.

Instrumentation of the engines intended for operation in unattended engine rooms is subject to PRS approval in each particular case.

1.18 General Technical Requirements

1.18.1 The design of fixings of the rotating parts of engines and machinery as well as parts situated in positions which are not readily accessible shall prevent loosening of the fixings.

1.18.2 The surfaces of machinery, equipment and pipelines, which can heat up to temperatures exceeding 220 °C shall be provided with thermal insulation. The insulation shall fulfil the requirements specified in paragraph 1.11.6.

1.18.3 The design of fixings of the rotating parts of engines and machinery intended to have contact with the corrosive media shall be made of corrosion-resistant materials or properly protected against corrosion.

1.18.4 Electrical equipment of the engines and machinery shall fulfil the requirements specified in *Part VII – Electrical Equipment and Automatic Control*.

1.19 Automation and Remote Control

1.19.1 Automation and remote control of machinery, equipment and systems shall fulfil the relevant requirements specified in Chapter 15 of *Part VII – Electrical Equipment and Automatic Control*.

1.19.2 Automatic control of the system equipment shall not preclude the local control.

1.20 Limitation on Oil Fuel Use

1.20.1 Unless provided otherwise in the *Rules*, the following provisions apply to the use of oil fuel in vessels:

.1 except the below listed cases, no oil fuel with a flashpoint of less than 55 °C shall be used;

.2 for the drive of such machinery as windlasses, vessel tenders, portable I.C. engine-driven pumps and start-up auxiliary machinery oil fuel with a flashpoint of less than 55°C may be used.

1.20.2 For I.C. engines installed on board vessels oil fuel with a flashpoint exceeding 55 °C shall be used.

2 INTERNAL COMBUSTION ENGINES

2.1 General Requirements

2.1.1 The requirements specified in this Chapter apply to all internal combustion engines of 55 kW and more.

Application of these requirements to diesel engines below 55 kW is subject to special consideration by PRS in each particular case.

2.1.2 Rated power of the internal combustion engines shall be ensured in the following ambient conditions:

- barometric pressure 100 kPa;
- suction air temperature +45 °C;
- relative humidity of air 60%;
- ambient water temperature +20 °C.

2.1.3 Main propulsion engines shall fulfil the requirements specified in sub-chapter 1.10.

2.1.4 The minimum speed of the main engines used for the direct propeller drive shall be not more than 30 % of the rated speed.

2.1.5 While the vessel is running astern, the reversible engines shall develop the power of 65 % of the rated power or more.

2.1.6 The engines of emergency power generating sets shall be provided with self-contained starting, fuel, cooling as well as lubricating systems.

2.2 Engine Frame

2.2.1 The crankcase and its detachable or opened covers of openings shall be of suitable strength, the fastenings of covers shall be strong enough to prevent displacement of the covers in the case of explosion.

2.2.2 The engine frame and adjacent parts shall be provided with draining arrangements (drain grooves, pipes, etc.) or other means preventing penetration of fuel and water into lubricating oil as well as penetration of oil into the cooling water.

The cooling spaces of cylinder blocks shall be fitted with drain arrangements providing for complete drying.

2.2.3 In general, crankcases shall not be provided with ventilation, nor any arrangements shall be fitted which could cause the inrush of outside air into the crankcase. Where forced gas exhaust from the crankcase is fitted (e.g. to detect smoke inside crankcase), the vacuum shall not exceed 0.25 kPa.

Interconnection of air pipes or lubricating oil drain pipes of two or several engines is not permitted.

The turbo-blowers can be used for crankcase ventilation only for the engines with rated power not exceeding 750 kW, provided reliable oil separators are fitted.

The diameter of crankcase venting pipes shall be as small as practicable. The ends of venting pipes shall be provided with flame-arresting fittings and arranged in the way preventing water from getting into the engine. The vent pipes shall be led to the weather deck to the places excluding the suction of vapours into accommodations and service spaces.

2.2.4 Crankcases of engines having a cylinder bore of 200 mm and above or a volume of 0.6 m^3 and above shall be provided with safety devices (explosion relief valves) of a suitable type as follows:

- **.1** engines having a cylinder bore not exceeding 250 mm shall have at least one valve near each end of the crankcase; but engines having 8 cylinders or more shall have an additional valve 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 alternate crankthrow, with a minimum of two valves (not less than 2 devices for each engine)
- **.3** engines having a cylinder bore exceeding 300 shall have at least one valve in way of each main crankthrow.

Additional safety valves shall be fitted on such separate spaces of the crankcase as gear or chain cases for camshaft or similar drives, where the gross volume of such spaces exceeds 0.6 m^3.

2.2.5 Crankcase safety devices (explosion relief valves) shall fulfil the following requirements:

- **.1** the valves shall be type-approved by PRS;

.2 the valves shall be designed and built to open quickly at an overpressure of not more than 0.02 MPa and to close quickly and automatically in order to avoid inrush of air in the crankcase;

.3 crankcase safety valve discharges shall be properly shielded in order to reduce the possible danger from emission of flame.

2.2.6 The free area of each safety valve shall be not less than 45 cm^2 the combined free area of the valves fitted on an engine must not be less than 115 cm^2 per cubic metre of the crankcase gross volume. The volume of the fixed parts in the crankcase may be deduced in estimating the gross volume.

2.2.7 On the both sides of the engine there shall be fitted plates or notices warning against opening the doors, covers or sight glasses for a period of time necessary for cooling down the engine parts after stopping the engine. It is accepted to place such warning on the engine control position.

2.2.8 Engines having a cylinder bore 230 mm or more shall be fitted with cylinder overpressure alarms indicating its permissible value.

2.3 Crankshaft

2.3.1 The crankshaft shall be designed for loads resulting from the engine rated power. The dimensions of the parts of monoblock or semi-built shafts shall fulfil the requirements of *PRS Publication No. 8/P – Calculations of Crankshafts for I.C.Engine.*

2.3.2 The constructions of crankshafts not covered by *PRS Publication No. 8/P* or crankshafts made of nodular cast iron with $500 \leq R_m \leq 700$ MPa are subject to PRS acceptance in each particular case, provided that complete strength calculations or experimental data are submitted.

2.3.3 Fillet radii at the base of the flange shall in each case be not less than 0.08 times the actual shaft diameter.

2.3.4 Surface hardening of the crank pins and journals shall not be applied to the fillets except that the whole shaft has been subjected to surface hardening.

2.3.5 Reference marks shall be made on the outer side of the connection of the crank webs with the main journals of semi-built crankshafts.

2.3.6 Where the thrust bearing is built into the engine frame, the diameter of the thrust shaft shall not be less than that specified in sub-chapter 3.4.

2.4 Supercharging

2.4.1 In the event of turbocharger failure, the main engine of a single-engine arrangement shall develop a power not less than 20 % of the rated power.

2.4.2 Main engines for which the turbochargers do not provide sufficient charging pressure during the engine start-up and operation at low speed, shall be fitted with additional air charging system to ensure obtaining such an engine speed at which the required charging will be ensured by the turbochargers.

2.5 Fuel System

2.5.1 High pressure fuel pipelines shall be made of thick-wall seamless steel pipes without welded or soldered intermediate joints.

2.5.2 All external high pressure fuel pipelines led between high pressure fuel pumps and injectors shall be protected by a shielding system which is capable of retaining fuel in case of damage to high pressure pipeline. The shielding system shall be provided with leak collecting devices and a fuel pipeline damage alarm. The alarm is not required for engines with no more than two cylinders. Jacketed piping system need not be applied to engines on open decks operating windlasses and capstans.

Flexible hoses may be used for shielding purpose provided they are type approved.

If pressure pulsation with peak to peak values exceeds 2 MPa in return piping, shielding of such piping shall be also provided.

2.5.3 All surfaces whose temperature exceeds 220 ºC where there is a risk of fuel stream blow-out from the damaged fuel pipeline shall be properly insulated.

2.5.4 Fuel piping shall be properly (as far as practicable) shielded or otherwise protected against fuel leak or fuel spray onto the hot surfaces, air inlets for machinery devices or other sources of ignition. The number of joints in such installation shall be limited to a minimum.

2.5.5 Where a feed pump is attached to the engine, a hand pump shall be provided to feed oil fuel before the engine start-up.

2.5.6 The design of the oil fuel filters on the line supplying oil fuel to the injection pump of the main engine shall be such as to ensure uninterrupted supply of filtered fuel during cleaning of the filtering equipment. Where either an interchangeable duplex filter or an automatic filter is provided, this requirement is fulfilled.

For auxiliary engines, a single filter may be accepted.

2.6 Lubrication

2.6.1 Main pumps of lubricating oil driven by the engine shall be so designed that sufficient supply of the lubricating oil is ensured over the whole range of operation.

2.6.2 The main and auxiliary engines of power output more than 40 kW shall be equipped with alarm devices giving audible and luminous alarms in the case of the lubricating system failure.

2.6.3 Every branch piece which supplies lubricating oil to the engine cylinders, as well as the branch pieces installed in the upper part of a cylinder liner shall be provided with non-return valves.

2.6.4 The design of the lubricating oil filters on the line supplying lubricating oil to the oil pump of the main engine shall be such as to ensure uninterrupted supply of filtered lubricating oil under cleaning conditions of the filter equipment. Where either an interchangeable duplex filter or an automatic filter is provided, this requirement is fulfilled.

By-pass filters, i.e. through which only a part of the oil supplied by the pump flows, are not accepted.

2.6.5 On main engines with a rated power not exceeding 220 kW with the oil pump situated in the lubricating oil sump, a simplex oil filter is sufficient, provided that:

.1 an alarm device is provided to give alarm of excessive pressure drop across lubricating oil filter, and

.2 uninterrupted supply of filtered lubricating oil under cleaning conditions is ensured. By-pass supply line fitted with a hand operated stop valve is accepted for that purpose.

2.6.6 For auxiliary engines, a simplex filter is accepted.

2.7 Cooling

2.7.1 Main cooling water pumps driven by the engine shall be so designed as to maintain the supply of cooling water over the entire operating range of the engine.

2.7.2 Notwithstanding the provisions of paragraph 15.1.10, in the system of internal circulation of fresh water cooling the engine short segments of hose pipe connected with a pipeline by a hose clip is permitted. Pipes connected to the hose pipes shall be safely fixed to the engine, and the hoses so shaped and fixed with band pipe hangers as to preclude their disconnection due to the engine vibration.

2.7.3 If cooling air is drawn from the engine room, the design of the cooling system shall be based on a room temperature of at least 40 ºC (see paragraph 1.5.1).

The exhaust air of air-cooled engines shall not cause any unacceptable heating of the spaces in which the plant is installed. The exhaust shall normally be led to the open air through special ducts.

2.8 Starting Equipment

2.8.1 The diesel engine starting air pipes shall be provided with the following equipment:

.1 non-return shut-off valve or equivalent:
- for each engine – on the compressed air inlet to the engine;

.2 bursting disk or flame arrester:
- for reversible engines with the main starting manifold – at each branch piece supplying compressed air to starting vessels;
- for non-reversible engines – on the compressed air inlet to the starting manifold.

The requirement mentioned in .2 above applies to engines with a cylinder bore greater than 230 mm.

2.8.2 It is recommended that electrically started engines be equipped with engine driven generators for automatic charging the starting batteries.

2.9 Exhaust Gas System

2.9.1 In engines fitted with the exhaust gas turbo-blowers operating on the pulse principle provision shall be made to prevent broken piston and valve pieces from entering the turbo-blower.

2.10 Controls and Governors

2.10.1 The main engines shall be fitted with limiters of torque (fuel dose) preventing the engine load exceeding the rated torque, resulting from the power output defined in conditions specified in paragraph 2.1.2.

If, according to owner's demand, it should be possible to overload the engine in operation, the maximum overload torque shall not exceed 1.1 of the rated torque. In that case the engine shall be fitted with torque limiter meeting one of the following requirements:

.1 the torque limiter shall be of two-stage type to be changed-over by the crew into the rated torque and maximum overload torque, the change-over into the overload torque being indicated on the engine control stand;

.2 the torque limiter shall be set to the maximum overload torque and a visual or audible signalling device shall be provided to give a continuous signal when the rated torque is exceeded.

2.10.2 Engines of power generating sets shall be capable of withstanding a short duration overload with torque equal to 1.1 of the rated torque, at the rated engine speed.

The engines of power generating sets shall be fitted with limiters of torque (fuel dose) preventing the engine against load exceeding 1.1 of the rated torque, resulting from the power output defined for the conditions specified in paragraph 2.1.2.

2.10.3 The starting and reversing equipment shall be so arranged as to preclude:

- **.1** engine operation in the direction opposite to the desired one;
- **.2** reversing the engine when the fuel supply is on;
- **.3** starting the engine before reversal is completed;
- **.4** starting the engine while the turning gear is engaged.

2.10.4 Each main engine shall be provided with speed governor preventing the rated speed from being exceeded by more than 15%.

Apart from the speed governor, each main engine of an output of 220 kW and more which may have a disengaged clutch or which drives a controllable pitch propeller, shall be provided with a separate overspeed governor to prevent the rated speed from being exceeded by more than 20%.

An alternative solution is subject to PRS approval in each particular case.

The device protecting against overspeed, inclusive of the dedicated driving system, shall be independent of the required speed governor.

Each engine intended to drive the main or emergency power generator shall be provided with a governor ensuring fulfilment of the following requirements:

- **.1** Prime movers for driving generators of the main and emergency sources of electrical power shall be fitted with a speed governor which will prevent transient frequency variations in the electrical network in excess of ± 10 % of the rated frequency with a recovery time to steady state conditions not exceeding 5 seconds, when the maximum electrical step load is switched on or off.

  In the case when a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10 % of the rated speed ma be acceptable, provided this does not cause the intervention of the overspeed device (see paragraph 2.10.4).
- **.2** Within the range of loads 0 – 100% of the rated load the permanent speed after a change of load shall not differ by more than 5% from the rated speed;
- **.3** Application of electrical load shall be possible with two load steps (see also .4 below) – so that the generator running at no load can be loaded to 50% of the rated output of the generator, followed by the remaining 50% after restoring the steady state speed. The steady state condition shall be achieved in no more than 5 seconds. The steady state conditions are those at which the fluctuation of speed variation do not exceed +1% of the declared speed at the new load.
- **.4** In special cases, PRS may permit the application of electrical load in more than two load steps in accordance with Fig. 2.10.5.4, provided that this has been already allowed for at the design stage and confirmed by the tests of the ship electric power plant. In that case, the power of electrical equipment switched on automatically and sequentially after the voltage recovery in bus-bars shall be taken into account, and – for generators operating in parallel – the case of taking over the load by one generator when the other one is switched off shall also be considered.
- **.5** The requirements specified in .1 and .2 above for rapid load with rated power apply to emergency power generators.

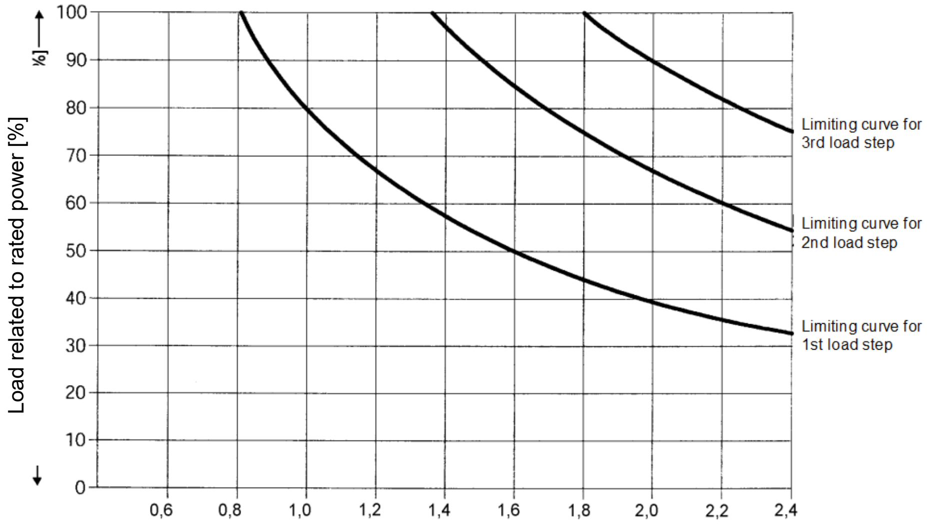


Fig. 2.10.4.
Limiting curves for loading 4-stroke engines step-by-step from "no load" to rated power as the function of brake mean effective pressure P_e, [MPa]

Each engine driving a generator of rated power 220 kW and more shall be fitted with a separate overspeed protective device so adjusted that the speed cannot exceed the rated value by more than 15%.

2.11 Emission of Gaseous and Particulate Pollutants from Diesel Engines

2.11.1 All engines with a rated power output more than 19 kW installed in inland waterways vessels or in machinery on board such a vessel shall ensure effective reduction in emission of gaseous and particulate pollutants from diesel engines in accordance with the requirements of Regulation (EU) 2016/1628 as set out in Article 9 of ES –TRIN technical standard being Annex II to Directive (EU) 2016/1629.

2.11.2 For each engine type-approved in accordance with the requirements specified above the following documents or copies of them shall be kept available on board:

.1 Type-approval certificate;
.2 engine manufacturer's instructions on monitoring the components and engine parameters of relevance in an exhaust gas context;
.3 engine parameter protocol.

The identification number, as well as the type approval number where applicable, of all internal combustion engines on board the vessel shall be entered in item 52 of the inland navigation vessel certificate.

3 SHAFTING AND PROPELLERS

3.1 General Provisions

3.1.1 The formulae given in this Chapter determine the minimum shaft diameters without allowance for subsequent machining of journals in the process of repairs.

Diameters calculated in accordance with the formulae given in sub-chapters 3.2, 3.4 and 3.5 are sufficient if additional stresses caused by torsional vibrations do not exceed the permissible values determined in Chapter 4.

3.1.2 The shafting shall be provided with a braking device. The following devices may be used: brake, turning gear or other locking equipment precluding the shafting rotation in case of failure of the main engine.

3.1.3 Where the main propulsion gear box works in tandem with a piston engine, an appropriate flexible coupling shall be fitted between them.

3.1.4 The method of keyless fitting of the propeller and shafting couplings is subject to PRS approval.

3.1.5 The design of propellers other than classical screw propellers is subject to PRS approval.

3.1.6 Guidelines for the repair of propellers are given in *Publication No. 7/P – Repair of Cast Copper Alloy Propellers*.

3.2 Intermediate Shaft

3.2.1 The design diameter of intermediate shaft d_p shall not be less than that determined in accordance with the following formula:

$$d_p = Fk\sqrt[3]{\frac{PB}{nA}} \text{ [mm]} \quad (3.2.1\text{-}1)$$

where:

P – rated power on the intermediate shaft, [kW];
n – rated number of intermediate shaft revolutions, [r.p.m.];
A – correction coefficient of the coaxial hole in hollow shafts determined in accordance with the formula:

$$A = 1 - \left(\frac{d_o}{d_a}\right)^4 \quad (3.2.1\text{-}2)$$

where:
d_o – coaxial hole diameter, [mm];
d_a – actual outside diameter of the shaft, [mm];
if d_o $0,4d_a$ then $A = 1$ may be adopted;

B – material coefficient determined in accordance with the formula:

$$B = \frac{560}{R_m + 160} \quad (3.2.1\text{-}3)$$

for intermediate and thrust shafts 0.5833 B 1;
R_m – shaft material tensile strength, [MPa], for intermediate and thrust shafts 400 MPa R_m 800 MPa;

F – coefficient taking into account the main propulsion type:
F = 95 – for the turbine drive, for diesel engine drive where the slip clutch is fitted and for electric motor drive,
F = 100 – for other types of drive;

k – shaft design coefficient:
k = 1 – for the shafts forged together with couplings (see also sub-chapter 3.6) and for shafts with shrink-fitted couplings;
k for shafts with key-fitted couplings and for shafts with keyways, holes and cuts – see sub-chapter 3.3.

3.3 Holes and Cuts in Intermediate Shafts

3.3.1 Where intermediate shafts are provided with keyways, radial holes or longitudinal cuts, the following values of coefficient k shall be taken in formula 3.2.1-1:

.1 k = 1.10 for the shaft portion with a keyway:
- after a length of not less than $0.2d_p$ from the end of the keyway where the fillet radii in the transverse section of the bottom of the keyway shall not be less than $0.0125d_p$ or 1 mm, whichever is greater
- over the length of $0.2d_p$ from the cone base where the coupling flange or disk is fitted on the key; the dimensions of the key and keyways in both shaft and coupling shall fulfil the requirements specified in paragraph 3.6.6; in the case of a coupling key-fitted the cone taper shall not exceed 1:12;

.2 k = 1.10 for the shaft portion with a radial hole or a hollow in the middle of this portion, over the length of not less than 7 diameters of the hole, while the hole diameter shall not exceed $0.3d_p$ and its edges shall be rounded off to a radius of not less than 0.35 of the hole diameter and the inner surface shall be thoroughly ground;

.3 k = 1.20 for the portion of shaft with the longitudinal slots over the length exceeding at least $0.25d_p$ at each side of the slot length; while the slot length shall not exceed $1.4d_p$ and the breadth – $0.2d_p$ (calculated for k = 1); the ends of the slots shall be rounded off to a radius equal to 0.5 of the slot breadth, the edges shall be rounded off to a radius not less than 0.35 of the same breadth, the surface of the slot shall be thoroughly ground.

3.3.2 For the holes and cuts other than those specified in 3.3.1, the value of coefficient k is subject to PRS' acceptance in each particular case.

3.3.3 Beyond the portions specified in 3.3.1, the shaft diameter may be smoothly reduced to diameter d_p calculated for k = 1.

3.3.4 The distance between the middle sections of two neighbouring bearings of intermediate and propeller shafts shall not be greater than $26d$ (d – shaft actual diameter) for shafts of more than 90 mm in diameter and $22d$ – for shafts of less than or equal to 90 mm.

3.4 Thrust Shaft

3.4.1 The diameter d_{op} of the thrust shaft which is not an integral part of the propulsion engine shall not be less than determined using formula 3.2.1-1 for k = 1.10. This applies to:
- the shaft portion of the length not less than diameter d_{op} on both sides of the thrust collar where slide bearings are used, and
- the shaft portion in way of the axial bearing where a roller bearing is used as a thrust bearing.

The shaft diameter outside the above-determined lengths may be smoothly reduced to the diameter obtained using formula 3.2.1-1 for the material and design of the thrust shaft.

3.4.2 Holes and cuts like in the intermediate shaft are permitted in the thrust shaft provided that the requirements specified in sub-chapter 3.3 are fulfilled.

3.5 Propeller Shaft

3.5.1 The diameter d_{sr} of the propeller shaft shall not be less than the value determined using formula 3.2.1-1, where:
F = 100 for all types of propulsion;
A = 1; (i.e. $d_o \le 0{,}4\, d_a$);
$0.7368 \le B \le 1$ (400 MPa $\le R_m \le$ 600 MPa).

The value of coefficient k for the propeller shaft is:

k = 1.22 where the propeller is fitted on the propeller shaft cone using an approved keyless shrink method or fixed to a flange integrally forged with the propeller shaft and the propeller shaft is provided with a continuous liner or is oil lubricated and provided with an oil sealing gland of the approved type;

k = 1.26 where the propeller is key-fitted on the propeller shaft and the propeller shaft is provided with a continuous liner or is oil lubricated and provided with an oil sealing gland of the approved type;

k = 1.35 where the propeller shaft is grease lubricated inside the stern tube.

The above values of coefficient k apply to the portion of propeller shaft between the forward edge of the after shaft bearing and the forward face of the propeller boss or, if applicable, the forward face of the propeller shaft flange, but over a length of not less than $2.5d_{sr}$ in each particular case.

k = 1.15 for the forward portion of the propeller shaft over the length covered by the stern tube.

The diameter of propeller shaft may be smoothly reduced to the actual diameter of the intermediate shaft over the distance from the forward edge of the forward seal. Changes from larger to smaller shaft diameters due to different coefficients k shall be effected by tapering or ample radiusing.

For other designs of the propeller shaft, the value of coefficient k is subject to PRS' acceptance in each particular case.

3.5.2 Where a shrink-fitted or key-fitted coupling is provided on the forward end of the propeller shaft, coefficient k for this portion of the shaft shall be properly taken like for the intermediate shaft (see paragraphs 3.2.1 and 3.3.1.1).

3.5.3 Propeller shaft coupling with the propeller shall fulfil the following requirements:

.1 where the propeller and a coupling are joined with the propeller shaft without a key, the taper of the propeller shaft cone shall not exceed 1:12. If the taper of the shaft cone is 1:50 or less, the coupling of the shaft with the propeller may be arranged without the retaining nut (or equivalent securing);

.2 where the propeller is and a coupling are joined with the propeller shaft with a key, the taper of the propeller shaft cone shall not exceed 1:12;

.3 the end of the keyway in the propeller shaft cone intended for the propeller shall be at a distance, from the cone base, not less than 0.2 of the propeller shaft diameter. For shafts of 100 mm in diameter and over, the end of the keyway shall be so designed that the forward end of the groove makes a gradual transition to the full shaft section. In addition, the forward end of the keyway shall be spoon-shaped. The edges of the keyway at the surface of the shaft taper shall not be sharp. The lower keyway corners shall be rounded to a radius of about 0.0125 of the propeller shaft diameter d_{sr}, but not less than 1.0 mm;

.4 the dimensions of a key and keyways in both the shaft and the propeller boss shall be such that the requirements specified in 3.6.6 are fulfilled;

.5 where threaded holes are provided to accommodate the securing screws for propeller keys, such holes shall be located either in the middle length of the keyway or in the forward half of the keyway;

.6 the propeller shaft coupling flanges shall fulfil the requirements specified in paragraphs 3.6.3 to 3.6.5 inclusive;

.7 means shall be provided to secure the propeller nut against unscrewing by structural fixing it to the shaft;

.8 the propeller boss seating shall be effectively protected against the ingress of water;

.9 the part of the propeller shaft between the propeller boss and stern tube shall be effectively protected against corrosion.

3.5.4 Propeller shaft liners shall be made of high quality copper alloy resistant to the corrosive effect of sea-water.

The thickness of the liner *s* shall be not less than that determined using the following formula:

$$s \geq 0.03d_{sr} + 4.0 \quad [\text{mm}] \tag{3.5.4}$$

where:
d_{sr} – see paragraph 3.5.1.

The thickness of the shaft liner between the bearings may be reduced to 0.75*s*.

3.5.5 Continuous, i.e. solid, liners are recommended to be used. Liners consisting of lengths may be recognised as the continuous ones, provided the joining methods are approved by PRS and the joints are not in way of bearings.

Non-continuous liners, where parts between them are coated with the materials approved by PRS and also using a method approved by PRS, may be recognised as a means of effective protection of the propeller shaft.

The ends of a shrink-fitted liner shall be provided with relief lines.

3.6 Shaft Couplings

3.6.1 The outer diameter d_s of the fitted bolts shall not be less than that determined applying the following formula:

$$d_s = 0.65\sqrt{\frac{d_p^3(R_{mp}+160)}{iDR_{ms}}} \quad [\text{mm}] \tag{3.6.1}$$

where:
d_p – the design diameter of intermediate shaft, taking into account the ice strengthening, if required, [mm]; where the diameter is increased due to ice excitation torsional vibration d_p shall be taken equal to the actual diameter of the intermediate shaft;
i – number of fitted bolts in the coupling;
D – diameter of the pitch circle of the coupling bolts, [mm];
R_{mp} – tensile strength of the shaft material, [MPa];
R_{ms} – tensile strength of the bolt material, [MPa], where

$R_{mp} \leq R_{ms} \leq 1.7R_{mp}$, but not exceeding 1000 MPa.

In a flange coupling the number of fitted bolts shall be at least 50 % of the total bolts' number, however the number shall not be fewer than three.

3.6.2 Flange joints transmitting the torque by friction only (with controlled-tension bolts instead of fitted bolts) may be used subject to PRS' approval in each particular case.

The shank necked-down bolts shall be designed to a minimum diameter of plain coupling bolts not less than 0.9 of the thread root diameter for that joint.

3.6.3 The thickness of coupling flanges (under the bolt heads) of the intermediate shafts and thrust shafts and of the forward coupling flange of the propeller shaft shall not be less than $0.2d_p$ or d_s, determined in accordance with formula 3.2.1-1 or d_s determined in accordance with formula 3.6.1 for the shaft material, whichever is greater.

The thickness of the coupling flange of the propeller shaft, by means of which the propeller shaft is connected with the propeller, shall not be less than 0.25 of the actual shaft diameter in way of the flange.

The use of flanges having non-parallel external surfaces is subject to PRS' approval in each particular case, however their thickness shall not be less than d_s determined in accordance with formula 3.6.1.

3.6.4 For the flange which couples the propeller shaft with the propeller, the fillet radius shall not be less than 0.125 (whereas for the other coupling flanges connecting shafts not less than 0.08) of the actual shaft diameter in way of the flange.

The fillet surface shall be smooth and not affected by the recesses for heads and nuts of coupling bolts.

3.6.5 Where coupling flanges are fitted on the shaft, the tensile strength of their material shall not be less than that of the shaft, and the fitting shall be so designed as to transmit the propeller thrust force during the vessel running ahead and astern. To avoid stress concentration, the coupling boss end shall be provided with the relief line in way of the shaft cone contact.

3.6.6 For key-fitted flanges the dimensions of both the keyway and key shall be such as to ensure that the unit interface pressure induced by the average torque at the rated number of revolutions and rated output of the engine on the side surface of the keyway does not exceed 0.5 of the yield point of the material of the shaft or flange respectively.

3.7 Propeller Shaft Bearings

3.7.1 The length of the shaft bearing next to the propeller shall be determined as follows:

.1 for water lubricated bearings lined with lignum vitae – not less than $4d_{sr}$ (d_{sr} – see paragraph 3.5.1);

Note: Lignum vitae stands for various species of hard resin wood. As the original lignum vitae is hardly available, other species such as Bulnesia Sarmiento or Paolo Santo or Bulnesia Arabia are used presently.

.2 for oil lubricated bearings lined with white metal – not less than $2d_{sr}$, however, if the nominal bearing pressure does not exceed 0.8 MPa, the bearing length may be reduced to the value not less than $1.5d_{sr}$;

.3 for water lubricated bearings of synthetic material – not less than $4d_{sr}$; however reduction of the bearing length to $2d_{sr}$ may be considered, for the bearing types of a proven construction confirmed by satisfactory service results;

.4 for oil lubricated bearings of synthetic rubber, reinforced resins or plastics, – not less than $2d_{sr}$, however, if the nominal bearing pressure does not exceed 0.6 MPa, the bearing length may be reduced to the value not less than $1.5d_{sr}$.

Note:

The nominal bearing pressure in the stern bearing is defined as the combined weight of the propeller shaft and propeller divided by the surface area of horizontal cross projection of the bearing.

3.7.2 In the case of propeller shafts in water-lubricated bearings, the piping supplying water shall be provided (in way of either stern tube or afterpeak bulkhead) with a lockable non-return valve operable from the engine room. A mesh filter and a flow indicator visible from the steering stand shall be provided in the piping supplying water lubricating the bearing. Cleaning of the filter shall not bring the necessity to stop the supply of lubricating water to the bearing.

The water may be supplied from the main engine cooling system by a dedicated or independent pump attached to the engine. An alarm the shall be provided at the steering stand to indicate the stop of such a pump.

It is recommended that a device preventing the stern tube freezing be provided.

3.7.3 For oil lubricated bearings the gravity tanks shall be located above the waterline and provided with level indicators and low oil level alarm.

Propeller shaft bushings shall be so designed as to prevent the spread of water-polluting lubricants.

3.8 Propellers

3.8.1 The blade thickness shall not be less than that determined using the formula:

$$s = 0.95 \frac{3.65kA}{\sqrt[3]{\left(0.312+\frac{H}{D}\right)^2}} \sqrt{\frac{P}{nbZM}} \text{ [mm]} \qquad (3.8.1)$$

where:

- s – maximum thickness of expanded cylindrical section of blade, measured perpendicularly to the blade pressure side or geometrical chord of the section at the radius $0.2R$ for solid propellers, $0.25R$ or $0.3R$ for built-up propellers, $0.35R$ for CP propellers and $0.6R$ for all propellers, irrespective of their design, [mm];
- k = 1; for ships with ice class **L1** – see paragraph 28.1.4;
- A – coefficient determined in accordance with Table 3.8.1, for the radius $0.2R$, $0.25R$, $0.3R$, $0.35R$ or $0.6R$, respectively, and also for the required rake at blade tip; if the rake differs from the values given in the Table, coefficient A shall be assumed as for the nearest maximum value of that rake;
- P – propeller shaft power at the rated output of main engine, [kW];
- n – rated number of propeller shaft revolutions, [rpm];
- Z – number of blades;
- b – developed blade width of cylindrical sections at the radius of $0.2R$, $0.25R$, $0.3R$, $0.35R$ or $0.6R$, respectively, [m];
- D – propeller diameter, [m];
- R – propeller radius, [m];
- H/D – pitch ratio at the radius of $0.7R$;
- M = $0.6R_{m(s)} + 180$, but no more than 570 MPa for steel and no more than 610 MPa for non-ferrous alloys;
- $R_{m(s)}$ – ultimate tensile strength of the blade material, [MPa].

Table 3.8.1
Values of coefficient *A*

Blade radius, [m]	Rake at blade tip, as measured along the blade pressure side, [deg]								
	0	2	4	6	8	10	12	14	16
$0.20R$	390	391	393	395	397	400	403	407	411
$0.25R$	378	379	381	383	385	388	391	394	398
$0.30R$	367	368	369	371	373	376	379	383	387
$0.35R$	355	356	357	359	361	364	367	370	374
$0.60R$	236	237	238	240	241	243	245	247	249

3.8.2 The thickness at the blade tip shall not be less than $0.0035D$ (for vessels with ice class **L1** – see paragraph 28.1.5).

3.8.3 The intermediate thicknesses of blade shall be so chosen that the contour lines of the maximum blade thickness sections run smoothly from the root, through intermediate profiles to the tip.

3.8.4 In justified cases PRS may consider proposals different from the requirements specified in paragraphs 3.8.1 and 3.8.2, provided that detailed strength calculations are submitted.

3.9 Bosses and Plate Fastening Parts

3.9.1 Fillet radii of the transition from blade to boss at the location of maximum blade thickness shall be at least 0.04D at the blade suction side and at least 0.03D at the blade pressure side (D – propeller diameter).

Where the blade is not raked the fillet radius at both sides shall be at least 0.03D.

To avoid stress concentration, the propeller boss end contact shall be provided with the relief line in way of the shaft cone contact.

3.9.2 The propeller boss shall be provided with holes to fill the void spaces between the boss and the shaft cone with grease. The grease is also to fill the void space inside the propeller cap.

The grease used for filling the above-mentioned spaces shall not cause corrosion.

3.9.3 Where propeller blades are bolted to the hub, the thread root diameter of these bolts shall not be less than d_s determined using the following formula:

$$d_s = ks\sqrt{\frac{bR_{m(s)}}{d_1 R_{e(sm)}}} \qquad \text{[mm]} \qquad (3.9.3)$$

where:

k = 0.205 for 3 bolts used at the blade pressure side;
k = 0.186 for 4 bolts used at the blade pressure side;
k = 0.174 for 5 bolts used at the blade pressure side;
s – maximum thickness of the blade, measured at the boss, in the section calculated in accordance with 3.8.1, [mm];
b – developed blade width (calculated section) measured at the boss, [m];
$R_{m(s)}$ – tensile strength of the blade material, [MPa];
$R_{e(sm)}$ – tensile strength of the bolt material, [MPa];
d_1 – diameter of the fixing bolts' circle; in the case of different arrangement of bolts, i.e. outside the circle, d_1 = 0.85l (where l – distance between the remotest bolts), [m].

The minimum diameter of the cylindrical portion of the blade fastening bolt shall not be less than 0.9d_s.

The blade fixing bolts shall be tightened using a controlled torque and shall also be secured against unintentional loosening.

3.10 Controllable Pitch Propellers

3.10.1 Hydraulic power operating system of the propeller blades pitch adjustment device shall be served by two independent pumps of equal capacity – one service and one standby pump.

Ships equipped with two CP propellers may be provided with one independent standby pump for both propellers.

The standby pump may be hand-operated or hand-operated arrangement shall be provided to control the propeller pitch.

3.10.2 The propeller blades pitch setting device shall be so designed as to allow the positioning of blades for running ahead in the case of failure of the hydraulic power operating system.

3.10.3 Controllable pitch propeller systems shall be provided with an indicator showing the actual setting of the blades.

3.10.4 Hydraulic power operating systems of the propeller blades pitch adjustment device shall be constructed in accordance with the requirements specified in Chapter 8, and their piping shall undergo the tests specified in sub-chapter 1.6.

3.10.5 The time of reversing the propeller blades from ”full ahead” to ”full astern” position, with the main engine not running, shall not exceed 20s.

3.10.6 Means shall be provided to secure the engine against overload due to the propeller blades' reversing.

3.11 Balancing Screw Propellers

3.11.1 After final machining screw propellers shall be balanced in accordance with the requirements of the relevant standards.

3.11.2 The difference in mass between basic and spare blades of built-up propellers and controllable pitch propellers shall not exceed 1.5 %.

4 TORSIONAL VIBRATION

4.1 General Provisions

4.1.1 The scope and methodology of calculating the torsional vibrations of propulsion systems shall be such as to enable a complete analysis of the torsional vibration stresses to be expected in the main engine shafting system including its branches.

PRS shall be submitted, for examination, the calculations performed for both:
– normal operation,
– departures from normal operation due to irregularities in ignition. In this respect, the calculations shall assume operation with that cylinder without ignition whose malfunction might cause the most adverse dynamic loads.

An analysis of emergency modes of operation of the system (e.g. damper failure, flexible coupling failure, propeller blade break-off, etc.) which are considered by the design engineer the most likely and significant shall be carried out. In justified cases, PRS may require that the results of such an analysis be submitted for examination.

Where modifications are introduced into the system which have a substantial effect on the torsional vibration characteristics, the calculation of the torsional vibrations characteristics shall be repeated and submitted to PRS for approval.

The torsional vibration stresses are the stresses that are added to the torsional stresses resulting from mean torque at the considered engine speed and power output.

For vessels with ice class notation L1 additionally ice excitation torsional vibration analysis shall be performed.

4.1.2 Calculations of torsional vibrations shall include:
.1 input data:
– mass moments of inertia and rigidity of particular components of a system;

- logic diagrams of all the applicable modes of system operation;
- type and rated parameters of the torsional vibration dampers, flexible couplings, transmission gears and generators – where applied;

.2 tables of successive forms of free vibrations with resonance within the range from $0.2n_z$ to $1.2n_z$, with their harmonics as specified in .3;

.3 firing order in the engine cylinders and the values of vector sum of the relative amplitudes of torsion angles of the cranks for all considered modes and harmonic orders within the range from 1 to 16 for two-stroke engines and from 0.5 to 12 for four-stroke engines;

.4 values of stresses caused by all significant harmonic excitation torques within the range from $0.2n_z$ to $1.05n_z$ for main engines and from $0.5n_z$ to $1.1n_z$ for power generating set engines at the weakest cylindrical cross sections of the shafting;

.5 dynamic torques in flexible couplings and on the pinion of transmission gears within the speed range as specified in .4;

.6 for power generating sets – dynamic torques on the generator's rotor;

.7 vibration amplitudes taken at the assumed point of measurement (on the mass where measurements are taken), corresponding to the calculated values of the synthesised stresses and dynamic torques as specified in .4, .5 and .6;

.8 graphical and tabular presentation of dynamic loads and parameters of the torsional vibrations specified in items from .4 to .7. The graphs and tables shall include both combined values and the most significant harmonic ones.

4.2 Allowable Stresses

4.2.1 Crankshafts

4.2.1.1 The combined torsional stresses during continuous operation of the engines shall not exceed those determined in accordance with the following formulae:

.1 within the range of crankshaft rpm:

$0.7n_z \le n \le 1.05n_z$ – for main engines of ice-breakers,
$0.85n_z \le n \le 1.05n_z$ – for main engines of tugboats and pushers,
$0.9n_z \le n \le 1.05n_z$ – for main engines of other vessels,
$0.9n_z \le n \le 1.10n_z$ – for engines driving generators or other auxiliary machinery,

- where the maximum value of variable torsional stresses $\tau_{N\,\max}$ has been determined by the crankshaft calculation method given in *Publication No. 8/P – Calculation of Crankshafts for I.C. Engines*:

$$\tau_{1k} \le \pm\tau_{N\max} \qquad (4.2.1.1.1\text{-}1)$$

- where the above-mentioned method has not been applied:

$$\tau_{2k} \le \pm 30.36 C_D \qquad (4.2.1.1.1\text{-}2)$$

.2 within the rpm ranges of crankshaft lower than those mentioned in .1, respectively:

$$\tau_{3k} \le \pm\frac{\tau_k\left[3-2\left(\frac{n}{n_z}\right)^2\right]}{1.38} \qquad (4.2.1.1.2\text{-}1)$$

or

$$\tau_{4k} \le \pm 22 C_D \left[3 - 2\left(\frac{n}{n_z}\right)^2\right] \qquad (4.2.1.1.2\text{-}2)$$

where:

τ_{1k}, τ_{2k}, τ_{3k}, τ_{4k} – permissible stresses [MPa];
C_D – size factor determined using the formula below:
$C_D = 0.35 + 0.93d^{-0.2}$;

d – shaft diameter at the weakest section, [mm];
$d = \min [d_{journal}, d_{crankpin}]$;
n – speed under consideration, [rpm];
n_z – rated speed, [rpm].

In the propulsion systems operated for prolonged periods of time with rated torque in the range of operational speed below the rated one (e.g. tug-boats and pushers), the stresses shall not exceed those determined in accordance with formula 4.2.1.1.1-1 or 4.2.1.1.1-2.

4.2.1.2 The combined torsional stresses for the barred speed ranges, which shall be passed quickly, shall not exceed the values determined in accordance with the following formula:

$$\tau_{1kz} = \pm 1.9\tau_{3k} \qquad (4.2.1.2\text{-}1)$$

or

$$\tau_{2kz} = \pm 1.9\tau_{4k} \qquad (4.2.1.2\text{-}2)$$

depending on the calculation method applied, where:
τ_{1kz} and τ_{2kz} – permissible stress for quick passing through the barred range, [MPa];
τ_{3k} and τ_{4k} – see paragraph 4.2.1.1.

4.2.2 Intermediate, Thrust, Propeller and Generator Shafts

4.2.2.1 The combined torsional stresses for continuous operation shall not exceed, in any part of the shaft, the values determined in accordance with the following formulae:

.1 within the range of shaft rpm:
$0.7n_z \le n \le 1.05n_z$ – for icebreakers,
$0.85n_z \le n \le 1.05n_z$ – for tugboats and pushers,
$0.9n_z \le n \le 1.05n_z$ – for other vessels,
$0.9n_z \le n \le 1.10n_z$ – for generators

$$\tau_{1w} = \pm 1.38 C_w C_k C_D \qquad (4.2.2.1.1)$$

.2 within the rpm ranges lower than specified in .1:

$$\tau_{2w} = C_w C_k C_D \left[3 - 2\left(\frac{n}{n_z}\right)^2\right] \qquad (4.2.2.1.2)$$

where:

τ_{1w}, τ_{2w} – permissible stresses, [MPa];

C_w – material coefficient determined using the following formula: $C_w = \frac{R_m + 160}{18} \le 42,2$ (R_m > 600 MPa shall not be taken into account);
R_m – shaft material tensile strength, [MPa];
C_k – shaft structure coefficient:
= 1.0 for intermediate shafts and generator shafts with flanges forged together with shaft,
= 0.6 for intermediate shafts and generator shafts in way of keyways,
C_k = 0.85 for the thrust shaft parts specified in sub-chapter 3.4,
= 0.55 for the propeller shaft parts for which the coefficient value 1.22 or 1.26 shall be taken, in accordance with paragraph 3.5.1;
C_D, n, n_z – see paragraph 4.2.1.1.2.

In the propulsion systems operated for prolonged periods of time with the rated torque at speeds below the rated one (e.g. tugboats, fishing trawlers, etc.), the stresses shall not exceed those determined in accordance with formula 4.2.2.1.1.

4.2.2.2 The combined torsional stresses for the barred speed ranges, which shall be passed quickly, shall not exceed the value determined in accordance with the following formula:

$$\tau_{WZ} = \pm \frac{1.7\tau_{2w}}{\sqrt{C_k}} \quad (4.2.2.2)$$

where:

τ_{wz} – permissible stress for quick transition through the barred range, [MPa].

For other symbols – see paragraph4.2.2.1.

4.2.2.3 The stress values defined in paragraphs 4.2.2.1 and 4.2.2.2 refer to the shafts with diameters equal to those specified in 3.2, 3.4 or 3.5. Where actual diameters of the shafts are greater than required, PRS may accept higher values of the torsional vibration stresses.

PRS may accept stresses exceeding those specified in 4.2.2.1 and 4.2.2.2 where justified by calculation.

4.2.3 Allowable Dynamic Torques

4.2.3.1 Dynamic moments in flexible couplings and vibration dampers shall not exceed the values specified by the manufacturer.

4.2.3.2 It is recommended that the dynamic torques occurring in any stage of a transmission gear do not exceed 1/3 of the rated torque within the rpm range from $0.9n_z$ to $1.05n_z$.

4.2.3.3 Dynamic moments occurring in generator rotor shall not exceed the values specified by the manufacturer – depending on the employed construction of connection with the generator shaft.

4.3 Measurements of Torsional Vibration Parameters

4.3.1 The results of calculation of combined torsional vibration stresses shall be confirmed by measurements taken on the first vessel of the series. When estimating these stresses, their harmonic analysis shall be done.

4.3.2 The measured frequencies of free vibrations shall not differ from the calculated values by more than 5%. Where this requirement is not fulfilled – the calculations shall be corrected accordingly.

4.3.3 Where, as a result of calculations, it is not necessary to apply barred speed ranges, or in other justified cases, PRS may allow taking measurements to be waived.

4.4 Barred Speed Ranges

4.4.1 Where the combined actual torsional stresses exceed the permissible values for continuous operation, the barred speed ranges shall be determined. The barred speed ranges shall not occur within the following ranges:

– $n \geq 0.7n_z$ – for propulsion system of icebreakers,
– $n \geq 0.8n_z$ – for propulsion system of other vessels,
– $n \geq 0.85n_z$ – for power generating sets.

4.4.2 In the case of exceeding the permissible stresses due to resonance, the barred speed range shall be determined in accordance with the following formula:

$$\frac{16n_k}{18-\frac{n_k}{n_z}} \leq n \leq \frac{\left(18-\frac{n_k}{n_z}\right)n_k}{16} \quad (4.4.2)$$

where:
n – barred speed range [rpm];
n_k – resonance speed [rpm];
n_z – rated speed [rpm].

4.4.3 The limits of barred speed may also be determined by extending by $0.03n_z$ to both sides the range within which the combined torsional vibration stresses or torques in the flexible couplings or transmission gear, exceed the permissible values.

4.4.4 Where normal operation of the engine is accompanied by calculated, and confirmed by measurements, speed ranges in which the combined stresses or dynamic torques in couplings or in transmission gears exceed the permissible values, then the ranges of barred speed shall be marked in accordance with paragraph 1.17.2. Proper warning plates shall be located at the engine control stations.

4.4.5 Where during the engine operation with one cylinder without ignition (see paragraph 4.1.1) the stresses and torques defined in paragraph 4.4.4 exceed the allowable values, then:

.1 the engine shall be provided with an automatic alarm system, indicating the lack of ignition in a cylinder, and the engine control stations shall be fitted with the plates indicating the barred speed ranges, determined in accordance with paragraph 4.4.2 or 4.4.3 for such a condition of engine;

.2 where the alarm system defined in .1 is not provided, the additional barred speed ranges for the engine operation with one cylinder without ignition shall be marked on the tachometers and warning plates.

5 GEARING, DISENGAGING AND FLEXIBLE COUPLINGS

5.1 General Requirements

5.1.1 The construction of a gear shall ensure normal operation in the conditions defined in paragraph 1.5.1.

5.1.2 Rotating parts of gears and couplings shall be balanced by the manufacturer with the accuracy defined by general and manufacturer's standards. The balancing should be documented by a report.

.1 Static balancing shall be applied to parts rotating with the following tangential velocity:
$v \geq 40$ m/s,if subjected to complete machining securing their alignment;
$v \geq 25$ m/s,if not subjected to such machining.

.2 Dynamic balancing shall be applied to parts rotating with a tangential velocity:
$v \geq 50$ m/s.

5.2 Gearing

5.2.1 General Provisions

5.2.1.1 The requirements specified in this sub-chapter apply to the propulsion gears and auxiliary gears with cylindrical wheels of external and internal mesh having spur or helical teeth of involute profile. Other types of transmission gear are subject to PRS approval in each particular case.

5.2.1.2 The technical documentation of gears (see paragraph 1.3.3.2) shall contain all the data necessary for calculation carried out following the procedure specified in sub-chapter 5.2.3. The calculation applies to gear wheels and shafts transmitting the power from the engine output to gear output.

5.2.2 Input Data for Stress Calculation in Gear Wheel Teeth

5.2.2.1 The symbols and definitions used in this sub-section are based mainly on standards ISO 6336, PN-92/M-88509/00 and PN-93/14-88509/01 concerning the calculation of gear transmission capacity taking into account the contact stress (following the procedure specified in sub-chapter 5.2.4) and bending stress in the tooth root (following the procedure specified in sub-chapter 5.2.5).

5.2.2.2 In order to simplify the requirement provisions, the following definitions have been adopted:

pinion – the gear wheel of the pair with the smaller number of teeth (all the symbols concerning this wheel are marked with subscript character 1),

wheel – the gear wheel of the pair with the greater number of teeth (all the symbols concerning this wheel are marked with subscript character 2).

For the purposes of ship gearings' (gear wheels) calculation the following symbols apply:

a – centre distance, [mm];
b – face width, [mm];
b_1 – toothed rim width – pinion,, [mm];
b_2 – toothed rim width – wheel, [mm];
d – pitch cylinder diameter (reference diameter), [mm];
d_1 – pitch cylinder diameter – pinion, [mm];
d_2 – pitch cylinder diameter – wheel, [mm];
d_{a1} – tip circle diameter – pinion [mm];
d_{a2} – tip circle diameter – wheel, [mm];
d_{b1} – base circle diameter – pinion, [mm];
d_{b2} – base circle diameter – wheel, [mm];
d_{f1} – root circle diameter – pinion, [mm];
d_{f2} – root circle diameter – wheel, [mm];
d_{w1} – working circle diameter – pinion, [mm];
d_{w2} – working circle diameter – wheel, [mm];
F_t – rated tangential force at working cylinder, [N];
F_b – rated tangential force at transverse section of base cylinder, [N];
h – tooth depth, [mm];
m_n – normal module, [mm];
m_t – transverse module, [mm];
n_1 – rotational speed – pinion, [rpm];
n_2 – rotational speed – wheel, [rpm];
P – maximum power transmitted by gearing, [kW];
T_1 – torque transmitted by pinion, [Nm];
T_2 – torque transmitted by wheel, [Nm];
u – gear ratio;
v – tangential velocity at generating cylinder, [m/s];
x_1 – correction coefficient of basic rack tooth profile – pinion
x_2 – correction coefficient of basic rack tooth profile – wheel;
z_1 – number of teeth – pinion;
z_2 – number of teeth – wheel;
z_n – virtual number of teeth;
α_n – profile angle at normal section of pitch cylinder, [°];
α_t – profile angle at transverse section of pitch cylinder, [°];

α_{tw} – profile angle at transverse section of working cylinder, [°];
β – base helix angle at pitch cylinder, [°];
β_b – base helix angle at base cylinder, [°];
ε_α – transverse contact ratio, [–];
ε_β – pitch contact ratio, [–];
ε_γ – total contact ratio, [–];
$inv\ \alpha$ – tooth profile involute angle associated with considered profile angle α, [rad];
α – profile angle (for definition of involute angle), [°].

Note:

1. z_2, α, d_2, d_{a2}, d_{b2} and d_{w2} are negative for internal mesh.
2. In the formula defining the teeth contact stress, b is the mesh width at the working cylinder.
3. In the formula defining the bending stress in teeth roots, b_1 and b_2 are the widths at respective teeth roots. In no case b_1 and b_2 shall be greater than b by more than one module (m_n) at each side.
4. Gearing width b may be used in the formula defining the bending stress in teeth roots if barrel shape or relieve of teeth tips has been applied.

5.2.2.3 Selected Formulae for Gearing:

Gearing ratio is defined as follows:

$$u = \frac{z_2}{z_1} = \frac{d_{w2}}{d_{w1}} = \frac{d_2}{d_1} \tag{5.2.2.3}$$

where u takes the following signs:

– plus – for external mesh,
– minus – for internal mesh.

$$\mathrm{tg}\alpha_t = \frac{\mathrm{tg}\alpha_n}{\cos\beta}$$

$$\mathrm{tg}\beta_b = tg\beta \cdot cos\alpha_t$$

$$d = \frac{z \cdot m_n}{\cos\beta}$$

$$d_b = d \cdot cos\alpha_t = d_w \cdot cos\alpha_{tw}$$

$$a = \frac{d_{w1} + d_{w2}}{2}$$

$$z_n = \frac{z}{\cos^2\beta_b \cdot \cos\beta}$$

$$m_t = \frac{m_n}{\cos\beta}$$

$$inv\alpha = tg\alpha - \frac{\pi \cdot \alpha}{180}$$

$$inv\alpha_{tw} = inv\alpha_t + 2tg\alpha_n \cdot \frac{x_1 + x_2}{z_1 + z_2}$$

$$\varepsilon_\alpha = \frac{0.5\sqrt{d_{a1}^2 - d_{b1}^2} \pm 0.5 \cdot \sqrt{d_{a2}^2 - d_{b2}^2} - a \cdot \sin\alpha_{tw}}{\pi \cdot m_n \cdot \dfrac{\cos\alpha_t}{\cos\beta}}$$

Note:

In the above formula (±) symbol shall be interpreted as follows:
(+) for external mesh,
(–) for internal mesh.

$$\varepsilon_\beta = \frac{b \cdot \sin\beta}{\pi \cdot m_n}$$

Note:
For double helical gear, *b* shall be taken as the single helical width.

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$v = \frac{\pi \cdot d_1 \cdot n_1}{60\ 000} = \frac{\pi \cdot d_2 \cdot n_2}{60\ 000}$$

$$d_{w1} = 2a \cdot \frac{z_1}{z_1+z_2};\ d_{w2} = 2a \cdot \frac{z_2}{z_1+z_2} \qquad [\text{mm}]$$

5.2.2.4 Rated Tangential Force F_t

Rated tangential force F_t, tangent to working cylinder and positioned in the plane perpendicular to the rotation axis is calculated from the maximum continuous power transmitted by the gear, using the following formulae:

$$T_1 = 9549\frac{P}{n_1}; T_2 = 9549\frac{P}{n_2} \qquad (5.2.2.4\text{-}1)$$

$$F_t = 2000\frac{T_1}{d_1} = 2000\frac{T_2}{d_2} \quad [\text{N}] \qquad (5.2.2.4\text{-}2)$$

5.2.3 Coefficients Common for Checked Strength Conditions (Contact and Bending Stresses)

This section defines the coefficients applied in the formulae checking gear wheel teeth strength for the contact stress (in accordance with 5.2.4) and for the bending stress (in accordance with sub-chapter 5.2.5). Other coefficients specific for the strength formulae are included in sub-chapters 5.2.4 and 5.2.5.

All the coefficients shall be calculated using respective formulae or following particular instructions.

5.2.3.1 Application Factor K_A

The application factor takes into account the dynamic overloads generated in the gear by the external forces.

For gears designed for unlimited life-span the K_A shall be defined as the ratio of maximum torque occurring in the gear (assuming periodically variable load) to the rated torque.

The rated torque used in further calculations shall be taken as the ratio of rated power to the rated rotational speed.

K_A factor depends mainly on:
– driving and driven equipment characteristics,
– mass ratio,
– type of couplings,
– operating conditions (overspeed, variation of propeller load, etc.).

Operating conditions shall be carefully analysed in the rotational speed range near the critical speed.

K_A factor shall be determined by measurements or using an analytical method approved by PRS. Where the factor is impossible to be determined that way, its value may be taken in accordance with Table 5.2.3.1.

Table 5.2.3.1
Values of K_A for different applications

Gear driving machine	K_A	
	Main propulsion gears	Auxiliary gears
Diesel engine with hydraulic or electromagnetic slip clutch	1	1
Diesel engine with high elastic coupling	1.3	1.2
Diesel engine with other couplings	1.5	1.4
Electric motor	–	1

5.2.3.2 Load Sharing Factor K_γ

The load-sharing factor takes into account uneven distribution of load in multi-stage or multi-way gears (double tandem, planetary, double helical, etc. gears).

K_γ is defined as the ratio of the maximum load in true mesh to the evenly distributed load. This factor depends mainly on accuracy and flexibility of gear stages and the ways of load distribution.

K_γ shall be determined by measurements or using an analytical method. Where such methods are unavailable, K_γ shall be calculated as follows:
– for planetary gears:

$$K_\gamma = 1 + 0.25\sqrt{n_{pl} - 3} \qquad (5.2.3.2\text{-}1)$$

where:
$n_{pl} \geq 3$ – number of planet wheels

– for double tandem gears:

$$K_\gamma = 1 + \frac{0.2}{\phi} \qquad (5.2.3.2\text{-}2)$$

where:
ϕ – twist of shaft relieving liner at full load, [°]
– for double-helical gears:

$$K_\gamma = 1 + \frac{F_{ext}}{F_t \cdot \text{tg}\beta} \qquad (5.2.3.2\text{-}3)$$

where:

F_{ext} – external axial force (generated outside the gear) [N].

5.2.3.3 Dynamic Factor K_v

Dynamic factor K_v takes into account the dynamic load arising inside the gear as a result of vibrations of pinion and wheel in respect to each other.

K_v is defined as the ratio of the maximum load acting on the tooth side surface to the maximum external load defined as ($F_t \cdot K_A \cdot K_\gamma$).

This factor depends mainly on:
– mesh errors (depending on pitch and profile errors),
– pinion's and wheel's weights,
– changes in mesh rigidity during the wheel loading cycle,
– tangential velocity at working cylinder,
– dynamical unbalance of wheels and shaft,
– rigidity of shaft and bearings,

– gear damping characteristics.
Where all the following conditions are met:

a) steel gear wheels or wheels with heavy rims,

b) $\frac{F_t}{b} > 150$ [N/mm],

c) $z_1 < 50$,

d) parameter $\frac{v \cdot z_1}{100}$ is within the sub-critical range:
   – for helical gears $\frac{v \cdot z_1}{100} < 14$;
   – for spur gears $\frac{v \cdot z_1}{100} < 10$;
   – for other types of gears $\frac{v \cdot z_1}{100} < 3$

dynamic factor K_v may be calculated as follows:

.1 for spur gears:
K_v – in accordance with Fig. 5.2.3.3-2,

.2 for helical gears:
if $\varepsilon_\beta > 1$
K_v – in accordance with Fig. 5.2.3.3-1,
if $\varepsilon_\beta < 1$
K_v – is obtained by linear interpolation using the following formula:
$K_v = K_{v2} - \varepsilon_\beta \cdot (K_{v2} - K_{v1})$,
where:
K_{v1} – value of K_v for helical gears, see Fig. 5.2.3.3-1,
K_{v2} – value of K_v for spur gears see, Fig. 5.2.3.3-2.

.3 For all gear types, factor K_v may also be calculated using the following formula:

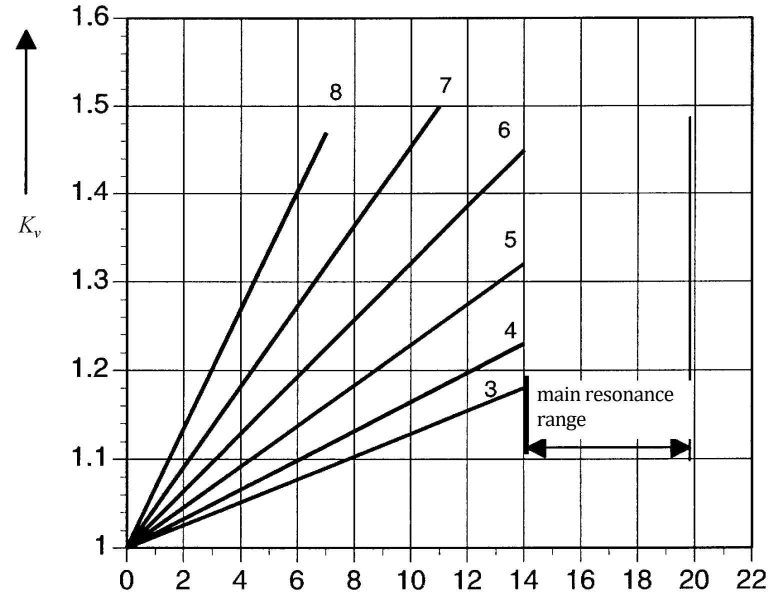
$$K_v = 1 + K_1 \cdot \frac{v \cdot z_1}{100} \qquad (5.2.3.3.3)$$

where:
K_1 – in accordance with Table 5.2.3.3.

Table 5.2.3.3
Values of K_1 for calculation of K_v

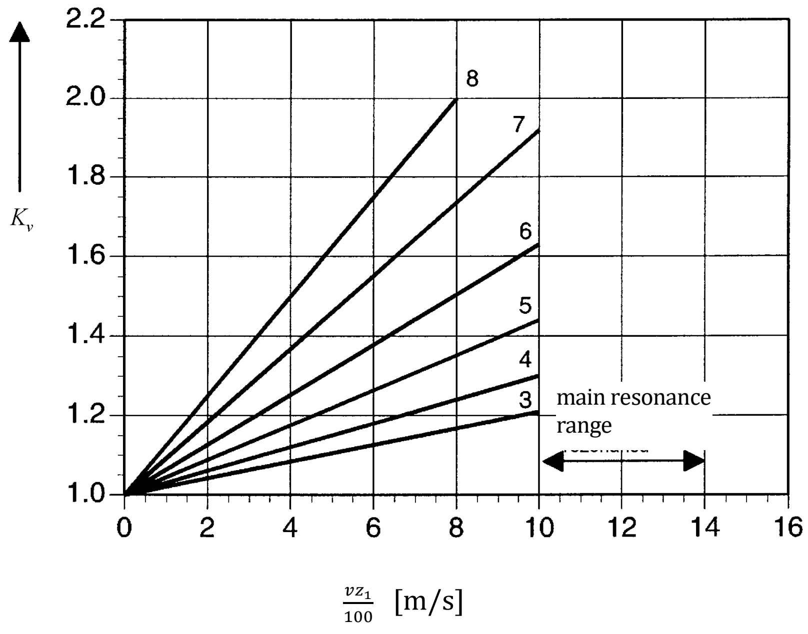
	K_1					
	Accuracy class acc. to ISO 1328					
	3	4	5	6	7	8
Spur gear	0.022	0.030	0.043	0.062	0.092	0.125
Helical gear	0.0125	0.0165	0.0230	0.0330	0.0480	0.0700

Note:
If gear wheels have been made with different accuracy classes, then the lowest class shall be taken for calculation.



$\frac{vz_1}{100}$ [m/s]

Fig.. 5.2.3.3-1.
Dynamic factor for helical gears. Accuracy classes 3 ÷ 8 acc. to ISO 1328



$\frac{vz_1}{100}$ [m/s]

Fig. 5.2.3.3-2.
Dynamic factor for spur gear. Accuracy classes 3 ÷ 8 acc. to ISO 1328

For other gears than specified above, factor K_v shall be calculated in accordance with the requirements of standard ISO 6336 – method B.

5.2.3.4 Longitudinal Load Distribution Factors $K_{H\beta}$ and $K_{F\beta}$

Longitudinal load distribution factors: $K_{H\beta}$ – for contact stress and $K_{F\beta}$ – for tooth root bending stress, take into account the effects of uneven load distribution throughout the tooth face width.

$K_{H\beta}$ is defined as:

$$K_{H\beta} = \frac{max\ contact\ stress}{mean\ contact\ stress}$$

$K_{F\beta}$ is defined as:

$$K_{F\beta} = \frac{tooth\ foot\ \max\ bending\ stress}{tooth\ foot\ mean\ bending\ stress}$$

The tooth foot mean bending stress is referred to the face width b_1 or b_2 under consideration.

Factors $K_{H\beta}$ and $K_{F\beta}$ depend mainly on:
- teeth machining accuracy;
- assembly errors due to hole boring errors;
- bearings' clearances;
- misalignment of pinion and wheel axes;
- deformations due to insufficient rigidity of gear parts, shafts, bearings, casing and foundation;
- thermal elongations and other deformations at working temperature;
- compensating construction of parts (barrel shape, tooth tips' relief etc.).

The relationship between factors $K_{F\beta}$ and $K_{H\beta}$ is as follows:

.1 For greater interface pressure at tooth tips, $K_{F\beta}$ shall be determined in accordance with the following equation:

$$K_{F\beta} = (K_{H\beta})^N \qquad (5.2.3.4.1)$$

where: $N = \frac{\left(\frac{b}{h}\right)^2}{1+\frac{b}{h}+\left(\frac{b}{h}\right)^2}$ $\frac{b}{h} = min\left(\frac{b_1}{h_1};\frac{b_2}{h_2}\right)$

Note:
For double helical gear, b shall be taken as a half of the wheel width.

.2 Where the teeth tips are subjected to low interface pressure or are relieved (barrel shape, tips' relief):

$$K_{F\beta} = K_{H\beta}$$

Contact load distribution factor $K_{H\beta}$ and tooth root bending load distribution $K_{F\beta}$ may be determined in accordance with the requirements specified in standard ISO 6336/1 – method C2.

5.2.3.5 Transverse Load Distribution Factors $K_{H\alpha}$ and $K_{F\alpha}$

Transverse load distribution factors such as:
$K_{H\alpha}$ – for contact stress,
$K_{F\alpha}$ – for tooth root bending stress,
involve the effects of pitch and profile errors on the transverse distribution of the load between two or more pairs in mesh.

Factors $K_{H\alpha}$ and $K_{F\alpha}$ depend mainly on:
- general rigidity of mesh;
- total tangential force ($F_t \cdot K_A \cdot K_\gamma \cdot K_v \cdot K_{H\beta}$);
- pitch error on pitch cylinder;
- tooth tip blunting;
- permissible variability of tangential velocity.

Transverse load distribution factors $K_{H\alpha}$ – for contact stress and $K_{F\alpha}$ – for tooth root bending stress shall be determined in accordance with the requirements specified in standard ISO 6336 -3– method B.

5.2.3.6 Factor selection methods other than those specified in sub-chapter 4.2.3 may be used subject to PRS approval in each particular case.

5.2.4 Contact Stress in Gear Wheel Teeth

5.2.4.1 The strength criterion for the contact stress is specified using Hertzian formulae for calculation of interface pressure at the active mesh point (or at the internal mesh point) of a single pair of teeth. The contact stress σ_H shall not exceed the permissible contact stress σ_{HP}.

5.2.4.2 The basic formula for calculation of the contact stress σ_H is as follows

$$\sigma_H = \sigma_{H0}\sqrt{K_A \cdot K_\gamma \cdot K_v \cdot K_{H\alpha} \cdot K_{H\beta}} \leq \sigma_{HP} \quad [\text{N/mm}^2] \qquad (5.2.4.2)$$

where:

σ_{H0} – basic value of contact stress in pinion and wheel determined using the following formulae:

$$\sigma_{H0} = Z_B \cdot Z_H \cdot Z_\varepsilon \cdot Z_\beta \cdot Z_E \cdot \sqrt{\frac{F_t}{d_{w1} \cdot b} \cdot \frac{u+1}{u}} \quad [\text{N/mm}^2] \quad \text{– for pinion,}$$

$$\sigma_{H0} = Z_D \cdot Z_H \cdot Z_\varepsilon \cdot Z_\beta \cdot Z_E \cdot \sqrt{\frac{F_t}{d_{w2} \cdot b} \cdot \frac{u+1}{u}} \quad [\text{N/mm}^2] \quad \text{– for wheel,}$$

where:

F_t, b, d, u (see sub-chapter 5.2.2);
Z_B – single tooth pair contact factor – for pinion (see paragraph 5.2.4.4);
Z_D – single tooth pair contact factor – for wheel (see paragraph 5.2.4.4);
Z_H – zone factor (see paragraph 5.2.4.5);
Z_E – flexibility factor (see paragraph 5.2.4.6);
Z_ε – contact ratio factor (see paragraph 5.2.4.7);
Z_β – helix angle factor (see paragraph 5.2.4.8);
K_A – application factor (see paragraph 5.2.3.1);
K_γ – load sharing factor (see paragraph 5.2.3.2);
K_v – dynamic factor (see paragraph 5.2.3.3);
$K_{H\alpha}$ – transverse load distribution factor (see paragraph 5.2.3.5);
$K_{H\beta}$ – longitudinal load distribution factor (see paragraph 5.2.3.4).

5.2.4.3 Calculation of Allowable Contact Stress σ_{HP}

Allowable load stresses σ_{HP} shall be calculated separately for each gear pair (pinion and wheel) using the following formula:

$$\sigma_{HP} = \frac{\sigma_{Hlim}}{S_H} \cdot Z_N \cdot Z_L \cdot Z_v \cdot Z_R \cdot Z_W \cdot Z_X \quad [\text{N/mm}^2] \qquad (5.2.4.3)$$

where:

σ_{Hlim} – fatigue strength of tooth material for contact stress, [N/mm^2] (see paragraph 5.2.4.9);
S_H – safety factor for contact stress (see paragraph 5.2.4.14);
Z_N – life factor for contact stress (see paragraph 5.2.4.10);
Z_L – lubrication factor (see paragraph 5.2.4.11);
Z_v – velocity factor (see paragraph 5.2.4.11);
Z_R – roughness factor (see paragraph 5.2.4.11);
Z_W – hardness ratio factor (see paragraph 5.2.4.12);
Z_X – size factor (see paragraph 5.2.4.13).

5.2.4.4 Single Tooth Pair Contact Factors Z_B and Z_D

Single tooth pair contact factors, Z_B – for pinion and Z_D – for wheel, take into account the tooth side curvature effect on the contact stress at the pitch point (line) of single pair of teeth with respect to Z_H.

These factors enable conversion of the contact stress determined at the pitch point into the contact stress taking into account the tooth side surface curvatures at the central point of a single pair contact.

Factors: Z_B – for pinion and Z_D – for wheel shall be determined as follows:

– for spur gearing ($\varepsilon_\beta = 0$):

$$Z_B = \max(M_1;1) \qquad (5.2.4.4\text{-}1)$$

$$Z_D = \max(M_2;1) \qquad (5.2.4.4\text{-}2)$$

where:

$$M_1 = \frac{tg\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \frac{2\pi}{z_1}\right] \cdot \left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_2}\right]}}$$

$$M_2 = \frac{tg\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - \frac{2\pi}{z_2}\right] \cdot \left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_1}\right]}}$$

– for helical gearing where,
if $\varepsilon_\beta \geq 1$

$$Z_B = Z_D = 1$$

if $\varepsilon_\beta < 1$, the values of Z_B and Z_D shall be determined by linear interpolation from the corresponding values of Z_B and Z_D for spur gears and for helical gears, for which $\varepsilon_\beta \geq 1$.

Therefore:

$$Z_B = max\{[M_1 - \varepsilon_\beta \cdot (M_1 - 1)]; 1\} \qquad (5.2.4.4\text{-}3)$$

$$Z_D = max\{[M_2 - \varepsilon_\beta \cdot (M_2 - 1)]; 1\} \qquad (5.2.4.4\text{-}4)$$

5.2.4.5 Zone Factor Z_H

Zone factor Z_H takes into account the effect of tooth side curvature at the pitch point on the interface pressure defined by Hertzian formulae and on the ratio of the tangent forces at pitch cylinder to the normal forces at working cylinder.

Zone factor Z_H shall be calculated using the following formula:

$$Z_H = \sqrt{\frac{2\cos\beta_b \cdot \cos\alpha_{tw}}{\cos^2\alpha_t \cdot \sin\alpha_{tw}}} \qquad (5.2.4.5)$$

5.2.4.6 Material Elasticity Factor Z_E

Material elasticity factor Z_E takes into account the effect of the material elasticity determined by Young's modulus and Poisson ratio on the contact stress calculated using Hertzian formulae.

Factor Z_E shall be calculated using the following formula:

$$Z_E = \sqrt{\frac{E_1 \cdot E_2}{\pi[(1-v_1^2) \cdot E_1 + (1-v_2^2) \cdot E_2]}} \quad [\text{N}^{1/2}/\text{mm}] \tag{5.2.4.6}$$

where:

E_1, E_2 – Young's modulus for tooth material, [N/mm²];
ν_1, ν_2 – Poisson ratio for tooth material, [–].

For steel gear wheels where $E_1 = E_2 = 206\,000$ N/mm² and $\nu_1 = \nu_2 = 0.3$, the elasticity factor is:

$$Z_E = 189.8 \quad [\text{N}^{1/2}/\text{mm}].$$

Standard ISO 6336 may be used to determine the value of Z_E .

5.2.4.7 Contact Ratio Factor Z_ε

Contact ratio factor Z_ε takes into account transverse contact ratio ε_α and pitch overlap ratio ε_β on the specific teeth contact load.

Contact ratio factor Z_ε shall be calculated as follows:

– for spur gears using the following formula:

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}} \tag{5.2.4.7-1}$$

– for helical gears using an appropriate alternative formula:

if $\varepsilon_\beta < 1$

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3} \cdot (1-\varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \tag{5.2.4.7-2}$$

if $\varepsilon_\beta \geq 1$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \tag{5.2.4.7-3}$$

5.2.4.8 Helix Angle Factor Z_β

Helix angle factor Z_β takes into account the effect of helix angle on the surface durability, considering such variables as load distribution along the contact line. Z_β depends on the helix angle only.

Helix angle factor Z_β shall be calculated using the following formula:

$$Z_\beta = \sqrt{\cos\beta} \tag{5.2.4.8}$$

5.2.4.9 Endurance Limit for Hertzian Contact Stress $\sigma_{H\lim}$

The value of $\sigma_{H\lim}$ represents the permissible continuously repeated contact stress for a certain material. This value may be considered a level of contact stress which the material can endure throughout at least $5 \cdot 10^7$ stress cycles with no pitting effect.

For this purpose pitting may be determined:

– for not hardened surfaces of teeth, if the pitting area exceeds 2% of the total working surface,
– for hardened surfaces of teeth, if pitting area is greater than 0.5% of the total working surface or exceeds 4% of a single tooth total surface.

The value of $\sigma_{H\lim}$ corresponds to 1% (or lower) likelihood of damage.

The endurance limit for Hertzian contact stress depends mainly on:
- material composition, homogeneity and defects;
- mechanical properties;
- residual stress;
- hardening process, hardened layer depth, hardening gradient;
- material structure (forged, rolled, cast).

The allowable value of contact stress $\sigma_{H\text{lim}}$ shall be determined in accordance with the test results of the material used for the construction. If such results are unavailable, the contact stress shall be determined in accordance with the requirements of standard ISO 6336-5 – Quality Class MQ.

5.2.4.10 Life Factor for Contact Stress Z_N

Life factor for contact stress Z_N takes into account higher allowable contact stress where limited durability (i.e. lower number of load cycles) is required.

The factor depends mainly on:
- material and hardening method;
- number of load cycles;
- Z_R, Z_v, Z_L, Z_W, Z_X factors.

Life factor for contact stress Z_N shall be determined in accordance with the requirements specified in standard ISO 6336/2 – method B.

5.2.4.11 Lubrication, Velocity and Roughness Factors Z_L, Z_v and Z_R

Lubrication factor Z_L takes into account the lubricant type and viscosity, velocity factor Z_v , and also takes into account the effect of tangential velocity (v) at pitch diameter, while roughness factor Z_R takes into account the effect of surface roughness on its durability.

These factors shall be calculated for the softer material where the intermating teeth have different hardness.

These factors depend mainly on:
- the lubricating oil viscosity in the teeth contact area;
- the sum of momentary velocities on the teeth surfaces;
- the load;
- the relative radius of curvature at pitch point;
- roughness of tooth surface;
- hardness of pinion and wheel.

These factors shall be determined as follows:

.1 Lubrication factor Z_L shall be calculated using the following formula:

$$Z_L = C_{ZL} + \frac{4(1-C_{ZL})}{\left(1.2+\frac{134}{v_{40}}\right)^2} \qquad (5.2.4.11.1)$$

where:

ν_{40} – rated kinematic viscosity of the oil used in the gear at temperature of 40 °C.

$C_{ZL} = \left(\frac{\sigma_{Hlim}-850}{350}\right)0.08 + 0.83$ for $850 \le \sigma_{H\text{lim}} \le 1200$ [N/mm²]

Note:

If $\sigma_{H\text{lim}} < 850$ MPa, then $C_{ZL} = 0.83$.

If $\sigma_{H\text{lim}} > 1200$ MPa, then $C_{ZL} = 0.91$.

.2 Velocity factor Z_v shall be calculated using the following formula:

$$Z_v = C_{ZV} + \frac{2(1-C_{ZV})}{\sqrt{0{,}8+\frac{32}{v}}} \quad (5.2.4.11.2)$$

where:

$C_{ZV} = \left(\frac{\sigma_{Hlim}-850}{350}0.08\right) + 0.85$ for $850 \le \sigma_{Hlim} \le 1200$ [N/mm²]

Note:

If $\sigma_{Hlim} < 850$ MPa, then $C_{ZV} = 0.85$.

If $\sigma_{Hlim} > 1200$ MPa, then $C_{ZV} = 0.93$.

.3 Roughness factor Z_R shall be calculated using the following formula:

$$Z_R = \left(\frac{3}{R_{Z10}}\right)^{C_{ZR}} \quad (5.2.4.11.3)$$

where:

$C_{ZR} = 0.32 - 0.0002\sigma_{Hlim}$ for $850 \le \sigma_{Hlim} \le 1200$ [N/mm²]

Note:

If $\sigma_{Hlim} <$ 850 N / mm², then $C_{ZR} = 0.150$.
If $\sigma_{Hlim} >$ 1200 N / mm², then $C_{ZR} = 0.080$.

R_{Z10} – mean amplitude of roughness in intermating wheels referred to the relative radius of teeth curvature, [μm]

$$R_{Z10} = R_{red}\sqrt[3]{\frac{10}{\rho_{red}}}$$

where:

R_{red} – mean amplitude of roughness height in intermating wheels (to be calculated in accordance with standard ISO 6336), [μm]

$$R_{red} = \frac{R_{Z1}+R_{Z2}}{2}$$, where

if the roughness is given as mean value – R_a

$$R_{Z1} = 6R_{a1}$$

$$R_{Z2} = 6R_{a2}$$

where:

R_{Z1} – pinion roughness height, [μm];
R_{Z2} – wheel roughness height, [μm];
R_{a1} – arithmetic mean of profile deviation from mean pinion profile, [μm];
R_{a2} – arithmetic mean of profile deviation from mean wheel profile, [μm].

Note:
Roughness shall be measured at sides of several teeth.

ρ_{red} – relative radius of teeth curvature in intermating wheels

$$\rho_{red} = \frac{\rho_1\rho_2}{\rho_1+\rho_2}$$

where: $\rho_{1,2} = 0.5d_{b1,2}tg\alpha_{tw}$

Note:
d_{b2} is negative for internal gearing.

5.2.4.12 Hardness Ratio Factor Z_W

Hardness ratio factor Z_W takes into account the durability effect of teeth made of soft steel, intermating with much harder teeth with smooth surface.

Factor Z_W applies only to softer teeth and depends mainly on:
- softer teeth hardness;
- alloying components of softer teeth;
- roughness of harder teeth sides.

Factor Z_W shall be calculated using the following formula:

$$Z_W = 1.2 - \frac{HB-130}{1700} \qquad (5.2.4.12)$$

where:
HB – softer material Brinell hardness (BHN),
- if $HB < 130$, then $Z_W = 1.2$;
- if $HB > 470$, then $Z_W = 1$.

5.2.4.13 Size Factor Z_X

Size factor Z_X takes into account the tooth size effect on permissible contact stress as well as inhomogeneity of the materials' properties.

This factor depends mainly on:
- material and its heat treatment;
- teeth and gear box sizes;
- hardening depth ratio to tooth dimensions;
- hardening depth ratio to virtual radius of curvature.

For through hardened teeth and surface hardened teeth with hardening depth appropriate to both the teeth size and relative radius of curvature $Z_X = 1$. If hardening depth is relatively low, then the lesser values of Z_X shall be adopted.

5.2.4.14 Contact Stress Safety Factor S_H

The magnitude of safety factor for contact stress S_H depends on the intended use of a gear box, as well as whether it is intended to be used as a single unit or as an element of a set consisting of two or more gear boxes.

The safety factor shall be selected from Table 5.2.4.14.

Table 5.2.4.14

Drive type	S_H	
	Multiple set	Single set
Main propulsion gears	1.2	1.4
Auxiliary gears	1.15	1.2

For gearing of independent duplicated propulsion or auxiliary machinery installed onboard the vessel in the number greater than required by the *Rules*, a reduced value of S_H may be assumed subject to PRS acceptance in each particular case.

5.2.5 Bending Stress in Gear Wheel Tooth Root

5.2.5.1 A criterion for bending stress in tooth root determines the permissible level of local tensile stress in the tooth root. The root bending stress σ_F and the permissible root bending stress σ_{FP} shall be calculated separately for the pinion and wheel. The value of σ_F shall not exceed that of σ_{FP}. The following formulae apply to gears with toothed rim thickness greater than 3.5 m_n for $\alpha_n \leq 25°$ and $\beta \leq 30°$. For greater values of α_n and β the calculation results shall be confirmed experimentally or verified in accordance with the requirements specified in standard ISO6336 – Method A.

5.2.5.2 The basic formula for bending stress calculation is as follows:

$$\sigma_F = \frac{F_t}{b \cdot m_n} \cdot Y_F \cdot Y_S \cdot Y_\beta \cdot K_A \cdot K_\gamma \cdot K_v \cdot K_{F\alpha} \cdot K_{F\beta} \leq \sigma_{FP} \quad [\text{N/mm}^2] \qquad (5.2.5.2)$$

where:

F_t, b, m_n (see paragraph 5.2.2.2);
Y_F – tooth-form factor (see paragraph 5.2.5.4);
Y_S – stress correction factor (see paragraph 5.2.5.5);
Y_β – helix angle factor (see paragraph 5.2.5.6);
K_A – application factor (see paragraph 5.2.3.1);
K_γ – load sharing factor (see paragraph 5.2.3.2);
K_v – dynamic factor (see paragraph 5.2.3.3);
$K_{F\alpha}$ – transverse load distribution factor (see paragraph 5.2.3.5);
$K_{F\beta}$ – longitudinal load distribution factor (see paragraph 5.2.3.4).

5.2.5.3 The basic formula for allowable bending stress calculation σ_{FP} is as follows:

$$\sigma_{FP} = \frac{\sigma_{FE}}{S_F} \cdot Y_d \cdot Y_N \cdot Y_{\delta relT} \cdot Y_{RrelT} \cdot Y_X \quad [\text{N/mm}^2] \qquad (5.2.5.3)$$

where:

σ_{FE} – endurance limit for bending stress, [N/mm^2] (see paragraph 5.2.5.7);
S_F – safety factor for root bending stress (see paragraph 5.2.5.13);
Y_d – design factor (see paragraph 5.2.5.8);
Y_N – life factor for tooth root (see paragraph 5.2.5.9);
$Y_{\delta relT}$ – relative notch sensitivity factor (see paragraph 5.2.5.10);
Y_{RrelT} – relative surface finish factor (see paragraph 5.2.5.11);
Y_X – size factor (see paragraph 5.2.5.12).

5.2.5.4 Tooth Profile Factor Y_F

Tooth profile factor Y_F takes into account an effect of the tooth profile on the nominal bending stress caused by the force applied in the single tooth pair external contact. Factor Y_F shall be determined separately for the pinion and wheel. For helical gears, the tooth form factor shall be determined for the normal section, i.e. for the virtual spur gear with virtual number of teeth z_n .

Tooth profile factor Y_F shall be determined in accordance with the formula below:

$$Y_F = \frac{6 \cdot \frac{h_F}{m_n} \cdot \cos\alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n}\right)^2 \cdot \cos\alpha_n} \quad \text{for } \alpha \leq 25° \text{ and } \beta \leq 30° \qquad (5.2.5.4)$$

where:

h_F – bending moment arm for root stress caused by the force applied in the single tooth pair external contact [mm];
s_{Fn} – tooth root chord in critical section [mm];

α_{Fen} – pressure angle in the single tooth pair external contact at normal section, [°].

Note:
The quantities used to determine Y_F are shown in Fig. 5.2.5.5.

To determine h_F, s_{Fn} and α_{Fen}, the guidelines specified in standard ISO 6336 may be applied.

5.2.5.5 Stress Concentration Factor Y_S

Stress concentration factor Y_S is used for conversion of the nominal bending stress into local stress in the tooth root at the assumption that not only bending stress occurs in the tooth root.

Factor Y_S concerns the force applied in the single tooth pair external contact and shall be determined separately for the pinion and wheel.

Stress concentration factor Y_S shall be determined in accordance with the formula below:

$$Y_S = (1.2 + 0.13 \cdot L) \cdot q_S^{\left(\frac{1}{1.12+\frac{2.3}{L}}\right)} \quad \text{for } 1 \le q_S < 8 \qquad (5.2.5.5)$$

where:
q_S – notch parameter determined in accordance with the formula below:

$$q_S = \frac{S_{Fn}}{2\rho_F}$$

where:
ρ_F – tooth root fillet radius, [mm];
L – bending factor determined in accordance with the formula below:

$$L = \frac{S_{Fn}}{h_F}$$

h_F, s_{Fn} – see paragraph 5.2.5.4.

To determine ρ_F, the guidelines specified in standard ISO 6336 may be applied.

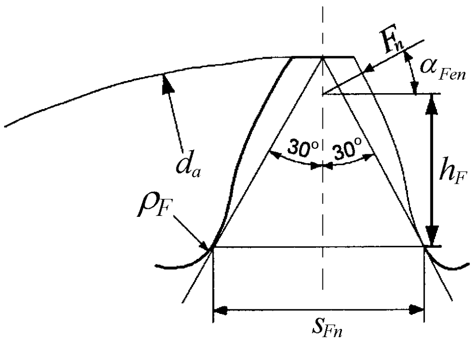


Fig. 5.2.5.5

5.2.5.6 Helix Angle Factor Y_β

Helix angle factor Y_β takes into account the difference between the helix gears and virtual spur gears in the and virtual spur gearing at normal section for which the calculations are performed. As the contact lines are helical and along the tooth side surface, more favourable stress conditions in the tooth root are taken into account.

The helix angle factor depends on ε_β as well as β, and shall be determined in accordance with the formula below:

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120} \qquad (5.2.5.6)$$

It shall be taken that:
$\varepsilon_\beta = 1$, where $\varepsilon_\beta > 1$ and
$\beta = 30°$, where $\beta > 30°$.

5.2.5.7 Endurance Limit For Bending Stress σ_{FE}

Endurance limit for bending stress σ_{FE} for the particular material represents the value of local tooth root stress limit for long life.

According to standard ISO 6336, 3 x 10^6 stress cycles is considered to be the beginning of the long life strength range for bending stress is considered the stress limit determined for the number of 3 x 10^6 stress cycles.

The quantity of σ_{FE} is determined as non-directional fluctuating load of the minimum value equal to zero (the residual stress due to heat treatment is neglected). Other conditions, such as fluctuating stress, overload etc., are taken into account by the design factor Y_d.

The quantity of σ_{FE} corresponds to the probability of damage not exceeding 1%.

The endurance limit depends mainly on:
- material composition, purity and imperfections;
- mechanical conditions;
- residual stress;
- hardening procedure, hardened zone depth, hardness gradient;
- material structure (forging, casting, rolled material).

Endurance limit for bending stress σ_{FE} shall be determined in accordance with the results of the tests of actual materials applied. Where such test results are unavailable, the value of the endurance limit for bending stress σ_{FE} shall be determined in accordance with the requirements specified in standard ISO 6336-5 – quality grade MQ.

5.2.5.8 Design Factor Y_d

Design factor Y_d takes into account the effect of load while the vessel is going astern and overload due to shrink fit on the tooth root strength compared to the strength of tooth root loaded non-directionally as determined for σ_{FE}.

Design factor Y_d for the load while the vessel is going astern shall be determined in accordance with Table 5.2.5.8.

Table 5.2.5.8

	Y_d
In general	1
For gear wheels sporadically loaded with partial power output while the vessel is going astern, such as main wheels in reversing gears	0.9
For idle running gear wheels	0.7

5.2.5.9 Life Factor for Tooth Root Y_N

Life factor for tooth root Y_N takes into account the possibility of increased allowable bending stress where the gear box limited life (number of stress cycles) is permitted.

This factor depends mainly on:
- material and hardening;
- number of stress cycles;
- factors $Y_{\delta relT}$, Y_{RrelT}, Y_X.

The life factor for tooth root shall be determined in accordance with the requirements specified in standard ISO 6336-5 – method B.

5.2.5.10 Relative Notch Sensitivity Factor $Y_{\delta relT}$

Relative notch sensitivity factor $Y_{\delta relT}$ indicates the range where theoretical stress concentration is greater than the endurance limit.

This factor depends mainly on the material and relative gradient of stress.

The factor shall be taken as follows:
- for notch parameters (see paragraph 5.2.5.5) within $1.5 \le q_S < 4$, $Y_{\delta relT} = 1$;
- for notch parameters beyond that interval, in accordance with the requirements specified in standard ISO 6336.

5.2.5.11 Relative Surface Finish Factor Y_{RrelT}

Relative surface finish factor Y_{RrelT} takes into account the relation between the tooth root strength and the surface finish of the tooth root fillet, mainly the roughness amplitude.

Relative surface finish factor Y_{RrelT} shall be determined in accordance with Table 5.2.5.11:

Table 5.2.5.11

	$R_Z < 1$	$1 \le R_Z \le 40$	Material
Y_{RrelT}	1.120	$1{,}675 - 0{,}53 \cdot (R_Z + 1)^{0{,}1}$	carburized steels, through hardened steels ($\sigma_B \ge 800$ N/mm²)
	1.070	$5{,}3 - 4{,}2 \cdot (R_Z + 1)^{0{,}01}$	normalized steels ($\sigma_B < 800$ N/mm²)
	1.025	$4{,}3 - 3{,}26 \cdot (R_Z + 1)^{0{,}005}$	nitrided steels

Note:
1. R_Z – average maximum height of the roughness profile of the tooth root fillet.
2. Where the roughness is defined as the arithmetical mean deviation of the profile (R_a), the following formula applies:

$$R_Z = 6R_a.$$

This method is applicable only where scratches and similar surface defects are not greater than $2R_Z$.

5.2.5.12 Size Factor Y_X

Size factor Y_X takes into account the reduction in the strength as the tooth size grows.

This factor depends mainly on:
- material and heat treatment;
- tooth module and dimensions of gear wheels;
- case depth to tooth size ratio.

Size factor Y_X shall be determined in accordance with Table 5.2.5.12.

Table 5.2.5.12
Size factor Y_X

$Y_X = 1.00$	for $m_n \leq 5$	In general
$Y_X = 1.03 - 0.006\, m_n$	for $5 < m_n < 30$	normalized steels and through hardened steels
$Y_X = 0.85$	for $m_n \geq 30$	
$Y_X = 1.05 - 0.010\, m_n$	for $5 < m_n < 25$	skin hardened steels
$Y_X = 0.80$	for $m_n \geq 25$	

5.2.5.13 Safety Factor for Tooth Root Bending Stress S_F

The quantity of safety factor for tooth root bending stress S_F depends on the gear box intended service and also on whether it is applied in a single unit, or in two or more units.

Safety factor for tooth root bending stress S_F shall be determined in accordance with Table 5.2.5.13.

Table 5.2.5.13

	S_F	
Drive type	Two and more units	Single unit
Main drive	1.55	2
Auxiliary drive	1.4	1.45

For independent duplicated main propulsion gears and gears of auxiliary machinery installed on board the vessel in the number greater than required by the *Rules*, the value of S_H may be reduced subject to PRS acceptance in each particular case.

5.2.6 Shafts

Shafts which are not subjected to variable bending loads shall fulfil, to the applicable extent, the requirements specified in sub-chapters 3.2, 3.3, 3.4, 3.6.

5.2.7 Gear Wheel Manufacturing – General Notes

5.2.7.1 Welded gear wheels shall be in the stress-relieved condition.

5.2.7.2 Shrink fitted toothed wheel rims shall be so designed to transmit double maximum dynamic torque.

Friction factors for the calculation of shrink fit shall be taken in accordance with Table 5.2.7.2.

Table 5.2.7.2

Fitting method	steel/steel	steel/cast iron, including nodular cast iron
Oil heated rim	0.13	0.10
Rim heated in gas furnace (not protected against oil penetration to the rim-wheel contact surface)	0.15	0.12
Contact surfaces degreased and protected against oil penetration	0.18	0.14

Instead of the shrink fit calculations, the results of shrink fit tests with the proof load (in the full range); the testing procedure and proof load selection are subject to PRS acceptance in each particular case.

5.2.8 Bearing System

5.2.8.1 Thrust bearing and its foundation shall have sufficient stiffness to prevent adverse deflection and longitudinal vibration of shaft.

5.2.8.2 In general, roller bearings of the main propulsion gear shall be calculated to life time L_{10} equal to:
- 40 000 hours for propeller thrust bearings;
- 30 000 hours for other bearings.

Shorter lifetime may be considered where bearing condition monitoring equipment is provided or operating instructions require inspection of bearings with proper frequency.

The required lifetime of astern propulsion bearings shall be taken as 5% of the above specified values.

5.2.9 Gearcases

5.2.9.1 Gearcases and their supports shall be designed sufficiently stiff so that movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

Inspection openings shall be provided in gearcases to enable the teeth of pinions and of wheels to be readily examined.

5.2.9.2 Gearcases fabricated by fusion welding or casting shall be stress relieved before machining operations.

5.2.10 Lubrication

5.2.10.1 Lubrication system shall ensure proper supply of oil to the bearings, teeth and other parts which need lubrication.

5.2.10.2 In gears with medium loads and speeds provided with roller bearings, splash lubrication is permitted.

5.2.10.3 In pressure oil systems, adequate filtering arrangements shall be provided.

Filters in lubrication systems of single main gears shall be so designed as to enable their cleaning without stopping the propulsion system.

5.2.10.4 In pressure oil systems, arrangements for measurement of input and output pressure and temperature as well as alarms giving warning of reaching low oil pressure shall be provided.

In splash lubrication systems, arrangements shall be provided for measurement of oil level in the gearcase.

5.3 Disengaging and Flexible Couplings

5.3.1 General Requirements

5.3.1.1 The requirements specified in this sub-chapter apply to disengaging and flexible couplings.

5.3.1.2 Documentation concerning flexible couplings (see paragraph 1.3.3.2.9) shall include the following characteristics:
T_{KN} – rated torque for continuous operation;
$T_{K\max}$ – maximum torque for operation in transient conditions;

T_{KW} – allowable dynamic torque for the full range of torques from 0 to T_{KN};
$C_{T\ DYN}$ – dynamic stiffness for the full ranges of torques T_{KN} and T_{KW};
– rotational speed limit;
– allowable torque transmitted by the angular displacement limiter (where provided).

Additionally – for information – the following data shall be provided:
- damping coefficient for the full variation ranges of torques T_{KN} and T_{KW};
- allowable power loss P_{KV} in coupling;
- allowable axial and radial displacements as well as angular misalignment;
- allowable service time of flexible components until compulsory replacement.

5.3.1.3 Rigid elements transmitting torque (except for bolts) shall be made from a material with tensile strength $400 < R_m \leq 800$ MPa.

5.3.1.4 Flange couplings shall fulfil the requirements specified in sub-chapter 3.6.

The procedure of keyless fitting of couplings is subject to PRS acceptance in each particular case.

5.3.2 Flexible Couplings

5.3.2.1 Flexible couplings intended for shafting of the vessels with one main engine shall be provided with proper arrangements to enable maintaining sufficient speed of vessel to ensure its steering qualities when flexible elements have been damaged.

5.3.2.2 If the requirement specified in paragraph 5.3.2.1 is not fulfilled, the static torque breaking elements made from rubber or other synthetic materials shall not be less than eightfold value of the coupling rated torque.

5.3.2.3 The static torque breaking flexible elements in generating sets shall not be less than the torque resulting from the short-circuit current.

Where relevant data are unavailable, the breaking torque shall not be less than 4.5 times as much as the coupling rated torque.

5.3.2.4 Flexible couplings shall endure long-lasting continuous load with the rated torque within the range of temperatures from 5 °C to 60 °C.

5.3.3 Disengaging Couplings

5.3.3.1 Disengaging couplings of main engines shall be operated from the engine control stands, and shall also be provided with local control arrangements. The control devices shall ensure so smooth engagement of the coupling that the momentary dynamic load does not exceed the maximum torque specified by the manufacturer or double rated engine torque.

5.3.3.2 Where one propeller shaft is driven by two or more main reversible engines through disengaging couplings – the controllers shall be so designed that their simultaneous engagement is impossible unless the engines provide the same direction of the vessel motion.

5.3.4 Emergency Means

Where the propeller shaft is driven through:
- hydraulic or electromagnetic transmission,
- hydraulic or electromagnetic clutch,

provision shall be made to maintain the vessel motion with a speed enabling its steering qualities in case of failure of the above-mentioned couplings.

6 AUXILIARY MACHINERY

6.1 Power-driven Air Compressors

6.1.1 General Requirements

6.1.1.1 Compressors shall be so designed that the air temperature at the air cooler outlet does not exceed 90 °C.

6.1.1.2 Each compressor stage or stub pipe at the immediate outlet from the compressor stage shall be fitted with safety valve preventing the pressure rise in the stage above 1.1 times the rated pressure when the delivery pipe valve is closed.

The construction of safety valve shall preclude the possibility of its adjustment or disconnection after being fitted on the compressor.

6.1.1.3 Compressor crankcases of more than 0.5 m^3 in volume shall be fitted with safety valves which fulfil the requirements specified in paragraph 2.2.6.

6.1.1.4 Delivery stub pipe or the immediate outlet of compressor shall be fitted with a fuse or an alarm with the activation temperature not exceeding 120 °C.

6.1.1.5 Bodies of coolers shall be fitted with safety devices ensuring a free outlet of air in case of the pipes' breakage.

6.1.2 Crankshaft

6.1.2.1 The method of verifying calculations specified in paragraphs 6.1.2.3 and 6.1.2.4 applies to the steel crankshafts of naval air compressors with in-line, and V-shaped arrangement of cylinders with single and multi-stage compression.

6.1.2.2 Crankshafts shall be made of steel having tensile strength R_m ranging from 410 to 780 MPa.

Application of steel having a tensile strength over 780 MPa is subject to PRS acceptance in each particular case.

Crankshafts may be made of nodular cast iron with a tensile strength $500 \le R_m \le 700$ MPa as required in Chapter 15 of *Part IX – Materials and Welding* of the *Rules for Classification and Construction of Sea-going Ships*.

Crankshafts with other dimensions than those determined by the formulae given below may be applied subject to PRS acceptance in each particular case, provided that complete strength calculations are submitted.

6.1.2.3 Crank pin diameter (d_k) of the compressor shall not be less than determined in accordance with the formula below:

$$d_k = 0.25K\sqrt[3]{D^2 p\sqrt{0.3L^2 f + (S\varphi)^2}} \quad \text{[mm]} \qquad (6.1.2.3\text{-}1)$$

where:

D – design diameter of cylinder, [mm], equal to:
- for single-stage compression
  $D = D_C$ (D_C – cylinder diameter),
- for two- and multi-stage compression in separate cylinders
  $D = D_W$ (D_W – high pressure cylinder diameter),

– for two-stage compression by a step piston
$D = 1.4\ D_W$,
– for two-stage compression by a differential piston
$D = \sqrt{D_n^2 - D_W^2}$ (D_n – low pressure cylinder diameter);

p – compression pressure in high pressure cylinder, [MPa];
L – design distance between main bearings, [mm], equal to:
– where one crank is arranged between two main bearings $L = L'$
– (L' – actual distance between centres of main bearings);
– where two cranks with 180° angle are arranged between two main bearings $L = 1{,}1\ L'$;
S – piston stroke, [mm];
K, f, φ – coefficients determined in accordance with Tables 6.1.2.3-1, 6.1.2.3-2 and 6.1.2.3-3.

Table 6.1.2.3-1
Values of coefficient *K*

Tensile strength, [MPa]	390	490	590	690	780	880
K	1.43	1.35	1.28	1.23	1.2	1.18

Table 6.1.2.3-2
Values of coefficient *f*

Angle between cylinder axes	0° (in line)	45°	60°	90°
f	1.0	2.9	1.96	1.21

Table 6.1.2.3-3
Values of coefficient φ

Number of cylinders	1	2	4	6	8
φ_1	1.0	1.1	1.2	1.3	1.4

If crankshaft journals have co-axial holes with diameters exceeding 0.4 d_k, then the journal diameters shall be determined in accordance with the formula below:

$$d_{k0} \geq d_k \sqrt[3]{\frac{1}{1-\left(\frac{d_0}{d_a}\right)^4}} \ \text{[mm]} \qquad (6.1.2.3\text{-}2)$$

d_k – see formula 6.1.2.3-1;
d_0 – co-axial hole diameter, [mm];
d_a – actual diameter of shaft [mm].

Edges of oil holes on journal surfaces shall be rounded to a radius not less than 0.25 times the hole diameter with a smooth finish.

6.1.2.4 Thickness of the crank web h_k shall not be less than that determined in accordance with the formula below:

$$h_k = 0.105 K_1 D \sqrt{\frac{(\psi_1 \psi_2 + 0.4) P C_1 f_1}{b}} \ \text{[mm]} \qquad (6.1.2.4\text{-}1)$$

K_1 – coefficient taking into account the effect of shaft material and determined in accordance with the formula below:

$$K_1 = a \sqrt[3]{\frac{R_m}{2R_m - 430}} \qquad (6.1.2.4\text{-}2)$$

a = 0.9 for shafts with entire surface nitrided or subjected to other kind of heat treatment accepted by PRS,
a = 0.95 for die forged shafts with the fibre continuity being maintained,
a = 1 for shafts not subjectet to quenching and tempering;
ψ_1 and ψ_2 – coefficients determined in accordance with Tables 6.1.2.4-1 and 6.1.2.4-2;
P – compression pressure taken in accordance with relevant provisions of paragraph 6.1.2.3;
C_1 – distance from the centre of the main bearing to the midplane of the crank web, [mm]; where two cranks are arranged between two main bearings, the distance to the midplane of the web located further from the support under consideration shall be taken;
b – breadth of crank web, [mm];
f_1 – coefficient taken in accordance with Table 6.1.2.4-3;
R_m – tensile strength, [MPa].

Table 6.1.2.4-1
Values of coefficient ψ_1

r/h_k \ ε/h_k	0	0.2	0.4	0.6	0.8	1.0	1.2
0.07	4.5	4.5	4.28	4.1	3.7	3.3	2.75
0.10	3.5	3.5	3.34	3.18	2.85	2.57	2.18
0.15	2.9	2.9	2.82	2.65	2.4	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	2.2	2.1	1.9	1.7	1.4

Note:
r – fillet radius of the transition from crank web to crank pin, [mm];
ε – value of overlap, [mm].

For crankshafts without the crank pin overlap, coefficient ψ_1 shall be taken as for ε/h_k = 0.

Table 6.1.2.4-2
Values of coefficient ψ_2

b/d_k	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

d_k – see formula 6.1.2.3-1.

Intermediate values of the coeffieints specified in Tables 6.1.2.4-1 and 6.1.2.4-2 shall be determined by linear interpolation.

Table 6.1.2.4-3
Values of coefficient f_1

Angle between cylinder axes	0° (in line)	45°	60°	90°
f_1	1.0	1.7	1.4	1.1

6.1.2.5 The radius of fillet of the crank pin and crank web shall not be less than 0.05 the crank pin diameter.

The radius of fillet of the crank pin and the coupling flange shall not be less than 0.08 the crank pin diameter.

Surface hardening of crank pins and journals shall not be applied to fillets, except when the entire shaft has been subjected to hardening.

6.2 Pumps

6.2.1 General Requirements

6.2.1.1 Unless the pumped liquid is used for the lubrication of bearings, provision shall be made to prevent the pumped liquid from penetration into the bearings.

6.2.1.2 It is recommended that the pump sealing on the suction side be fitted with hydraulic seals.

6.2.1.3 Where the pump construction enables the rise of pressure above the rated value, a safety valve shall be fitted on the pump casing or on the delivery pipe before the first stop valve.

6.2.1.4 Provision shall be made to prevent water hammer. Application of overflow valves for this purpose is not recommended.

6.2.1.5 Strength Calculation

Critical speed of pump impeller shall not be less than 1.3 of the rated r.p.m.

6.2.1.6 Self-priming pumps

Self-priming pumps shall ensure operation under "dry-suction" conditions and it is recommended that they be fitted with arrangements preventing the self-priming device against being damaged as a result of impure water pumping.

6.2.2 Additional Requirements for Flammable Liquid Pumps

6.2.2.1 Safety valve (see paragraph 6.2.1.3) shall let the liquid into the suction side of a pump.

6.2.2.2 Pump seals shall be of such construction and materials, that no vapour/air explosive mixture is generated in case of leakage.

6.2.2.3 The construction of dynamic seals shall prevent the possibility of overheating and self-ignition of seals due to friction of the moving elements.

6.2.2.4 The construction of pumps made of low electrical conductivity materials (plastics, rubber, etc.), shall prevent accumulation of electrostatic charges, or special means for electric charge neutralisation shall be provided.

6.3 Fans, Air Blowers and Turbochargers

6.3.1 General Requirements

6.3.1.1 The requirements specified in this sub-chapter apply to fans intended for systems covered by requirements of *Part VI*, as well as to internal combustion engine turbo-blowers.

6.3.1.2 Impellers of fans and air blowers, including couplings, as well as the assembled rotors of turbochargers shall be dynamically balanced together with couplings in accordance with the requirements specified in paragraph 5.1.2.

6.3.1.3 Suction ports shall be protected against the entry of incidental solids.

6.3.1.4 Lubrication system of the turbo-blower bearings shall prevent the possibility of penetration of oil into the supercharging air.

6.3.1.5 Strength Calculations

The impeller parts shall be so designed that the equivalent stress at any section will not exceed 0.95 of the material yield point at rotational speed equal to 1.3 of the rated speed.

For turbo-blowers, other safety factors may be applied subject to PRS acceptance in each particular case, provided that calculation methods determining the maximum local stress or elastoplastic methods have been used.

6.3.2 Additional Requirements for Pump Room Fans

6.3.2.1 The air gap between the casing and rotor shall not be less than 0.1 of the rotor shaft bearing journal diameter and not less than 2 mm, but it is not required for the air gap to be greater than 13 mm.

6.3.2.2 Terminals of ventilation ducts shall be protected from entering of foreign matters into the fan casings by means of wire net, with square net mesh of the side length not exceeding 13 mm.

6.3.2.3 Pump room ventilation fans shall be of non-sparking design. The fan is not sparking if in both normal and abnormal conditions there is no risk of spark generation. Casing and rotating parts of fan shall be made of such materials, which do not cause electric charge accumulation, and the fans installed shall be properly earthed to the hull of vessel in accordance with the requirements specified in *Part VII – Electrical Equipment and Automatic Control*.

6.3.2.4 Except the cases specified in paragraph 6.3.2.5, rotors and fan casings in way of rotor shall be made of such materials which do not generate sparks, as confirmed by appropriate tests.

6.3.2.5 The tests mentioned in paragraph 6.3.2.4 may be waived for fans made of the following combinations of materials:

.1 rotor and/or casing made of non-metallic materials with anti-electrostatic properties,
.2 rotor and casing made of non-ferrous metal alloys,
.3 rotor made of aluminium or magnesium alloy and steel casing (including stainless austenitic steel), where a ring made of non-ferrous material of adequate thickness is used inside the casing in way of rotor,
.4 any combination of steel rotor and casing (including stainless austenitic steel) provided that the radial clearance between them is not less than 13 mm.

6.3.2.6 Rotors and fan casings made of the following materials are considered as sparking and their application is not permitted:

.1 rotor made of an aluminium or magnesium alloy and steel casing, irrespective of the radial clearance value,
.2 casing made of an aluminium or magnesium alloy and steel rotor, irrespective of the radial clearance value,
.3 any combination of rotor and casing made of steel with the design radial clearance less than 13 mm.

7 DECK MACHINERY

7.1 General Requirements

7.1.1 Deck machinery shall be designed for the service in conditions specified in sub-chapter 1.5.

7.1.2 Brake linings and their fixing arrangements shall be resistant to sea water and oil as well as heat resistant at temperatures up to 250 °C.

Heat resistance of the brake lining connection to the brake structure shall be greater than for the temperature which may occur in combination of any working conditions of the mechanism.

7.1.3 Machinery items which are both manually-operated and power-driven shall be provided with interlocking arrangements preventing simultaneous operation of these drives.

7.1.4 It is recommended that the deck machinery controls be so arranged that lifing will be performed by rotating the handwheel clockwise or by moving the lever backwards, whereas descending – by rotating the hand wheel counter clockwise or by moving the lever forwards. Braking shall be performed by rotating the hand wheel clockwise, whereas brake releasing – anti-clockwise.

7.1.5 Measurement and control instruments and gauges shall be so located as to be capable of being watched from the control station.

7.1.6 The machinery with hydraulic drive or control shall also fulfil the requirements specified in Chapter 8.

7.1.7 Winch drums on which ropes are put in several layers and subjected to load shall have flanges extending beyond the external layer of winding by not less than 2.5 times the rope diameter.

7.2 Steering Gears and Their Installation on Board Vessels

7.2.1 General Requirements

7.2.1.1 Vessels shall be fitted with two reliable steering gears – the main and auxiliary steering gear – which provide the manoeuvrability required in *Publication No. 27/P – Principles for Manoeuvrability Trials of Inland Waterways Vessels and Push Trains* (available in Polish only.

The main and auxiliary steering gears shall be able to operate the rudder on its own and independent of the other system; the steering gears, however, may have components (e.g. tiller, sector, guide or cylinder block) being used jointly by the main and auxiliary steering gear.

Steering gears shall be so designed that the rudder position cannot be changed unintentionally.

7.2.1.2 The main steering gear shall be capable of changing the rudder position up to 35° port or starboard at the speed of 3.5° per second while the rudder is fully immersed and the vessel is travelling at full speed.

In justified cases, for reason of the navigating conditions on particular routes, PRS may permit a lower rudder position changing speed, however not less than 2.5° per second. Also, power-operated main steering gear shall be capable of changing the rudder position from port to starboard and vice versa while the vessel is going astern at full speed.

The main steering gear shall be power-operated.

7.2.1.3 Manual operation is acceptable for rudder stock diameters up to 150 mm.

For the manually-operated steering gear, no more than 30 turns of the handwheel shall be necessary to put the rudder from one hard position to the other, as required in paragraph 7.2.1.2. In general, the force required to operate the handwheel shall not exceed 160 N.

As a means of protection against the overload by the pressure on the rudder blade, the manual-operation system of steering gear may be provided with cushion springs.

Manual steering wheel shall not be driven by a powered drive unit. Regardless of the rudder position, a kick-back of the wheel shall be prevented when the manual drive is engaged automatically.

7.2.1.4 Auxiliary steering gears shall be so designed as to ensure continuous adequate manoeuvrability with the rudder fully immersed and the vessel travelling forwards at reduced speed.

Manual operation of auxiliary steering gear system is permitted where the rated torque on the rudder stock allows this.

7.2.1.5 Construction of the main and auxiliary steering gear shall be such as to ensure that the following requirements are fulfilled:

.1 failure of one of the steering gears will not render the other one inoperative;

.2 if the steering apparatus has a powered drive unit, the second independent drive unit or an additional manual drive shall be provided. In case of failure or malfunction of the drive unit of the rudder system, the second independent drive unitor the manual drive shall be in operation within 5 seconds. If the second drive unit or manual drive is not put in service automatically, it shall be possible to do so immediately by means of a single operation by the helmsman that is both simple and quick;

.3 the possibility of imposing loads by power-operated main steering gear on the steering wheel of the manually operated auxiliary steering gear shall be precluded.

7.2.1.6 Where the main and auxiliary steering gears are power-operated, the following requirements shall be fulfilled:

.1 pumps intended for those gears shall be provided with independent drives, e.g. if the main steering gear pump is main engine driven, then the auxiliary steering gear pump have electric drive;

.2 if the auxiliary steering gear pump is driven by the auxiliary engine which is not in continuous service, then an emergency arrangement shall be provided to drive the pump until the auxiliary engine drives the pump;

.3 installations intended for the service of these steering gears shall separate hydraulic reservoirs for each of the two steering gears.

7.2.1.7 Where the hydraulic main steering gear is power-operated, and the hydraulic auxiliary steering gear is operated manually, each of the two steering gears shall operate independently.

7.2.1.8 Where power-operated hydraulic main steering gear is equipped with two or more identical power units, no auxiliary steering gear need be installed provided that the following conditions are fulfilled:

.1 in the event of failure of a single component of the piping system or a power unit means shall be provided to isolate the damaged system or unit for quick regaining of control of the steering system;

.2 in the event of a loss of hydraulic oil, it shall be possible to isolate the damaged system in such a way that the second control system remains fully serviceable.

7.2.1.9 Power-operated steering gears shall be provided with alarms which give audible and visual warning at the control station in case of failure or inadvertent tripping out.

7.2.1.10 Overload Protection

Power-operated steering gear systems shall be fitted with overload protection against the torque greater than 1.5 the rated torque value.

Hydraulic power-operated steering gears shall be fitted with relief valves having a setting range not less than 1.5 the rated pressure of the system. The flow capacity of the valves shall not be less than 1.1 the combined capacity of the pumps connected. In no case shall the rise of pressure exceed 1.1 the valve setting value. Relief valves shall be adjusted to be sealed with lead.

Manually operated steering gear may be protected against the overload with cushion springs in the driving unit.

7.2.1.11 Locking Equipment

Power-operated steering gear shall be equipped with a brake or other means to enable the rudder to be fixed in any position when the rudder is loaded with the rated torque.

Hydraulic power-operated steering gears whose unit may be fixed by closing valves in the hydraulic system piping need not be provided with specific locking equipment.

7.2.1.12 Rudder Position Indication

A rudder gear part rigidly coupled with the rudder stock (tiller, quadrant, etc.) shall be fitted with a dial, calibrated for accuracy not less than 1°, to indicate the position of the rudder related to ship's centre line.

7.2.1.13 Limit Switches

Each steering gear shall be provided with an arrangement for stopping its operation before the rudder reaches its limit switches; the steering gear capability to move the rudder immediately in the opposite direction shall be maintained.

The limit switches shall be fitted to the steering gear only where they are not fitted to the hull of vessel.

7.2.1.14 Power Source

Steering systems fitted with two powered drive units shall have at least two power sources: the main and auxiliary ones.

If the second power source for the powered steering apparatus is not constantly available while the vessel is under way, a buffer device carrying adequate capacity shall provide back-up during the period needed for start-up.

In the case of electrical power sources, no other power consumers may be supplied by the main power source for the steering system.

7.2.2 Installation of Hydraulic Systems

7.2.2.1 No other power consumers may be connected to the hydraulic steering apparatus drive unit.

7.2.2.2 Hydraulic steering gear drive units shall be provided with:
- **.1** arrangements for the hydraulic oil clean;
- **.2** low level alarm of hydraulic oil in each tank.
- **.3** alarm warning of the decrease of service pressure of the hydraulic system.

7.2.2.3 Pipes of the hydraulic steering systems shall fulfil the requirements relevant to class I piping and flexible joints specified in sub-chapter 15.1.

Flexible piping is only permitted where its use is essential in order to damp vibrations or to allow freedom of movement of components.

Flexible piping components shall be designed for at least the maximum service pressure and shall be renewed at the latest every eight years.

7.2.2.4 Piping shall be so made as to enable easy switching on and off individual cylinders and units and shall additionally fulfil the requirements specified in Chapter 8.

A possibility of bleeding air from the pipelines shall be provided, where necessary.

7.2.2.5 Hydraulic steering gear pumps shall be provided with protective means to prevent reverse rotation of an inoperative pump or with automatic arrangements to shut off the flow of liquid through the inoperative pump.

7.2.3 Connection to Rudder Stock

Connection of the steering gear to the elements rigidly fixed to the rudder stock shall be such as to preclude the steering gear damage due to axial displacement of the rudder stock.

7.2.4 Tests on Board Ship

The steering gear shall be subjected to tightness and operating tests after its installation on board the ship.

7.2.4.1 The steering gear shall be inspected by PRS surveyor in the following cases:
a) before being put into service;
b) after a failure;
c) after any modification or repair;
d) regularly at least every three years.

7.2.4.2 The scope of tests in the presence of PRS surveyor shall include:
a) visual inspection according to the approved drawings; visual inspection during periodical surveys whether any modifications in steering gear system were made;
b) functional test of the steering system for all operational possibilities; checking compliance with the requirements specified in paragraphs 7.2.1.2 and 7.2.1.3 regarding the rudder deflection, by main and standby steering gear.
c) power units of the steering gear testing and their switching on/off, if applicable;
d) switching off and cutting off the working power unit, check of time to recover the steering abilities, if applicable;
e) visual check and hydraulic test of the hydraulic components, if applicable;
f) visual check of the electrical components, if applicable;
g) alarm system and indicators operation in accordance with the requirements specified in paragraph 7.2.2.2 as well as in sub-chapters 5.2 and 8.4 of Part VII – Electrical Installations and Control Systems;
h) checking communication means between wheelhouse, machinery room and steering gear compartment, if applicable;

7.3 Windlasses

7.3.1 Drive

7.3.1.1 Power of the windlass driving motor shall ensure continuous heaving up a chain cable with an anchor of normal holding force for at least 30 minutes with a speed at least 9 m/min (0.15 m/s) and chain cable pull P_1 on the cable lifter not less than that determined in accordance with the formula below:

$$P_1 = ad^2 \quad [\mathrm{N}] \qquad (7.3.1.1)$$

where:

a – coefficient taking the following values:
27.5 – for steel grade 1 chain cables,
31.4 – for steel grade 2 chain cables,

(for chain cable steel grades – see Chapter 11 of *Part IX – Materials and Welding* of the *Rules for Classification and Construction of Sea-going Ships*);

d – chain cable diameter, [mm].

It is recommended that the chain speed while drawing the anchor to the hawse pipe be not greater than 6 m/min. (0.1 m/s).

7.3.1.2 To extract the anchor from the bottom, the windlass power unit shall produce, in a rated working cycle, a continuous pull of one cable lifter equal at least $2P_1$ for a period not less than 2 minutes. However, the requirement specified in paragraph 7.3.1.1 concerning the heave-up speed need not be fulfilled.

7.3.2 Clutches and Brakes

7.3.2.1 Windlasses shall be fitted with disengageable clutches between the cable lifter and the drive shaft.

Windlass with a gear mechanism which is not of self-locking type shall be fitted with automatic cable lifter brakes to prevent paying out of the chain in case of the power failure or power unit failure.

The automatic cable lifter brake shall be capable of maintaining the cable lifter pull not less than $1.3P_1$.

7.3.2.2 Cable lifters shall be fitted with brakes which are capable to stop safely paying out of the chain. The brake shall ensure holding a load equal to 80% of the nominal breaking load of the chain cable when the cable lifter is declutched.

The force applied to the brake handle shall not be greater than 750 N.

Cable lifter brake shall also be possible to be operated manually irrespective of the control type applied.

7.3.3 Cable Lifters

Cable lifters shall have not less than five cams. For horizontal axis cable lifters, the wrapping angle shall not be less than 117°, whereas for vertical axis cable lifters – not less than 150°.

7.3.4 Overload Protection

Where the maximum torque of the windlass motor may cause the (equivalent) stress in the windlass components exceeding 0.95 the yield point of the material used, or a rise to the force on the sprocket exceeding 0.5 the test load, a safety coupling shall be installed between the motor and the windlass to prevent overload.

7.3.5 Strength Calculation

Stress of the windlass parts being in flux of the strain lines shall not exceed:

$0.4\ R_e$ – when loaded with rated power of driving motor,

$0.95\ R_e$ – when loaded with the maximum torque of driving motor, 0.95 R_e – when subjected to maximum load caused by anchor cable held by brake – in accordance with 7.3.2.2; this requirement applies to those parts of windlass which are subjected to the above mentioned load;

(R_e – yield point of material of the parts in question).

When designing windlasses, special attention shall be paid to:
– notch stress concentration,
– dynamic loads caused by abrupt start or stop of driving motor,
– calculation methods and approximations applied for finding stress value and cycle,
– reliable fastening the windlass to the foundation.

7.3.6 Hand-Operated Windlasses

Hand-operated windlass shall ensure the cable being heaved up with the mean speed at least 2.0 m/min (0.033 m/s) and the chain cable pull P_1 (see paragraph 7.3.1.1) on the cable lifter. This shall be achieved without exceeding a manual force of 160 N applied to the crank turned by one man.

Hand-operated winches shall be fitted with devices to prevent kickback of the crank.

Windlass with additional hand-operated drive shall ensure the cable being heaved up with the chain cable pull on the cable lifter not less than $0.6P_1$. This shall be achieved without exceeding a manual force of 160 N applied to the crank turned by one man.

7.3.7 Winches that are both power- and manually driven shall be so designed that the motive-power control cannot actuate the manual control.

7.4 Towing Winches

7.4.1 Where automatic appliances are used to control the tension and length of the dispensed towline, provision shall be made for continuous checking the value of tension at every moment. The tension and length indicators shall be fitted at the towing winch and in the wheelhouse.

7.4.2 Alarm system which gives warning when the maximum permissible length of the towline is dispensed shall be provided.

7.4.3 Towline shall be so fastened to the winch drum that in case of the towline full release it will be disconnected from the drum due to the load equal to or slightly greater than the rated pull of the towing winch.

7.4.4 Towing winches shall fulfil the requirements specified in paragraph 7.1.7 and shall be provided with fairleads. In the case two or more drums are installed, separate fairleads shall be applied. The rope drum shall be provided with clutches disengaging the drum from the driving gear.

The dimensions of the towing winch drums shall ensure the possibility of smooth releasing of the towline.

7.4.5 Brakes

Towing winch brakes shall fulfil the following requirements:

.1 Towing winch shall be provided with automatic braking device stopping the winch when the pull is at least 1.5 times the rated pull in case of power decay or failure in the driving system;

.2 Rope drum shall be fitted with a slipless brake capable of stopping the declutched drum with the tension not less than the towline breaking load. Power operated drum brakes shall also be provided with a manual control system. The brake design shall enable quick release of the brake to ensure free heaving-in of the towline.

7.4.6 Strength Calculation

7.4.6.1 Strength of the towing winch components shall be checked for stress occurring when the drum is subjected to the loads corresponding to the maximum torque of motor, as well as when the drum is subjected to load equal to the towline breaking load. The reduced stress occurring in those components which may be subjected to forces caused by the above-mentioned loads shall not exceed 0.95 of the component material yield point.

7.4.6.2 The towline designed to be used in the towing gear shall be marked with the towline strength characteristics.

8 HYDRAULIC DRIVES

8.1 Application

8.1.1 The requirements specified in this Chapter apply to all hydraulic appliances and systems aboard the vessel except for those mentioned in paragraph 8.1.2.

8.1.2 Independent appliances – cased in individual housings – fulfilling recognised standards which are not associated with the vessel propulsion, steering and manoeuvring need not fulfil the requirements specified in this Chapter.

8.2 General Requirements

8.2.1 Hydraulic oil shall not be a source of corrosion in the hydraulic system. Its ignition temperature shall not be less than 150 ºC. Hydraulic oil shall be suitable for working within the range of operating temperatures of the hydraulic arrangement or system. In particular, this regards the range of viscosity change.

8.2.2 Hydraulic arrangements shall be protected with relief valves. Unless provided otherwise in other parts of the *Rules*, the opening pressure of the relief valve shall not exceed 1.1 of the maximum working pressure.

The nominal flow rate of the relief valves shall be so selected that the generated hydraulic oil pressure does not exceed 1.1 of the pre-set pressure of valve opening at the maximum pump output.

8.2.3 In the case of hydraulic systems and appliances working continuously such as hydraulic main propulsion, steering gears, hydrodynamic couplings, the possibility of cleaning oil filters without stopping the system shall be provided.

8.2.4 A failure of the hydraulic system shall not cause damage to the associated piece of machinery or equipment.

8.2.5 Dimensions, design and arrangement of the pipework shall as far as possible exclude mechanical damage or damage resulting from fire.

8.2.6 Hydraulic cylinders, hydraulic pumps and hydraulic motors as well as electric motors shall be examined at the latest every eight years by a specialised firm and repaired if required.

8.3 Flammable Hydraulic Oil Tanks

Flammable oil tanks shall fulfil the same requirements as oil fuel tanks, with the following exceptions:

.1 in the case of tanks not adjacent to vessel shell plating which are situated outside the machinery compartments, in compartments situated above the load waterline where there are not sources of ignition such as internal combustion engines or boilers, the application of cylindrical level indicator glasses is permitted;

.2 in the case of tanks with the capacity less than 100 dm^3, situated in machinery compartments, PRS may consider acceptance of cylindrical level indicator glasses.

8.4 Pipe Connections

Pipe connections shall fulfil the requirements specified in sub-chapter 15.1, and additionally:

.1 pipes installed on board the vessel shall have the inside surface as clean as it is required for hydraulic components,

.2 in pipelines with a nominal diameter less than 50 mm, threaded sleeve joints of the type approved by PRS shall be applied; however, the joints with the rubber washer may only be applied for connection of hydraulic components but not for connection of pipe segments,

.3 pipe joints without PRS approval may only be applied, subject to PRS acceptance in each particular case, where they fulfil the requirements specified in the relevant national standard and are provided with an appropriate inspection certificate,

.4 pipelines shall not have soldered joints,

.5 flexible hoses with connection fittings shall fulfil the requirements specified in paragraph 15.1.10 and be type-approved by PRS. Subject to PRS acceptance in each particular case, fireproof hoses without PRS approval may be applied, except in the installations of steering gears and hydraulic control systems of watertight doors, ports and ramps in the vessel shell, provided they fulfil the relevant national standard and have an appropriate inspection certificate.

8.5 Hydraulic Components

8.5.1 Hydraulic accumulators shall fulfil the strength requirements for pressure vessels of the particular class. Each accumulator, which may be cut off the hydraulic system shall be provided with an individual relief valve. A safety valve or other protecting device shall be installed on the gas side to prevent overpressure.

8.5.2 Hydraulic Cylinders

8.5.2.1 Hydraulic cylinders shall fulfil the strength requirements for pressure vessels of the particular class.

8.5.2.2 Hydraulic cylinders shall be type-approved by PRS.

8.5.2.3 Subject to PRS acceptance in each particular case, hydraulic cylinders which are not type-approved by PRS may be applied if they fulfil the requirements specified in the relevant national standard and are provided with an appropriate inspection certificate.

8.5.3 Valves, pumps, hydraulic motors and high pressure filters shall be type-approved by PRS.

8.5.4 Hydraulic cylinders which do not fulfil the requirements specified in paragraphs 8.5.2.2 and 8.5.2.3 as well as other hydraulic components which do not fulfil the requirement specified in paragraph 8.5.3 may be applied if they have been manufactured under PRS survey in accordance with the approved documentation and have been approved by PRS surveyor on the manufacturer's premises in accordance with the approved testing programme.

8.6 Testing

8.6.1 Tests shall be performed in accordance with the testing programme approved by PRS.

8.6.2 Testing programme shall determine the type and scope of tests, acceptance criteria, test site and – if necessary – testing procedure.

8.6.3 Tests shall include:

.1 pressure tests of piping in accordance with the requirements specified in sub-chapter 1.6.5;
.2 post-rinsing check of piping cleanness;
.3 operating tests;
.4 hydraulic oil check for impurities before and after operating tests.

9 INSTALLATIONS FOR VARIABLE-HEIGHT WHEELHOUSES

9.1 General Requirements

9.1.1 The requirements specified in this Chapter apply to:

– hoistable wheelhouses,
– lowerable wheelhouses, i.e. split, in the horizontal plane, into the fixed lower portion and lowerable upper portion.

9.1.2 Variable-height wheelhouses shall enable effective navigation of the vessel.

9.1.3 Variable-height wheelhouses and their locking arrangements shall be so constructed to ensure the safety of persons on board when the wheelhouse is being fixed at any position.

Provisions shall be made to enable immediate disconnection of the locking arrangements in all service positions, including total loss of power supply.

9.1.4 Hoisting and lowering of the wheelhouse shall not interrupt the operations performed in the wheelhouse.

9.1.5 Wheelhouse hoisting mechanism shall be capable of hoisting at least 1.5 times the weight of the wheelhouse fully equipped and manned.

9.1.6 Wheelhouse hoisting and lowering mechanism shall be operational in all intended service conditions.

9.1.7 Wheelhouse installations shall be provided with alarms which give audible and visual warning both inside and outside the wheelhouse during the hoisting and lowering operations.

9.1.8 Retractable wheelhouses shall be fitted with an emergency lowering system, which is independent from the normal lifting mechanism and can be used even in the event of power failure. This emergency system shall be operated from inside the wheelhouse. When using the emergency system the lowering speed shall not be less than the lowering speed under normal conditions.

Arrangements shall be provided to avoid uncontrolled lowering of the wheelhouse. Appropriate protection features shall be installed to prevent the risk of injury which may result from lowering.

9.1.9 The lifting mechanism shall enable the wheelhouse to stop in all positions. If the possibility exists to lock the wheelhouse in a certain position, the lifting mechanism shall be automatically disabled when locking takes place. Releasing the locks shall be possible under all operating conditions.

9.1.10 Limit switches shall be provided for automatic stopping of the wheelhouse hoisting mechanism.

9.1.11 Application of self-locking arrangements in a wheelhouse hoisting mechanism is not permitted.

9.1.12 It shall be possible to operate the lifting mechanism from inside the wheelhouse. The following indications shall be arranged at the steering position:

.1 voltage present
.2 wheelhouse in lowest position,
.3 wheelhouse in highest position,
.4 wheelhouse locked in fixed position (if applicable).

9.2 Power-operated Variable-height Wheelhouses

9.2.1 Wheelhouse hoisting mechanisms which are both power-operated and hand-operated shall be provided with locking arrangements precluding the possibility of simultaneous use of these driving systems.

9.2.2 Distance from the hydraulic system piping and flexible hoses to the electrical wiring system shall not be less than 100 mm.

9.2.3 Hydraulic hoses are:

.1 only permissible, if vibration absorption or freedom of movement of components makes their us
Inevitable;
.2 to be designed for at least the maximum service pressure;
.3 to be renewed at the latest every eight years.

9.2.4 The possibility of connecting the wheelhouse hoisting hydraulic system piping to other hydraulic systems is subject to PRS acceptance in each particular case.

Hydraulic-operated wheelhouse hoisting mechanisms shall additionally fulfil the requirements specified in Chapter 8.

10 WINCHES FOR COUPLING ARRANGEMENTS

10.1 General Requirements

10.1.1 Winches for coupling arrangements shall enable easy coupling and decoupling of push trains.

10.1.2 Stress in loaded components of the winch shall be determined in accordance with the requirements specified in sub-chapter 7.3.5.

10.1.3 Forces occurring in the coupling arrangements shall be determined in accordance with the requirements specified in *Part III – Hull Equipment*.

10.1.4 Hand-operated coupling winch shall ensure the coupling pull by the force not greater than 0.6 kN applied to the handle of the winch drum wheel.

11 INSTALLATIONS ON CABLE FERRIES

11.1 Self-propelled Ferries

Engines, machinery, piping systems, motive power systems and safety systems shall fulfil the requirements specified in this Part of the *Rules* either in full or to the extent specified by PRS in each particular case.

11.2 Ferries without Motive Power

Machinery and piping systems shall fulfil the relevant requirements specified in this Part of the *Rules*.

12 THRUSTERS

12.1 Application

12.1.1 The requirements specified in Chapter 12 apply to the vessel propulsion, steering or manoeuvring devices which in this Chapter are also referred to as ”devices”. In particular, these requirements cover:
– azimuth thrusters,
– cycloidal propellers,
– retractable and foldable devices,
– devices for dynamic positioning of the vessel,
– water-jet propulsion,
– tunnel thrusters.

12.1.2 Devices intended for the main propulsion and steering as well as dynamic positioning of the vessel are considered as main thrusters and are also referred to as ”main devices”.

Other thrusters are considered as auxiliary ones.

12.2 General Requirements

12.2.1 Where the vessel is propelled solely by thrusters, at least two separate devices with independent power supply shall be applied. This requirement does not apply to water-jet propulsion.

The possibility of application of a single device or devices with common power supply is subject to PRS acceptance in each particular case.

12.2.2 The devices shall withstand the loads occurring in stationary and transient operating conditions.

12.2.3 Components of thrusters with turning columns which transmit a torque or revolving force shall be calculated taking into account the maximum torque caused by the hydraulic motor turning the column at the maximum difference in pressure of the hydraulic liquid or taking into account the starting torque of the electric motor turning the column. These components shall withstand stoppage of the column turning.

12.2.4 Adequate means to prevent outboard water penetration into both the device and hull shall be provided.

12.2.5 Dynamic seals preventing outboard water penetration into the device or hull shall be type-approved by PRS.

12.2.6 Inspection holes shall be provided to enable the necessary periodical survey of the main parts of thrusters.

12.2.7 Thrusters, which are so installed inside the vessel's hull as to enable their stretching out or turning, shall be located in a separate watertight compartment unless double seals are arranged in accordance with the requirement specified in paragraph 12.2.5. An alarm system warning of water ingress between the seals as well as the possibility of inspection of the seals during dry-docking shall be provided.

12.2.8 Construction of nozzles shall fulfil the relevant requirements specified in *Part III – Hull Equipment*.

12.2.9 In the case of azimuth thrusters where reverse manoeuvre is effected through the column turning by 180°, the time for such turning shall not exceed 30 s.

12.2.10 Main thrusters shall enable the thrust vector to be controlled from all the main propulsion remote control stands and from the thruster compartment. In each of these locations, indication of the propeller pitch and thrust vector direction, and also means to stop the propeller immediately as well as communications with all other control stands shall be provided. The means for immediate stopping of the propeller shall be independent of the thruster remote control system.

12.3 Drive

12.3.1 Internal combustion engines which drive thrusters directly shall fulfil the requirements specified in Chapter 2. Installations serving the engines shall fulfil the relevant requirements specified in Chapter 15, except for the requirement for application of stand-by and spare pumps and other similar appliances.

12.3.2 Hydraulic motors, pumps and other hydraulic components shall be type-approved by PRS.

12.3.3 For main thrusters, a permanently connected spare hydraulic oil storage tank of the capacity sufficient for full oil exchange in at least one thruster shall be provided.

12.3.4 Electric motors, irrespective of their power output, used for powering the main thrusters are subject to PRS survey during their production.

12.4 Gearing and Bearing

12.4.1 Gearings applied in thrusters shall fulfil the relevant requirements specified in Chapter 5.

12.4.2 Gearings of auxiliary devices intended for short-time operation may be calculated for a limited number of operating hours. Calculations of these gears, performed in accordance with the standards in force, are subject to PRS acceptance in each particular case.

12.4.3 Basic rating life L1O of rolling-element bearings in main thrusters shall be at least 20 000 hours.

12.4.4 Basic rating life L1O of rolling-element bearings in auxiliary devices shall not be less than 5 000 hours.

12.4.5 Bearing of the turning column shall ensure compensation of axial forces in both directions.

12.5 Propulsion Shafting

12.5.1 Shafts shall fulfil the relevant requirements specified in Chapter 3, including the requirements for ice class where if applicable.

12.5.2 With respect to torsional vibrations, the relevant requirements specified in Chapter 4 apply.

12.6 Propellers

Fixed pitch propellers and controllable pitch propellers shall fulfil the relevant requirements specified in Chapter 3.

12.7 Control Systems

Where the thrust vectoring of main thrusters' installations is remotely actuated by electric, hydraulic or pneumatic means, there shall be two actuation systems, each independent of the other, between the wheelhouse and the thrusters. Where there are two thruster installations that are independent of each other, the second actuation system is not necessary if the vessel retains adequate manoeuvrability in the event of a failure of one of the systems.

12.8 Monitoring

Indication system shall clearly display, at every steering position, at least the following data:
- rotating direction and rotational speed for fixed pitch arrangements;
- pitch and rotational speed for controllable pitch arrangements;
- thrust angle.

12.9 Survey and Testing

12.9.1 The scope of survey of auxiliary thrusters with the motors having power less than 200 kW is subject to PRS consideration in each particular case.

12.9.2 PRS survey of the production and testing of thrusters covers:
- checking of conformity of the applied materials and manufacturing procedures with the approved documentation,
- checking the conformity of workmanship with the approved documentation,
- testing of thrusters' installations including pressure tests of housings, piping and fittings as well as operational tests at the manufacturer's shop.

12.9.3 Operational tests at the manufacturer's shop shall be performed on a test stand which allows the test to be performed at the rated rotational speed and full torque load on the shaft and column, if any. PRS may consider performance of some or all operation tests on board the vessel.

Operation tests include:

.1 start and stop tests of the drive, and reversing tests;
.2 operation tests of thruster as a steering unit;
.3 tests of control systems.

Factory operating tests shall be performed in accordance with the approved programme and in the presence of PRS surveyor.

12.9.4 After the operating tests, visual examination of the whole thruster and, in justified cases, also internal examination shall be performed with particular regard to gearing.

12.9.5 Thruster trials on board the vessel shall be performed in accordance with the approved programme.

The trials shall confirm the thruster ability to provide propulsion and steering in all intended modes of service and manoeuvring.

The trials shall be performed at different operational speeds of the vessel, different settings and power output of thrusters as well as during rapid manoeuvring started in the most adverse combinations of the vessel speed and thruster settings.

After the operating tests at the manufacturer's shop and on board the vessel, a lubricating oil sample shall be checked for the content of metallic and non-metallic solids.

13 PRESSURE VESSELS AND HEAT EXCHANGERS

13.1 Construction of Pressure Vessels and Heat Exchangers

13.1.1 Components of pressure vessels and heat exchangers being in contact with overboard water or other possibly corrosive media shall be constructed from corrosion-resistant materials. In the case of other materials, the method of their protection against corrosion is subject to PRS acceptance in each particular case.

13.1.2 Construction of pressure vessels and heat exchangers shall provide their reliable in the conditions specified in sub-chapter 1.5.

13.1.3 Pipe wall thickness deceased due to bending shall not be less than the design thickness.

13.1.4 Where necessary, construction of pressure vessels and heat exchangers shall take account of possible thermal expansion of the shell and other components.

13.1.5 Shells of heat exchangers and pressure vessels shall be fixed to their seatings by supports. Where necessary, upper fixing arrangements shall be provided (see also paragraph 1.13.1).

13.2 Fittings and Gauges

13.2.1 Pressure vessels and heat exchangers or their inseparable sets shall be fitted with non-disconnectable safety valves. In the case of several non-interconnected spaces, safety valves shall be provided for each space. Hydrophore tanks shall be fitted with safety valves located on the waterside.

In justified cases PRS, PRS may waive the above-mentioned requirements.

13.2.2 In general, safety valves shall be of a spring-loaded type. Safety diaphragms of a type approved by PRS are permitted in fuel and oil heaters provided they are installed on the fuel and oil side.

13.2.3 The discharge capacity of safety valves shall be such that under no conditions the working pressure is exceeded by more than 10%.

13.2.4 Safety valves shall be so designed as to be capable of being sealed or fitted with an equivalent means to prevent their unauthorised adjustment. Materials used for springs and sealing surfaces of valves shall be resistant to corrosive effect of the medium.

13.2.5 Level indicators and sight glasses may only be installed on pressure vessels and heat exchangers where required by the conditions of control and inspection. Level indicators and sight glasses shall be of reliable construction and protected adequately. For fuel and other oils, flat glass plates shall be used for level indicators and sight glasses.

13.2.6 Pressure vessels and heat exchangers shall be provided with flanges or flanged branch pieces for installation of fittings and mountings.

In hydrophore tanks, threaded branch pieces may also be applied.

13.2.7 Branch pieces installed on pressure vessels and heat exchangers shall be of rigid construction and of the minimum length sufficient for fixing and dismantling of mountings and fittings without their insulation removal. Branch pieces shall not be exposed to excessive bending stresses and shall be reinforced by stiffening fins where necessary

13.2.8 Flanges intended for installation of mountings, fittings and piping, as well as branch pieces and sleeves passing through the entire thickness of pressure vessels and heat exchangers shall be fixed by welding, preferably with double welds. Branch pieces may be welded from one side, using a temporary backing strip or a different method ensuring full penetration of the wall.

13.2.9 Pressure vessels and heat exchangers shall be provided with adequate blowdown arrangements as well as drain arrangements.

13.2.10 Pressure vessels and heat exchangers shall be provided with manholes for internal examination. The minimum dimensions of the manholes are as follows:
- 300 x 400 mm – for oval manholes,
- 400 mm – for round manholes.

In justified cases PRS may consider the possibility of reduction of the dimensions to 280 x 380 mm – for oval manholes, and to 380 mm – for round manholes.

Oval manholes in shells shall be so situated that the minor axis be parallel with the shell axis.

13.2.11 Where the manholes mentioned in paragraph 13.2.10 are impracticable, adequate sight holes shall be provided. Pressure vessels and heat exchangers with more than 2.5 m in length shall be provided with the inspection holes at both ends.

Where the pressure vessel or heat exchanger is of dismountable construction or where corrosion and contamination of internal surfaces is precluded, manholes or inspection holes are not required.

Manholes or sight holes are not required where the construction of pressure vessel or heat exchanger precludes the possibility of inspection through such holes.

13.2.12 Where non-metallic gaskets are used, the construction of manholes and other holes shall preclude the possibility of gaskets being forced out.

13.2.13 Pressure vessels and heat exchangers, as well as their inseparable units shall be equipped with a pressure gauge or a compound pressure gauge. In heat exchangers divided into several spaces, a pressure gauge or a compound pressure gauge shall be provided for each space (see also sub-chapter 1.17).

13.3 Requirements for Particular Types of Pressure Vessels and Heat Exchangers

13.3.1 Air Receivers

13.3.1.1 Safety valves of starting air receivers for main and auxiliary engines, as well as of fire protection systems, after being lifted, shall completely stop the air escape at the pressure inside the receiver not less than 0.85 of the working pressure.

13.3.1.2 Where air compressors, reducing valves or pipes from which air is supplied to the receivers are provided with safety valves so adjusted to prevent the receivers from being supplied with air of the pressure higher than the working pressure, safety valves need not be fitted on such receivers. In that case, fusible plugs shall be fitted on the receivers instead of the safety valves.

13.3.1.3 The fusible plugs shall have a fusion temperature within 100 – 130°C. The fusion temperature shall be permanently marked on the fusible plug. Air receivers having a capacity over 0.7 m^3 shall be fitted with plugs not less than 10 mm in diameter.

13.3.1.4 Air receivers shall be equipped with water-draining arrangements. In air receivers positioned horizontally, the water draining arrangements shall be installed at both ends of the receiver.

13.3.2 Cylinders for Compressed Gasses and Extinguishing Media

13.3.2.1 Cylinders for compressed gases are portable pressure vessels, which are stored on board the vessel for its operational purposes, but must not be filled by means of the vessel's equipment.

13.3.2.2 Strength calculations shall be performed in respect of the requirements specified in sub-chapter 14.2.8, and the following:
- design pressure shall not be less than the pressure which may occur at temperature 45°C, at the predetermined filling level;
- allowable stress σ shall be determined in accordance with sub-chapter 14.2.4, whereas the safety factor in accordance with paragraph 14.2.5.1;
- allowance c for cylinders being exposed to corrosion shall not be taken less than 0.5 mm.

Cylinders may be made of steel with the yield stress greater than 750 MPa but not exceeding 850 MPa subject to PRS acceptance in each particular case.

13.3.2.3 Non-disconnectable safety devices of approved construction shall be provided to prevent a dangerous overpressure in the cylinder in case of temperature increase. Safety valves or burst disks activated at a pressure exceeding 1.1 times the working pressure but not higher than 0.9 times the test pressure are permitted.

13.3.2.4 Cylinders shall be permanently marked to include the following information:
- **.1** manufacturer name,
- **.2** serial number,
- **.3** year of manufacture,
- **.4** kind of gas,
- **.5** capacity,
- **.6** test pressure,
- **.7** tare,
- **.8** maximum load (pressure/weight),
- **.9** stamp and date of testing.

13.3.2.5 Cylinders shall be hydraulically tested under pressure equal to 1.5 times the working pressure.

13.3.2.6 Cylinders which are designed for the storage of compressed gases, refrigerants or extinguishing agents shall be approved by PRS or manufactured in accordance with the relevant standards under survey of a competent technical inspection body approved by PRS.

13.3.3 Filters and Coolers

13.3.3.1 Filters and coolers of the main and auxiliary engines shall fulfil the requirements for heat exchangers and pressure vessels with respect to the materials and construction.

13.3.3.2 Oil fuel filters installed in parallel to enable their cleaning without cutting off the fuel oil supply to engines (duplex filters) shall be provided with arrangements protecting the filter under pressure against being opened inadvertently.

13.3.3.3 Filters or filter chambers shall be provided with adequate means for:
– air venting when being put into operation,
– pressure equalisation before being opened.

Valves or cocks with drain pipes leading to a safe location shall be used for this purpose.

14 STRENGTH CALCULATIONS OF PRESSURE VESSELS AND HEAT EXCHANGERS

14.1 General Provisions

Depending on the construction and characteristics, boilers, pressure vessels and heat exchangers are divided into classes as indicated in Table 14.1.

Table 14.1

Kind of equipment	Class I	Class II	Class III
Pressure vessels and heat exchangers	$p > 4{,}0$ or $t > 350$ or $s > 35$	$1{,}6 < p \le 4{,}0$ or $120 < t \le 350$ or $16 < s \le 35$	$p \le 1{,}6$ and $t \le 120$ and $s \le 16$
Pressure vessels and heat exchangers containing toxic, inflammable or explosive media	Irrespective of parameters	–	–

p – design pressure, i.e. the valve taken for strength calculations, not less than the opening pressure of the safety valves or other protective devices, [MPa];
t – design wall temperature, [°C];
s – wall thickness, [mm].

14.2 Strength Calculations

14.2.1 General Requirements

14.2.1.1 Wall thicknesses determined by calculation are the lowest permissible values under normal operating conditions. The formulae and strength calculation methods do not take into account the manufacturer's tolerances for thickness and these shall be added as special allowances to the design thickness values.

Additional stresses due to external loads (axial forces, bending moments, torques) imposed on the calculated parts (particularly loads due to dead mass or the mass of attached parts) shall be taken into account on PRS' request.

14.2.1.2 The dimensions of structural components of boilers, pressure vessels and heat exchangers for which no strength calculation method is given in this *Part* of the *Rules* shall be determined on the basis of experimental data and recognized theoretical calculations, and are subject to special consideration by PRS in each particular case.

14.2.2 Design Pressure

14.2.2.1 Where hydrostatic pressure is greater than 0.05 MPa, the design pressure shall be increased by that value.

14.2.2.2 For flat walls subjected to pressure from both sides, the design pressure shall be taken as the greatest of the acting pressures. Walls in the form of curved surfaces which are subjected to pressure from both sides shall be calculated for the greatest outer and inner pressures. If the pressure on one side of the flat wall or the wall in the form of curved surface is lower than the atmospheric pressure, than the maximum pressure on the other side of the wall increased by 0.1 MPa shall be taken as the design pressure.

14.2.3 Design Temperature

14.2.3.1 For the purpose of determining the allowable stresses depending on the temperature of the medium and heating conditions, the design wall temperature shall not be taken lower than indicated in Table 14.2.3.1.

Table 14.2.3.1

Item	Components of pressure vessels and heat exchangers and their operating conditions	Design wall temperature
1	Heated components	T_v
2	Not heated components [1)]	T_m

Notes:
T_m –maximum temperature of heated medium, [°C];
T_v –maximum temperature of heating medium, [°C].
[1)] component is considered as not heated if it is separated from the heat source or heating medium with fire-proof insulation situated from that component by at least 300 mm or is shielded with fire-proof insulation not exposed to radiant heat.

14.2.3.2 Design temperature for tank walls and pressure vessel walls operating under refrigerant pressure shall be taken equal to 20°C, if higher temperatures are not likely to occur.

14.2.4 Strength Characteristics of Materials and Allowable Stresses

14.2.4.1 For steels with $(R_e/R_m) \leq 0.6$ the strength characteristics shall be assumed equal to physical yield point or proof stress R_e^t or $R_{0.2}^t$, as well as average creep strength $R_{z/100\,000/t}$ after 10^5 h, at design temperature t.

For steels with $(R_e/R_m) > 0.6$, R_m^t, tensile strength at design temperature t shall also be taken into account.

The minimum values of R_e^t, $R_{0.2}^t$ and R_m^t and average values of $R_{1/100\,000/t}$ and $R_{z/100\,000/t}$ shall be taken for calculations.

14.2.4.2 For materials whose stress-strain curve does not show a specific yield stress, the tensile strength at the design temperature shall be taken for calculations.

14.2.4.3 For cast iron and non-ferrous alloys, the minimum value of ultimate tensile strength at normal temperature shall be taken for calculations.

14.2.4.4 When using non-ferrous materials and their alloys, it shall be taken into account that the heating during processing and welding reduces the strengthening effect achieved by cold processing. Therefore the strength characteristics to be used for strength calculations of the components and assemblies made of such materials shall be those applicable to their annealed condition.

14.2.4.5 Allowable stresses σ assumed for strength calculations shall be determined as the minimum out of the following three values:

$$\sigma = \frac{R_m^t}{\eta_m},\ \sigma = \frac{R_e^t}{\eta_e}\ \text{or}\ \ \sigma = \frac{R_{0,2}^t}{\eta_e}$$

$$\sigma = \frac{R_{z/100000/t}}{\eta_z},\ \sigma = \frac{R_{1/100000/t}}{\eta_p}$$

where:

η_m – safety factor for tensile strength R_m^t

η_z – safety factor for creep strength $R_{z/100\,000/t}$

η_e – safety factor for yield point R_e^t i $R_{0,2}^t$

η_p – safety factor for creep point $R_{1/100\,000/t}$.

For values of factors – see sub-chapter 14.2.5.

14.2.5 Safety Factors

14.2.5.1 For components made of steel forgings or rolled steel, subjected to internal pressure, the safety factors shall not be less than:

$$\eta_e = \eta_z = 1{,}6;\ \ \eta_m = 2{,}7\ \text{ and }\ \eta_p = 1{,}0$$

For components subjected to external pressure, safety factors η_e, η_z and η_m shall be increased by 20%.

14.2.5.2 For components of boilers, heat exchangers and pressure vessels of Class II and Class III, made of steels with $(R_e/R_m) \le 0.6$, the safety factors may be reduced, however they shall not be less than:

$$\eta_e = \eta_z = 1{,}5;\ \ \eta_m = 2.6\ .$$

14.2.5.3 For components of heat exchangers and pressure vessels made of cast steel and subjected to internal pressure, the safety factors shall not be less than:

$$\eta_e = \eta_z = 2{,}2;\ \ \eta_m = 3{,}0\ \text{ and }\ \eta_p = 1{,}0$$

For components subjected to external pressure, the safety factors η_e and η_m shall be increased by 20% (η_z remains unchanged).

14.2.5.4 Safety factors η_m for components made of cast iron shall not be taken less than 4.8 – for internal and external pressure.

This factor for non-ferrous metals – shall not be less than 4.6 for internal pressure and 5.5 for external pressure. For conical walls, in the latter case, η_m shall not be taken less than 6.0.

14.2.6 Strength Factors

14.2.6.1 Strength factors of welded joints φ shall be determined in accordance with Table 14.2.6.1-1 depending on the joint type and welding process. For particular classes of boilers, pressure vessels and heat exchangers (see Table 14.1), strength factor φ shall not be less than that specified in Table 14.2.6.1-2.

Table 14.2.6.1-1

Welding process	Joint type	Weld type	φ
Automatic	Butt joint	Double-sided Single-sided with backing Single-sided without backing	1.0 0.9 0.8
	Overlap joint	Double-sided Single-sided	0.8 0.7
Semi-automatic and manual	Butt joint	Double-sided Single-sided with backing Single-sided without backing	0.9 0.8 0.7
	Overlap joint	Double-sided Single-sided	0.7 0.6

Notes to Table 14.2.6.1-1:
1. Full penetration shall be achieved in each case.
2. For welded joints made in electroslag process, $\varphi = 1$ shall be taken.

Table 14.2.6.1-2

Equipment type	Factor φ		
	Class I	Class II	Class III
Pressure vessels and heat exchangers	0.9	0.7	0.6

14.2.6.2 Strength factor of cylindrical walls weakened by holes with identical diameter shall be taken equal to the least of the following three values:

.1 strength factor of cylindrical walls weakened by a longitudinal row or a field of equally spaced holes (Fig. 14.2.6.2-1), as determined using the formula below:

$$\varphi = \frac{a-d}{a} \quad (14.2.6.2.1)$$

.2 strength factor, reduced to the longitudinal direction, of cylindrical walls weakened by a transverse row or a field of equally spaced holes (Fig. 14.2.6.2-1), as determined using the formula below:

$$\varphi = 2\frac{a_1-d}{a_1} \quad (14.2.6.2.2)$$

.3 strength factor, reduced to the longitudinal direction, of cylindrical walls weakened by a field of equally spaced staggered holes (Fig. 14.2.6.2-2 and Fig. 14.2.6.2-3), as determined using the formula below:

$$\varphi = k\frac{a_2-d}{a_2} \quad (14.2.6.2.3\text{-}1)$$

where:

φ – strength factor of walls weakened by holes;
d – diameter of the hole for expanded tubes or inner diameter of welded-on tubes and extruded branch pieces, [mm];
a – spacing between axes of two adjacent holes arranged along the wall, [mm];

a_1 – spacing between axes of two adjacent holes in the transverse (circumferential) direction, taken as the mean circumference arc length, [mm];

a_2 – spacing between axes of two adjacent holes in staggered rows, taken as mean circumference arc length, [mm], as determined using the formula below:

$$a_2 = \sqrt{l^2 + l_1^2} \quad [\text{mm}] \qquad (14.2.6.2.3\text{-}2)$$

l – spacing between axes of two adjacent holes in the longitudinal direction (Fig. 14.2.6.2.-2 and Fig. 14.2.6.2-3), [mm];

l_1 – spacing between axes of two adjacent holes in the transverse or circumferential direction (Fig. 14.2.6.2.-2 and Fig. 14.2.6.2-3), [mm];

k – factor depending on ratio $\frac{l_1}{l}$, taken from Table 14.2.6.2.3.

Table 14.2.6.2.3

$\frac{l_1}{l}$	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 shall be determined by linear interpolation.

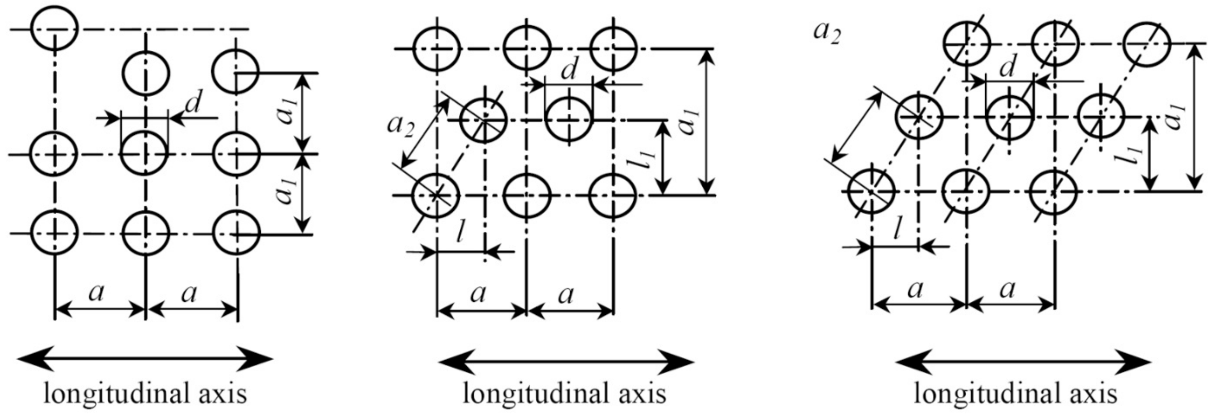


Fig. 14.2.6.2-1 Fig. 14.2.6.2-2 Fig. 14.2.6.2-3

14.2.6.3 Where rows or fields of equally spaced holes contain holes of different diameters, value d in the formulae for strength factor determination (14.2.6.2.1, 14.2.6.2.2, 14.2.6.2.3-1, 14.2.6.2.3-2) shall be taken as the value equal to the arithmetic mean of the two largest adjacent holes. In the case of uneven spacing between the holes of equal diameters, the lowest values of a, a_1 or a_2, respectively, shall be applied in the formulae for strength factor determination.

14.2.6.4 In the case of weld seams with holes, the strength factor shall be taken as the product of the seam strength factor and the strength factor of the wall weakened by the holes.

14.2.6.5 For seamless cylindrical walls not weakened by a seam or row/field of holes, strength factor φ shall be taken as equal to 1.0. In no case factor φ shall be taken greater than 1.0.

14.2.6.6 Strength factor of walls weakened by holes for expanded tubes, as determined in accordance with formulae 14.2.6.2.1, 14.2.6.2.2, 14.2.6.2.3, shall not be taken less than 0.3. Calculations with the lesser value of the strength factor are subject to PRS acceptance in each particular case.

14.2.6.7 For walls of cylindrical components made of sheets with different thickness, joined by longitudinal weld seam, the thickness calculation shall be done separately for each sheet, taking account of the actual weakenings.

14.2.6.8 For tubes with longitudinal weld seam, the strength factor is subject to PRS acceptance in each particular case.

14.2.6.9 Strength factors for walls weakened by openings requiring full or partial strengthening shall be determined in accordance with sub-chapter 14.2.17.

14.2.6.10 Strength factors for flat flue sheets shall be determined in accordance with formula 14.2.6.2.1 for tangential and radial spacings respectively. The lesser obtained strength factor shall be taken for calculation of the flat flue sheet thickness.

14.2.7 Design Thickness Allowances

14.2.7.1 In every case where the design wall thickness allowance c, is not expressly specified, it shall be taken at least 1 mm. For steel walls with more than 30 mm in thickness, as well as for walls of corrosion-resistant non-ferrous metals or high alloy materials, and for materials adequately protected against corrosion, e.g. by cladding or coating with a protective compound, the design thickness allowance may be waived subject to PRS acceptance in each particular case.

14.2.7.2 For pressure vessels and heat exchangers inaccessible for internal examination and for those whose are subjected to heavy corrosion or wear, PRS may require an increased allowance c to the design thickness.

14.2.8 Cylindrical and Spherical Elements and Tubes Subjected to Internal Pressure

14.2.8.1 The requirements specified in this sub-chapter apply where the following conditions are fulfilled:

$\frac{D_a}{D} \leq 1.6$ – for cylindrical elements,

$\frac{D_a}{D} \leq 1.7$ – for tubes,

$\frac{D_a}{D} \leq 1.2$ – for spherical elements.

Cylindrical elements with a diameter $D_a \leq 200$ mm shall be considered as tubes.

For D_a , D – see paragraph 8.2.8.2.

14.2.8.2 Thickness of cylindrical walls and tubes shall not be less than that calculated in accordance with the formulae below:

$$s = \frac{D_a p}{2\sigma\varphi + p} + c \quad [\text{mm}] \qquad (14.2.8.2\text{-}1)$$

or

$$s = \frac{D p}{2\sigma\varphi - p} + c \quad [\text{mm}] \qquad (14.2.8.2\text{-}2)$$

s – wall thickness, [mm];
p – design pressure, [MPa];
D_a – outside diameter, [mm];
D – inside diameter, [mm];
φ – strength factor (see sub-chapter 14.2.6);
σ – allowable stress (see paragraph 14.2.4.5), [MPa];
c – design thickness allowance (see sub-chapter 14.2.7), [mm].

14.2.8.3 Spherical wall thickness shall not be less than those obtained from the formulae:

$$s = \frac{D_a p}{4\sigma\varphi + p} + c \quad [\text{mm}] \qquad (14.2.8.3\text{-}1)$$

or

$$s = \frac{Dp}{4\sigma\varphi - p} + c \quad [\text{mm}] \qquad (14.2.8.3\text{-}2)$$

For symbols – see paragraph 14.2.8.2.

14.2.8.4 Irrespective of the values obtained in accordance with formulae 14.2.8.2-1, 14.2.8.2-2, 14.2.8.3-1 and 14.2.8.3-2, the thickness of spherical and cylindrical walls as well as 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-on tubes;
.4 specified in Table 14.2.8.4 – for tubes.

Table 14.2.8.4

Tube outside diameter [mm]	≤20	>20 ≤30	>30 ≤38	>38 ≤51	>51 ≤70	>70 ≤95	>95 ≤102	>102 ≤121	>121 ≤152	>152 ≤191	>191
Minimum wall thickness [mm]	1.75	2.0	2.2	2.4	2.6	3.0	3.25	3.5	4.0	5.0	5.4

Note:
The decrease in wall thickness due to expanding or bending shall be compensated by allowances.

14.2.8.5 The minimum wall thickness of pipes made of non-ferrous alloys and stainless steel may be less than those specified in paragraph 14.2.8.4, however not less than those determined in accordance with formulae 14.2.8.2 and 14.2.8.3.

14.2.9 Elements Subjected to External Pressure

14.2.9.1 The requirements specified in this sub-chapter apply to cylindrical walls with:

$$\frac{D_a}{D} \leq 1.2.$$

Wall thickness of pipes with $D_a \leq 200$ mm in diameter shall be determined in accordance with paragraph 14.2.8.2.

14.2.9.2 Plain wall thickness of cylindrical elements, with or without stiffeners, shall not be less than that determined in accordance with the formula below:

$$s = \frac{50(B + \sqrt{B^2 + 0{,}04AC}}{A} + c \quad [\text{mm}] \qquad (14.2.9.2\text{-}1)$$

where:

$$A = 200\frac{\sigma}{D_m}\left(1 + \frac{D_m}{10l}\right)\left(1 + \frac{5D_m}{l}\right) \qquad (14.2.9.2\text{-}2)$$

$$B = p\left(1 + \frac{5D_m}{l}\right) \qquad (14.2.9.2\text{-}3)$$

$$C = 0{,}045 \cdot p \cdot D_m \qquad (14.2.9.2\text{-}4)$$

s – wall thickness, [mm];
p – design pressure (see sub-chapter 14.2.2), [MPa];
D_m – mean diameter, [mm];
σ – allowable stress (see paragraph 14.2.4.5), [MPa];
c – design thickness allowance (see sub-chapter 14.2.7), [mm];

l – design length of cylindrical portion between stiffeners, [mm].

End plates and stiffening rings (Fig. 14.2.9.2) or similar structures may be considered as stiffeners.

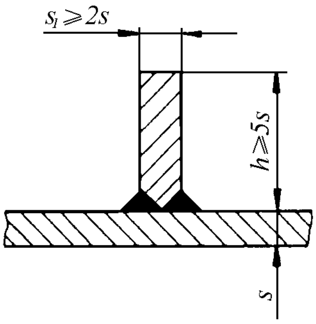


Fig. 14.2.9.2

14.2.9.3 Strengthening means shall be provided in way of holes and openings in cylindrical and spherical walls in accordance with the requirements specified in sub-chapter 14.2.17.

14.2.10 Conical Elements

14.2.10.1 Wall thickness of conical elements subjected to internal pressure shall not be less than:

.1 for $\alpha \leq 70°$ – the greater value out of those determined in accordance with the formulae below:

$$s = \frac{D_a p y}{4\sigma\varphi} + c \quad [\text{mm}] \qquad (14.2.10.1.1\text{-}1)$$

and

$$s = \frac{D_c p y}{(4\sigma\varphi - p)\cos\alpha} + c \quad [\text{mm}] \qquad (14.2.10.1.1\text{-}2)$$

.2 for $\alpha > 70°$ – the value determined in accordance with the formula below:

$$s = 0{,}3[D_a - (r + s)]\sqrt{\frac{p}{\sigma\varphi} \cdot \frac{\alpha}{90°}} + c \quad [\text{mm}] \qquad (14.2.10.1.2)$$

s – wall thickness, [mm];
D_c – design diameter (see Figures. 14.2.10.1.2-1 to 14.2.10.1.2-4), [mm];
D_a – outside diameter (see Figures 14.2.10.1.2-1 to 14.2.10.1.2-4), [mm];
p – design pressure (see sub-chapter 14.2.2), [MPa];
y – shape factor (see Table 14.2.10.1);
α, α_1, α_2, α_3 – angles (see Figures 14.2.10.1.2-1 to 14.2.10.1.2-4), [°];
σ – allowable stress (see paragraph 14.2.4.5), [MPa];
φ – strength factor (see sub-chapter 14.2.6). In formulae 14.2.10.1.1-1 and 14.2.10.1.2, the strength factor for circumferential weld seam shall be applied, whereas in formula 14.2.10.1.1-2 – for longitudinal weld seam. For seamless conical shell segments, and also where circumferential seam is at the distance from the edge exceeding:
$0{,}5\sqrt{\frac{D_a s}{\cos\alpha}}$ strength factor $\varphi = 1$ shall be taken;
r – edge radius (Figures 14.2.10.1.2-1, 14.2.10.1.2-2 and 14.2.10.1.2-4), [mm];
c – design thickness allowance (see sub-chapter 14.2.7), [mm].

Table 14.2.10.1

α [deg]	Shape factor y as function of r / D_a ratio											
	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 welded joints (see Fig. 14.2.10.1.2-3), shape factor y shall be determined for $r / D_a = 0.01$.

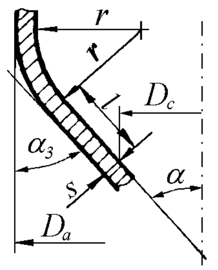


Fig. 14.2.10.1.2-1

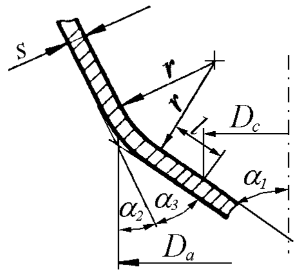


Fig. 14.2.10.1.2-2

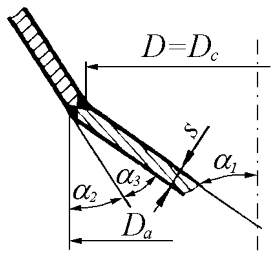


Fig. 14.2.10.1.2-3

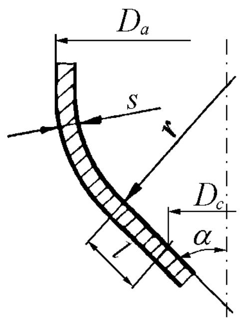


Fig. 14.2.10.1.2-4

l – distance from the edge of the wide end of conical shell, along the generatrix, taken as tenfold wall thickness, however not greater than half the length of the conical shell generatrix segment (Figures 14.2.10.1.2-1, 14.2.10.1.2-2 and 14.2.10.1.2-4), [mm];

14.2.10.2 The wall thickness of conical elements subjected to external pressure shall be determined in accordance with paragraph 14.2.10.1, provided the following conditions are fulfilled:

.1 strength factor of welded joint φ shall be taken equal to 1;
.2 allowance c shall be taken equal to 2 mm;
.3 design diameter D_c shall be determined in accordance with the formula below:

$$D_c = \frac{d_1 + d_2}{2\cos\alpha} \text{ [mm]} \qquad (14.2.10.2.3)$$

d_1, d_2–the greatest and the smallest diameter of the cone, respectively, [mm];

.4 for $\alpha < 45°$ it shall be demonstrated that the walls are not subject to plastic strain. Pressure p_1, at which plastic strain occurs, shall be determined in accordance with the formula below:

$$p_1 = 26E10^{-6}\frac{D_c}{l_1}\left[\frac{100(s-c)}{D_c}\right]^2\sqrt{\frac{100(s-c)}{D_c}} \quad [\text{MPa}] \qquad (14.2.10.2.4)$$

E – modulus of elasticity, [MPa];
l_1 – the maximum length of the cone or distance between its restrains, [mm].

Fulfilment of inequality $p_1 > p$ (p – design pressure, [MPa]) is the condition of absence of plastic strain of the cone walls.

14.2.10.3 Welded joints (see Fig. 14.2.10.1.2-3) are permitted only with the values of angle $\alpha_3 \leq 30°$ and wall thickness $s \leq 20$ mm. The joints shall be double-side welded. In conical shell segments with $\alpha \geq 70°$, welded joints may be made without edge bevelling provided that the requirements specified in paragraph 14.2.10.2 are fulfilled.

14.2.10.4 In way of holes and openings in conical walls, adequate strengthening shall be provided in accordance with the requirements specified in sub-chapter 14.2.17.

14.2.11 Flat End Plates and Covers

14.2.11.1 The thickness of the flat end plates unsupported by stays, as well as of welded or bolted covers (Figures 14.2.11.1-1 to 14.2.11.1-8 and Fig. 1.2 in the Annex) shall not be less than that determined in accordance with the formula below:

$$s = KD_c\sqrt{\frac{p}{\sigma}} + c \quad [\text{mm}] \qquad (14.2.11.1\text{-}1)$$

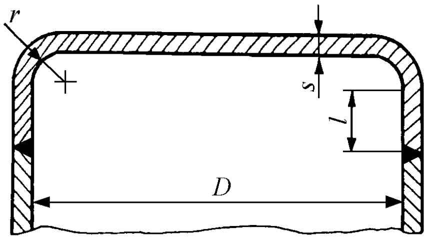
s – wall thickness, [mm];
K – design factor for the design patterns shown in Figures 14.2.11.1-1 to 14.2.11.1-8 and items 1.1 to 1.6 in the Annex;
D_c – design diameter (Figures 14.2.11.1-2 to 14.2.11.1-7 and item 1.2 in the Annex), [mm]; for end plates such as shown in Fig. 14.2.11.1-1 and item 1.1 in the Annex, the design diameter shall be determined in accordance with the formula below:

$$D_c = D - r \quad [\text{mm}] \qquad (14.2.11.1\text{-}2)$$

for rectangular or oval covers the design diameter shall be determined in accordance with the formula below:

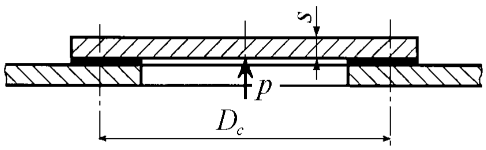
$$D_c = m\sqrt{\frac{2}{1+\left(\frac{m}{n}\right)^2}} \quad [\text{mm}] \qquad (14.2.11.1\text{-}3)$$

D_b – pitch circle diameter of bolts (Fig. 14.2.11.1-6), [mm];
D – internal diameter, [mm];
n and m – the maximum and minimum length of the axis or the side of the opening respectively, measured to the axis of the packing arrangement, [mm] (Fig. 14.2.11.1-8);
r – inner curvature radius of the dished end plate, [mm];
p – design pressure (see sub-chapter 14.2.2), [MPa];
σ – allowable stress (see paragraph 14.2.4.5), [MPa];
c – design thickness allowance (see sub-chapter 14.2.7), [mm];
l – length of end plate cylindrical portion (see Fig. 14.2.11.1-1 and item 1.1 in the Annex), [mm].



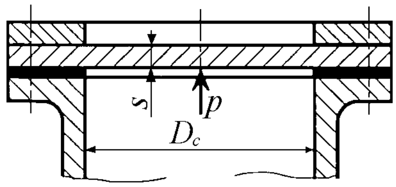
$K = 0.30$

Fig. 14.2.11.1-1



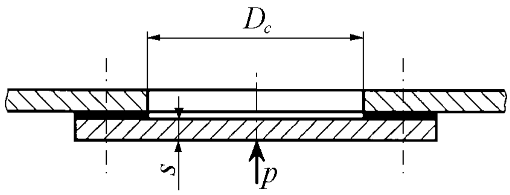
$K = 0.41$

Fig. 14.2.11.1-2



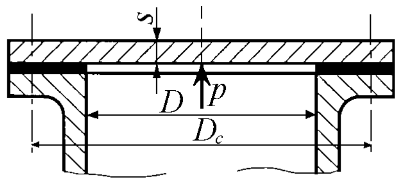
$K = 0.41$

Fig. 14.2.11.1-4



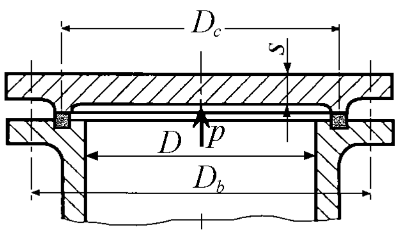
$K = 0.45$

Fig. 14.2.11.1-3



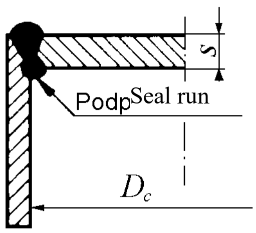
$K = 0.35$

Fig. 14.2.11.1-5



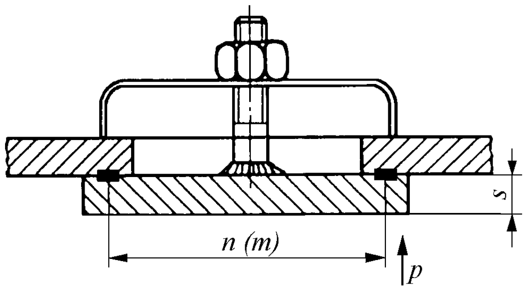
D_b/D	K
1,25	0,6
1,50	0,7
1,75	0,8

Fig. 14.2.11.1-6



$K = 0.50$

Fig. 14.2.11.1-7



$K = 0.53$

Fig. 14.2.11.1-8

14.2.11.2 Thickness of the plates shown in item 1.2 of the Annex shall not be less than that determined in accordance with formula 14.2.11.1-1. Additionally, the following requirements shall be fulfilled:

.1 For circular end plates

$$0.77s_1 \geq s_2 \geq \frac{1.3p}{\sigma}\left(\frac{D_c}{2} - r\right) \qquad (14.2.11.2.1)$$

.2 For rectangular end plates

$$0.55s_1 \geq s_2 \geq \frac{1.3p}{\sigma} \cdot \frac{nm}{(n+m)} \qquad (14.2.11.2.2)$$

s – end plate thickness, [mm];
s_1 – shell thickness, [mm];
s_2 – end plate thickness within the relieving groove, [mm].

For other symbols – see sub-chapter 14.2.11.1.

Thickness s_2 shall never be less than 5 mm.

The above conditions apply to end plates with not more than 200 mm in diameter or side length. The dimensions of relieving grooves in end plates with diameters or side lengths over 200 mm are subject to PRS acceptance in each particular case.

14.2.12 Flanging Flat Walls

14.2.12.1 In flat wall and end plate calculations, the flanging can be taken into account only when the inner flanging radius is not less than that given in Table 14.2.12.1.

Table 14.2.12.1

End plate outer diameter [mm]	Flanging radius [mm]
up to 350	25
from 350 to 500	30
from 500 to 950	35

The inner flanging radius shall not be less than 1.3 times the wall thickness.

14.2.12.2 The length of cylindrical portion of a flanged flat end plate shall not be less than determined in accordance with the formula below:

$$l = 0.5\sqrt{Ds}$$

for symbols *l, D, s* – see Fig. 14.2.11.1-1.

14.2.13 Strengthening of Openings in Flat Walls

14.2.13.1 In flat walls, end plates and covers, openings with diameters greater than four times the thickness shall be strengthened by means of welded-on branch pieces or pads, or by increasing the design wall thickness. The openings shall be arranged at a distance not less than 0.125 times the design diameter from the design diameter outline.

14.2.13.2 If the actual wall thickness is greater than that determined in accordance with formula 14.2.11.1-1, ,the maximum diameter of a not strengthened opening shall be determined in accordance with the formula below:

$$d = 8s_r\left(1{,}5\frac{s_r^2}{s^2} - 1\right) \quad [\text{mm}] \qquad (14.2.13.2)$$

d – diameter of not strengthened opening, [mm];
s_r – actual wall thickness, [mm];

s – design wall thickness determined in accordance with formula 14.2.11.1-1, [mm].

14.2.13.3 Edge strengthening shall be provided for openings with diameters greater than those determined in accordance with formulae 14.2.13.1 and 14.2.13.2 to fulfil the condition below:

$$s_k\left(\frac{h^2}{s_r^2}-0.65\right)\geq 0.65d-1.4s_r \qquad (14.2.13.3)$$

s_k – branch piece wall thickness, [mm], (see Fig. 14.2.13.3);
d – branch piece inside diameter, [mm];
s_r – see paragraph 14.2.13.2, [mm];

$h=h_1+h_2$ [mm], (see Fig. 14.2.13.3).

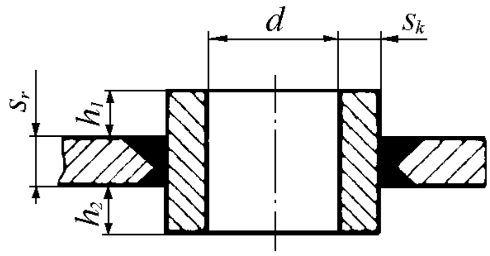


Fig. 14.2.13.3

14.2.14 Tube Plates

14.2.14.1 Thickness s_1 of flat tube plates of heat exchangers shall not be less than that determined in accordance with the formula below:

$$s_1=0{,}9KD_W\sqrt{\frac{P}{\sigma\varphi}}+c \quad \text{[mm]} \qquad (14.2.14.1)$$

K – factor depending on the ratio of shell wall thickness s to tube plate thickness s_1; for tube plates welded to the shell, K shall be determined in accordance with diagram 14.2.14.1 on the preliminary assumption of s_1 thickness, and the calculation shall be corrected if the difference between assumed value of s_1 and that determined in accordance with formula 14.2.14.1 exceeds 5%;
for the tube plate fixed by bolts or stud-bolts between the shell and cover flanges K = 0.5;
D_W – shell inner diameter, [mm];
P – design pressure (see sub-chapter 14.2.2), [MPa];
σ – allowable stress (see paragraph 14.2.4.5), [MPa];
for heat exchangers of rigid structure where the thermal elongation factors of shell and pipe materials are different, σ shall be reduced by 10%;
φ – strength factor of tube plate weakened by holes for pipes (see paragraph 14.2.14.2);
c – design thickness allowance, [mm] (see sub-chapter 14.2.7).

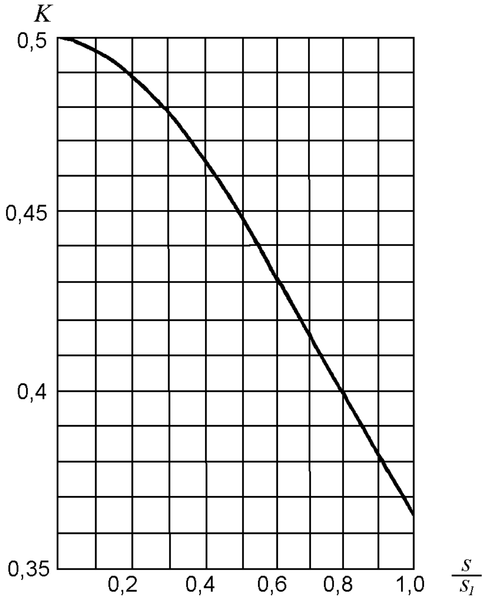


Fig. 14.2.14.1

14.2.14.2 Where $0.75 > \frac{d}{a} > 0.4$ and $\frac{D_w}{s_1} \geq 40$, the strength factor of a tube plate shall be calculated in accordance with the following formulae:

– where holes are arranged in an equilateral triangle pattern:

$$\varphi = 0.935 - 0.65\frac{d}{a} \qquad (14.2.14.2\text{-}1)$$

– where holes are arranged in a row or in transposition:

$$\varphi = 0.975 - 0.68\frac{d}{a_2} \qquad (14.2.14.2\text{-}2)$$

d – diameter of tube plate holes, [mm];
a – spacing of hole-axes arranged in triangle pattern, [mm];
a_2 – spacing of hole-axes arranged in row or in transposition (as well as arranged concentrically), whichever is lesser, [mm].

14.2.14.3 For quotients $\frac{d}{a} = 0.75 \div 0.80$, tube plate thickness determined in accordance with formula 14.2.15.1 shall fulfil the condition below:

$$f_{\min} \geq 5d$$

$f_{\min}$ – minimum allowable cross sectional area of bridge in tube plate, [mm^2].

For values of $\frac{d}{a}$ and $\frac{D_W}{s_1}$ other than those specified above, as well as for heat exchangers with rigid structure when the difference in mean temperatures exceeds 50°C, the thickness of tube plates is subject to PRS acceptance in each particular case.

14.2.14.4 In addition to the requirement specified in paragraph 14.2.14.1, the thickness of tube plates with expanded tubes shall fulfil the condition below:

$$s \geq 10 + 0.125d \;\; \text{[mm]} \qquad (14.2.14.4)$$

Expanded connections of tubes to tube plates shall also fulfil the requirements specified in paragraphs 14.2.18.1, 14.2.18.2 and 14.2.18.3.

14.2.15 Dished Ends

14.2.15.1 Thickness of dished ends, whether unpierced or pierced, subjected to internal or external pressure (see Fig. 14.2.15.1) shall not be less than that determined in accordance with the formula below:

$$s = \frac{D_a p y}{4\sigma\varphi} + c \quad \text{[mm]} \qquad (14.2.15.1)$$

s –end wall thickness, [mm];
p –design pressure, [MPa];
D_a –end outer diameter, [mm].

The end shall be flanged within the distance not less than 0.1 D_a measured from the outer edge of the end cylindrical portion (see Fig. 14.2.15.1);

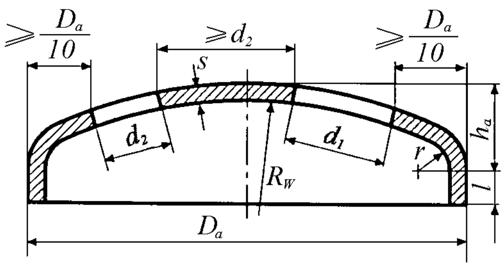


Fig. 14.2.15.1

φ – strength factor (see sub-chapter 14.2.6);
σ – allowable stress (see paragraph 14.2.4.5), [MPa];
y – shape factor determined in accordance with Table 14.2.15.1 depending on the ratio of the height to outside diameter of the end and on the value of weakening by holes; for intermediate values of $\frac{h_a}{D}$ and $\frac{d}{\sqrt{D_a s}}$, shape factor y may be determined by linear interpolation.

To determine y in accordance with Table 14.2.15.1, the preliminary value s shall be preliminary taken from the standardized thickness series. The final value of s shall not be less than that determined in accordance with formula 14.2.15.1.

For elliptical and basket shaped ends, R_W is the maximum radius of curvature.

Table 14.2.15.1

End shape	Ratio $\frac{h_a}{D_a}$	Shape factor							
		y – for flanged area and unpierced ends	y_A – for dished part of end with not strengthened holes with respect to $\frac{d}{\sqrt{D_a s}}$						y_C – for dished part of end with strengthened holes
			0.5	1.0	2.0	3.0	4.0	5.0	
Dished elliptical or basket shaped ends with $R_W = D_a$	0.20	2.9	2.9	2.9	3.7	4.6	5.5	6.5	2.4
Dished elliptical or basket shaped ends with $R_W = 0.8\ D_a$	0.25	2.0	2.0	2.3	3.2	4.1	5.0	5.9	1.8
Dished spherical ends with $R_W = 0.5\ D_a$	0.50	1.1	1.2	1.6	2.2	3.0	3.7	4.35	1.1

c – design thickness allowance, to be taken equal to:
2 mm – if subjected to internal pressure,
3 mm – if subjected to external pressure;

for wall thickness exceeding 30 mm, the above values of allowance may be reduced by 1 mm;

d – the greatest diameter of not strengthened hole, [mm].

Formula 14.2.15.1 is applicable if the following conditions are fulfilled:

$$\frac{h_a}{D_a} \geq 0.18;\ \frac{s-c}{D_a} \geq 0.0025;\ R_W \leq D_a;\ r \geq 0,1D_a;\ l \leq 150 \text{ mm},$$

where:
$l \geq 25$ mm for $s \leq 10$ mm,
$l \geq 15 + s$, [mm] for $10 < s \leq 20$ mm,
$l \geq 25 + 0,5\,s$, [mm] for $s > 20$ mm.

The symbols for dimensions of dished end elements are shown in Fig. 14.2.15.1.

14.2.15.2 Unpierced ends as well as ends with holes whose diameter is not greater than 4s and not greater than 100 mm arranged at a distance not less than $0.2D_a$ from the outer cylindrical portion of the end are also considered as unpierced ends. Not strengthened holes with the diameter less than the wall thickness, however not exceeding 25 mm, are permitted in way of the end curvature.

14.2.15.3 Dished ends subjected to external pressure, except for those made of cast iron, shall be checked for shape stability in accordance with the formula below:

$$\frac{36.6E_T}{R_W^2} \cdot \frac{(s-c)^2}{100p} > 3.3 \qquad (14.2.15.3)$$

E_T – modulus of elasticity at design temperature, [MPa],
for steel modulus of elasticity – see Table 14.2.15.3, for non-ferrous materials the modulus of elasticity value is subject to PRS acceptance;

R_W – maximum inner radius of curvature, [mm].

For other symbols – see paragraph 14.2.15.1.

Table 14.2.15.3

Design temperature T, [°C]	20	250	300	400	500
Modulus of elasticity E_T for steel, [MPa]	206 000	186 000	181 000	172 000	162 000

14.2.15.4 The minimum wall thickness of dished steel ends shall not be less than 5 mm. For ends manufactured of non-ferrous alloys, the minimum wall thickness may be reduced subject to PRS acceptance.

14.2.15.5 Application of dished ends of welded construction is subject to PRS acceptance in each particular case.

14.2.16 Flanged End Plates

Thickness of unpierced flanged end plates (Fig. 14.2.16), subjected to internal pressure shall not be less than that determined in accordance with the formula below:

$$s = \frac{3Dp}{\sigma} + c \quad \text{[mm]} \qquad (14.2.16)$$

s – wall thickness, [mm];
p – design pressure (see sub-chapter 14.2.2), [MPa];
D – inside diameter of end plate, taken equal to shell internal diameter, [mm];
σ – allowable stress (see paragraph 14.2.4.5), [MPa];
c – design thickness allowance (see sub-chapter 14.2.7), [mm].

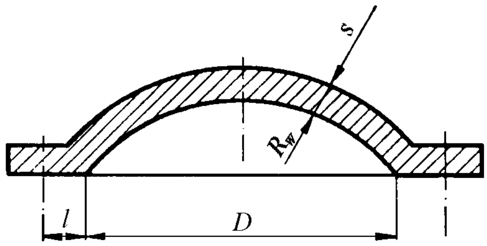


Fig. 14.2.16

Flanged end plates are allowed within a range of diameters D up to 500 mm and for working pressures not higher than 1.5 MPa. The end plate curvature radius R_W shall not be less than 1.2 D, and the distance l shall not exceed 2s.

14.2.17 Openings in Cylindrical, Spherical, Conical Walls and in Dished Ends

14.2.17.1 Strengthening arrangements shall be provided in way of openings. The following strengthening methods are permitted:

- **.1** wall thickness increased above the design thickness (Fig. 14.2.17.1-1 and Fig. 14.2.17.1-2);
- **.2** disk-shaped strengthening plates welded on the wall being strengthened (Fig. 14.2.17.1-3 and Fig. 14.2.17.1-4);
- **.3** welded-on pipe elements, such as branch pieces, sleeves etc. (Figures 14.2.17.1-5 to 14.2.17.1-7).

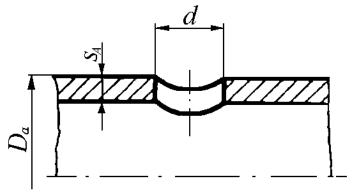


Fig. 14.2.17.1-1

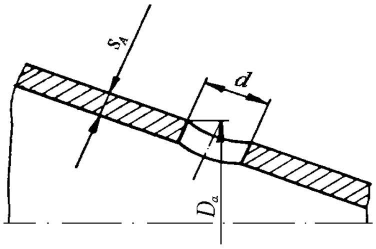


Fig. 14.2.17.1-2

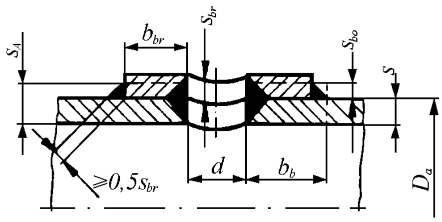


Fig. 14.2.17.1-3

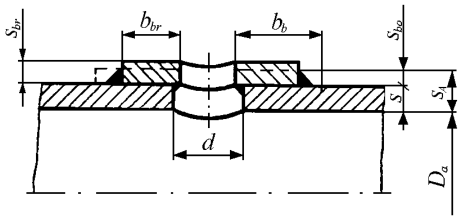


Fig. 14.2.17.1-4

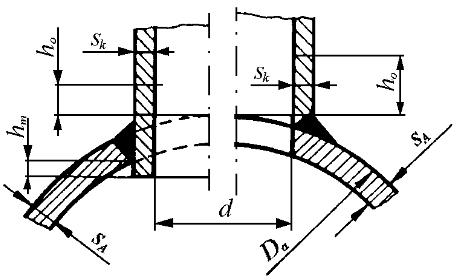


Fig. 14.2.17.1-5

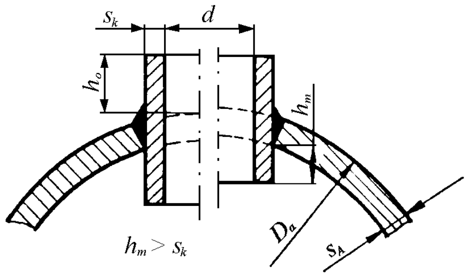


Fig. 14.2.17.1-6

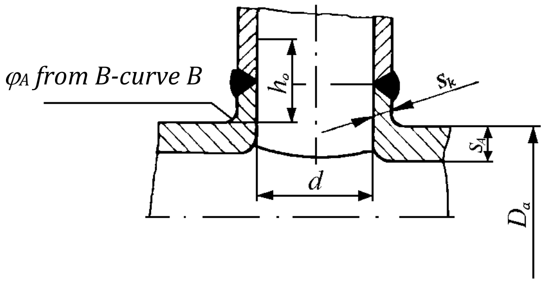


Fig. 14.2.17.1-7

It is recommended that opening strengthening elements, as shown in Figures 14.2.17.1-5 to 14.2.17.1-7, be welded with temporary backing or using other techniques ensuring proper penetration of the welded joint.

14.2.17.2 Thickness of pierced walls shall fulfil the requirements specified in sub-chapters 14.2.8 and 14.2.9 for cylindrical walls, in sub-chapter 14.2.10 – for conical walls and in sub-chapter 14.2.15 – for dished ends.

14.2.17.3 Materials used for the walls being strengthened and for strengthening elements shall have identical strength characteristics, if possible. Where the materials of strengthening elements have worse strength characteristics than the wall material, the cross-sectional area strengthening elements shall be increased respectively.

Strengthening elements shall be properly connected to the wall being strengthened.

14.2.17.4 Openings in walls shall be located at a distance equal at least triple wall thickness, however not less than 50 mm from the welded joints. The arrangement of openings at the distance less than 50 mm from the welded joints is subject to PRS acceptance in each particular case.

14.2.17.5 Opening diameter (or the largest dimension of an opening other than circular) shall not exceed 500 mm. Application of openings greater than 500 mm and their strengthening methods are subject to PRS acceptance in each particular case.

14.2.17.6 In general, wall thickness of tubular elements (branch pieces, sleeves or nozzles) welded to the walls of pressure vessels and heat exchangers shall not be less than 5 mm. Application of elements less than 5 mm in thickness is subject to PRS acceptance in each particular case.

14.2.17.7 Opening may be strengthened by increasing design thickness of the wall. In that case, increased wall thickness s_A shall not be less than the value determined in accordance with the following formulae:

for cylindrical shells

$$s_A = \frac{pD_a}{2\sigma\varphi_A + p} + c \quad \text{[mm]} \qquad (14.2.17.7\text{-}1)$$

for spherical shells

$$s_A = \frac{pD_a}{4\sigma\varphi_A + p} + c \quad \text{[mm]} \qquad (14.2.17.7\text{-}2)$$

for conical shells

$$s_A = \frac{pD_a}{(2\sigma\varphi_A - p)\cos\alpha} + c \quad \text{[mm]} \qquad (14.2.17.7\text{-}3)$$

s_A – required wall thickness without strengthening elements, [mm];

φ_A – strength factor of wall weakened by opening which is being strengthened, determined for the pattern curve A (see diagram in Fig. 14.2.17.7) depending on dimensionless parameter $\frac{d}{\sqrt{D_a(s_A-c)}}$, and to determine this parameter, the value of s_A obtained in accordance with formulae 14.2.17.7-1 to 14.2.17.7-3 shall be taken;

d – diameter of the opening (inner diameter of a branch piece, sleeve) or the dimension of an oval or elliptical opening along the longitudinal axis, [mm].

For other symbols – see paragraphs 14.2.8.2 and 14.2.10.1.

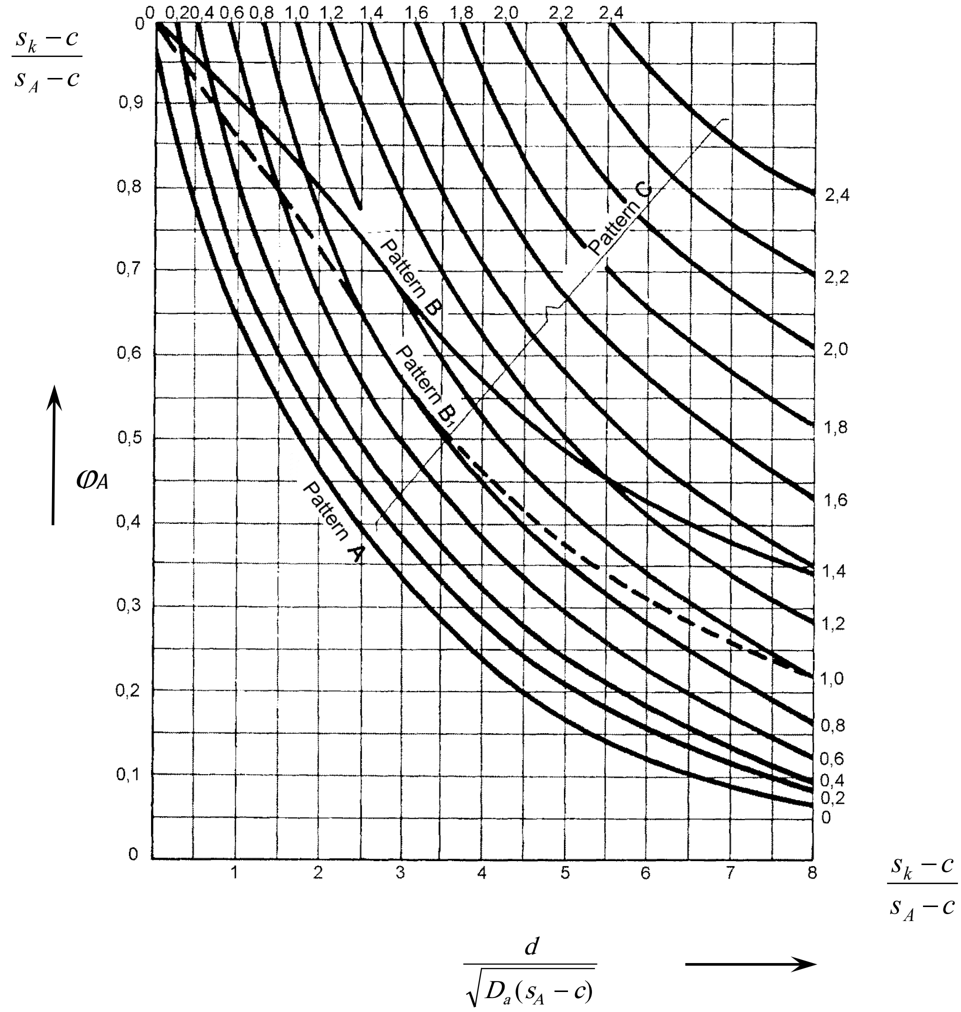


Fig. 14.2.17.7

14.2.17.8 Where disc-shaped plates are used to strengthen openings in cylindrical, spherical or conical walls, the dimensions of the strengthening plates shall be determined in accordance with the following formulae:

$$b_b = \sqrt{D_a(s_A - c)} \quad \text{[mm]} \qquad (14.2.17.8\text{-}1)$$

$$s_{bo} \geq s_A - s_r \quad \text{[mm]} \qquad (14.2.17.8\text{-}2)$$

b_b – maximum effective width of plate (see Figures 14.2.17.1-3 and 14.2.17.1-4), [mm];
s_{bo} – plate thickness (see Figures 14.2.17.1-3 and 14.2.17.1-4), [mm];
s_A – total thickness of wall being strengthened and strengthening plate, determined in accordance with the requirements specified in paragraph 14.2.17.7, [mm];

s_r – actual thickness of wall being strengthened, [mm].

For other symbols – see paragraph 14.2.17.7.

Where the actual width of strengthening plate is less than that resulting from formula 14.2.17.8-1, the plate thickness shall be increased respectively, in accordance with the formula below:

$$s_{br} \geq s_{bo} \frac{1+\frac{b_b}{b_{br}}}{2} \text{ [mm]} \quad (14.2.17.8\text{-}3)$$

s_{br} – actual thickness of plate, [mm];
b_{br} – actual width of plate, [mm].

Thickness of weld seam connecting the strengthening plate to the wall shall not be less than 0.5 s_{br} (Fig. 14.2.17.1-3).

14.2.17.9 Dimensions of welded tubular elements used to strengthen openings in cylindrical, spherical and conical walls shall not be less than those determined as follows:

.1 Wall thickness s_k of a tubular element (branch piece, sleeve, etc.), [mm], shall be determined as a function of the following dimensionless parameter

$$\frac{d}{\sqrt{D_a(s_A - c)}}$$

and the strength factor φ_A, from curves *C* shown in Fig. 14.2.17.7. Quantities φ_r and s_r shall be substituted for φ_A and s_A shown in Fig. 8.2.19.7, where:
s_r – actual thickness of wall, [mm];
φ_r – actual strength factor of wall with thickness s_r, as determined in accordance with formulae 14.2.8.2-1, 14.2.8.2-2, 14.2.8.3-1, 14.2.8.3-2 and 14.2.10.1.2 by re-arranging the said formulae to determine φ.

Ratio: $\frac{s_k - c}{s_A - c}$

obtained from the diagram in Fig. 14.2.17.7 shall be used to determine the minimum thickness s_k, [mm] of a branch piece or sleeve. In this ratio, actual thickness s_r shall be substituted for s_A.

.2 The minimum design height h_0 [mm] of a tubular strengthening element (branch piece, sleeve, pipe) shall be determined in accordance with the formula below:

$$h_0 = \sqrt{d(s_k - c)} \quad (14.2.17.9.2\text{-}1)$$

If actual height, h_r, of a tubular strengthening element is less than that determined in accordance with formula 14.2.17.9.2-1, thickness s_k shall be increased respectively as follows:

$$s_{kr} = s_k \frac{h_0}{h_r} \text{ [mm]} \quad (14.2.17.9.2\text{-}2)$$

14.2.17.10 Dimensions of the elements strengthening openings in dished ends shall be determined as follows:

.1 For openings strengthened by increasing the dished end wall thickness, factor y_A obtained from Table 14.2.15.1 shall be substituted for factor y in formula 14.2.15.1.

.2 For openings strengthened by means of disk-shaped strengthening plates, the plate dimensions shall be determined in accordance with paragraph 14.2.17.8, and the total thickness of the strengthened end wall, s_A, shall be determined in accordance with the formula below:

$$s_A = \frac{p(R_W + s)y_0}{2\sigma\varphi_A} + c \text{ [mm]} \quad (14.2.17.10.3)$$

R_W – inner radius of curvature in way of opening [mm];
y_0 – shape factor determined in accordance with Table 14.2.15.1.

For other symbols – see paragraphs 14.2.15.1 and 14.2.17.7.

.3 The dimensions of tubular elements strengthening openings shall be determined in accordance with paragraph 14.2.17.9, except that the expression $2(0.5D_a + s)$ shall be substituted for D_a in the following dimensionless parameter

$$\frac{d}{\sqrt{D_a(s-c)}}$$

and the actual strength factor φ for the dished end wall thickness, s , shall be determined in accordance with formula 14.2.15.1, assuming $\varphi = \varphi_A$, $y = y_0$ and $s = s_A$ (see paragraph 14.2.15.1).

14.2.17.11 For through tubular strengthening elements with the inward projecting portion $h_m \geq s_r$ (Figures 14.2.17.1-5 and 14.2.17.1-6), thickness of the tubular element may be reduced by 20%, however its thickness shall not be less than that required for the design pressure.

14.2.17.12 The ratio of a tubular strengthening element thickness, s_k , to the thickness of wall being strengthened, s , shall not be greater than 2.4. If, this ratio is taken as more than 2.4, for construction reasons, tubular strengthening element thickness, s_k , shall be assumed not greater than 2.4 times the thickness of the wall being strengthened in the calculation.

14.2.17.13 Disk-shaped strengthening plates and tubular strengthening elements may also be used in combination (Fig. 14.2.17.13). In that case, the dimensions of strengthening elements shall be determined taking account of the requirements for both the disk-shaped and tubular strengthening element.

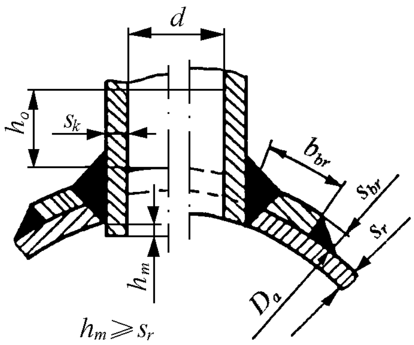


Fig. 14.2.17.13

14.2.17.14 For branch pieces drawn from the wall being strengthened (Fig. 14.2.17.1-7), thickness s_A, shall not be less than that determined in accordance with formulae 14.2.17.7-1 to 14.2.17.10.3.

Strength factor φ_A for the wall weakened due to a drawn branch piece shall be obtained from diagram 14.2.17.7 as follows:

for $\frac{d}{D_a} \leq 0.4$ – from curve B,

for $\frac{d}{D_a} = 1.0$ – from curve B_1,

for $0.4 < \frac{d}{D_a} < 1.0$ – by interpolation of curves B and B_1.

Thickness of a drawn branch shoulder, s_k , shall not be less than that determined in accordance with the formula below:

$$s_k \geq s_A \frac{d}{D_a} \quad \text{[mm]} \qquad (14.2.17.14)$$

however not less than that required for the design pressure.

14.2.17.15 The effect of adjacent openings may be disregarded provided that:

$$(l + s_{kr1} + s_{kr2}) \geq 2\sqrt{D_a(s_r - c)} \qquad (14.2.17.15\text{-}1)$$

$(l + s_{kr1} + s_{kr2})$ – distance between two adjacent openings (Figures 14.2.17.15-1 and 14.2.17.15-2) [mm];
D_a – outside diameter of wall being reinforced [mm];
s_r – actual thickness of wall being reinforced [mm];
c – design thickness allowance [mm], (see sub-chapter 14.2.7) [mm].

Where $(l + s_{kr1} + s_{kr2}) < \sqrt{D_a(s_r - c)}$, the stress occurring in the wall cross-section between the openings due to design pressure shall be checked. Both longitudinal and lateral stresses in that section shall not exceed the allowable values determined in accordance with the formula below:

$$\frac{F}{f_c} \leq \sigma \qquad (14.2.17.15\text{-}2)$$

σ – allowable stress (see paragraph 14.2.4.5) [MPa];
F – load exerted by the design pressure upon the cross-section between openings (see paragraph 14.2.17.16) [N];
f_c – cross sectional area between openings (see paragraph 14.2.17.17) [mm²].

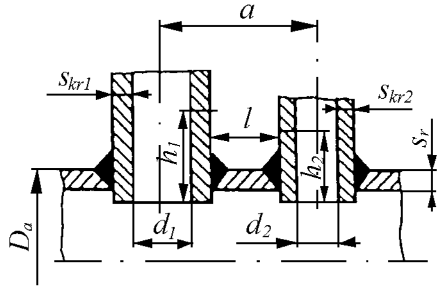


Fig. 14.2.17.15-1

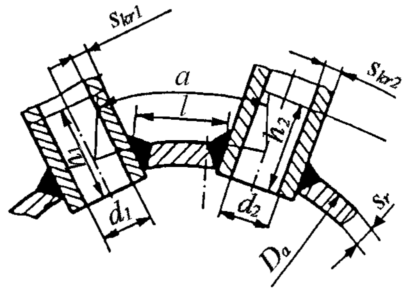


Fig. 14.2.17.15-2

14.2.17.16 Load exerted by the design pressure on the cross sectional area between two openings shall be determined as follows:

.1 for openings arranged longitudinally along a cylindrical wall:

$$F_a = \frac{Dpa}{2} \text{ [N]} \qquad (14.2.17.16.1)$$

.2 for openings arranged circumferentially in cylindrical or conical walls, as well as in spherical walls:

$$F_b = \frac{Dpa}{4} \quad \text{[N]} \qquad (14.2.17.16.2)$$

.3 for openings in dished ends:

$$F_b = \frac{R_B pay}{2} \quad \text{[N]} \qquad (14.2.17.16.3\text{-}1)$$

a – spacing between two adjacent openings, measured at the outside circumference, as shown in Fig. 14.2.17.15-2, [mm];
D – inside diameter (for conical walls measured at the centre of the opening) [mm];

p – design pressure [MPa];
R_B – inner radius of curvature (see paragraph 14.2.17.10) [mm];
y – shape factor (see paragraph 14.2.15.1).

Where openings are arranged in cylindrical walls with a diagonal pitch, the load in question shall be determined in accordance with formula 14.2.17.16.2, and the obtained results shall be multiplied by the following factor:

$$K = 1 + \cos 2\alpha \qquad (14.2.17.16.3\text{-}2)$$

α – angle between the line of a row of openings and longitudinal axis.

14.2.17.17 For tubular strengthening elements, cross sectional area, f_c, [mm²] between two adjacent openings shall be determined in accordance with the formula below:

$$f_c = l(s - c) + 0.5[h_1(s_{kr} - c) + h_2(s_{kr2} - c)] \ \text{[mm}^2\text{]} \qquad (14.2.17.17\text{-}1)$$

h_1 and h_2 – height of strengthening elements, [mm], determined in accordance with the following formulae:
for blind strengthening elements:
$h_{1,2} = h_0 + s$ (14.2.17.17-2)
for through strengthening elements:
$h_{1,2} = h_0 + s + h_m$ (14.2.17.17-3)
l – width of bridge between two adjacent openings (Figures 14.2.17.15-1 and 14.2.17.15-2) [mm];
s – thickness of wall being reinforced [mm];
s_{kr1} and s_{kr2} – thicknesses of tubular strengthening elements (Figures 14.2.17.15-1 and 14.2.17.15-2) [mm];
c – design thickness allowance [mm], (see sub-chapter 14.2.7);
h_0 – design height of tubular strengthening element (see formula 14.2.17.9.2-1) [mm];
h_m – design height of tubular strengthening element projecting inwards (see Figures 14.2.17.1-5, 14.2.17.1-6 and 14.2.17.13) [mm].

For openings to be strengthened by other means (combined or disc-shaped strengthening elements, etc.), the values of f_c shall be determined in accordance with the same procedure.

14.2.17.18 For drawn branch pieces arranged in a row, strength factor φ, determined for this row in accordance with formula 14.2.6.2.1, shall not be less than strength factor φ_A, obtained from curves B and B1 in Fig. 14.2.17.7. For $\varphi < \varphi_A$, the value of φ shall be used to determine the wall thickness in accordance with paragraph 14.2.17.14.

This requirement also applies to welded branch pieces arranged in a row, whose thickness is determined only for the internal pressure effect.

14.2.18 Flared Tube Joints in Tube Plates

14.2.18.1 Flared tube joints shall be checked for secure connection of the tubes in tube plates due to axial loads. The tubes are considered as securely connected, if the value obtained in accordance with the following formula:

$$\frac{pf_s}{20sl} \qquad (14.2.18.1)$$

is not greater than:
15 – for plain tube joints,
30 – for joints with sealing grooves,
40 – for joints with tube flanging;
p – design pressure (see paragraph 14.2.2), [MPa];

f_s – maximum sector of the area of wall being strengthened per tube, [mm^2]. This sector is bounded by lines passing at right angles through the centres of the lines connecting the axis of tube in question with the adjacent tubes.
s – wall thickness of tube, [mm];
l – expansion belt length, [mm].

Length of the flared belt of tubes l shall not be taken greater than 40 mm.

14.2.18.2 Length of the flared belt of plain tubes shall not be less than that determined in accordance with the formula below:

$$l = \frac{p f_s K_r}{q} \quad [\text{mm}] \qquad (14.2.18.2\text{-}1)$$

where:
K_r = 5.0 – safety factor of flared joint;
p, f_s – see paragraph 14.2.18.1.
q – strength of pipe joint per 1 mm of flared belt, determined experimentally in accordance with the formula below, [N/mm]:

$$q = \frac{F}{l_1} \quad [\text{N/mm}] \qquad (14.2.18.2\text{-}2)$$

where:
F – axial force necessary to extract the flared tube from the tube plate, [N];
l_1 – length of flared belt used for experimental determination the of value of q [mm].

In the case of flared tubes, the belt length flared on the tube plate shall not be less than 12 mm. In flared tube joints intended for working pressure exceeding 1.6 MPa, sealing grooves shall be provided.

15 PIPING SYSTEMS

15.1 Class, Material, Manufacture and Application of Piping

15.1.1 The requirements specified in this sub-chapter apply to piping systems, normally employed in inland waterways vessels, made of carbon steel, carbon-manganese steel, alloy steel or non-ferrous materials, specified in the scope of the documentation subject to be considered (see also paragraph 15.1.9).

The requirements do not cover open-ended exhaust gas lines from internal combustion engines.

15.1.2 For the purpose of determining the scope of tests, joint type, heat treatment and welding procedure, piping systems, depending on their service and the conveyed medium parameters, are subdivided into classes as specified in Table 15.1.2.

Table 15.1.2
Piping classes

Piping for:	Class I	Class II	Class III
Toxic [2] or strongly corrosive media	Without special safeguards [1]	With special safeguards [1]	
Flammable media with service temperature above the flashpoint or with the flashpoint below 60 °C, liquefied gases	Without special safeguards [1]	With special safeguards [1]	
Steam [4]	p >1.6 or t >300	Any combination of pressure p and	$p \le 0.7$ and $t \le 170$
Thermal oil [4]	p >1.6 or t >300		$p \le 0.7$ and $t \le 150$

Piping for:	Class I	Class II	Class III
Oil fuel, lubricating oil flammable hydraulic oil, oil cargo 4)	*p* >1.6 or *t* >150	temperature *t* beyond the scope of class I or III – see Fig. 15.1.2	*p* ≤ 0.7 and *t* ≤ 60
Other media 4), 5), 6)	*p* >4.0 or *t* >300		*p* ≤ 1.6 and *t* ≤ 200

Notes to Table 15.1.2

1) Special safeguards are intended to reduce the possibility of leakage and prevent damage in the immediate vicinity or potential risk of ignition sources, such safeguards may include pipe ducts, shielding, screening etc.
2) Pipelines conveying toxic media belong to Class I.
3) Except oil cargo systems.
4) *p* – design pressure, [MPa], (see paragraph 15.2.1).
t – design temperature, [° C], (see paragraph 15.2.1).
5) Including water, air, gas, lubricating oil and non-combustible hydraulic oil.
6) Open-ended pipes (drains, overflow pipes, air pipes, exhaust gas lines and steam discharge pipes from safety valves) belong to Class III.

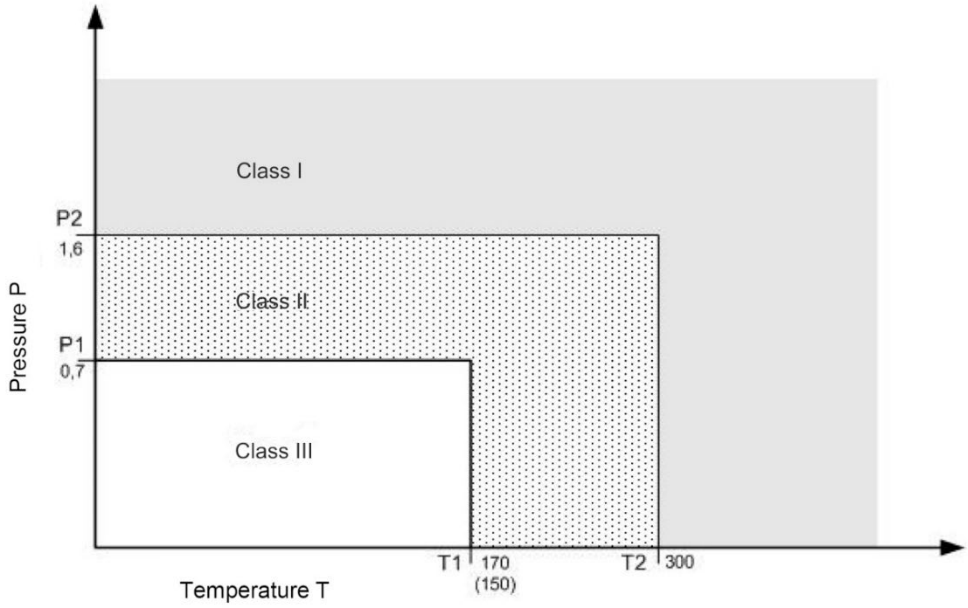


Fig. 15.1.2

15.1.3 Materials intended for pipes, valves and fittings shall fulfil the requirements specified in *Part IX – Materials and Welding* of the *Rules for Construction and Classification of Sea-going Ships*.

Materials for pipes, valves and fittings intended to be exposed to strongly corrosive media are subject to PRS acceptance in each particular case.

Fabrication of piping systems shall fulfil the requirements specified in *Publication No. 23/P – Pipelines Prefabrication.*

15.1.4 Steel pipes intended for Class I or Class II piping systems shall be seamless, hot or cold drawn pipes. Welded pipes, approved by PRS as equivalent to seamless pipes, may also be used.

15.1.5 Pipes, vales and fittings of nodular ferritic cast iron (with unit elongation A_5 not less than 12 %) may be accepted for media with temperatures not exceeding 350 °C for the purposes including:

– bilge, ballast and cargo pipes within double bottom or cargo tanks,
– side valves and fittings, as well as valves and fittings installed on collision bulkhead and on fuel and oil tanks.

Application of nodular ferritic cast iron for other valves, fittings and pipes as well as for Class II or Class III piping is subject to PRS acceptance in each particular case.

15.1.6 Grey cast iron may be used for class III piping systems and in oil tankers for cargo and stripping piping within cargo tanks.

Grey cast iron may be used for pipes, valves and fittings in other service piping systems is subject to PRS acceptance in each particular case.

Grey cast-iron shall not be used for:
- pipes, valves and fittings for media with temperature exceeding 220°C,
- pipes, valves and fittings subjected to hydraulic shock or excessive strains and vibrations,
- pipes, valves and fittings of fire-extinguishing systems,
- pipes connected directly to the shell plating,
- valves and fittings installed on the shell plating or collision bulkhead,
- valves and fittings installed directly on oil fuel, lubricating oil or other flammable oil tanks under hydrostatic pressure, unless proper means have been provided to protect them against damage.

15.1.7 Copper and copper alloy pipes shall be seamless or other type approved by PRS. These pipes for class I and class II piping systems shall be seamless.

Copper and copper alloy pipes, valves and fittings shall not be used for media with temperature exceeding:
200°C – for copper and copper-aluminium alloys,
260°C – for high-temperature bronze,
300°C – for copper-nickel alloys.

15.1.8 Application of aluminium and aluminium alloys is subject to PRS acceptance in each particular case.

Aluminium and aluminium alloys and aluminium alloys shall not be used for:
- pipes, valves and fittings for media with temperature exceeding 200°C,
- pipes, valves and fittings fire-extinguishing systems.

15.1.9 The requirements for plastic pipes as well as conditions for their application in ships are specified in *Publication No. 53/P – Plastic Pipelines on Ships*.

15.1.10 Type and construction of non-metallic flexible joints used in systems whose documentation is required to be submitted to PRS are subject to PRS approval.

Flexible joints shall be fabricated as assemblies complete with flange or screw connection pieces ready to be inserted in a pipeline. Installation of flexible joints in pipelines by means of hose clips is not permitted. The joints shall be located in conspicuous and readily accessible positions. Arrangement of cut-off valves shall be such as to allow replacement of flexible joints without stopping the machinery other than that served by the joint.

Flexible joints shall be fire-resistant when used in piping:
- conveying oil fuel or lubricating oil,
- serving watertight doors,
- leading to openings in shell plating (including bilge system),
- conveying other flammable oil, if the joint damage may cause hazard to the ship or crew and passengers.

Flexible joint is considered as fire-resistant which endures exposition to a fire of temperature 800 °C for 30 minutes with flowing water at the maximum service pressure. The outlet temperature shall not be less than 80 °C and shall be recorded throughout the test [*)].

Material for flexible hoses shall be selected taking account of the hose intended use for certain type of fluid, its pressure, temperature and ambient conditions.

The hose bursting pressure shall be at least 4-times the design pressure.

The length of hoses shall be such as to ensure flexibility of joints and normal operation of the machinery.

15.2 Pipe Wall Thickness

15.2.1 The formulae given below are applicable when the ratio of the pipe outside diameter to its inside diameter is not greater than 1.7.

Wall thickness *s* for straight or bent metal pipe exposed to internal pressure (considering the requirements specified in paragraph 15.2.2) shall not be less than that determined in accordance with the formula below:

$$s = s_o + b + c \quad [\text{mm}] \qquad (15.2.1\text{-}1)$$

$$s_o = \frac{dp}{2\sigma_d \varphi + p} \quad [\text{mm}] \qquad (15.2.1\text{-}2)$$

where:

d – outside diameter of pipe [mm];

p – design pressure [MPa] – maximum working pressure, not less than the maximum opening pressure of any safety or overflow valve setpoint; however:

- piping for oil fuel heated up to a temperature exceeding 60 °C – not less than 1.4 MPa,
- for piping of CO_2 fire extinguishing systems – according to the notes to Table 3.6.1 in *Part V – Fire Protection*;

φ – safety factor equal to 1.0 for seamless pipes and for welded pipes, considered as equivalent to seamless pipes; for all other welded pipes, the value of safety factor is subject to PRS acceptance in each particular case;

b – allowance for a reduction of pipe wall thickness due to bending; the value of *b* shall be so determined that the calculated stress in the bend, due to the internal pressure only, does not exceed the allowable stress; where the actual value of thickness reduction due to bending is not available, the value of *b* may be determined in accordance with the formula below:

$$b = 0{,}4(d/R)s_o \quad [\text{mm}] \qquad (15.2.1\text{-}3)$$

R – mean inside bend radius, [mm];

c – corrosion allowance, [mm], to be taken:

- for steel pipes – in accordance with Table 15.2.1-1,
- for non-ferrous metal pipes – in accordance with Table 15.2.1-2;

σ_d – allowable stress, [MPa], to be taken as follows:

- for steel pipes for media (inside the pipe) with temperatures not exceeding 200 °C, in accordance with the formula below:

$$\sigma_d = \frac{R_m}{2.7} \qquad (15.2.1\text{-}4)$$

[*)] Fire test of the flexible joint with flowing water at a pressure of at least 0.5 MPa and subsequent hydraulic pressure test with twice the design pressure is an alternative.

where:

R_m – minimum tensile strength at 20 °C, [MPa]; for pipes made from steel whose tensile strength is not required to be checked (i.e. for design pressures not exceeding 1 MPa) R_m = 300 MPa shall be taken;

- for steel pipes for media (inside the pipe) with temperatures exceeding 200 °C, σ_d is subject to PRS acceptance in each particular case;
- for copper and copper alloy pipes, σ_d shall be determined in accordance with Table 15.2.1-3;

Table 15.2.1-1
Corrosion allowance *c* for steel pipes

Piping service	*c* [mm]
Compressed air systems	1.0
Hydraulic oil systems	0.3
Lubricating oil systems	0.3
Oil fuel systems	1.0
Cargo oil systems	2.0
Fresh water systems	0.8
Sea-water systems	3.0

Notes to Table 15.2.1-1:

1) If the pipes are properly protected against corrosion, then the corrosion allowance may be reduced – subject to PRS acceptance – however not more than by 50%.
2) In the case of special alloy steel pipes with sufficient corrosion resistance, corrosion allowance *c* may be reduced down to zero.
3) For pipes passing through tanks, the values given in the table for inside medium shall be increased by the corrosion allowance, for external medium, taken from this Table.

Table 15.2.1-2
Corrosion allowance *c* for copper and copper alloy pipes

Pipe material	*c* [mm]
Copper and copper alloys except those with lead contents	0.8
Copper-nickel alloys (with nickel content 10% and more)	0.5

Note to Table 15.2.1-2:

For special alloy pipes with sufficient resistance to corrosion, the corrosion allowance *c* may be reduced to zero.

Table 15.2.1-3
Allowable stress σ_d for copper and copper alloys depending on medium temperature

Pipe material	Material condition	R_m [MPa]	Temperature of medium [°C]										
			50	75	100	125	150	175	200	225	250	275	300
			σ_d [MPa]										
Copper	Annealed	215	41	41	40	40	34	27.5	18.5	–	–	–	–
Aluminium brass	Annealed	325	78	78	78	78	78	51	24.5	–	–	–	–
Copper-nickel alloy 95/5 and 90/10	Annealed	275	68	68	67	65.5	64	62	59	56	52	48	44
Copper-nickel alloy 70/30	Annealed	365	81	79	77	75	73	71	69	67	65.5	64	62

Notes to Table 15.2.1-3:

1) Intermediate values shall be determined by linear interpolation.
2) For materials not included in the Table, the allowable stress is subject to PRS acceptance in each particular case.

15.2.2 For pipes with fabricated with negative tolerance of thickness, the wall thickness shall be determined in accordance with the formula below:

$$s_1 = \frac{s}{1-0{,}01a} \qquad (15.2.2)$$

where:
s – wall thickness determined in accordance with formula 15.2.1-1 [mm];
a – negative tolerance of pipe thickness [%].

15.3 Pipe Connections

The following pipe connections of pipe lengths may be used:
– direct welding,
– flanges,
– threaded joints,
– mechanical joints.

Each of the above mentioned connections shall be made in accordance with a recognised standard or of a proven construction for the intended application and shall be approved by PRS.

15.3.1 Welded Connections

15.3.1.1 Welding and non-destructive testing of welds shall be performed in accordance with the requirements specified in *Publication No. 23/P – Pipelines Prefabrication* and *Part IX – Materials and Welding* of the *Rules for Classification and Construction of Sea-going Ships*.

15.3.1.2 Butt welded joints shall be of full penetration type. Such joints made with special provision for a high quality of root side [*)] may be used for pipelines of Class II and Class III, irrespective of the outside diameter.

15.3.1.3 Slip-on sleeve and socket welded joints shall have sleeves, sockets and weldments conformant to a recognised standard. Application of pipe connections in the relevant class of piping is specified in Table 15.3.1.3.

Table 15.3.1.3
Application of slip-on and socket welded joints

Class of piping	Pipe outside diameter [mm]	Type of connection	
		Sleep-on sleeve	Socket welded joint
I	≤ 88.9	Both types are permitted except piping systems: – conveying toxic media, – subjected to fatigue loads, – where severe corrosion is expected to occur	
II			
III	Irrespective of pipe diameter	Both types are permitted	

15.3.2 Flange Connections

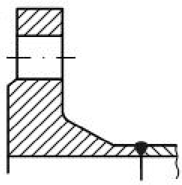
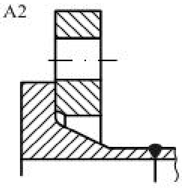
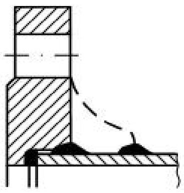
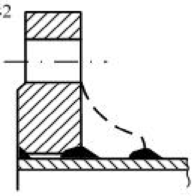
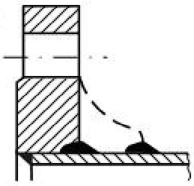
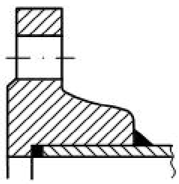
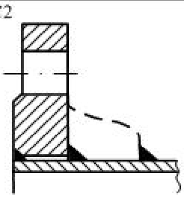
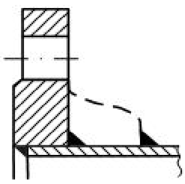
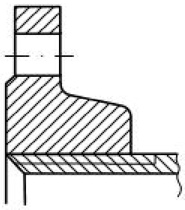
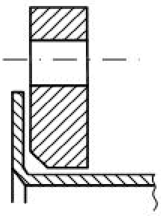
15.3.2.1 Dimensions and type of flanges as well as bolts used to connect them shall conform to a recognised standard. Non-standard flanges and bolts may be used subject to PRS acceptance in each particular case.

[*)] The term "joints made with special provision for a high quality of root side" shall be understood as a double side weld, or the weld performed with the use of backing ring or with use of inert gas backing when laying the first weld run. Other methods to ensure special provision of root side quality are permitted under PRS consent.

15.3.2.2 The material of gaskets shall be resistant to the effect of the medium conveyed and to the surrounding environment. The construction of gaskets shall correspond to the design pressure and temperature whereas their dimensions and shape shall conform to a recognised standard. Gaskets of connections in fuel oil piping shall ensure tightness at the temperature of the conveyed medium not less than 120 °C.

15.3.2.3 Flange types acceptable for piping connections are shown in Table 15.3.2.3. Other flanges may be used for piping connections subject to PRS acceptance in each particular case.

Table 15.3.2.3
Flange types acceptable for piping connections

A	A1 	A2 	
B	B1 	B2 	B3 
C	C1 	C2 	C3 
D			
E			

Note to Table 15.3.2.3:

In flanges of type D taper pipe thread shall be used. The minor diameter of pipe thread shall not be appreciably less than the pipe outside diameter. For certain types of thread, after the flange has been screwed hard home, the pipe shall be expanded into the flange.

15.3.2.4 Depending on the pipeline class and type of the conveyed medium, flange connections shown in Table 15.3.2.4 may be used for piping connections.

Table 15.3.2.4
Required types of flange connection

Class of piping	Toxic, strong corrosive, flammable media [4] and liquefied gases	Lubricating and fuel oil	Steam [3] and thermal oil	Other media [1], [2], [3], [4], [5]
I	A, B [6]	A, B	A, B [6]	A, B
II	A, B, C	A, B, C	A, B, C, D [5]	
III	Not applicable	A, B, C, E	A, B, C, D, E	A, B, C, D, E

Notes to Table 15.3.2.4:

1) Including water, air, gas and hydraulic oil.
2) Type E flanges shall be used for water pipes and open-ended lines only.
3) Only type A where design temperature exceeds 400 °C.
4) Only type A where design pressure exceeds 1.0 MPa.
5) Types D and E shall not be used for pipes where design temperature exceeds 250 °C.
6) Type B flanges may be used for pipes with outside diameter not greater than 150 mm only.

When selecting flange type for pipe connections, outside loads and cyclic loads imposed on pipelines as well as location of pipelines on board the vessel shall be taken into account.

15.3.3 Slip-on Threaded Joints

15.3.3.1 Slip-on threaded joints having threads where pressure-tight joints are made on pipes with parallel or tapered threads shall conform to a recognised standard.

15.3.3.2 Screwed joints may be used in piping of CO_2 fire extinguishing systems within the spaces covered only.

15.3.3.3 Screwed joints shall not be used in pipelines conveying flammable or toxic media or in those pipelines where crevice corrosion, appreciable erosion or changing loads are expected to occur.

15.3.3.4 Slip-on threaded joints acceptable for piping connections with regard to the pipe outside diameter and thread type are shown in Table 15.3.3.4. Slip-on threaded joints conformant to a recognised standard may be used for greater pipe diameters than those specified in Table 15.3.3.4 subject to PRS acceptance in each particular case.

Table 15.3.3.4
Acceptable applications of slip-on threaded joints

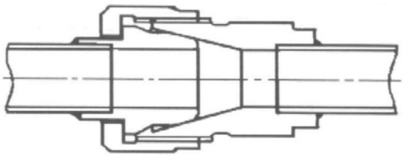
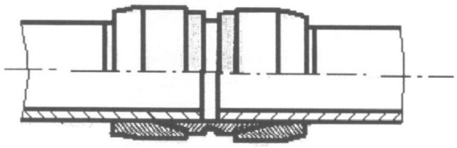
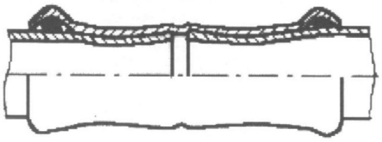
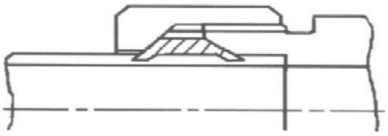
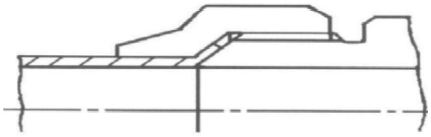
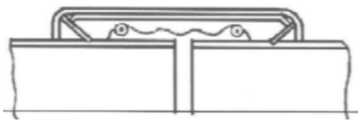
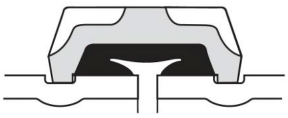
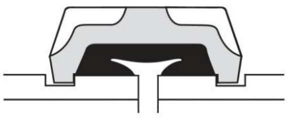
Class of piping	Pipe outside diameter [mm]	Type of thread	
		Parallel thread	Tapered thread
I	≤ 33.7	No	Yes
II	≤ 33.7	No	Yes
III	≤ 60.3	Yes	Yes

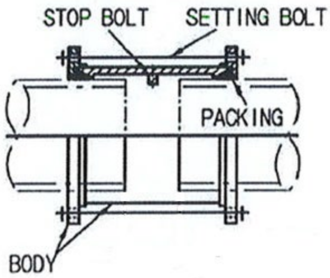
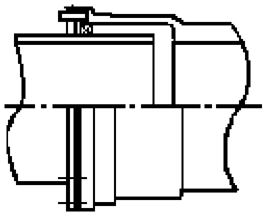
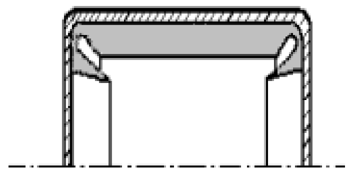
15.3.4 Mechanical Joints

15.3.4.1 Due to the great variations in design and configuration of mechanical joints, no specific recommendation regarding a calculation method for theoretical calculations is given in these requirements. The type approval is based on the results of testing of the actual joints. The type approval procedure is specified in *Publication No. 57/P – Type Approval of Mechanical Joints*. The provisions of *Publication No. 102/P – European Union Recognized Organizations Mutual Recognition Procedure for Type Approval* should be taken into account, if applicable.

15.3.4.2 The requirements specified in this sub-chapter apply to pipe unions, compression couplings, and slip-on joints as shown in Table 15.3.4.2. Similar joints complying with the requirements specified in this sub-chapter may be accepted by PRS.

Table 15.3.4.2
Examples of mechanical joints

PIPE UNIONS	
Welded or brazed types	
COMPRESSION COUPLINGS	
Swage type	
Press type	
Bite type	
Flared type	
SLIP-ON JOINTS	
Grip type	
Machine grooved type	 Roll Groove  Cut Groove

Slip type	  

15.3.4.3 Mechanical joints shall be type approved by PRS for the intended application and service conditions.

15.3.4.4 Where the application of mechanical joints results in reduction of the 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 (see sub-chapter 15.2).

15.3.4.5 Material of mechanical joints shall be compatible with the piping material as well as internal and external media.

15.3.4.6 Mechanical joints in which tightness failure may occur in the event of damage shall not be used in piping sections directly connected to the hull shell or tanks containing flammable liquids.

15.3.4.7 Mechanical joints shall withstand external and internal pressure as well as vacuum, as applicable.

15.3.4.8 The number of mechanical joints in flammable fluid system shall be kept to a minimum. In general, flanged joints shall be used.

15.3.4.9 Piping in which a mechanical joint is fitted shall be adequately adjusted in accordance with the joint manufacturer's specifications. Supports or hangers shall not be used to force alignment at the point of connection.

15.3.4.10 Slip-on joints shall not be used in pipelines in cargo holds, tanks and other spaces which are not easily accessible, unless approved by PRS. Application of these joints inside tanks may be permitted only for the same media that are 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.

15.3.4.11 Unrestrained slip-on joints may be used only in the cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

15.3.4.12 Application of mechanical joints and their acceptable use for each service, depending on the class of piping and outside d_Z, is indicated in Table 15.3.4.13.

Table 15.3.4.13
Application of mechanical joints depending upon piping class

Types of joints	Class of piping		
	I	II	III
PIPE UNIONS			
Welded and brazed type	Yes (for $d_Z \le 60.3$ mm)	Yes (for $d_Z \le 60.3$ mm)	Yes
COMPRESSION COUPLINGS			
Swage type	Yes	Yes	Yes
Press type	No	No	Yes
Bite type	Yes (for $d_Z \le 60.3$ mm)	Yes (for $d_Z \le 60.3$ mm)	Yes
Flared type	Yes (for $d_Z \le 60.3$ mm)	Yes (for $d_Z \le 60.3$ mm)	Yes
SLIP-ON JOINTS			
Grip type	No	Yes	Yes
Machine grooved type	Yes	Yes	Yes
Slip type	No	Yes	Yes

15.3.4.13 Application of specific mechanical joints for particular piping systems is indicated in Table 15.3.4.14.

Table 15.3.4.14
Application of mechanical joints

Systems		Kind of connections		
		Pipe unions	Compression couplings [6)]	Slip-on joints
Flammable fluids (flash point ≤ 60°C)				
1	Cargo oil lines	Yes	Yes	Yes [5)]
2	Crude oil washing lines	Yes	Yes	Yes [5)]
3	Vent lines	Yes	Yes	Yes [3)]
Inert gas				
4	Water seal effluent lines	Yes	Yes	Yes
5	Scrubber effluent lines	Yes	Yes	Yes
6	Main lines	Yes	Yes	Yes [2), 5)]
7	Distribution lines	Yes	Yes	Yes [5)]
Flammable fluids (flash point > 60°C)				
8	Cargo oil lines	Yes	Yes	Yes [5)]
9	Fuel oil lines	Yes	Yes	Yes [2), 3)]
10	Lubricating oil lines	Yes	Yes	Yes [2), 3)]
11	Hydraulic oil	Yes	Yes	Yes [2), 3)]
12	Thermal oil	Yes	Yes	Yes [2), 3)]

	Systems	Kind of connections		
		Pipe unions	Compression couplings [6)]	Slip-on joints
	Sea water			
13	Bilge lines	Yes	Yes	Yes [1)]
14	Water filled fire extinguishing systems, e.g. foam, drencher systems	Yes	Yes	Yes [3)]
15	Non water filled fire extinguishing systems, e.g. foam, drencher systems	Yes	Yes	Yes [3)]
16	Fire main (not permanently filled)	Yes	Yes	Yes [3)]
17	Ballast system	Yes	Yes	Yes [1)]
18	Cooling water system	Yes	Yes	Yes [1)]
19	Tank cleaning services	Yes	Yes	Yes
20	Non-essential systems	Yes	Yes	Yes
	Fresh water			
21	Cooling water systems	Yes	Yes	Yes [1)]
22	Condensate return	Yes	Yes	Yes [1)]
23	Sanitary and drinking water systems	Yes	Yes	Yes
	Miscellaneous			
24	Deck drains (internal)	Yes	Yes	Yes [4)]
25	Sanitary drains	Yes	Yes	Yes
26	Scuppers and discharge (overboard)	Yes	Yes	No
27	Sounding/vent pipes for water tanks and dry spaces	Yes	Yes	Yes
28	Sounding/vent pipes for flammable liquid tanks with flash point > 60°C	Yes	Yes	Yes [2), 3)]
29	Starting/control air [1)]	Yes	Yes	No
30	Service air (other than those specified in 29)	Yes	Yes	Yes
32	CO_2 system [1)]	Yes	Yes	No
33	Steam [7)]	Yes	Yes	No

Notes to Table 15.3.4.14:

1) Inside machinery spaces of category A – only approved fire resistant types.
2) Not inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces, provided the joints are located in easily visible and accessible positions.
3) Approved fire resistant types.
4) Above free board deck only.
5) Only in pump rooms and open decks – only approved fire resistant types.
6) If compression couplings include any components which readily deteriorate in case of fire, they shall be of approved fire resistant type as required for slip-on joints.

General note:

7) Slip type slip-on joints as shown in Table 15.3.4.14 may be used for pipes on deck with a design pressure of 1 MPa (10 bar) or less.

15.3.4.14 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.

15.4 Tube Bend Radii

The mean radius of bend of the steel and copper pipes subjected to a pressure exceeding 0.5 MPa or to a temperature of the internal medium exceeding 60 °C, as well as the radius of bend of the pipes intended for self-expansion shall not be less than 2.5*d*.

If, during the bending, no reduction of the pipe wall thickness occurs then, subject to PRS acceptance of the bending process in each particular case, the specified radius may be reduced.

15.5 Protection Against Overpressure

15.5.1 Where the pressure is likely to develop in excess of the working pressure, the piping shall be provided with means preventing the pressure in the pipeline to rise above the working pressure.

Open escape of oil fuel, lubricating oil and other flammable oil from the safety valves is not permitted.

15.5.2 Where provision is made for a reducing valve on the pipeline, a pressure gauge and safety valve shall be installed thereafter. An arrangement for bypassing the reducing valves is recommended.

15.6 Corrosion Protection

15.6.1 Upon completion of bending and welding steel pipes of bilge, ballast and sea-water systems, air, sounding and overflow pipes of water tanks and ballast/fuel tanks, gas freeing and vent pipes of cargo tanks and cofferdams in tankers shall be protected against corrosion by a method accepted by PRS in each particular case.

15.6.2 Where bottom and side fittings or their parts are made of copper alloys, provision shall be made for protection of the shell plating and all other elements being in contact with the said fittings against electrolytic corrosion.

15.7 Valves and Fitting

15.7.1 Covers of valves with internal diameter of more than 32 mm, equipped with turning spindles, shall be secured to the bodies by bolts or studs.

Screwed-on covers of valves shall be reliably secured against loosening.

The nut of cock plug shall be secured against unscrewing from the taper.

15.7.2 Valves and fittings shall be suitable having regard to the hydraulic test pressure not less than the hydraulic test pressure for the piping for which they are intended to serve (see sub-chapter 1.6.5).

15.7.3 Remote controlled valves, operating with auxiliary source of power except those mentioned in 15.7.5, shall have local manual control, the operation of which shall be independent of the remote control. Manual control of the valves shall not render any failure in the remote control system.

The construction of remote controlled valves shall be such as to ensure that in the case of failure of remote control system the valves remain in a position that will not render any state of emergency to the ship or they automatically set to such position.

15.7.4 Valves installed inside cargo tanks shall not be compressed air controlled.

15.7.5 Hydraulically controlled valves installed inside cargo tanks shall be so designed as to be capable of being emergency controlled by means of a hand operated pump. The pump shall be connected by a separate line at a place suitable for emergency control of each valve of the system or directly to the valves' actuators.

15.7.6 The tank containing working liquid of hydraulic control system of the valves installed inside cargo tanks shall be located above the cargo tanks upper level, as high as practicable, whereas all the hydraulic installation pipes shall be led to the cargo tanks in their upper part. Moreover, the tank shall be provided with an air pipe terminating in a safe place on the open deck and fitted with a flame arrester.

Audible and visual alarms of the low level of liquid in the tank shall be provided.

15.7.7 Shut-off devices shall be fitted with nameplates clearly specifying their purpose.

15.7.8 For remote controlled valves, nameplates specifying their purpose, as well as the indications (valve open/valve closed), shall be provided in the control stations. Where the remote control is intended for closing the valves only, such indicators need not be provided.

15.7.9 Valves and fittings installed on watertight bulkheads shall be secured by studs screwed into pads fitted to the bulkhead, or they may be attached to bulkhead penetration pieces.

The stud holes shall not be through holes.

15.7.10 Valve chests and manually controlled valves shall be situated in positions always accessible during the normal operation of the vessel.

15.8 Bottom and Side Valves and Fittings and Openings in Hull Shell

15.8.1 Inlet and discharge openings in the shell plating shall be so arranged as to preclude the possibility of sucking the drains and other wastes by sea-water pumps.

15.8.2 Openings in the shell plating for the bottom and side sea chests shall be fitted with protective gratings or screens. The width of slots between the grating bars shall not exceed 12 mm, whereas the dimensions of meshes in screens shall not exceed 12x12 mm. The total area of the slots or meshes shall not be less than 2.5 times the total cross-sectional area of the installed sea-water inlet valves.

Where compressed air is used to blow through the sea chests, screw-down non-return valves shall be fitted on the compressed air pipes and the pressure shall not exceed 0.2 MPa.

15.8.3 The number of discharge openings in the shell plating shall be kept to a minimum. Therefore, where possible, the pipes of similar purpose shall be connected to common discharge openings.

15.8.4 Side inlet and discharge openings located in machinery spaces shall be fitted with readily accessible valves with a local control. The valve controls shall be fitted with indicators (valve open/valve closed).

Side discharge valves of piping systems serving the main and auxiliary machinery shall be of a spring-loaded screw-down non-return type. The lower edge of a discharge opening shall be situated as high as practicable above the deepest load line.

If the lower edge of the opening is situated higher than 200 mm above the deepest load line, then the side valve may be of a non-spring-loaded screw-down non-return type.

If the lower edge of the opening is situated higher than 300 mm above the deepest load line, then the side valve may be of a shut-off type.

15.8.5 The means for operating the bottom sea inlet valves shall be situated in readily accessible positions and fitted with indicators (valve open/valve closed). It is recommended that these means be located above the floor plating of the machinery space.

15.8.6 The bottom and side valves and fittings shall be installed on welded pads. The holes for the fastening bolts or studs shall not be of through type and shall end in welded pads. Gaskets shall not be made of materials which readily deteriorate in case of fire.

The valves and fittings may be installed on the welded distance pieces, provided the latter are of rigid construction and of a minimum length. The wall thickness of a distance piece shall not be less than the minimum thickness of the shell plating at the ship ends, however, it need not be more than 8 mm.

15.8.7 Spindles and closing parts of the bottom and side valves and fittings shall be made of materials resistant to the corrosive effect of sea-water.

15.9 Piping Arrangement

15.9.1 Piping Arrangement in Watertight Constructions

15.9.1.1 The number of pipes led through watertight bulkheads shall be kept to a minimum.

15.9.1.2 Only one pipeline is permitted to be led below the upper deck through the collision bulkhead for handling the liquid contained in the forepeak. Where the forepeak is divided by a longitudinal bulkhead into two watertight compartments, one suction branch pipe serving each compartment may be provided.

On each pipeline mentioned above, a shut-off valve shall be provided being installed on the welded pad on the fore side of the bulkhead. Such valves shall be controllable from a ready accessible position on the deck and fitted with indicators (valve open/valve closed).

15.9.1.3 Where the pipes pierce watertight bulkheads, decks or other watertight structures, provision shall be made for penetration pieces, bulkhead flanges or other arrangements ensuring watertight integrity of the structure concerned.

Holes for bolts and studs shall not pierce the watertight structures, but shall terminate in the pads. Gaskets shall not be made of materials which readily deteriorate in case of fire.

Penetration pieces attached by welding to watertight decks and bulkheads shall be thicker by 1.5 to 3 mm than the wall thickness of a pipe to be connected, depending on its diameter.

15.9.1.4 Penetration of pipes through fire-resisting divisions shall be so made that fire resistance of the division does not deteriorate.

15.9.2 Piping Arrangement in Tanks

15.9.2.1 Drinking water pipes may be led through oil tanks and oil pipes may be led through drinking water tanks only in tight tunnels, forming an integral part of the tank structure.

Leading sea-water pipes, oil pipe, vent pipes, overflow pipes and sounding pipes inside tunnels is not required provided that within the tanks pipes are seamless with wall thickness not less than 3 mm and connected by means of permanent joints. Where the use of detachable joints is indispensable, they shall be of a flange type with oil resistant gaskets.

15.9.2.2 Where no tunnels are used in leading the pipes through tanks, strain compensation shall be ensured by means of bends within the tanks.

Where pipes are led in tunnels, it is recommended that the compensation bends be situated outside the tunnels.

15.9.3 Piping Arrangement in Cargo Holds and Other Spaces

15.9.3.1 Means used to secure pipes shall not cause stresses therein due to thermal expansion, deformation of ship structure or vibration.

15.9.3.2 Pipes passing through cargo holds, chain lockers and other spaces where they are liable to mechanical damage shall be efficiently protected.

15.9.3.3 Oil fuel pipes, hydraulic pipes and water pipes, except bilge pipes, shall not be led through cargo holds.

In exceptional cases, which are subject to individual acceptance by PRS, such pipes may be led through cargo holds, however only in tunnels or using pipes with increased wall thickness and protecting them with robust steel shielding.

15.9.3.4 In penetrations of considerably heated pipes through the divisions made of flammable materials, structural means shall be provided to prevent excessive heating of the division.

15.9.3.5 Oil fuel pipes shall not be led through accommodation and service spaces except bunkering pipes led through sanitary spaces provided that the wall thickness is not less than 3 mm and the pipes have no detachable joints within those spaces.

15.9.3.6 Pipes carrying chemically aggressive media shall not be led through spaces used for the carriage of dangerous materials.

15.9.3.7 Pipes intended to convey hot media as well as long pipes led along the ship shall be fitted with expansion pieces or sufficient number of bends securing free compensation of strain.

15.9.4 Piping Arrangement near Electrical Appliances

15.9.4.1 In no case pipes subjected to pressure shall be led above and behind the main or emergency switchboards, or the control panels of important arrangements and machinery.

In front of and alongside the switchboards and control panels such pipes may be led at a distance of at least 500 mm provided that the pipes have no detachable joints or special shielding is provided.

Pipes shall not be led through special electrical spaces (see definitions in sub-chapter 1.2 in *Part VII – Electrical Equipment and Automatic Control*) and accumulator battery rooms, with the exception of pipes of the CO_2 fire extinguishing system and pipes serving the electrical equipment installed in such spaces.

16 BILGE SYSTEM

16.1 Pumps

16.1.1 Vessels requiring a crew shall be equipped with two independent bilge pumps which shall not be installed within the same space. At least one of these shall be motor driven. However, for vessels with a power of less than 225 kW or with a deadweight of less than 350 t, or where vessels not intended for the carriage of goods have a displacement of less than 250 t, one pump will suffice which can be either manually-operated or motor-driven.

Each of the required pumps shall be capable of being used on each watertight compartment.

Additional requirements for passenger vessels are contained in paragraph 29.4.1.

16.1.2 The minimum pumping capacity, Q_1, of the first bilge pump shall be calculated using the following formula:

$$Q_1 = 0.1D^2 \quad [l/\text{min}] \tag{16.1.2-1}$$

where:

D – internal diameter of the bilge main, determined in accordance with 16.2.1, [mm].

The minimum pumping capacity, Q_2, of the second bilge pump shall be calculated using the following formula:

$$Q_2 = 0.1d^2 \quad [l/\text{min}] \tag{16.1.2-2}$$

where:

d – internal diameter of the branch suctions determined in accordance with 16.2.2 , [mm]; for l, the length of the longest watertight compartment shall be taken, [m].

16.1.3 Bilge pumps driven from the main engine with the capacity less than determined in accordance with paragraph 16.1.2 is permitted provided that the capacity of independent pumps is increased respectively.

16.1.4 Ballast pumps, fire pumps or general-purpose pumps of adequate capacity may be used as independent bilge pumps if the piping system fulfils the requirements specified in sub-chapter 16.3.

16.1.5 Centrifugal bilge pumps shall be of self-priming type or connected to an air extracting devise.

16.1.6 Where a vessel is provided with more than one bilge pump, the bilge pumps shall not be situated in the same watertight compartment.

16.1.7 The minimum capacity of a manually operated pump intended to drain only one watertight compartment shall not be less than $0.1d^2$ [l/min], where d [mm] is determined in accordance with formula 16.2.2.

16.1.8 In self-propelled vessels with a power of less than 225 kW having no auxiliary engines in the engine room, a hand-operated bilge pump with the capacity not less than that determined in accordance with formula 16.1.7 may be provided in addition to the main engine-driven bilge pump.

16.1.9 In vessels with no motive power, at least two hand-operated pumps with the combined capacity not less than determined in accordance with formula 16.1.7 shall be provided to drain bilges.

16.2 Pipe Diameters

16.2.1 Internal diameter D of the bilge main and of the branch suctions connected directly to the pump shall not be less than that determined in accordance with the formula below:

$$D = 1.5\sqrt{L(B+H)} + 25 \quad [\text{mm}] \tag{16.2.1}$$

where:

L, B, H – see sub-chapter 1.2.1 in *Part II – Hull*.

16.2.2 Internal diameter d of the branch suctions connected to the bilge main shall not be less than that determined in accordance with the formula below:

$$d = 2.0\sqrt{l(B + H)} + 25 \ \ [\text{mm}] \qquad (16.2.2)$$

where:
l – length of compartment to be drained, measured over its bottom, [m];
B, H – see sub-chapter 1.2.1 in *Part II – Hull*.

16.2.3 In no case the internal diameter of the bilge main and of the branch suctions connected directly to the pump shall be less than that of the suction branch of the pump.

16.2.4 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 the two largest branch bilge suctions connected to this chest, however not greater than the cross-sectional area of the bilge main.

16.2.5 In vessels having length L less than 25 m, the internal diameter of the bilge main and of the branch suctions may be reduced to 35 mm.

16.3 Arrangement of Pipes and Joints

16.3.1 Arrangement of bilge pipes and branch suctions shall be such as to enable any watertight compartment to be drained by any of the bilge pumps.

This requirement does not apply to the tanks intended for the carriage of liquids, fore- and afterpeaks as well as compartments that are normally sealed hermetically during operation.

Each space or group of spaces, which are not drained by means of the bilge system pipes, shall be provided with other means to remove water.

16.3.2 Arrangement of bilge pipes shall preclude the possibility of passage of sea-water into the vessel or passage of water from one watertight compartment into another. For this purpose the suction valves of bilge piping distribution chests as well as the valves on branch suctions connected directly to the bilge main shall be of a lockable non-return type.

Flap check valves shall not be applied.

Compartments or other spaces that are capable of carrying ballast shall be connected to the drainage system only by means of a simple closing device.

That requirement shall not apply to holds that are capable of carrying water ballast. Such holds shall be filled with ballast water by means of ballast piping that is permanently installed and independent of the drainage pipes, or by means of branch pipes that can be connected to the main drainage pipe by flexible pipes or flexible adaptors. Water intake valves located in the bottom of the hold shall not be permitted for this purpose.

16.3.3 Where a bilge pump is intended to be also used for pumping water over the ship's side and from ballast water tanks (see paragraph 16.1.4), the suction lines shall be separated by three-way valves with L plugs or a shut-off non-return valve shall be installed – in addition to that required in accordance with paragraph 16.3.2 – on the suction branch between the pump and the bilge main.

16.3.4 Where a fire pump is used as bilge pump, provision shall be made to prevent bilge water from being delivered to the fire line in addition to fulfilment of the requirement specified in paragraph 16.3.3.

16.3.5 Arrangement of bilge pipes shall be such as to enable the machinery space drainage through a suction branch led directly to an independent bilge pump while bilges in other spaces are being drained by the remaining pumps.

16.3.6 Arrangement of bilge pipes shall be such as to enable the compartment drainage while the water fire extinguishing system is being used in this compartment.

16.3.7 Arrangement of bilge pipes shall be such as to enable one of the pumps to be operated while the remaining pumps are under repair or being used for other services.

16.3.8 In general, bilge pipes shall be led outside the double bottom space. Where it is necessary to lead bilge pipes through oil or drinking water tanks, the pipes shall fulfil the requirements specified in paragraph 15.9.2.1.

Where pipes are led through the double bottom tanks, open ends of suction pipes shall be fitted with non-return valves.

16.3.9 Arrangement of bilge pipes shall also fulfil the requirements specified in Chapter 17.

16.4 Drainage of Watertight Spaces

16.4.1 Flat-bottomed drainable compartments that are wider than 5 m shall be provided with at least one strainer on both the starboard and port sides.

In justified cases, PRS may consider the possibility of reducing the number of suction branches.

Suction branches shall be fitted with easily detachable strum boxes.

16.4.2 Flat-bottomed drainable compartments that are longer than 5 m shall be provided with at least two strainers on both the starboard and port sides. One of the suction branches shall be connected directly to an independent bilge pump having the maximum capacity.

In suction branches for the machinery space drainage, easily accessible settling tanks shall be provided. The pipes connection settling tanks with bilges shall be as straight as practicable. Lower ends of these pipes shall not be fitted with strum boxes.

Settling tanks shall be provided with readily openable covers.

16.4.3 Arrangement of suction branches shall enable access to bilges and bilge wells for cleaning.

16.4.4 Cargo hold bilges shall be provided with arrangements for bilge water level measurement.

16.4.5 Bilge-bottom drainage pipes, mentioned in paragraph 16.3.1, intended to extract oily water from watertight compartments shall be equipped with closures that have been sealed. The number and position of those closures shall be entered on the inland navigation vessel certificate.

Padlocks locking the closures in position shall be regarded as equivalent. The keys for the padlocks of the closures shall be indicated properly and kept in a marked and easily accessible location in the engine room.

16.5 Drainage of Fore- and Afterpeaks

16.5.1 The peaks, which are not used as tanks may be drained by means of separate hand pumps.

16.5.2 Where the after peak terminates at the engine room, it may be drained to the engine room bilge through a pipe with a shut-off valve fitted to the bulkhead on the engine room side. It is recommended that the valve be self-closing.

16.6 Drainage of Other Spaces

16.6.1 Chain locker and boatswain's store may be drained by means of hand pumps or other arrangements.

16.6.2 Drainage of steering gear rooms and other small compartments situated above the afterpeak may be carried out by means of hand pumps or by means of drain pipes led into the machinery space bilges. The drain pipes shall be fitted with self-closing valves located in easily visible and accessible positions.

The internal diameter of the drain pipes shall not be less than 39 mm.

17 RESIDUES SYSTEMS FOR COLLECTING AND DISCHARGE OF OILY BILGE WATER AND OIL RESIDUES

17.1 General Requirements

17.1.1 Vessels provided with oil fuel systems shall be provided with:

.1 oily water tank with the system designed to discharge its content into the proper shore or floating reception facilities (barges, vessels etc.);

.2 portable tanks for oil residues (used oil) or fixed receptacles with the system designed to discharge its content into the shore or floating reception facilities.

17.1.2 The engine room bilge may be used to store on board , oily water accumulated during operation, subject to PRS acceptance in each particular case.

17.1.3 Filtering equipment intended to purify oily bilge water may be substituted for the equipment mentioned in paragraph 17.1.1.1.

In the case filtering equipment is applied on board the vessel, its arrangement and construction of the associated systems is subject to PRS acceptance in each particular case.

Filtering equipment shall be type-approved by PRS.

17.1.4 The requirements concerning arrangements for collecting of oil fuel leakage are specified in sub-chapter 22.4.

17.2 Capacity and Construction of Tanks

17.2.1 Capacity of the oily bilge water shall be sufficient to collect all the oily bilge water produced during the voyage.

17.2.2 Oil residues shall be stored in portable tanks situated in the machinery space. The tanks shall be secured firmly and provided with tight closing appliances.

Combined capacity of the tanks for oil residues shall be at least 1.5 times the combined volume of oil sumps of the combustion engines and installed equipment, including the volume of hydraulic oil tanks.

Where vessels are only used in short-haul operation, PRS may grant the exception from the requirement to fit the vessel with receptacles for oil residues.

17.2.3 If the quantity of oil residues on board the vessel, as specified in paragraph 17.2.2, exceeds 300 l, then an integral tank for oil residues shall be provided.

17.2.4 The tank for oily bilge water and tank for oil residues shall be provided with:
- alarm which gives audible and visual warning in the wheelhouse when the tank is filled more than in 80% of its volume,
- manhole to enable access to the tanks for cleaning.

17.3 Discharge of Tanks' Content

17.3.1 The content of tank for oily water and tank for oil residues shall be possible only into the proper shore or floating reception facilities by means of piping fitted with standard discharge connections (see paragraph 17.3.3) located on deck.

This piping shall not have connections to overboard discharge valves.

17.3.2 The discharge connections may provide for the discharge of both oily bilge water and oil residues provided that an effective arrangement (e.g. a three-way cock) is fitted to preclude the oil residues from penetration to the oily bilge water system.

17.3.3 Standard discharge connections shall fulfil the requirements specified in standard PN-EN 1305:2018-05 – Inland Waterways Vessels. Connections for the Discharge of Oily Mixture.

The discharge connections shall be installed on both sides of the vessel and so located as to enable easy connection of a reception hose. The discharge connections are shall fitted with blank flanges and nameplates.

17.3.4 Where oily water is collected in the machinery space bilges, its discharge may be performed using the recipient's pumps and hoses.

Overboard discharge valves shall be sealed with lead to preclude inadvertent discharge the oily water. In the case of remotely operated valves, proper buttons shall be applied on the control panel. Additionally, the overboard discharge valves (in the case of remotely operated valves – the appropriate control panel buttons) shall be provided with nameplates marked:

„Oily bilge water. Opening of the valve during the normal operation of the vessel is forbidden"

18 BALLAST SYSTEM

18.1 General Requirements

18.1.1 At least one ballast pump shall be provided for filling and emptying the ballast tanks.

It is recommended that the capacity of the ballast pump be determined on the assumption that when pumping out water from the largest ballast tank, the velocity of the water flow is not less than 2 m/s, with the suction pipe diameter determined in accordance with formula 18.2.1.

18.1.2 General service pumps, as well as fire or sanitary pumps may be used as ballast pumps.

18.1.3 Pumps used for taking ballast water from the double bottom tanks shall be of self-priming type.

18.1.4 Ballast tanks shall not be used for the carriage of fuel oil. Where fulfilment of this requirement is impracticable, administrative requirements shall be provided for the discharge of oily ballast water.

18.2 Pipe Diameters

18.2.1 Internal diameters d_w of suction branches of the ballast pipes for particular tanks shall not be less than those determined in accordance with the formula below:

$$d_w = 18\sqrt[3]{V} \quad [\text{mm}] \qquad (18.2.1)$$

where:
V – ballast tank volume [m³].

The actual internal diameter may have the nearest standard size.

18.2.2 The internal diameter of the ballast main shall not be less than the maximum diameter of suction branch determined in accordance with formula 18.2.1.

18.3 Arrangement of Pipes and Joints

18.3.1 Arrangement of the suction branches shall ensure the discharge of water from every ballast tank when the ship is upright or inclined not more than 5°.

19 AIR, OVERFLOW AND SOUNDING PIPES

19.1 Air Pipes

19.1.1 Each ship's tank intended for the storage of liquid, each cofferdam, and the side and bottom sea chests as well as boxes of shell coolers shall be fitted with air pipes.

Air pipes of side and bottom sea chests and boxes of shell coolers shall be fitted with shut-off valves installed directly on those chests and boxes (see also sub-chapter 15.8).

Air pipes of tanks adjacent to the shell plating, side and bottom sea chests and boxes of shell coolers shall terminate above the open deck.

19.1.2 Tank air pipes shall be led from the upper part of the tank from a place situated at the maximum distance from the filing pipe. The number and arrangement of the air pipes shall be such as to preclude the formation of air pockets.

19.1.3 Tanks extending from ship's side to side shall be fitted with air pipes at both sides. Air pipes shall not be used as filling pipes unless the tank is fitted with more than one air pipe.

Air pipes of tanks intended for different kinds of liquids shall not be interconnected.

19.1.4 The height of air pipes measured from the open deck to the uppermost level of the liquid in the filled up air pipe shall be at least 450 mm.

In justified cases PRS may consider the possibility for reducing that height.

19.1.5 Open ends of air pipes situated on the freeboard open decks shall be fitted with self-acting closing appliances – the so called vent heads – to prevent the entry of outboard water into the tanks.

This requirement does not apply to the air pipes of compartments permanently filled with outboard water and air pipes on vessels engaged on voyages only in operating region **3**. In those cases, air pipe ends may be made as an elbow with its opening facing downwards or in a different way subject to PRS acceptance in each particular case.

19.1.6 Open ends of air pipes of tanks containing readily ignitable liquids (oil fuel, lubricating oil, etc.) and air pipes of cofferdams adjacent to such tanks shall be led to the places on the open deck where the escaping vapours will not cause any fire hazard and shall be fitted with devices preventing flame passage of the construction accepted by PRS in each particular case. Free area of the cross-section of such devices shall not be less than the cross-sectional area of the air pipe.

This requirement also applies to human waste water tanks or human waste water treatment facilities where flammable gas may accumulate.

19.1.7 Open ends of air pipes of drinkable water tanks shall be led to the open deck and protected against the entry of insects.

19.1.8 Air pipes of lubricating oil storage tanks and not heated tanks of oil residues not forming an integral part of the vessel's structure may terminate in the spaces where the tanks are located. It is necessary to ensure that no leaking oil may spread onto electrical equipment or heated surfaces in case of tank overfilling.

19.1.9 Wall thickness of steel air pipes shall not be less than 2.5 mm.

19.1.10 The total cross-sectional area of air pipes of the tanks filled by gravity shall not be less than the total cross-sectional area of all pipes by which the liquid may be simultaneously delivered into the tank.

19.1.11 The total cross-sectional area of air pipes of pump filled tanks shall be at least 1.25 times the cross-sectional area of the tank filling pipe. Cross-sectional area of an air pipe serving several tanks shall be at least 1.25 times the cross-sectional area of the common filling pipeline.

19.1.12 Where a tank is provided with an overflow pipe, the total cross-sectional area of the air pipes of the tank shall not be less than 1/3 of the cross-sectional area of the filling pipe.

19.1.13 Arrangement of air pipes shall be such that under normal list and trim conditions no hydraulic seals may occur in the pipes.

19.1.14 Air pipes of oil fuel tanks shall have no detachable joints in accommodation and refrigerated spaces.

19.1.15 Nameplates shall be affixed to the upper ends of air pipes.

19.1.16 Air pipes of internal combustion engine crankcases shall fulfil the requirements specified in paragraph 2.2.3.

19.2 Overflow Pipes

19.2.1 Overflow pipes shall be provided for tanks whose air pipes are led to such a height that in case of their filling with liquid, the tank pressure test will be exceeded see also sub-chapter 8.3 in *Part II – Hull*).

19.2.2 It is recommended that oil fuel tanks be provided with overflow pipes. If the fuel system is so arranged that the possibility of oil fuel spill overboard during bunkering or transfer is precluded, overflow pipes need not be provided.

19.2.3 Cross-sectional area of overflow pipes and their arrangement shall be such as required in paragraphs 19.1.10, 19.1.11, 19.1.13, and 19.1.14 for air pipes.

19.2.4 Air pipes being also overflow pipes shall not be connected to the air pipe of the overflow tank, but directly to that tank or to other overflow pipe, of a sufficient diameter, connected to that tank.

19.2.5 Overflow pipes of oil fuel tanks and oil tanks shall be led to the oil fuel overflow tanks or to a storage tank of the properly increased capacity.

Overflow pipes of oil fuel tanks and oil tanks shall not be led to bilges.

19.2.6 A heat-proof sight glass or an alarm giving warning of oil fuel overflow shall be fitted on the overflow tank or a vertical segment of the overflow pipe.

19.3 Overflow Tanks

19.3.1 Capacity of oil fuel overflow tanks shall not be less than 10-minute capacity of the fuel transfer pump.

19.3.2 Overflow tank shall be provided with visual and audible alarms giving warning of the tank being filled above 75% of its capacity.

19.4 Sounding Pipes and Arrangements

19.4.1 Tanks and cofferdams, as well as bilges and bilge wells which are not readily accessible, shall be fitted with sounding pipes or other level indicating devices accepted by PRS.

19.4.2 Sounding pipes shall be led to the open deck and provided with tight closing devices.

Sounding pipes for cofferdams and tanks not forming part of the hull structure (e.g. saddleback tank) need not be led to the open deck provided they are readily accessible under all service conditions.

Sounding pipes shall be led straight or with slight curvature to permit easy passage of the sounding rod.

19.4.3 Where the vessel has a flat bottom and tanks or bilge extend from one side to the other, sounding pipes shall be installed at each side of the vessel.

19.4.4 Sounding pipes for bottom oil tanks and bottom oil fuel tanks may terminate in machinery spaces or shaft tunnels, provided that:

.1 top ends of sounding pipes are led to the places distant from the places of high risk of ignition or are fitted with shielding effectively preventing oil fuel from accidental leakage onto heated surfaces of boilers, engines, exhaust pipes, etc. as well as onto electric machinery and switchboards;

.2 op ends of sounding pipes are fitted with self-closing sounding cocks and terminate not less than 0.5 m above the floor level. Additionally, a self-closing test cock of a small diameter is fitted under the above-mentioned cock to enable the check that there is no oil fuel in the pipe prior to opening the sounding cock. The sounding and test cocks shall be corrosion resistant and of construction precluding sparking;

.3 sounding pipes shall not be used for tank filling or tank venting.

19.4.5 Sounding pipes of the double bottom water tanks may terminate in the spaces above the tanks if they are readily accessible. These pipes shall not be used as air pipes and shall be fitted with self-closing cocks.

19.4.6 Striking plate or an equivalent arrangement protecting the bottom plating against damage shall be fitted under each open ended sounding pipe, e.g. sounding rod foot or pipe closer.

19.4.7 Internal diameter of sounding pipes shall not be less than 32 mm.

Internal diameter of sounding pipes led through refrigerated spaces where the temperature may drop to 0°C and below, as well as of the pipes of tanks fitted with heating installation, shall not be less than 50 mm. Within refrigerated spaces the pipes shall be insulated.

19.4.8 Nameplates shall be affixed to the upper ends of sounding pipes.

19.4.9 Plugs and threaded parts of the sounding pipe deck sockets fitted in open decks shall be made of bronze, brass or stainless steel. Application of other materials is subject to PRS acceptance in each particular case.

19.4.10 Other level indicators, accepted by PRS, may be used for oil fuel instead of sounding pipes. The indicators shall fulfil the following requirements:

.1 capacity-gauging devices shall be legible right up to the maximum filling level; and neither glass gauge damage nor oil fuel tank overfilling shall result in oil fuel spill;

.2 level indicators with a transparent insert are permitted; this insert shall be made of unbreakable flat glass or plastic not losing its transparency in contact with oil. Cylindrical glass level gauges are not permitted;

.3 capacity-gauging devices shall be fitted with an automatic closing device at their base and their upper end shall be connected to the tanks above their maximum filling level. The material used for glass gauges shall not deform under normal ambient temperature.

In the case of oil tanks with a capacity less than 200 l, the self-closing cocks mentioned in paragraph 19.4.10.3 are not required.

20 EXHAUST GAS SYSTEM

20.1 Exhaust Gas Lines

20.1.1 Exhaust gas lines shall be tight throughout their length up to the location where they terminate on the open deck.

20.1.2 Where exhaust gas lines are led through the shell plating, near or below the load waterline, means shall be provided or the line shall be properly shaped to prevent overboard water ingress into the engine.

Inside the vessel, the exhaust gas line shall form a sort of loop whose lower edge is situated as high above the deepest waterline as practicable and at the distance from this waterline at least:

– 1000 mm for operating region **1**,
– 600 mm for operating region **2**,
– 300 mm for operating region **3**.

The wall thickness of the pipe segment from the loop lower edge to the point of connection to the hull shell shall not be less than the shell plating thickness in that location.

20.1.3 Exhaust pipes may be led through accommodation or the wheelhouse provided that they are covered by protective gas-tight sheathing. The gap between the exhaust pipe and this sheathing shall be open to the outside air.

Exhaust pipes shall not be led at the distance from the oil fuel tanks less than 450 mm being measured from the exhaust pipe insulation.

Leading exhaust gas lines through divisions made of combustible materials requires application of proper thermal insulation.

20.1.4 Each main internal combustion engine shall be provided with an individual exhaust line fitted with a silencer and a sufficient means of drainage. The possibility of a departure from this requirement is subject to PRS acceptance in each particular case.

20.1.5 Exhaust gas lines of auxiliary engines may be connected to a common exhaust line, provided that efficient measures are taken to prevent:

– exhaust gas from the common exhaust line from entering the engines which are not in operation,
– damage to any of the engines during start-up.

20.1.6 Exhaust pipes shall be effectively insulated in accordance with the requirements specified in paragraph 1.11.6 or cooled in the engine rooms. Protection against physical contact may suffice outside the engine rooms.

20.1.7 Where exhaust gas heat exchangers and wet type spark arresters are installed, measures shall be taken to prevent water from entering the engine in case of heat exchanger leakage or any other damage. Drain pipes shall be connected to bilges in the machinery spaces and provided with hydraulic seals.

20.1.8 The exhaust gas after-treatment system shall not impair the safe operation of the craft, including propulsion system and power supply, nor block the exhaust system.

20.1.9 When the exhaust gas after-treatment system is used and equipped with a bypassing device, the bypassing device must comply with the following conditions:

.1 in the event of a failure of the exhaust gas after-treatment system, the activation of the bypass device must allow the craft to continue to make steerageway under its own power;
.2 in the event of activation of the bypassing device, the by-pass device control system shall trigger an acoustic and optical alarm signal in the wheelhouse;
.3 a by-pass device control system shall record in non-volatile computer memory all incidents of engine operation with use of by -pass device. The information shall be readily available for the competent authorities.

20.1.10 When a control diagnostic system is installed according to Article 25(3)(f) of Regulation 2016/1628, the required alarms shall trigger an acoustic and optical alarm signal in the wheelhouse in case of malfunctions.

20.1.11 If an after-treatment system relies on the use of a reagent in order to reduce emissions, the required alarms shall alert crew to the need to refill the reagent tank before it is empty, or to replace the reagent if it does not meet the concentration specification.

20.1.12 When a control diagnostic system installed according to Article 25(3)(f) of Regulation 2016/1628 can activate power reduction of the internal combustion engine, the following requirements must be fulfilled:

.1 the activation of the power reduction must allow the craft to continue to make steerageway under its own power; or
.2 in the event of activation of the power reduction, the control system shall trigger an acoustic and optical alarm signal in the wheelhouse.

20.1.13 The requirement of par. 20.1.8 shall be deemed to be fulfilled when the vessel is equipped with:

.1 a second independent propulsion system (even if that second system also includes an exhaust gas after treatment system) allowing the craft to continue to make steerageway under its own power; or

.2 an after-treatment system with a by pass device acc. to par. 20.1.9.

21 VENTILATION SYSTEM

21.1 Ventilation Ducts

21.1.1 Ventilation ducts shall not be led through the watertight bulkheads below the upper deck (see definitions specified in sub-chapter 1.2.3 in *Part II – Hull*).

21.1.2 Trunks and vertical ventilation ducts led through the watertight decks within one watertight compartment, shall be watertight and shall have the strength equivalent to the strength of the hull local structures between those watertight decks.

21.1.3 Ventilation ducts shall be protected against corrosion or made of corrosion resistant material.

In the locations where moisture condensation may occur, ventilation ducts shall be insulated. In the locations where moisture condensation may occur, ventilation ducts shall be insulated. These portions of ventilation ducts where water may condense shall be fitted with drain plugs.

21.1.4 Ventilation ducts leading to cargo spaces, machinery spaces or other spaces protected against fire by smothering system shall be provided with closing arrangements operable from the deck.

21.1.5 Ventilation ducts intended for the removal of explosive or flammable vapours and gases shall be gastight and shall not be connected to the ducts led from other spaces.

21.2 Arrangement of Ventilator Heads

21.2.1 Supply ventilator heads shall be located in such places on open decks where the possibility of drawing in the air contaminated with oil vapours and the possibility of the entry of outboard water into ventilation ducts are reduced to a minimum.

21.2.2 Height of ventilator head coamings measured from the open deck shall be at least 450 mm.

In justified cases PRS may consider reduction of that height.

21.3 Ventilation of Machinery Spaces

21.3.1 Ventilation system of machinery spaces shall ensure sufficient influx of air necessary for the operation of engines and oil-fired boilers of heating appliances with closed skylights at all weather conditions.

Provision shall be made for the extraction of gases heavier than air from the lower parts of those spaces, from the places below the floor plates where the gases may accumulate.

21.3.2 In machinery spaces with CO_2 fire extinguishing system independent installed shall be provided with an independent mechanical exhaust ventilation system from the lowest parts of those spaces.

The independent mechanical exhaust ventilation system shall provide at least 10 air changes per hour.

21.4 Ventilation of Battery Rooms and Lockers

21.4.1 Ventilation system of battery rooms and lockers shall be independent and ensure removal of air from upper parts of the ventilated rooms and lockers.

The ventilation ducts shall be gastight.

21.4.2 Accumulators requiring a charging power of more than 2,0 kW shall be installed in a special room. If placed on deck, they may also be enclosed in a cupboard. If gas can escape from accumulators, this room or cupboard must be mechanically ventilated to the open deck (supply and exhaust air).

21.4.3 Accumulators requiring a charging power not exceeding 2,0 kW may also be installed below decks in a cupboard or chest. They may also be installed without casing in an engine room, electrical service room or any other well-ventilated place provided that they are protected against falling objects and dripping water.

21.4.4 Provision shall be made for effective ventilation when accumulators are installed in a closed room, cupboard or chest. Mechanical ventilation shall be provided for charging power of more than:
– 2,0 kW for nickel-cadmium accumulators;
– 3,0 kW for lead accumulators.

The air shall enter at the bottom and be discharged at the top so that a total evacuation of gases are ensured. Ventilation ducts shall not include devices which obstruct the air flow such as stop valves.

21.4.5 Outlets to the open of ventilation ducts shall be so arranged as to prevent water, precipitation and solids from entering into the ducts. Flame arresters shall not be fitted on these ducts. The outlets of the exhaust ventilation ducts shall be situated in such positions where the discharged gases will not cause any fire risk.

21.4.6 Ventilation of accumulator battery lockers containing batteries with charging capacity not exceeding 0.2 kW, may be effected through holes in the lower and upper parts of the locker.

21.4.7 The required air flow rate Q for ventilation of an accumulator battery room or accumulator battery locker shall be calculated by following formula:

$$Q = f \cdot I_{gas} \cdot n \quad [m^3/h]$$

where:
f = 0,11 for accumulators with liquid electrolytes;
f = 0,03 for accumulators with enclosed cells (electrolyte immobilised in gel, non-woven fibrous material);
I_{gas} = ¼ of the maximum current of the charging device in A;
n = number of cells in series circuit.

In the case of buffer accumulators of an onboard network, other methods of calculation taking into account the characteristic charging curve of the charging device may be accepted, provided that these methods are based on the provisions of recognised classification societies or on relevant standards.

21.4.8 Where natural ventilation is used, the cross -section of the air ducts shall be sufficient for the required air flow rate Q on the basis of an air flow velocity 0,5 m/s. However, the cross section shall have the minimum value of:

– 80 cm^2 for lead accumulators;
– 120 cm^2 for nickel-cadmium accumulators.

21.4.9 Where mechanical ventilation is used, a fan shall be provided, preferably with an exhauster device, its motor shall be clear of the gas stream and the air stream. Fans shall be of a construction precluding the production of sparks through contact between a blade and the fan casing and shall avoid any electrostatic charges.

21.4.10 A symbol for "Fire, naked flame and smoking prohibited" in accordance with Figure 2 of Annex 4 of ES-STRIN standard a diameter of at least 10 cm shall be affixed to the doors or covers of accumulator rooms, cupboard or chest.

21.4.11 Internal surfaces of the exhaust ducts, as well as the fans and their motors shall be protected against the action of electrolyte vapours. Natural ventilation ducts shall also be so protected.

21.5 Ventilation of Fire-Extinguishing Stations of Carbon Dioxide Systems

21.5.1 Fire-extinguishing stations of carbon dioxide systems located below the open deck shall be provided with an independent system of mechanical exhaust ventilation from the lower parts of the compartment which enables at least 6 air changes per hour.

Fans shall be activated automatically once the door/access hole have been opened.

22 OIL FUEL SYSTEM

22.1 Pumps

22.1.1 At least two power-driven pumps shall be provided for fuel transfer. In vessels with a daily fuel consumption not exceeding 2 tonnes, one hand operated pump may be accepted.

22.1.2 Oil fuel transfer pumps shall not be used for other purposes.

22.1.3 In addition to local control, oil fuel transfer pumps shall be capable of being stopped from a position outside the space in which they are situated.

22.2 Piping, Valves and Fittings

22.2.1 Oil fuel piping shall be separated from any other systems.

22.2.2 Oil fuel pipes shall not be led above internal combustion engines, heating appliances, exhaust gas pipes or other hot surfaces.

In exceptional cases oil fuel pipes may be lead above this piping and equipment, provided that no detachable joints have been installed on pipes in those locations and the pipes have been provided with drip trays preventing the oil fuel from coming into contact with this machinery and equipment.

22.2.3 Directly at tank outlets the pipework for the distribution of fuels shall be fitted with a quick-closing valve that can be operated from the deck, even when the rooms in question are closed. If the operating device is concealed, the lid or cover shall not be lockable.

The operating device shall be marked in red. If the device is concealed it shall be marked with a symbol for the quick-closing valve in accordance with Fig. 9 of *Annex 4 to ES -TRIN standard* with a side length of at least 10 cm.

This requirement does not apply to fuel tanks mounted directly on the engine.

22.2.4 Piping, valves and fittings of fuel systems shall not be exposed to excessive heating and shall be readily accessible. Fuel pipes, their connections, seals and fittings shall be made of materials that are able to withstand the mechanical, chemical and thermal stresses to which they are likely to be subjected. The fuel pipes shall not be subjected to any adverse influence of heat and it shall be possible to inspect them throughout their length.

22.3 Water Draining Arrangements for Tanks

Settling and daily service tanks shall be provided, in their lower part, with self-closing valves and drain pipes led to the drain tank. The drain pipes shall be fitted with sight glasses. Where a drip tray has been provided, an open funnel, instead of the sight glass, may be fitted.

22.4 Oil Fuel Leakage Collecting Arrangements

22.4.1 Drip trays shall be fitted where oil fuel leakage from tanks which do not form an integral part of the hull structure, pumps, filters and other equipment may be expected.

22.4.2 Drain pipes from the drip trays shall be led to drain tanks. The pipes shall not be led to bilges and overflow tanks.

The drain tank shall be provided with visual and audible alarms giving warning of the tank being filled above 80 % of its volume.

22.4.3 The internal diameter of the drain pipes shall not be less than 25 mm.

22.4.4 Drain system for drain tanks shall fulfil the requirements specified in sub-chapter 17.3.

22.5 Bunkering

22.5.1 Bunkering of oil fuel shall be effected by means of a permanent pipeline provided with necessary valves and fittings enabling all storage tanks to be filled with oil fuel.

The orifice for the fuel tank filler necks shall be on the deck, except for the daily-supply tanks. The filler neck shall be fitted with a connection piece in accordance with standard EN 12827: 2001.

Fuel tanks shall be safeguarded against fuel spills during bunkering by means of appropriate onboard technical devices which shall be entered in item 52 of the inland navigation vessel certificate.

If fuel is taken on from bunkering stations with their own technical devices to prevent fuel spills on board during bunkering, the above mentioned requirements does not apply

22.5.2 Filling pipes of the tanks shall be led through the tank wall in its upper part. Where such an arrangement is impracticable, the filling pipes shall be fitted with non-return valves installed directly on the tanks.

Filling pipes shall be connected to the tanks as close to the tank bottom as practicable.

If fuel tanks are fitted with an automatic shut-off device, the sensors shall stop fuelling when the tank is 97 % full, this equipment shall meet the 'failsafe" requirements.

If the sensor activates an electrical contact, which can break the circuit provided by the bunkering station by a binary signal, it shall be possible to transmit the signal to the bunkering station by means of a watertight connection plug meeting the requirements of International Standard IEC 60309 : 2012 for 40 to 50 DC, housing colour white, earthing contact position ten o'clock.

22.6 Oil Fuel Tanks

22.6.1 Liquid fuels shall be stored in steel tanks which are either an integral part of the hull or which are firmly attached to the hull. If so required by the design of the vessel, an equivalent material in terms of fire-resistance may be used. These requirements shall not apply to tanks having a capacity of no more than 12 litres that have been incorporated in auxiliaries during their manufacture.

Arrangement of oil fuel tanks in the machinery spaces shall fulfil the requirements specified in paragraph 1.12.2.

Fuel tanks for engines of working gear on floating equipment do not have to form an integral part of the hull or be firmly attached to it.

Mobile tanks may be used, provided that they fulfil the following conditions:
– capacity of these tanks does not exceed 1 000 litres,
– the tanks have been attached sufficiently firmly and earthed,
– the tanks are made of steel of a sufficient wall thickness and are installed in a drip tray. The latter shall be so designed as to prevent leaking fuel contaminating the waterways.

The drip tray may be waived if double-skin tanks with a leak protection or leakage warning system are used and which are filled only via an automatic delivery valve. These requirements are considered to be fulfilled if the construction of a tank has been approved by PRS. An appropriate entry shall be made in the Community certificate.

22.6.2 Oil fuel tanks shall be separated from accommodation spaces, water tanks and lubricating oil tanks by means of cofferdams.

22.6.3 Oil fuel tanks which do not form an integral part of the hull structure shall fulfil the requirements for hull tanks, where applicable.

Overflow tanks shall fulfil the requirements specified in sub-chapter 19.3.

22.6.4 Oil fuel tanks situated on open decks, superstructure decks and in other places open to the atmosphere shall be protected from exposure to the sun rays. Oil fuel tanks shall be provided with an access manhole (with oil-resistant seal) for the tank cleaning/maintenance.

22.6.5 Daily service tanks of self-propelled vessels shall not be integral wing tanks.

22.6.6 Fuel tanks directly supplying the main engines and engines needed for safe operation of the vessel shall be fitted with a device emitting both visual and audible signals in the wheelhouse if their level of filling is not sufficient to ensure further safe operation.

22.6.7 Fuel tanks shall be provided with openings having leak-proof closures that are intended to permit cleaning and inspection.

22.7 Oil Fuel Supply to Internal Combustion Engines

22.7.1 The equipment of oil fuel system shall provide the engine with oil fuel prepared and purified to such a degree as is required for the particular engine.

22.7.2 Fuel supply lines to continuously operating engines shall be fitted with duplex filters with a changeover cock or with self-cleaning filters. By-pass arrangements are not permitted.

Where the engine is provided with the fuel filter as required in paragraph 2.5.6, the above mentioned filters need not be fitted.

22.7.3 Where the main engines operate on two types of oil fuel (diesel oil and heavy fuel oil), measures shall be taken to prevent the mixing of the heavy fuel oil with the diesel oil for auxiliary engines.

22.7.4 In multi-engine installations supplied from the same source of oil fuel, means of isolating the oil fuel supply to individual engines shall be provided.

Isolation of oil fuel supply to one engine shall not affect operation of the other engines. Location of the means of isolation shall be such that they are not rendered inaccessible by a fire of any of the engines.

23 LUBRICATING OIL SYSTEM

23.1 Pumps

Each main and auxiliary engine as well as their gearing and hydraulic coupling filling systems shall be provided with individual independent lubricating oil systems.

23.2 Piping, Valves and Fittings

23.2.1 Lubricating oil system pipes shall not be connected to the pipes of other systems.

23.2.2 If lubricating oil drainage from the engine crankcase through a flexible joint is provided, then a steel, bronze or brass valve suitable to be secured in the closed position shall be installed before the flexible joint.

23.3 Lubricating Oil Tanks

23.3.1 Oils used in power transmission systems, control and activating systems and heating systems shall be stored in steel tanks which are either an integral part of the hull or which are firmly attached to the hull. If so required by the design of the vessel, an equivalent material in terms of fire-resistance may be used. These requirements shall not apply to tanks having a capacity of no more than 25 litres that have been incorporated in auxiliaries during their manufacture.

Lubricating oil tanks shall be separated from accommodation spaces as well as oil fuel tanks and drinking water tanks by cofferdams.

23.3.2 Lubricating oil tanks and their pipework and other accessories shall be laid out and arranged in such a way that neither lubricating oil nor lubricating oil vapour may accidentally reach the inside of the vessel.

23.3.3 The filler orifices for lubricating oil tanks shall be marked distinctly.

23.3.4 Lubricating oil tanks shall be provided with a suitable capacity-gauging device (requirements for level indicators see par. 19.4.10).

23.4 Lubricating Oil Supply to Internal Combustion Engines and Gears

23.4.1 Lubricating oil circulation system pipes shall be fitted with:
- **.1** magnetic strainer – on the suction pipe of lubricating pumps serving gears;
- **.2** coarse filter (gauze) – on the pumps' suction pipe;
- **.3** duplex filter with a changeover cock or with self-cleaning filter – on the discharge pipe of the lubricating pump serving the main engine.

The capacity of each lubricating oil filter shall be greater by 10% than the pump capacity.

23.4.2 In the case of remote starting of an engine or machinery requiring initial lubrication, it shall be activated automatically before the machinery has been brought into operation, and efficient lubrication shall condition the start-up of such machinery.

24 COOLING WATER SYSTEM

24.1 Arrangement of Pipes and Joints

Outboard water supply to the cooling system shall be provided by means of at least two inlet valves, one of which shall be located at the bottom, the other one on the side of the vessel. These valves shall be interconnected and the cooling water shall be taken from the interconnecting outboard water main.

24.1.1 Cooling water pumps for generation sets essential for the vessel safe operation shall be connected to the sea-chests by separate valves.

24.1.2 Suction lines of cooling water pumps for engines shall be fitted with filters. The arrangement of lines and valves shall be such as to enable cleaning of one filter while other filters are in service.

24.2 Cooling of Internal Combustion Engines

24.2.1 Overboard discharge of cooling water shall be effected through a side outlet valve situated above the water level in water space of engines, water coolers and oil coolers.

If this is impracticable, a loop shall be so arranged on the discharge pipe that the lower edge at the highest point of the loop will be above the water level in those spaces.

Water outlet from engines shall be so arranged that their water spaces will be fully and continuously vented.

24.2.2 In internal water cooling systems provision shall be made for fresh water expansion tank, in which water level shall be higher than the highest level of water in the engine. The expansion tank, which may serve the cooling systems of several engines, shall be connected to the suction piping of pumps and shall be fitted with an alarm to give warning on the minimum water level.

24.2.3 Where outboard water is intended to be used in an internal water cooling system, the construction of such a system is subject to PRS approval in each particular case.

25 COMPRESSED AIR SYSTEM

25.1 General Requirements

25.1.1 Pressure lines connected to air compressors shall be fitted with non-return valves at the compressor outlet.

25.1.2 Efficient oil and water traps shall be provided in the filling lines of compressed air receivers.

25.1.3 Tyfons shall be connected to at least two compressed air receivers.

25.1.4 Compressed air lines connected to the sea-chests shall fulfil the requirements specified in paragraph 15.8.2.

25.1.5 Overpressure protection of air pipes shall fulfil the requirements specified in sub-chapter 15.5.

25.1.6 Starting air system of main and auxiliary engines is subject to PRS approval in each particular case.

26 SANITARY DRAINAGE SYSTEM

26.1 General Requirements

26.1.1 At least the following sanitary installations shall be provided in vessels with accommodation:

- **.1** one toilet per accommodation unit or per six crew members; it shall be possible to ventilate these with fresh air;
- **.2** one washbasin with waste pipe and connected up to hot and cold potable water per accommodation unit or per four crew members;
- **.3** one shower or bath connected up to hot and cold potable water per accommodation unit or per six crew members.

There shall be toilets available for passengers. At least one toilet shall be fitted for use by persons with reduced mobility.

The sanitary installations shall be in close proximity to the accommodation. Toilets shall not have direct access to galleys, mess rooms or combined communal living quarters/galleys

26.1.2 Gravity system drain pipes shall slope in the direction of discharge so as to ensure that the sanitary drainage will not remain in the pipes under list and trim conditions expected during normal service.

26.1.3 Sanitary utensils, sinks, laundry tubes, scuppers, etc. connected to the gravity drain system shall be fitted with water seals (the so called drain traps).

26.1.4 Gravity systems drain pipes shall be fitted with air pipes led from the main vertical drains, as well as from the places most distant from the main vertical drains. The number, arrangement and diameter of air pipes shall be such as to prevent water from being sucked from water seals by the sanitary drainage flowing away.

26.1.5 Air pipes shall terminate away from doors, opening type windows, inlets to ventilation systems, etc. so as to prevent the escaping gases from entering the spaces where people may be present.

26.2 Capacity and Construction of Holding Tanks

26.2.1 Vessels shall be provided with a sewage holding tank with capacity V not less than that determined in accordance with the formula below:

$$V = 0.001qnt \text{ [m}^3\text{]} \quad (26.2.1)$$

where:

q – amount of sanitary wastes, in litres, per person in a day;
n – maximum number of persons the ship is certified to carry;
t – duration, in days, of holding wastes in tank.

26.2.2 Construction of the holding tank shall enable its cleaning. The tank shall be fitted with water washing system.

26.2.3 Holding tanks shall be provided with visual and audible alarms to give warning in the wheelhouse of the tank being filled in 80% of its capacity.

26.3 Tank Content Discharge

26.3.1 The system for discharging of the sanitary wastes holding tank content into the shore reception facilities shall be provided with:

.1 pump of suitable type and parameters having regard to the characteristics of the liquid being pumped, the size and the position of the tank and the overall discharge time. The requirement for the provision of such a pump may be waived provided that the holding tank discharge is possible using the recipient's pump;

.2 pipe fitted with standard discharge connections situated on the deck.

26.3.2 Standard discharge connections shall fulfil the requirements specified in standard PN-EN 1306:2018-05 – Inland navigation vessels. Connections for the discharge of waste water.

The discharge connections shall be installed on both sides of the vessel and so located as to enable easy connection of reception hose. The discharge connections shall be fitted with blank flanges and nameplates. In the case of small vessels, PRS may accept one discharge connection located close to the centreline.

26.4 Sewage Treatment Plants

26.4.1 Sewage treatment plant may be substituted for the sewage holding tank mentioned in sub-chapter 26.2.

Application of a sewage treatment plants on board the inland waterways vessel, their arrangement and construction is subject to PRS acceptance in each particular case.

Processes using products containing chlorine are not admissible. It is equally inadmissible to dilute domestic waste water so as to reduce the specific load and thereby also enable disposal.

Sewage treatment plants shall be type-approved by PRS. Requirements for sewage treatment plants are contained in Chapter 18 of ES-TRIN standard.

27 DRINKING WATER SYSTEM

27.1 General Requirements

27.1.1 Vessels with accommodation spaces shall be provided with a drinking water system.

27.1.2 Drinking water shall be supplied to the vessel by flexible hose assemblies. The assemblies shall be durable, covered with smooth coating and fitted with marked connections for shore hydrants.

27.1.3 Drinking water pumps shall not be used for other services.

27.1.4 Potable water installations shall, on their inner surfaces, and shall be made of a material which resists corrosion and poses no physiological danger and they shall be protected against excessive heating. Potable water pipes shall not pass through tanks containing other liquids. Pipes carrying gas or liquids other than potable water shall not pass through potable water tanks.

27.2 Drinking Water Tanks

27.2.1 Drinking water tanks shall be separated from other liquid tanks by means of cofferdams.

27.2.2 Potable water tanks shall have a capacity of at least 150 l per person normally living on board. Potable water tanks shall be fitted with a suitable lockable opening to enable the inside to be cleaned, water level indicator as well as ventilation pipes which lead to the open air or are fitted with appropriate filters.

27.2.3 Location of drinking water tanks shall preclude the possibility of heating the water inside the tanks. Pipes transporting sanitary sewage shall not be led over the drinking water tanks.

27.2.4 Pressure vessels for the storage of drinking water shall be filled with compressed air of natural composition.

Where the compressed air is taken from tanks of other systems on board the vessel or from compressors, an air filter or oil trap shall be fitted on the filling pipe just before the drinking water tank. This requirement is not applicable where the pressure vessel for the storage of drinking water is provided with a membrane separating the drinking water from the compressed air.

27.2.5 Pressure vessels for the storage of drinking water shall be either approved by PRS or made in accordance with the relevant standards under the survey of a competent technical inspection body.

28 ADDITIONAL REQUIREMENTS FOR VESSELS WITH ICE CLASS L1 OR L2

In vessels of ice class **L2** , additional strengthening of machinery construction is not required. The requirements specified in this sub-chapter apply to vessels of ice class **L1**.

28.1 Main Propulsion System

28.1.1 Rated power of main engines, P, measured at the coupling connecting them with the shafting shall not be less than that determined in accordance with the formula below:

$$P = 0.25D \text{ [kW]} \quad (28.1.2)$$

where:
D – fresh water load line displacement of vessel, [t].

28.1.2 Provision shall be made for pre-heating of the engine cooling water before starting the engines.

28.1.3 Propeller shaft and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings are to be designed to withstand the propeller/ice interaction loads (see also Publication 122/P). Calculation method is to include all the relevant loads on the complete shafting system under all permissible operating conditions. The max response torque is therefore to be calculated by means of torsional vibration analysis (ice excitation vibration) and taken into account for the sizing of the propeller shaft diameter, gearbox, flexible coupling and other shafting components.

28.1.4 The strength of the propulsion line is to be designed according to the pyramid strength principle. This means that the failure loss of the propeller blade is not to cause any significant damage to other propeller shaft components. In particular it concerns CPP mechanism which shall withstand the blade failure load; each time subject to PRS consideration case by case.

28.1.5 Propeller blade thickness shall be determined in accordance with formula 3.8.1, taking $k = 1.07$.

28.1.6 Thickness of the propeller blade tips shall not be less than $0.005D$ (where D – propeller diameter, [m]).

28.2 Sea Chests, Bottom and Side Valves and Fittings

28.2.1 One of the bottom sea chests shall be an ice chest. The ice chest is understood as watertight hull construction which forms an extension to the sea chest (on the bilge) and extending above the maximum load waterline.

The ice chest shall fulfil the following requirements:

.1 it shall be fitted with a manhole to enable cleaning whose lower edge shall not be located lower than 100 mm above the maximum load waterline;

.2 inlet openings in the ice chest shall be located near the vessel centre plane and in the aft portion of the chest, where practicable. The total free surface of the grid or screen (see paragraph 15.8.2), shall be at least 5 times the free surface of the water for cooling the engines;

.3 a recirculation line of outlet water from cooling of the engines shall be connected to the ice chest; the cross-sectional area of the line shall be at least equal to that of the overboard discharge pipeline.

Arrangements for clearing the sea chests' gratings with compressed air need not be provided.

28.2.2 Side valves and fittings installed above the maximum load waterline shall be heated.

29 ADDITIONAL REQUIREMENTS FOR PASSENGER VESSELS –– mark: pas

29.1 Piping Arrangement

29.1.1 Piping which has no open ends in watertight compartments shall not be located at a distance less than:

.1 $0.2B_F$ from the side (B_F – maximum breadth of the vessel measured from the deepest waterline), and

.2 0.5 m from the bottom.

29.1.2 Open ends of pipes shall be so located that no other spaces or tanks will be flooded in the event of outboard water ingress into the spaces where they are installed.

29.1.3 If several compartments are connected by piping, such piping shall open into an appropriate place above the waterline which corresponds to the worst possible flooding. Where this is not the case, transverse bulkheads shall be fitted with remote closing devices operated from above the bulkhead deck (see also paragraph 15.9.1.3).

29.2 Ventilation System

29.2.1 Ventilation ducts shall be fitted with fire dampers in the locations where they pass through fire-resisting divisions.

29.2.2 Ventilation ducts which pass through stairwell partition or engine room bulkheads shall be fitted with fire dampers.

Ventilation ducts shall be led in accordance with the requirements specified in sub-chapter 21.1.

29.2.3 The controls of fans serving machinery spaces shall be grouped in two places, one of which shall be located outside these spaces.

29.2.4 It shall be possible to close from outside the air inlet and outlet vents. The means of closing shall be readily accessible, clearly and permanently marked as well as fitted with indicators (open/ closed).

29.2.5 Where CO_2 bar-systems are situated in rooms below deck, these rooms shall be fitted with an automatic ventilation system which turns itself on automatically when the door or hatch to the room is opened. The ventilation ducts shall run down to 0.05 m from the floor of this room.

29.3 Control System for Watertight Doors

29.3.1 Watertight doors and their opening and closing devices shall not be located at a distance from the side less than $0.2B_F$ (see paragraph 29.1.1.1).

29.3.2 Watertight doors shall be provided with a visual alarm giving warning in the wheelhouse whenever a watertight door is open.

29.3.3 It shall be possible to close watertight doors from either side of the bulkhead as well as from an easily accessible location above the bulkhead deck.

Once the door has been remotely closed, it shall not preclude their possibility of being reopen and closed on the spot. Closing shall not be impeded by carpeting, or foot rails.

29.3.4 Duration of the remote closing operation shall be not less than 30 seconds and shall be not more than 60 seconds in normal position of the vessel. During the closing/opening operation, an automatic alarm signal shall sound close to the door. It shall be ensured that the door control and alarm are also operational independently of the power supply system.

At the point where the remote control operation is performed, there shall be a device to indicate whether the door is open or closed.

29.4 Bilge System

29.4.1 Two power driven bilge pumps shall be provided.

29.4.2 Each watertight compartment shall be fitted with a bilge water level alarm. If a bow steering system is necessary to fulfil the manoeuvring requirements specified in *Publication No. 27/P – Manoeuvrability Trials of Inland Waterways Vessels and Push Trains*, the room containing the bow steering system is considered to be the main engine room. This room shall be fitted with a bilge water level alarm.

29.5 Propulsion System

29.5.1 In addition to the main propulsion system, vessels shall be equipped with a second independent propulsion system so as to ensure that, in the event of breakdown affecting the main propulsion system, the vessel can continue to make steerageway under its own power.

29.5.2 The second independent propulsion system shall be located in a separate engine room.

29.5.3 If both engine rooms have common partitions, these shall be built in accordance with the requirements specified in *Part V – Fire Protection,* sub-chapter 6.1.2.

29.5.4 If a vessel is fitted with a directly reversible main engine, the compressed air system which is required to reverse the direction of thrust shall:

- be kept permanently pressurised by an automatically adjusting compressor,
- when an alarm is triggered in the wheelhouse, be pressurised by means of an auxiliary engine which can be started from the steering position. If the auxiliary engine has its own fuel tank, there shall be a warning device in the wheelhouse (see paragraph 22.6.6) to indicate if the level of filling is not sufficient to ensure further safe operation.

29.5.5 If the propulsion system has a daily-supply tank, the following requirements shall be fulfilled:

– its contents shall be sufficient to ensure an operation period of the propulsion system of 24 hours, assuming a consumption of 0.25 litres per kW per hour,
– the fuel supply pump for refilling the daily-supply tank shall be operated continuously; or
– the fuel supply pump for refilling the daily-supply tank shall be fitted with:
– a switch that automatically switches on the fuel supply pump when the daily-supply tank reaches a certain low level, and
– a switch that automatically switches off the fuel supply pump when the daily-supply tank is full.

The daily-supply tank shall have a level alarm device in accordance with the requirements specified in paragraph 22.6.6.

29.5.6 The above mentioned requirements do not apply to passenger vessels having length *L* not exceeding 25 m.

29.6 Exemptions for Existing Passenger Ships

For passenger vessels of a length not exceeding 24m constructed or modified before 31 December 2005 and engaged only on short domestic day trips, it is permitted that the main engines and propellers' control stand situated in the engine room be provided with two independent means of two-way communication with the navigation bridge instead of the engine room telegraph required in 1.16.1.

29.7 Waste water collection and disposal facilities

29.7.1 Passenger vessels shall be equipped with collection tanks for domestic waste water or appropriate on-board sewage treatment plants.

29.7.2 Waste water collection tanks shall have sufficient capacity. Tanks shall be fitted with a device to indicate their content level. There shall be on-board pumps and pipes for emptying the tanks, whereby waste water can be passed from both sides of the vessel. It shall be possible to pass waste water from other vessels onwards.

The pipes shall be fitted with a discharge connection according to European Standard EN 1306: 1996.

30 ADDITIONAL REQUIREMENTS FOR ICE-BREAKERS – mark: ld

30.1 Main Propulsion System

30.1.1 Effective power of main engines and dimensions of shafting components shall be determined in accordance with recognised theoretical calculations and the experimental data and are subject to PRS acceptance in each particular case.

30.1.2 Main propulsion machinery shall fulfil, as a minimum, the requirements specified in paragraphs: 28.1.2, 28.1.3, 28.1.4 and 28.1.5.

30.2 Torsional Vibrations of Propulsion System

30.2.1 The requirements concerning combined stresses due to torsional vibrations, and barred speed ranges for continuous operation of ships with ice strengthening, are specified in paragraphs 4.2.1.1, 4.2.2.1 and 4.4.1.

31 ADDITIONAL REQUIREMENTS FOR TUGS AND PUSHERS – mark: hol and pch

31.1 Torsional Vibrations of Propulsion System

31.1.1 The requirements concerning combined stresses due to torsional vibrations, and barred speed ranges for continuous operation of ships with ice strengthening, are specified in paragraphs 4.2.1.1, 4.2.2.1 and 4.4.1.

31.2 Exhaust Gas System

31.2.1 Spark arresters shall be provided in exhaust gas lines of tugs and pushers intended to serve vessels and barges carrying dangerous goods which are subject to ADN Rules.

32 PERMISSIBLE EXEMPTIONS FOR VESSELS ENGAGED ON DOMESTIC VOYAGES – mark: D

Vessels which are assigned with **D** mark affixed to the symbol of class may be exempted from some requirements specified in this part of the *Rules* as provided in table of exemptions for vessels of category **D** included in *Part I – Classification Regulations*.

33 ADDITIONAL REQUIREMENTS FOR CARGO VESSELS INTENDED TO CARRY PACKED DANGEROUS GOODS OR DRY BULK DANGEROUS GOODS – mark: ADN

33.1 Bilge System

33.1.1 Stripping pumps intended for the holds shall be installed in the protected area. This requirement does not apply where stripping is effected by eductors.

33.2 Air and Overflow Pipes

33.2.1 Air pipes of fuel oil tanks shall terminate at least 0.50 m above the open deck.

Outlets of air pipes and overflow pipes shall be provided with a protective device consisting of a gauze diaphragm or perforated plate.

33.3 Exhaust Gas System

33.3.1 Exhaust shall be evacuated from the vessel into the open air either upwards through an exhaust pipe or through the shell plating.

Exhaust outlet shall be located not less than 2 m from the hatchway openings.

33.3.2 Exhaust pipes shall be so arranged that the exhausts are led away from the vessel. The exhaust pipes shall not be located within the protected area.

33.3.3 The exhaust pipes of engines, boilers, incinerators, stoves and other equipment where sources of ignition exist shall be provided with spark arresters whose construction is subject to PRS acceptance.

33.4 Ventilation System

33.4.1 Air vents in the engine rooms as well as air intakes of the engines which do not take in the air directly from the engine room shall be located not less than 2 m from the protected area.

33.4.2 Ventilation hall be provided for the accommodation spaces and service spaces.

33.4.3 Ventilation of Cargo Holds

33.4.3.1 Ventilation of each hold shall be provided by two mutually independent extraction fans having a capacity not less than five changes of air per hour based on the volume of the empty hold. The fans shall be so designed that no sparks may be emitted and the requirements specified in sub-chapter 6.3.2 are fulfilled.

33.4.3.2 Extraction ducts shall be positioned at the extreme ends of the hold and extend down to not more than 50 mm. If the extraction ducts are removable, they shall be suitable for the fan assembly and capable of being firmly fixed.

Extraction of gases and vapours shall also be ensured for the carriage of bulk.

33.4.3.3 Ventilation systems of cargo holds shall be so arranged as to preclude the possibility of penetration of dangerous gases into the accommodation, wheelhouse and engine rooms.

33.5 Oil Fuel System

33.5.1 Double bottom within the hold area may be arranged as oil fuel tanks provided that their depth is not less than 0.6 m. Oil fuel pipes and openings to such tanks are not permitted in the holds.

33.5.2 The holds shall have no common bulkhead with the fuel tank.

34 ADDITIONAL REQUIREMENTS FOR TANKERS INTENDED TO CARRY DANGEROUS GOODS – mark: zb ADN-G

This Chapter contains general requirements concerning machinery and piping systems in tankers of type G (see sub-chapter 7.12.2 in *Part II – Hull*), which are the condition for assignment of an additional class notation zb ADN-G. Additional detailed requirements concerning the construction and equipment of such tankers in relation to the carriage of particular types of cargo are specified in ADN Rules (Chapter 3.2, Table C).

34.1 Machinery Spaces

34.1.1 Internal combustion engines for the vessel's propulsion as well as internal combustion engines for auxiliary machinery shall be located outside the cargo area.

34.1.2 Entrances and other openings of engine rooms shall fulfil the requirements specified in sub-chapter 6.5.1 of *Part V – Fire Protection*.

34.2 Penetrations through Watertight Division, Piping Arrangement

34.2.1 Driving shafts of the bilge or ballast pumps may penetrate through the bulkhead between the service space and the engine room, provided that the arrangement of the service space fulfils the following requirements:

.1 the bulkhead bounding the service space extends vertically to the bottom, and the bulkhead not facing the cargo area extends from one side of the vessel to the other side in one frame plane. This service space is accessible from the deck only;

.2 the service space is watertight with the exception of its access hatches and ventilation inlets;

.3 no pipes for cargo loading or unloading is fitted within the service space;

.4 penetration of the shaft through the bulkhead is gastight and its construction has been approved by PRS;

.5 necessary operating instructions are displayed.

34.2.2 Penetrations through the bulkhead between the engine room and service space in the cargo area, as well as the bulkhead between the engine room and the hold spaces may be provided for hydraulic lines and piping from measuring, control and alarm systems, provided that the penetrations are gastight and approved by PRS.

Penetrations through a bulkhead with A-60 fire protection insulation shall fulfil the requirements specified in paragraph 6.5.3.1 of *Part V – Fire Protection*.

34.2.3 Pipes may pass through the bulkhead between the engine room and the service space in the cargo area provided that these are pipes between the mechanical equipment in the engine room and the service space which do not have any openings within the service space and which are provided with shut-off valves at the bulkhead in the engine room.

34.2.4 Pipes from the engine room may pass through the service space in the cargo area or a cofferdam or a hold space or a double-hull space to the outside provided that within the service space or cofferdam or hold space or double-hull space they are of the thick-walled type and have no flanges or openings.

34.2.5 Pipes from the engine room may pass through the service space in the cargo area or a hold space to the outside provided that within the service space or hold space they are of a thick-walled type and have no flanges or openings.

34.2.6 Where a driving shaft of auxiliary machinery penetrates through a wall located above the deck, the penetration shall be gastight.

34.3 Cargo Pump Rooms

34.3.1 Service space located within the cargo area below the deck may be used as a cargo pump room for the vessel's own discharging system if the requirements specified in sub-chapter 6.5.3 of *Part V – Fire Protection* and the following requirements are fulfilled:

.1 all pipes for loading and unloading (at the suction side and delivery side) are led through the deck above the pump room. The necessary operation of the control devices in the pump room, starting of pumps or compressors and control of the liquid flow rate shall be effected from the deck;

.2 the pipes mentioned in **.1** above have no connections to other systems than the loading and unloading system;

.3 the ventilation system of the service space fulfils the requirements specified in paragraph 34.7.4.2.

34.4 Bilge and Ballast System

34.4.1 Bilge and ballast pumps for spaces within the cargo area shall be installed within this area.

This requirement does not apply to the pumps serving:

.1 double-side spaces and double bottoms which do not have a common boundary wall with the cargo tanks;

.2 cofferdams and hold spaces where ballasting is performed using the piping of the fire-fighting system in the cargo area and bilge-pumping is performed using eductors.

34.4.2 Where the double bottom is used as an oil fuel tank, it shall not be connected to the bilge system.

34.4.3 Where a ballast pump is installed in the cargo area, the standpipe and its outboard connection for suction of ballast water, shall be located within the cargo area.

34.4.4 It shall be possible for an under-deck pump room to be stripped in an emergency using a system located in the cargo area and independent of any other system. This stripping system shall be located outside the pump room.

34.5 Air and Overflow Pipes

34.5.1 Open ends of air pipes of oil fuel tanks shall extend to at least 0.50 m above the open deck.

Open ends of both air pipes and overflow pipes oil fuel tanks leading on the open deck shall be fitted with a protective device consisting of a gauze diaphragm or perforated plate.

34.6 Exhaust Gas System

34.6.1 Exhausts shall be evacuated from the vessel into the open air either upwards through an exhaust pipe or through the shell plating.

The exhaust outlet shall be located not less than 2 m from the cargo area.

34.6.2 Exhaust pipes of engines shall be so arranged that the exhausts are led away from the vessel. The exhaust pipes shall not be located in the cargo area.

34.6.3 Exhaust pipes of engines, boilers, incinerators, stoves and other equipment where sources of ignition exist shall be provided with spark arresters whose construction is subject to PRS acceptance.

34.7 Ventilation System

34.7.1 Double-side spaces and double bottoms within the cargo area which are not arranged for being filled with ballast water and cofferdams between engine rooms and pump rooms, if they exist, shall be provided with ventilation systems.

34.7.2 Engine Room Ventilation

34.7.2.1 Ventilation in the closed engine room shall be so designed that at an ambient temperature of 20°C, the average temperature in the engine room does not exceed 40°C.

34.7.2.2 Ventilation inlets of the engine room and, when the engines do not take in air directly from the engine room, the air intakes of the engines shall be located not less than 2 m from the cargo area.

34.7.3 Cargo Area Ventilation

34.7.3.1 Each hold space shall have two openings the dimensions and locations of which shall be such as to permit effective ventilation of any part of the hold space. If there are no such openings, it shall be possible to fill the hold spaces with inert gas or dry air.

34.7.3.2 Ventilators used in the cargo area shall be so designed that no sparks may be emitted and shall also fulfil the requirements specified in sub-chapter 6.3.2.

34.7.4 Ventilation of Accommodation Spaces, Service Spaces and Wheelhouse

34.7.4.1 Ventilation of accommodation and service spaces shall be possible.

34.7.4.2 Service space located within the cargo area below the deck which is used as a pump room for the vessel's own discharging system shall be fitted with the mechanical ventilation system providing at least 30 changes of air per hour based on the total volume of the service space.

Ventilation exhaust outlets shall be located at least 6 m from entrances and openings of the accommodation and service spaces outside the cargo area. Ventilation inlets shall be possible to be closed from the outside.

34.7.4.3 Any service space located in the cargo area below the deck except for the space mentioned in paragraph 34.7.4.2 above, shall be provided with a system of forced ventilation with sufficient power for ensuring at least 20 changes of air per hour based on the volume of the space.

34.7.4.4 Ventilation exhaust ducts from the service space mentioned in paragraphs 34.7.4.2 and 34.7.4.3 shall extend down to 50 mm above the bottom of the service space. The air shall be supplied through a duct at the top of the service space. The air inlets shall be located not less than 2 m above the deck, at a distance of not less than 2 m from tank openings and 6 m from the outlets of safety valves. Extension pipes, which may be necessary, may be of the hinged type.

Fans used for serving these spaces shall be so designed that no sparks may be emitted and the requirements specified in sub-chapter 6.3.2 are fulfilled.

34.7.4.5 Ventilation of the accommodation and service spaces as well as wheelhouse located outside the cargo area where electrical equipment is installed to be used during loading, unloading and gas-freeing during berthing shall be at least of the 'limited explosion risk' type (see sub-chapter 1.2 in *Part VII – Electrical Equipment and Automatic Control*) and shall ensure overpressure of 0.1 kPa and none of the windows shall be capable of being opened.

Air intakes of the ventilation system shall be located as far as practicable, however, not less than 6 m from the cargo area and not less than 2 m above the deck.

34.7.4.6 Noticeboards shall be fitted at the ventilation inlets indicating the conditions when they shall be closed. Ventilation inlets of accommodation and service spaces leading outside shall be fitted with fire flaps. Such ventilation inlets shall be located not less than 2 m from the cargo area.

Ventilation inlets of service spaces in the cargo area below deck may be located within this area.

34.8 Oil Fuel System

34.8.1 Double bottom within the cargo area may be used as oil fuel tanks, provided that their depth is not less than 0.6 m. Oil fuel pipes and openings of such tanks are not permitted in the hold space.

34.9 Loading and Unloading System

34.9.1 Pumps, compressors as well as loading and unloading piping shall be located in the cargo area.

Cargo pumps and compressors situated on the deck shall be located not less than 6 m from entrances to, or openings of, the accommodation and service spaces outside the cargo area.

Cargo pumps and compressors shall be capable of being shut down from the cargo area and, in addition, from a position outside.

34.9.2 Pipes for loading and unloading shall be independent of any other piping of the vessel. No cargo piping shall be located below the deck, except for those inside the cargo tanks and in the service spaces intended for the installation of the vessel's own gas discharging system.

34.9.3 Use of the cargo piping for ballasting purposes shall not be possible.

34.9.4 Pipes for loading and unloading shall be clearly distinguishable from other piping, e.g. by means of colour marking.

34.9.5 Pipes for loading and unloading on deck, vapour pipes with the exception of the shore connections but including the safety valves, and the valves shall be located within the longitudinal line formed by the outer boundaries of the domes and not less than one quarter of the vessel's breadth from the outer shell. This requirements does not apply to the relief pipes situated behind the safety valves.

If there is, however, only one dome athwartships, these pipes and their valves shall be located at a distance not less than 2.70 m from the shell.

34.9.6 Where cargo tanks are placed side by side, all the connections to the domes shall be located on the inner side of the domes. The external connections may be located on the fore and aft centre line of the dome. The shut-off devices shall be located directly at the dome or as close as practicable to it. The shut-off devices of the loading and unloading piping shall be duplicated, one of the devices being constituted by a remote-controlled quick action stop device. Where the inside diameter of a shut-off device is less than 50 mm, this device may be regarded as a safety device against bursts in the piping.

34.9.7 Shore connections shall be located not less than 6 m from the entrances to or openings of, the accommodation and service spaces outside the cargo area.

34.9.8 Each shore connection of the vapour pipe and shore connections of the pipes for loading and unloading, through which the loading or unloading operation is performed, shall be fitted with a shut-off device and a quick-action stop valve. However, each shore connection shall be fitted with a blind flange when it is not in operation.

34.9.9 The distances referred to in paragraphs 34.9.1 and 34.9.7 may be reduced to 3 m ,if:

.1 a transverse bulkhead which fulfils the requirements specified in paragraph 9.3.1.10.2 of ADN Rules is situated at the end of the cargo area;

.2 openings are fitted with doors on which the following notice shall be displayed: Do not open during loading and unloading without the permission of the master. Close immediately.

34.9.10 Stop valves and other shut-off devices of the pipes for loading and unloading shall indicate whether they are open or shut.

34.9.11 Pipes used for loading and unloading shall be fitted with pressure gauges at the inlet and outlet of the vessel's own gas discharging system. These gauges shall fulfil the requirements specified in paragraph 16.2.4.6 of *Part VII – Electrical Equipment and Automatic Control*.

34.9.12 Pipes for loading and unloading, and vapour pipes, shall not have flexible connections fitted with sliding seals.

34.10 Cargo Refrigeration System

34.10.1 Unless the entire cargo system is designed to resist the full effective vapour pressure of the cargo at the upper limits of the ambient design temperatures, the pressure of the tanks shall be kept below the permissible maximum set pressure of the safety valves. A system for regulation of the cargo tank pressure using mechanical refrigeration is one of the means to be provided for that purpose.

34.10.2 Refrigeration system mentioned in 34.10.1 shall be composed of one or more units capable of keeping the pressure and temperature of the cargo at the design upper limits of the ambient temperatures at the prescribed level for normal service, i.e:
– air: +30 °C,
– water: +20 °C.

34.10.3 Unless another means of regulating cargo pressure and temperature deemed satisfactory by PRS is arranged, provision shall be made for one or more stand-by units with an output at least equal to that of the largest prescribed unit

34.10.4 Stand-by unit shall include a compressor, its engine, its control system and all necessary accessories to enable it to operate independently of the units normally used. Provision shall be made for a stand-by heat-exchanger unless the system's normal heat-exchanger has a surplus capacity equal to at least 25% of the largest prescribed capacity. Separate piping need not be provided.

34.10.5 Cargo tanks, piping and accessories shall be so insulated that, in the event of failure of all cargo refrigeration systems, the entire cargo remains in a condition not causing the safety valves to open for at least 52 hours.

34.10.6 Security devices and connecting lines from the refrigeration system shall be connected to the cargo tanks above the liquid phase of the cargo when the tanks are filled to their maximum permissible degree of filling. They shall remain in the gaseous phase even if the vessel has a list up to 12 degrees.

34.10.7 When several refrigerated cargoes with a potentially dangerous chemical reaction are carried simultaneously, particular care shall be given to the refrigeration systems so as to prevent any mixing of the cargoes. For the carriage of such cargoes, separate refrigeration systems, each including the full stand-by unit mentioned in 34.10.4, shall be provided for each cargo. Where, however, refrigeration is ensured by an indirect or combined system and no leak in the heat exchangers can under any foreseeable circumstances lead to the mixing of cargoes, separate refrigeration units for different cargoes need not be fitted.

34.10.8 When several refrigerated cargoes are not soluble in each other under conditions of carriage such that their vapour pressures are added together in the event of mixing, particular care shall be given to the refrigeration systems to prevent any mixing of the cargoes.

34.10.9 Where the refrigeration systems require water for cooling, a sufficient quantity shall be supplied by a pump or pumps used exclusively for that purpose. This pump or pumps shall have at least two suction pipes, leading from two water intakes, one on port, the other on starboard.

Provision shall be made for a stand-by pump with a satisfactory capacity, this may be a pump used for other purposes provided that its use for supplying water for cooling does not impair any other essential service.

34.10.10 Refrigeration system may take one of the following forms:

.1 Direct system: cargo vapours are compressed, condensed and returned to the cargo tanks. This system shall not be used for certain cargoes specified in Table C of Chapter 3.2 of the ADN. This requirement is indicated by note 35 in column (20) in Table C of Chapter 3.2 of the ADN;

.2 Indirect system: cargo of the cargo vapours are cooled or condensed by means of coolant without being compressed;

.3 Combined system: cargo vapours are compressed and condensed in a cargo/refrigerant heat-exchanger and returned to the cargo tanks. This system shall not be used for certain cargoes specified in Table C in Chapter 3.2 of the ADN. This requirement is indicated by note 36 in column (20) in Table C of Chapter 3.2 of the ADN.

34.10.11 All refrigerants in primary systems and coolant fluids in secondary systems shall be compatible with each other and with the cargo with which they may come in contact. Heat exchange may take place either at a distance from the cargo tank, or by using cooling coils attached to the inside or the outside of the cargo tank.

34.10.12 Where the refrigeration system is installed in a separate service space, this space shall fulfil the requirements specified in paragraph 9.3.1.17.6 of the ADN.

34.10.13 Heat transmission coefficient shall be determined by calculations and submitted to PRS for consideration. The calculation correctness shall be verified by means of refrigeration test (heat balance test). The test programme is subject to PRS agreement in each particular case.

34.11 Water Spray System for Cargo Deck Cooling

34.11.1 Where water-spraying system is required (see column 9, Table C, Chapter 3.2 of ADN Rules), a water-spray system shall be installed in the cargo area on deck for the purpose of reducing vapours given off by the cargo by spraying water over the whole surface.

34.11.2 The system shall be fitted with a connection device for supply from the shore. The system shall be capable of being put into operation from the wheelhouse and from the deck.

34.11.3 Capacity of the water-spray system shall be such that when all the spray nozzles are in operation, the outflow is 50 litres per square metre of cargo deck area and per hour.

35 ADDITIONAL REQUIREMENTS FOR TANKERS INTENDED TO CARRY DANGEROUS GOODS – MARK: zb ADN-C

This Chapter contains general requirements concerning machinery and piping systems in type C tankers (see sub-chapter 7.12.2 in *Part II – Hull*), which are the condition for assignment of an additional class notation zb ADN-C. Additional detailed requirements concerning the construction and equipment of such tankers in relation to the carriage of particular types of cargo are specified in ADN Rules (Chapter 3.2, Table C).

35.1 Machinery Spaces

35.1.1 Internal combustion engines for the vessel's propulsion as well as internal combustion engines for auxiliary machinery shall be located outside the cargo area.

35.1.2 Entrances and other openings of engine rooms shall be located in accordance with the requirements specified in sub-chapter 6.5.1 of *Part V – Fire Protection*.

35.1.3 Boilers which are used for heating the cargo shall be located either in the engine room or in another separate space below the deck and outside the cargo area, which is accessible from the deck or from the engine room.

35.2 Penetrations through Watertight Division, Piping Arrangement

35.2.1 Driving shafts of the bilge or ballast pumps in the cargo area may penetrate through the bulkhead between the service space and the engine room, provided the following conditions are fulfilled:

.1 bulkheads bounding the service space (cofferdam, the centre part of cofferdam or another space) shall extend vertically to the bottom. This service space shall be accessible from the deck only;
.2 service space shall be watertight with the exception of its access hatches and ventilation inlets;
.3 no pipes for loading and unloading shall be fitted within the service space;
.4 penetration of the shaft through the bulkhead shall be gastight and shall have been approved by PRS;
.5 the necessary operating instructions shall be displayed.

35.2.2 Penetrations through the bulkhead between the engine room and the hold spaces may be provided for hydraulic piping and piping form measuring, control and alarm systems, provided that the penetrations have been approved by PRS. The penetrations shall be gastight.

Penetrations through a bulkhead with an A-60 fire protection insulation shall fulfil the requirements specified in paragraph 6.5.3.1 of *Part V – Fire Protection*.

35.2.3 Pipes may penetrate the bulkhead between the engine room and the service space in the cargo area provided that these are pipes between the mechanical equipment in the engine room and the service space which do not have any openings within the service space and which are provided with shut-off devices at the bulkhead in the engine room.

35.2.4 Pipes from the engine room may pass through the service space in the cargo area or through a cofferdam or a hold space or a double-hull space to the outside provided that within the service space in the cargo area or through a cofferdam or a hold space or a double-hull space they are of the thick-walled type and have no flanges or openings.

35.2.5 Where a driving shaft of auxiliary machinery penetrates through a wall located above the deck, the penetration shall be gastight.

35.3 Cargo Pump Rooms

35.3.1 Service space located within the cargo area below the deck may be used as a cargo pump-room for the loading and unloading system only when the requirements specified in sub-chapter 6.5.3 of *Part V – Fire Protection* as well as the following requirements are fulfilled:
.1 all pipes for loading and unloading as well as those of stripping systems are provided with shut-off devices at the pump suction side in the pump-room immediately at the bulkhead. The necessary operation of the control devices in the pump-room, starting of pumps and control of the liquid flow rate shall be effected from the deck.
.2 the bilge system of this service space fulfils the requirements specified in paragraph 35.4.5;
.3 the ventilation system of this service space fulfils the requirements specified in paragraph 35.7.4.2.

35.4 Bilge and Ballast Systems

35.4.1 Bilge and ballast pumps for spaces within the cargo area shall be installed within such an area.

This requirement does not apply to the pumps for:
.1 double-side spaces and double bottoms which do not have a common boundary wall with the cargo tanks;

.2 cofferdams and hold spaces where ballasting is performed using the piping of the fire-fighting system in the cargo area and bilge-pumping is performed using eductors.

35.4.2 Where the double bottom is used as an oil fuel tank, it shall not be connected to the bilge system.

35.4.3 Where a ballast pump is installed in the cargo area, the standpipe and its outboard connection for suction of ballast water, shall be located within the cargo area but outside the cargo tanks.

35.4.4 Cargo pump-room below the deck shall be capable of being drained in an emergency by an installation located in the cargo area and independent of any other installation. This installation shall be provided outside the cargo pump-room.

35.4.5 The bilge of the cargo pump-room below the deck shall be equipped with a gauging device for measuring the filling level which activates a visual and audible alarm in the wheelhouse when liquid is accumulating in the cargo pump-room bilge.

35.5 Air and Overflow Pipes

35.5.1 Open ends of air pipes of oil fuel tanks shall extend to at least 0.50 m above the open deck.

Open ends of both air pipes and overflow pipes oil fuel tanks leading on the open deck shall be fitted with a protective device consisting of a gauze diaphragm or perforated plate.

35.6 Exhaust Gas System

35.6.1 Exhausts shall be evacuated from the vessel into the open air either upwards through an exhaust pipe or through the shell plating.

The exhaust outlet shall be located at least 2 m from the hatch openings.

35.6.2 Exhaust pipes of engines shall be so arranged that the exhausts are led away from the vessel. The exhaust pipes shall not be located in the cargo area.

35.6.3 Exhaust pipes of engines, boilers, incinerators, stoves and other equipment where sources of ignition exist shall be provided with spark arresters whose construction is subject to PRS acceptance.

35.7 Ventilation System

35.7.1 Double-side spaces and double bottoms within the cargo area which are not arranged for being filled with ballast water shall be provided with ventilation systems.

35.7.2 Engine Room Ventilation

35.7.2.1 Ventilation in the closed engine room shall be so designed that at an ambient temperature of 20ºC, the average temperature in the engine room does not exceed 40ºC.

35.7.2.2 Ventilation inlets of the engine room and, when the engines do not take in air directly from the engine room, the air intakes of the engines shall be located not less than 2 m from the cargo area.

35.7.2.3 Ventilation system of the engine room shall be designed taking into account the air required for the boiler.

35.7.3 Cargo Area Ventilation

35.7.3.1 Hold spaces and cofferdams shall be provided with ventilation systems.

35.7.3.2 Each hold space shall have two openings the dimensions and locations of which shall be such as to permit effective ventilation of any part of the hold space. If there are no such openings, it shall be possible to fill the hold spaces with inert gas or dry air.

35.7.3.3 Ventilators used in the cargo area shall be so designed that no sparks may be emitted and fulfil the requirements specified in sub-chapter 6.3.2.

35.7.4 Ventilation of Accommodation Spaces, Service Spaces and Wheelhouse

35.7.4.1 Ventilation of accommodation and service spaces shall be possible.

35.7.4.2 Service space located within the cargo area below the deck which is used as a pump room for the vessel's own discharging system shall be fitted with the mechanical ventilation system providing at least 30 changes of air per hour based on the total volume of the service space.

Ventilation exhaust outlets shall be located at least 6 m from entrances and openings of the accommodation and service spaces outside the cargo area. Ventilation inlets shall be possible to be closed from the outside.

35.7.4.3 Any service space located in the cargo area below the deck except for the space mentioned in paragraph 35.7.5.2 above, shall be provided with a system of forced ventilation with sufficient power for ensuring at least 20 changes of air per hour based on the volume of the space.

35.7.4.4 Ventilation exhaust ducts from the service space mentioned in paragraphs 35.7.4.2 and 35.7.4.3 shall extend down to 50 mm above the bottom of the service space. The air shall be supplied through a duct at the top of the service space. The air inlets shall be located not less than 2 m above the deck, at a distance of not less than 2 m from tank openings and 6 m from the outlets of safety valves. Extension pipes, which may be necessary, may be of the hinged type.

Fans used for serving these spaces shall be so designed that no sparks may be emitted and the requirements specified in sub-chapter 6.3.2 shall be fulfilled.

35.7.4.5 Ventilation of the accommodation and service spaces as well as wheelhouse located outside the cargo area where electrical equipment is installed to be used during loading, unloading and gas-freeing during berthing shall be at least of the 'limited explosion risk' type (see sub-chapter 1.2 in *Part VII – Electrical Equipment and Automatic Control*) and shall ensure overpressure of 0.1 kPa and none of the windows shall be capable of being opened.

Air intakes of the ventilation system shall be located as far as practicable, however, not less than 6 m from the cargo area and not less than 2 m above the deck.

35.7.4.6 Ventilation system of the accommodation spaces where electrical equipment is installed for cargo heating during loading, unloading and gas-freeing shall ensure overpressure of 0.1 kPa and none of the windows shall be capable of being opened.

Inlets of the ventilation system shall be located not less than 2 m from the cargo area and not less than 6 m from the openings of cargo tanks or residual cargo tanks, loading pumps situated on the deck, openings of high velocity vent valves, pressure relief devices and shore connections of loading and unloading pipes and shall be located not less than 2 m above the deck.

35.7.4.7 Noticeboards shall be fitted at the ventilation inlets indicating the conditions when they shall be closed. Ventilation inlets of accommodation and service spaces leading outside shall be fitted with fire flaps. Such ventilation inlets shall be located not less than 2 m from the cargo area.

Ventilation inlets of service spaces in the cargo area below deck may be located within this area.

35.8 Oil Fuel System

35.8.1 Double bottom within the hold area may be arranged as oil fuel tanks provided that their depth is not less than 0.6 m. Oil fuel pipes and openings to such tanks are not permitted in the holds.

35.9 Loading and Unloading System

35.9.1 Pumps, compressors as well as loading and unloading piping shall be located in the cargo area.

Cargo pumps and compressors situated on the deck shall be located not less than 6 m from entrances to, or openings of, the accommodation and service spaces outside the cargo area.

Cargo pumps and compressors shall be capable of being shut down from the cargo area and, in addition, from a position outside.

35.9.2 If the vessel is carrying several dangerous substances liable to react with each other, a separate pump with its own piping for loading and unloading shall be installed for each substance.

The piping shall not pass through a cargo tanks containing dangerous substances with which the substance in question is liable to react.

35.9.3 Pipes for loading and unloading shall be independent of any other piping of the vessel. No cargo piping shall be located below the deck, except for those inside the cargo tanks and inside the cargo pump-room.

35.9.4 When pipes for loading and unloading are used for supplying the cargo tanks with washing or ballast water, the suctions of these pipes shall be located within the cargo area but outside the cargo tanks.

Additionally:

- **.1** a spring-loaded non-return valve shall be provided to prevent any gases from being expelled from the cargo area through the tank washing system,
- **.2** a non-return valve shall be fitted at the junction between the water suction pipe and the cargo loading pipe.

35.9.5 Pipes for loading and unloading shall be clearly distinguishable from other piping, e.g. my means of colour marking.

35.9.6 Pipes for loading and unloading shall be so arranged that, after loading or unloading operations, the liquid remaining in these pipes may be safely removed and may flow either into the vessel's tanks or the tanks ashore.

35.9.7 Pipes for loading and unloading located on the deck, with the exception of the shore connections, shall be located not less than a quarter of the vessel's breadth from the outer shell.

35.9.8 Shore connections shall be located not less than 6 m from the entrances to and openings of, the accommodation and service spaces outside the cargo area.

35.9.9 Shore connections of the vapour pipe and shore connections of the pipes for loading and unloading, through which the loading and unloading operation is performed, shall be fitted with a shut-off device. Shore connections, however, shall be fitted with a blind flange when they are not in operation.

Shore connections of the pipes for loading and unloading through which the loading and unloading operation is performed, shall be fitted with a device intended for the discharge of residual cargo described in paragraph 8.6.4.1 of the ADN.

35.9.10 Flanges and stuffing boxes shall be provided with a spray protection device.

35.9.11 The distances referred to in paragraphs 35.9.1 and 35.9.8 may be reduced to 3 m, provided that:

.1 a transverse bulkhead which fulfils the requirements specified in paragraph 9.3.2.10.2 of ADN Rules is situated at the end of the cargo area;

.2 openings are provided with doors. On the doors, the following notice shall be displayed: Do not open during loading and unloading without the permission of the master. Close immediately.

35.9.12 Pipes for loading and unloading shall extend down to the bottom of the cargo tanks.

35.9.13 Stop valves or other shut-off devices of the pipes for loading and unloading shall indicate whether they are open or shut.

35.9.14 Pipes for loading and unloading shall be fitted with pressure gauges at the pump outlet. The gauges shall fulfil the requirements specified in paragraph 16.2.4.6 of *Part VII – Electrical Equipment and Automatic Control*.

35.9.15 Pipes for loading and unloading shall be subjected to the hydraulic test to a gauge pressure not less than 1.0 MPa.

35.9.16 Pipes for loading and unloading as well as vapour pipes shall not have flexible connections fitted with sliding seals.

35.9.17 Permissible maximum loading and unloading flow rates for each cargo tank or each group of cargo tanks, taking into account the design of the ventilation system shall be calculated. These calculations shall take into consideration the fact that in the event of an unforeseen cut-off of the gas return piping or the compensation piping of the shore facility, the safety devices of the cargo tanks will prevent pressure in the cargo tanks from exceeding the following values:

– overpressure: 115% of the opening pressure of the high-velocity valve,
– vacuum pressure: not more than the construction vacuum pressure, however not exceeding 5 kPa (0.05 bar).

The main factors to be considered are the following:

1. Dimensions of the ventilation system of the cargo tanks;
2. Gas formation during loading by multiplying the greatest flow rate by a factor not less than 1.25;
3. Density of the vapour mixture of the cargo based on 50% volume vapour and 50% volume air;
4. Loss of pressure through vent pipes, valves and fittings. Account shall be taken of 30% clogging of the flame-arrester mesh;
5. Chocking pressure of the safety valves.

The permissible maximum loading and unloading pressure for each cargo tank or for each group of cargo tanks shall be specified in an on-board instruction

35.10 Stripping System

35.10.1 The vessel shall be provided with:

.1 at least one residual cargo tank for the liquid remaining in the pipes for loading and unloading and cargo tanks after the unloading operations but before pumping the residues. These tanks shall be located in the cargo area;

.2 slop tanks for slops (sludge, settlings, washings) which are not suitable for pumping. These tanks shall be located in the cargo area;

.3 a stripping system.

35.10.2 The maximum capacity of the residual cargo tank is 30 m^3.

The residual cargo tank shall be equipped with:

.1 a vacuum valve and high-velocity vent valve which fulfil the requirements specified in paragraph 35.11.5;

.2 a device for measuring the degree of filling;

.3 connections for with shut-off devices, for pipes and hoses.

Residual cargo tanks shall be connected to the vapour pipe of cargo tanks only for the time necessary to fill them.

35.10.3 Intermediate bulk containers (IBCs) or tank containers or portable tanks may be used instead of a fixed residual cargo tank provided that the following requirements are fulfilled:

.1 a maximum individual capacity does not exceed 2 m^3;

.2 not more than 6 such intermediate bulk containers, tank containers or portable tanks are carried;

.3 these intermediate bulk containers, tank containers or portable tanks are properly secured in the cargo area.

During filling of these intermediate bulk containers or tank-containers or portable tanks, means for collecting any leakage shall be placed under filling connections.

35.10.4 Slop tanks shall be fire resistant and shall be capable of being closed with lids (e.g. drums with lever closing ring lids). The tanks shall be marked and easy to handle.

35.10.5 Residual cargo tanks, intermediate bulk containers or tank containers, or portable tanks placed on the deck shall be located at a minimum distance from the side plating equal not less than one quarter of the vessel's breadth.

35.10.6 The stripping system shall be subjected to initial tests before being put into service or thereafter if any alteration has been made to it, using water as test medium. The test and the determination of the residual quantities shall be performed in accordance with the requirements specified in paragraph 8.6.4.2 of the ADN.

In this test, the following residual quantities shall not be exceeded:

– 5 dm^3 for each cargo tank,
– 15 dm^3 for each pipe system for cargo loading and unloading.

Note: According to the provision of paragraph 9.3.2.25.10 of the ADN, it is not necessary to apply this requirement yet. The date of its enforcement will be specified in due course

35.11 Cargo and Slop Tank Gas-Freeing System

35.11.1 Each cargo tank or group of cargo tanks connected to a common vapour pipe shall be fitted with:

.1 safety devices for preventing unacceptable overpressures or vacuums. When anti-explosion protection is required (see column 17 of Table C of Chapter 3.2 of ADN Rules), the vacuum valve shall be fitted with a flame arrester capable of withstanding a deflagration and the pressure-relief valve with a high-velocity vent valve capable of withstanding steady burning. The gases shall be discharged upwards. The opening pressure of the high-velocity vent valve and the opening pressure of the vacuum valve shall be indelibly indicated on the valves;

.2 a connection for the safe return ashore of gases expelled during loading;

.3 a device for the safe depressurisation of the tanks consisting of at least a fire-resistant flame-arrester and a stop valve which clearly indicates whether it is open or shut.

35.11.2 The outlets of high-velocity vent valves shall be located not less than 2.00 m above the deck and at a distance of not less than 6 m from the accommodation and from the service spaces outside the cargo area. This height may be reduced when within a radius of 1.00 m round the outlet of the high-velocity vent valve, there is no equipment, no work is being carried out and signs indicate the area. The setting of the high-velocity vent valves shall be such that during the transport operation they do not blow off until the maximum permissible working pressure of the cargo tanks is reached.

35.11.3 Insofar as anti-explosion protection is prescribed (see ADN Rules, Chapter 3.2, Table C, column 17), a vapour pipe connecting two or more cargo tanks shall be fitted, at the connection to each cargo tank, with:

.1 a flame arrester with a fixed or spring-loaded plate stack, capable of withstanding a detonation. Acceptable means of fulfilment this requirement are specified in paragraph 9.3.2.22.5(a) of ADN Rules.

When a fire-fighting installation is permanently mounted on deck in the cargo area and can be brought into service from the deck and from the wheelhouse, flame arresters need not be required for individual cargo tanks; or

.2 a pressure/vacuum relief valve incorporating a flame arrester capable of withstanding a detonation/deflagration; or

.3 a shut-off device capable of withstanding a detonation, where each cargo tank is fitted with a vacuum valve capable of withstanding a deflagration and a high-velocity vent valve capable of withstanding steady burning.

In each case described in .1, .2 and .3 above, only substances which do not react dangerously with each other may be carried simultaneously in cargo tanks connected to a common vapour pipe.

35.11.4 Insofar as anti-explosion protection is prescribed (see column (17) of Table C of Chapter 3.2 of ADN Rules), an independent vapour pipe for each cargo tank shall be fitted with a pressure/vacuum valve incorporating a flame arrester capable of withstanding a deflagration and a high velocity vent valve incorporating a flame arrester capable of withstanding steady burning.

35.11.5 Each residual cargo tank shall be equipped with a vacuum valve and a high-velocity vent valve. The high velocity vent valve shall be so regulated as not to open during carriage.

Where anti-explosion protection is required (see column (17) of Table C of Chapter 3.2 of ADN Rules), the vacuum valve shall be capable of withstanding deflagrations and the high velocity vent valve steady burning.

35.12 Cargo Heating System

35.12.1 The cargo heating system shall be so designed that the cargo is incapable of penetrating into the boiler in the case of a leak in the heating coils. A cargo heating system with artificial draught shall be ignited electrically.

35.12.2 Where the cargo heating system is used during loading, unloading or gas-freeing, the service space which contains this system shall fulfil the requirements specified in paragraph 35.7.4.6.

35.13 Water Washing System for Cargo Tanks

35.13.1 Where pipes for loading and unloading are used for supplying the cargo tanks with washing water (see paragraph 35.9.4), pumps for tank washing systems with associated connections may be located outside the cargo area, provided the discharge side of the system is arranged in such a way that the suction is not possible through that part.

35.14 Water Spray System for Cargo Deck Cooling

35.14.1 Where water-spraying system is required (see column 9, Table C, Chapter 3.2 of ADN Rules), a water-spray system shall be installed in the cargo area on the deck for the purpose of reducing vapours given off by the cargo by spraying water over the whole surface.

35.14.2 The system shall be fitted with a connection device for supply from the shore. The system shall be capable of being put into operation from the wheelhouse and from the deck.

35.14.3 Capacity of the water-spray system shall be such that when all the spray nozzles are in operation, the outflow is 50 litres per square metre of cargo deck area and per hour.

36 ADDITIONAL REQUIREMENTS FOR TANKERS INTENDED TO CARRY DANGEROUS GOODS – MARK: zb ADN-N

This Chapter contains general requirements concerning machinery and piping systems in type N tankers (see sub-chapter 7.12.2 in *Part II – Hull*), which are the condition for assignment of an additional class notation zb ADN-N. Additional detailed requirements concerning the construction and equipment of such tankers in relation to the carriage of particular types of cargo are specified in ADN Rules (Chapter 3.2, Table C).

Vessels intended for collection of oil wastes and supply vessels which are type N tankers with open cargo tanks of deadweight not exceeding 300 t, may be exempted from some requirements specified in this chapter, in accordance with the relevant provisions of ADN Rules (sub-chapter 9.3.3).

36.1 Machinery Spaces

36.1.1 Internal combustion engines for the vessel's propulsion as well as internal combustion engines for auxiliary machinery shall be located outside the cargo area.

36.1.2 Entrances and other openings of engine rooms shall be located in accordance with the requirements specified in sub-chapter 6.5.1 of *Part V – Fire Protection*.

36.1.3 Boilers which are used for heating the cargo shall be located either in the engine room or in another separate space below the deck and outside the cargo area, which is accessible from the deck or from the engine room.

36.2 Penetrations through Watertight Division, Piping Arrangement

36.2.1 Driving shafts of the bilge or ballast pumps in the cargo area may penetrate through the bulkhead between the service space and the engine room, provided the following conditions are fulfilled:

.1 bulkheads bounding the service space (cofferdam, the centre part of cofferdam or another space) shall extend vertically to the bottom. This service space shall be accessible from the deck only;

.2 service space shall be watertight with the exception of its access hatches and ventilation inlets;

.3 no pipes for loading and unloading shall be fitted within the service space;

.4 penetration of the shaft through the bulkhead shall be gastight and shall have been approved by PRS;

.5 the necessary operating instructions shall be displayed.

36.2.2 Penetrations through the bulkhead between the engine room and the hold spaces may be provided for hydraulic piping and piping form measuring, control and alarm systems, provided that the penetrations have been approved by PRS. The penetrations shall be gastight.

Penetrations through a bulkhead with an A-60 fire protection insulation shall fulfil the requirements specified in paragraph 6.5.3.1 of *Part V – Fire Protection*.

36.2.3 Pipes may penetrate the bulkhead between the engine room and the service space in the cargo area provided that these are pipes between the mechanical equipment in the engine room and the service space which do not have any openings within the service space and which are provided with shut-off devices at the bulkhead in the engine room.

36.2.4 Pipes from the engine room may pass through the service space in the cargo area or through a cofferdam or a hold space or a double-hull space to the outside provided that within the service space in the cargo area or through a cofferdam or a hold space or a double-hull space they are of the thick-walled type and have no flanges or openings.

36.2.5 Where a driving shaft of auxiliary machinery penetrates through a wall located above the deck, the penetration shall be gastight. This requirement does not apply to tankers with open cargo tanks.

36.3 Cargo Pump Rooms

The requirements specified in this sub-chapter do not apply to tankers with open cargo tanks.

36.3.1 Service space located within the cargo area below the deck may be used as a cargo pump-room for the loading and unloading system only when the requirements specified in sub-chapter 6.5.3 of *Part V – Fire Protection* as well as the following requirements are fulfilled:

.1 all pipes for loading and unloading as well as those of stripping systems are provided with shut-off devices at the pump suction side in the pump-room immediately at the bulkhead. The necessary operation of the control devices in the pump-room, starting of pumps and control of the liquid flow rate shall be effected from the deck.

.2 the bilge system of this service space fulfils the requirements specified in paragraph 36.4.5;

.3 the ventilation system of this service space fulfils the requirements specified in paragraph 36.7.4.2.

36.4 Bilge and Ballast Systems

36.4.1 Bilge and ballast pumps for spaces within the cargo area shall be installed within such an area.

This requirement does not apply to the pumps for:

.1 double-side spaces and double bottoms which do not have a common boundary wall with the cargo tanks;

.2 cofferdams and hold spaces where ballasting is performed using the piping of the fire-fighting system in the cargo area and bilge-pumping is performed using eductors.

36.4.2 Where the double bottom is used as an oil fuel tank, it shall not be connected to the bilge system.

36.4.3 Where a ballast pump is installed in the cargo area, the standpipe and its outboard connection for suction of ballast water, shall be located within the cargo area but outside the cargo tanks.

36.4.4 Cargo pump-room below the deck shall be capable of being drained in an emergency by an installation located in the cargo area and independent of any other installation. This installation shall be provided outside the cargo pump-room.

36.4.5 The bilge of the cargo pump-room below the deck shall be equipped with a gauging device for measuring the filling level which activates a visual and audible alarm in the wheelhouse when liquid is accumulating in the cargo pump-room bilge. This requirement does not apply to tankers with open cargo tanks.

36.5 Air and Overflow Pipes

36.5.1 Open ends of air pipes of oil fuel tanks shall extend to at least 0.50 m above the open deck.

Open ends of both air pipes and overflow pipes oil fuel tanks leading on the open deck shall be fitted with a protective device consisting of a gauze diaphragm or perforated plate.

36.6 Exhaust Gas System

36.6.1 Exhaust gas shall be extracted from the vessel into open air either upwards through an exhaust pipe or through the shell plating. The exhaust outlet shall be located not less than 2 m from the cargo area. This requirement does not apply to oil separator or supply vessels.

36.6.2 Exhaust pipes of engines shall be so arranged that the exhausts are led away from the vessel. The exhaust pipes shall not be located in the cargo area.

36.6.3 Exhaust pipes of engines, boilers, incinerators, stoves and other equipment where sources of ignition exist shall be provided with spark arresters whose construction is subject to PRS acceptance.

36.7 Ventilation System

36.7.1 Double-side spaces and double bottoms within the cargo area which are not arranged for being filled with ballast water shall be provided with ventilation systems.

36.7.2 Engine Room Ventilation

36.7.2.1 Ventilation in the closed engine room shall be so designed that at an ambient temperature of 20°C, the average temperature in the engine room does not exceed 40°C. This requirement does not apply to oil separator or supply vessels.

36.7.2.2 Ventilation inlets of the engine room and, when the engines do not take in air directly from the engine room, the air intakes of the engines shall be located not less than 2 m from the cargo area.

36.7.2.3 Ventilation system of the engine room shall be designed taking into account the air required for the boiler.

36.7.3 Cargo Area Ventilation

36.7.3.1 Hold spaces and cofferdams shall be provided with ventilation systems.

36.7.3.2 Each hold space shall have two openings the dimensions and locations of which shall be such as to permit effective ventilation of any part of the hold space. If there are no such openings, it shall be possible to fill the hold spaces with inert gas or dry air.

36.7.3.3 Ventilators used in the cargo area shall be so designed that no sparks may be emitted and shall also fulfil the requirements specified in sub-chapter 6.3.2. This requirement does not apply to open type N vessels.

36.7.4 Ventilation of Accommodation Spaces, Service Spaces and Wheelhouse

36.7.4.1 Ventilation of accommodation and service spaces shall be possible.

36.7.4.2 Service space located within the cargo area below the deck which is used as a pump room for the vessel's own discharging system shall be fitted with the mechanical ventilation system providing at least 30 changes of air per hour based on the total volume of the service space.

Ventilation exhaust outlets shall be located at least 6 m from entrances and openings of the accommodation and service spaces outside the cargo area. Ventilation inlets shall be possible to be closed from the outside.

The requirements specified above do not apply to tankers with open cargo tanks.

36.7.4.3 Any service space located in the cargo area below the deck except for the space mentioned in paragraph 35.7.5.2 above, shall be provided with a system of forced ventilation with sufficient power for ensuring at least 20 changes of air per hour based on the volume of the space.

The requirement to provide a system of forced ventilation does not apply to tankers with open cargo tanks.

36.7.4.4 Ventilation exhaust ducts from the service space mentioned in paragraphs 36.7.4.2 and 36.7.4.3 shall extend down to 50 mm above the bottom of the service space. The air shall be supplied through a duct at the top of the service space. The air inlets shall be located not less than 2 m above the deck, at a distance of not less than 2 m from tank openings and 6 m from the outlets of safety valves. Extension pipes, which may be necessary, may be of the hinged type.

Fans used for serving these spaces shall be so designed that no sparks may be emitted and the requirements specified in sub-chapter 6.3.2 shall be fulfilled. In open type N vessels, ventilators need not be of non-sparking construction.

36.7.4.5 Ventilation of the accommodation and service spaces as well as wheelhouse located outside the cargo area where electrical equipment is installed to be used during loading, unloading and gas-freeing during berthing shall be at least of the 'limited explosion risk' type (see sub-chapter 1.2 in *Part VII – Electrical Equipment and Automatic Control*) and shall ensure overpressure of 0.1 kPa and none of the windows shall be capable of being opened.

Air intakes of the ventilation system shall be located as far as practicable, however, not less than 6 m from the cargo area and not less than 2 m above the deck.

36.7.4.6 Ventilation system of the accommodation spaces where electrical equipment is installed for cargo heating during loading, unloading and gas-freeing shall ensure overpressure of 0.1 kPa and none of the windows shall be capable of being opened.

Inlets of the ventilation system shall be located not less than 2 m from the cargo area and not less than 6 m from the openings of cargo tanks or residual cargo tanks, loading pumps situated on the deck, openings of high velocity vent valves, pressure relief devices and shore connections of loading and unloading pipes and shall be located not less than 2 m above the deck.

36.7.4.7 Noticeboards shall be fitted at the ventilation inlets indicating the conditions when they shall be closed. Ventilation inlets of accommodation and service spaces leading outside shall be fitted with fire flaps. Such ventilation inlets shall be located not less than 2 m from the cargo area.

Ventilation inlets of service spaces in the cargo area below deck may be located within this area.

The requirements specified above do not apply to tankers with open cargo tanks.

36.8 Oil Fuel System

36.8.1 Double bottom within the hold area may be arranged as oil fuel tanks provided that their depth is not less than 0.6 m. Oil fuel pipes and openings to such tanks are not permitted in the holds.

36.9 Loading and Unloading System

36.9.1 Pumps, compressors as well as loading and unloading piping shall be located in the cargo area.

Cargo pumps and compressors situated on the deck shall be located not less than 6 m from entrances to, or openings of, the accommodation and service spaces outside the cargo area.

Cargo pumps and compressors shall be capable of being shut down from the cargo area and, in addition, from a position outside.

36.9.2 If the vessel is carrying several dangerous substances liable to react with each other, a separate pump with its own piping for loading and unloading shall be installed for each substance.

The piping shall not pass through a cargo tanks containing dangerous substances with which the substance in question is liable to react.

36.9.3 Pipes for loading and unloading shall be independent of any other piping of the vessel. No cargo piping shall be located below the deck, except for those inside the cargo tanks and inside the cargo pump-room.

36.9.4 When pipes for loading and unloading are used for supplying the cargo tanks with washing or ballast water, the suctions of these pipes shall be located within the cargo area but outside the cargo tanks.

Additionally:

.1 a spring-loaded non-return valve shall be provided to prevent any gases from being expelled from the cargo area through the tank washing system,

.2 a non-return valve shall be fitted at the junction between the water suction pipe and the cargo loading pipe.

36.9.5 Pipes for loading and unloading shall be clearly distinguishable from other piping, e.g. my means of colour marking.

36.9.6 Pipes for loading and unloading shall be so arranged that, after loading or unloading operations, the liquid remaining in these pipes may be safely removed and may flow either into the vessel's tanks or the tanks ashore.

36.9.7 Shore connections shall be located not less than 6 m from the entrances to and openings of, the accommodation and service spaces outside the cargo area.

36.9.8 Shore connections of the vapour pipe and shore connections of the pipes for loading and unloading, through which the loading and unloading operation is performed, shall be fitted with a shut-off device. Shore connections, however, shall be fitted with a blind flange when they are not in operation.

Shore connections of the pipes for loading and unloading through which the loading and unloading operation is performed, shall be fitted with a device intended for the discharge of residual cargo described in paragraph 8.6.4.1 of the ADN.

Note: According to the provision of paragraph 9.3.2.25.10 of the ADN, it is not necessary to apply this requirement yet. The date of its enforcement will be specified in due course.

36.9.9 Pipes for loading and unloading, and vapour pipes, shall not have flexible connections fitted with sliding seals if the substance carried has corrosive properties (see column (5) of Table C in Chapter 3.2, hazard 8 in the ADN).

This requirement does not apply to supply vessels.

36.9.10 The distances referred to in paragraphs 36.9.1 and 36.9.7 may be reduced to 3 m, provided that:

.1 a transverse bulkhead which fulfils the requirements specified in paragraph 9.3.2.10.2 of ADN Rules is situated at the end of the cargo area;

.2 openings are provided with doors. On the doors, the following notice shall be displayed: Do not open during loading and unloading without the permission of the master. Close immediately.

36.9.11 Pipes for loading and unloading shall extend down to the bottom of the cargo tanks. This requirement does not apply to tankers with open cargo tanks.

36.9.12 Stop valves or other shut-off devices of the pipes for loading and unloading shall indicate whether they are open or shut.

36.9.13 Pipes for loading and unloading shall be fitted with pressure gauges at the pump outlet. The gauges shall fulfil the requirements specified in paragraph 16.2.4.6 of *Part VII – Electrical Equipment and Automatic Control*.

36.9.14 Pipes for loading and unloading shall be subjected to the hydraulic test to a gauge pressure not less than 1.0 MPa.

36.9.15 Permissible maximum loading and unloading flow rates for each cargo tank or each group of cargo tanks, taking into account the design of the ventilation system shall be calculated. These calculations shall take into consideration the fact that in the event of an unforeseen cut-off of the gas return piping or the compensation piping of the shore facility, the safety devices of the cargo tanks will prevent pressure in the cargo tanks from exceeding the following values:

– overpressure: 115% of the opening pressure of the high-velocity valve,
– vacuum pressure: not more than the construction vacuum pressure, however not exceeding 5 kPa (0.05 bar).

The main factors to be considered are the following:

1. Dimensions of the ventilation system of the cargo tanks;
2. Gas formation during loading by multiplying the greatest flow rate by a factor not less than 1.25;
3. Density of the vapour mixture of the cargo based on 50% volume vapour and 50% volume air;
4. Loss of pressure through vent pipes, valves and fittings. Account shall be taken of 30% clogging of the flame-arrester mesh;
5. Chocking pressure of the safety valves.

The permissible maximum loading and unloading pressure for each cargo tank or for each group of cargo tanks shall be specified in an on-board instruction.

This requirement does not apply to oil separator vessels.

36.9.16 According to the provisions of paragraph 9.3.3.25.12 of the ADN, the requirements of the respective provisions of paragraphs 36.9.1, 36.9.3, 36.9.4, 36.9.7, 36.9.8 and 36.9.10 do not apply to open type N oil separator or supply vessels unless the substance carried has corrosive properties (see column (5) of Table C in Chapter 3.2, hazard 8 in the ADN).

36.10 Stripping System

Note: *The requirements specified in sub-chapter 36.10 need not be fulfilled yet. The date of its enforcement will be specified in due course (see paragraph 9.3.3.26 of the ADN).*

36.10.1 The vessel shall be provided with:

.1 at least one residual cargo tank for the liquid remaining in the pipes for loading and unloading and cargo tanks after the unloading operations but before pumping the residues. These tanks shall be located in the cargo area;

.2 At least one slop tank for slops (sludge, settlings, washings) which are not suitable for pumping. The tank shall be located in the cargo area;

.3 a stripping system.

The requirement specified in sub-paragraph .3 does not apply to open type N oil separator or supply vessels.

36.10.2 The maximum capacity of the residual cargo tank is 30 m^3.

The residual cargo tank shall be equipped with:

.1 in the case of an open system:
  – a device for ensuring pressure equilibrium,
  – an ullage opening,
  – connections, with stop valves, for pipes and hoses;

.2 in the case of a protected system:
  – a device for ensuring pressure equilibrium, fitted with a flame-arrester capable of withstanding steady burning;
  – an ullage opening,

– connections, with stop valves, for pipes and hoses;

.3 in the case of a closed system

– a vacuum valve and a high-velocity vent valve. The valve shall be so regulated that it does not open during carriage. When anti-explosion protection is required in (see column 17, Table C, Chapter 3.2 of ADN Rules), the vacuum valve shall be capable of withstanding deflagrations and the high-velocity vent valve steady burning;
– a device for measuring the degree of filling;
– connections, with stop valves, for pipes and hoses.

Residual cargo tanks shall be connected to the vapour pipe of cargo tanks only for the time necessary to fill them.

The requirement regarding the residual cargo tank capacity does not apply to oil separator vessels

36.10.3 The requirement regarding the residual cargo tank capacity does not apply to oil separator vesselsIntermediate bulk containers (IBCs) or tank containers or portable tanks may be used instead of a fixed residual cargo tank provided that the following requirements are fulfilled:

.1 a maximum individual capacity does not exceed 2 m^3;

.2 not more than 6 such intermediate bulk containers, tank containers or portable tanks are carried;

.3 these intermediate bulk containers, tank containers or portable tanks are properly secured in the cargo area.

During filling of these intermediate bulk containers or tank-containers or portable tanks, means for collecting any leakage shall be placed under filling connections.

36.10.4 Slop tanks shall be fire resistant and shall be capable of being closed with lids (e.g. drums with lever closing ring lids). The tanks shall be marked and easy to handle.

36.10.5 The stripping system shall be subjected to initial tests before being put into service or thereafter if any alteration has been made to it, using water as test medium. The test and the determination of the residual quantities shall be performed in accordance with the requirements specified in paragraph 8.6.4.2 of the ADN.

In this test, the following residual quantities shall not be exceeded:
– 5 dm^3 for each cargo tank,
– 15 dm^3 for each pipe system for cargo loading and unloading.

This requirement does not apply to oil separator or supply vessels.

36.10.6 Residual cargo tanks, intermediate bulk containers (IBCs), tank containers and portable tanks placed on the deck shall be located at a minimum distance from the shell plating equal to one quarter of the vessel's breadth.

36.11 Cargo and Slop Tank Gas-Freeing System

36.11.1 Each cargo tank or group of cargo tanks connected to a common vapour pipe shall be fitted with safety devices for preventing unacceptable overpressures or vacuums.

These safety devices shall be as follows:

.1 for tankers with open cargo tanks – safety devices to prevent any accumulation of water and its penetration into the cargo tanks;

.2 for tankers with open cargo tanks and flame arresters – safety equipment fitted with flame arresters capable of withstanding steady burning and designed to prevent any accumulation of water and its penetration into the cargo tanks;

.3 for tankers with closed cargo tanks:
- safety devices for preventing unacceptable overpressure or vacuum. Where antiexplosion protection is required (see ADN Rules, Chapter 3.2, Table C, column 17), the vacuum valve shall be fitted with a flame arrester capable of withstanding deflagration and the pressure relief valve with a high-velocity vent valve. Gases shall be discharged upwards. The opening pressure of the high-velocity vent valve and the opening pressure of the vacuum valve shall be permanently marked on the valves.
- a connection for the safe return ashore of gases expelled during loading;
- a device for the safe depressurisation of the cargo tanks consisting of at least a flame-arresters and a stop valve the position of which shall clearly indicate whether it is open or shut.

36.11.2 The outlets of high-velocity vent valves shall be located not less than 2.00 m above the deck and at a distance of not less than 6 m from the accommodation and from the service spaces outside the cargo area. This height may be reduced when within a radius of 1.00 m round the outlet of the high-velocity vent valve, there is no equipment, no work is being carried out and signs indicate the area. The setting of the high-velocity vent valves shall be such that during the transport operation they do not blow off until the maximum permissible working pressure of the cargo tanks is reached.

This requirement does not apply to open type N vessels with flame arresters and to open type N vessels.

36.11.3 Insofar as anti-explosion protection is prescribed (see ADN Rules, Chapter 3.2, Table C, column 17), a vapour pipe connecting two or more cargo tanks shall be fitted, at the connection to each cargo tank, with:

.1 a flame arrester with a fixed or spring-loaded plate stack, capable of withstanding a detonation. Acceptable means of fulfilment this requirement are specified in paragraph 9.3.2.22.5(a) of ADN Rules; or

.2 a pressure/vacuum relief valve incorporating a flame arrester capable of withstanding a detonation / deflagration; or

.3 a shut-off device capable of withstanding a detonation, where each cargo tank is fitted with a vacuum valve capable of withstanding a deflagration and a high-velocity vent valve capable of withstanding steady burning.

In each case described in .1, .2 and .3 above, only substances which do not react dangerously with each other may be carried simultaneously in cargo tanks connected to a common vapour pipe.

This requirement does not apply to open type N vessels with flame arresters and to open type N vessels.

36.11.4 Insofar as anti-explosion protection is prescribed (see column (17) of Table C of Chapter 3.2 of ADN Rules), an independent vapour pipe for each cargo tank shall be fitted with a pressure/vacuum valve incorporating a flame arrester capable of withstanding a deflagration and a high velocity vent valve incorporating a flame arrester capable of withstanding steady burning.

This requirement does not apply to open type N vessels with flame arresters and to open type N vessels.

36.11.5 Each residual cargo tank shall be fitted with safety devices, which fulfil the requirements specified in paragraph 36.10.2, for preventing unacceptable overpressures or vacuums.

36.12 Cargo Heating System

36.12.1 The cargo heating system shall be so designed that the cargo is incapable of penetrating into the boiler in the case of a leak in the heating coils. A cargo heating system with artificial draught shall be ignited electrically.

36.12.2 Where the cargo heating system is used during loading, unloading or gas-freeing, the service space which contains this system shall fulfil the requirements specified in paragraph 36.7.4.6.

36.13 Water Washing System for Cargo Tanks

36.13.1 Where pipes for loading and unloading are used for supplying the cargo tanks with washing water (see paragraph 36.9.4), pumps for tank washing systems with associated connections may be located outside the cargo area, provided the discharge side of the system is arranged in such a way that the suction is not possible through that part.

36.14 Water Spray System for Cargo Deck Cooling

36.14.1 Where water-spraying system is required (see column 9, Table C, Chapter 3.2 of ADN Rules), a water-spray system shall be installed in the cargo area on the deck for the purpose of reducing vapours given off by the cargo by spraying water over the whole surface.

36.14.2 The system shall be fitted with a connection device for supply from the shore. The system shall be capable of being put into operation from the wheelhouse and from the deck.

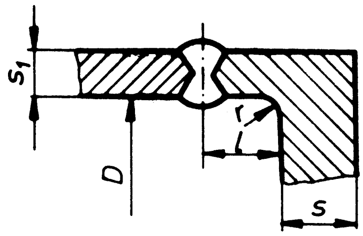
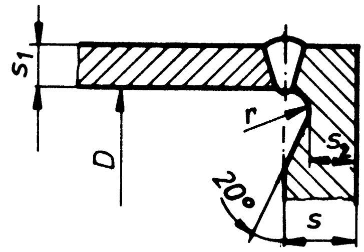
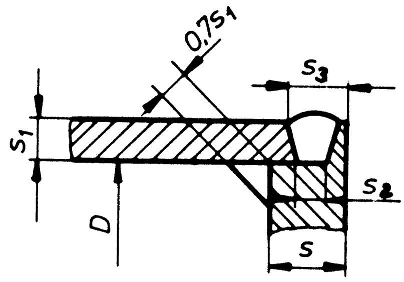
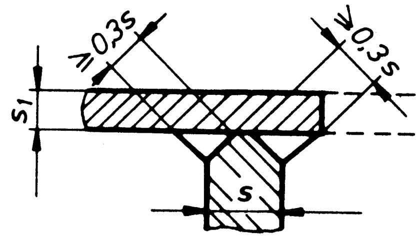
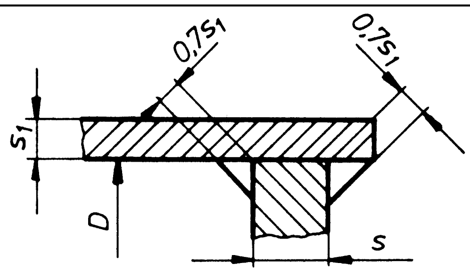
36.14.3 Capacity of the water-spray system shall be such that when all the spray nozzles are in operation, the outflow is 50 litres per square metre of cargo deck area and per hour.

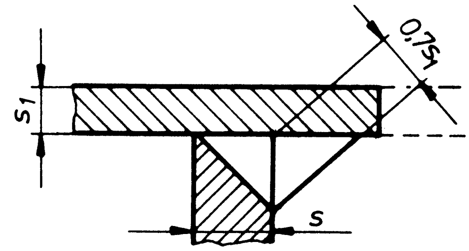
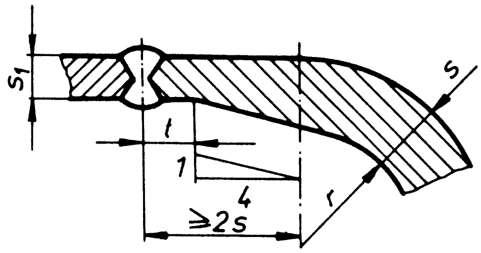
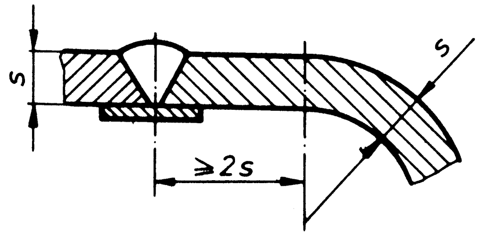
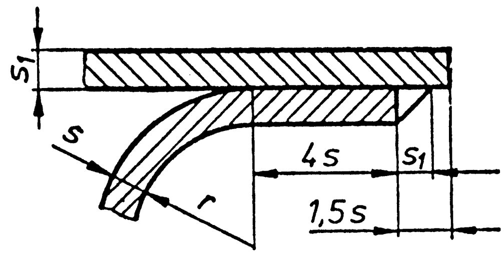
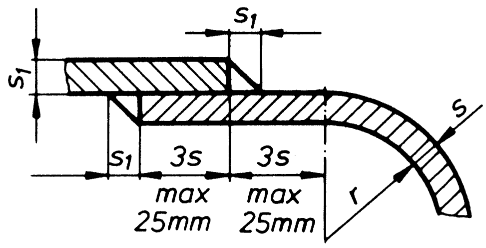
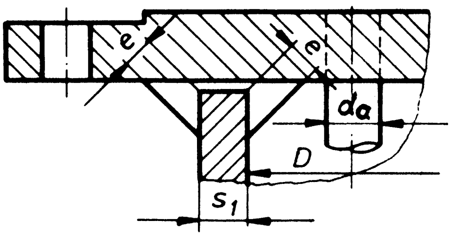
Annex

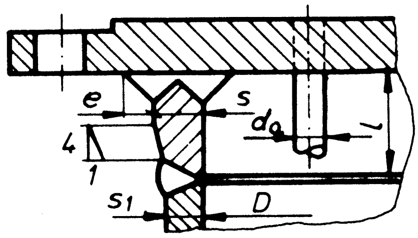
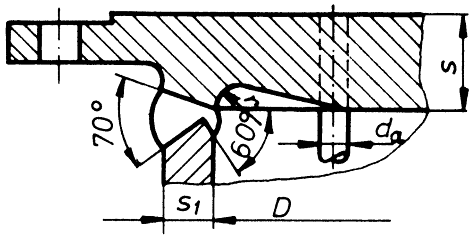
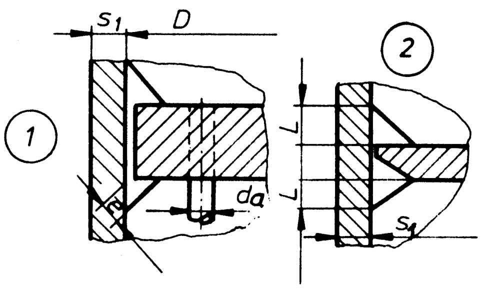
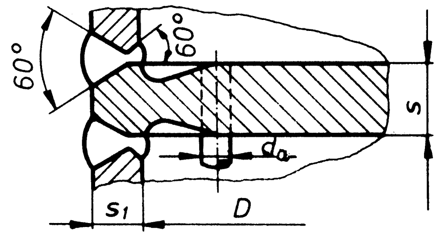
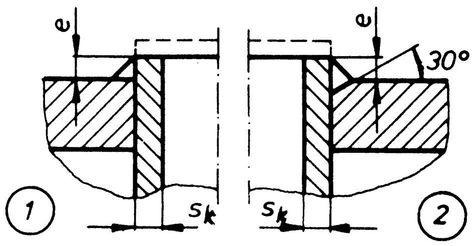
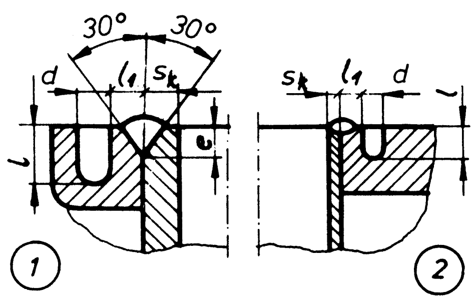
EXEMPLARY WELDED JOINTS USED IN BOILERS, PRESSURE VESSELS AND HEAT EXCHANGERS

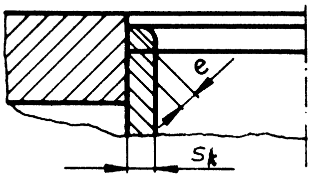
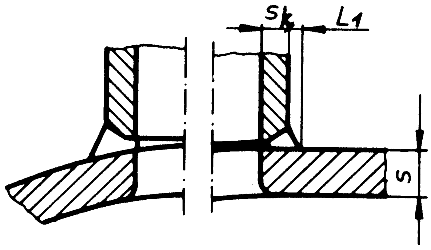
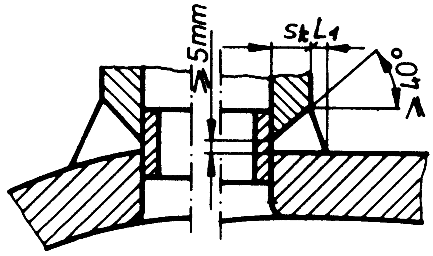
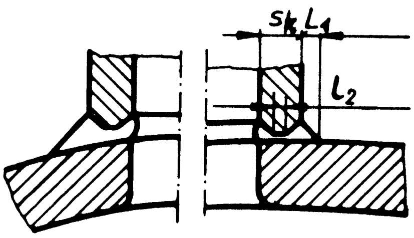
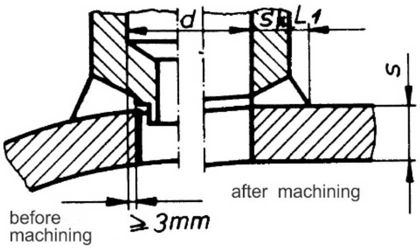
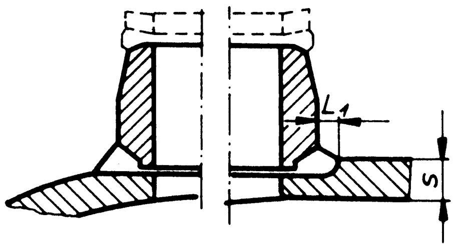
Dimensions of the components prepared for welding shall be determined in accordance with the national standards depending on the welding method. The examples of the most frequently used joints are shown in the tables below.

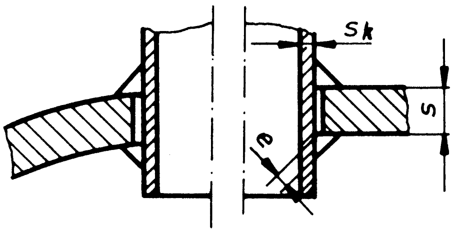
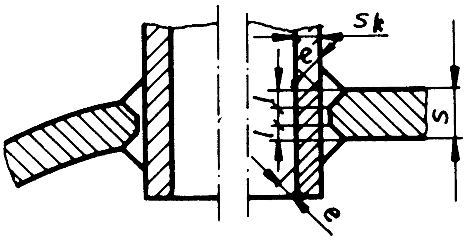
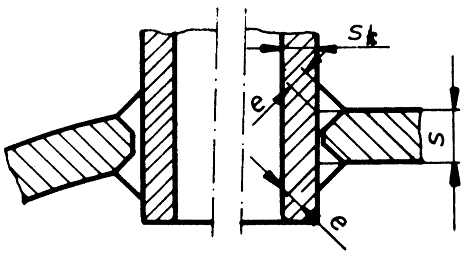
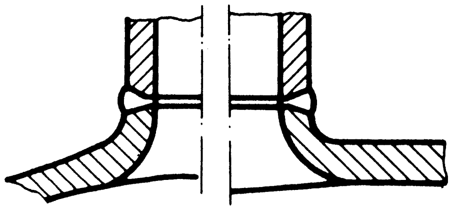
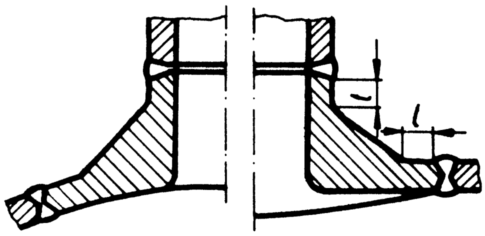
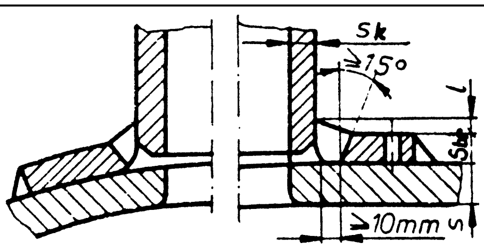
Other welded joints may also be performed having regard to the mechanical properties of parent materials and welding procedure. Such joints as well as necessary modifications to the exemplary joints are subject to PRS acceptance in each particular case.

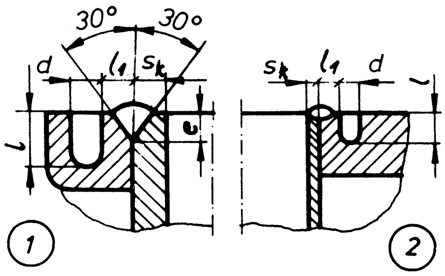
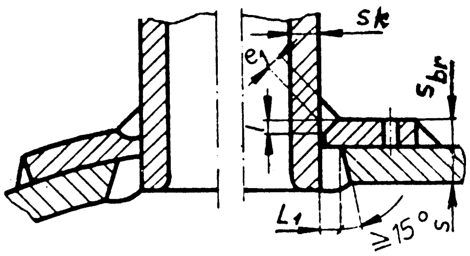
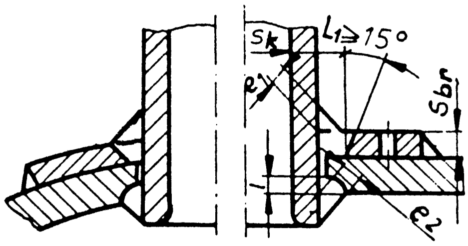
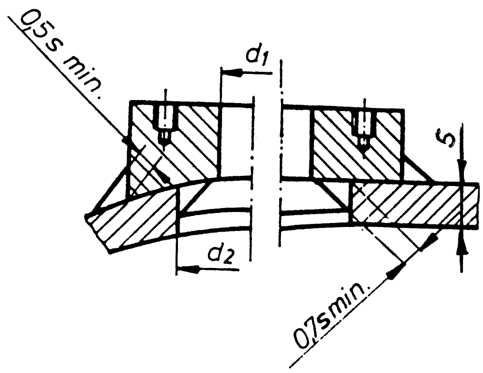
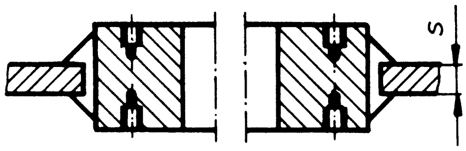
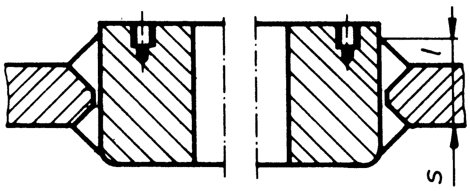
Item	Drawing (example)	Application
1	Flat end plates and covers	
1.1.		$K = 0.38$ $r \geq \frac{s}{3}$, however not less than 8 mm $l \geq s$
1.2		$K = 0.45$ $r \geq 0.2\,s$, however not less than 5 mm $s_2 \geq 5$ mm (see Note 1)
1.3		$K = 0.5$ $s_2 \leq s_1$, however not less than 6.5 mm $s_3 \geq 1.24\,s_1$ (see Note 1)
1.4		$K = 0.45$ (see Note 1)
1.5		$K = 0.55$ (see Note 1)

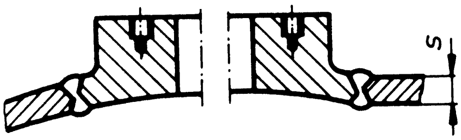
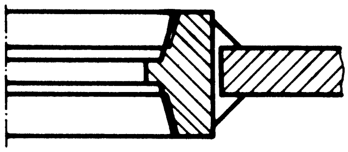
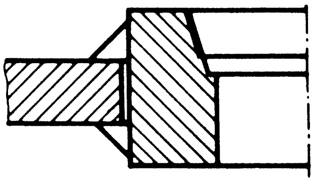
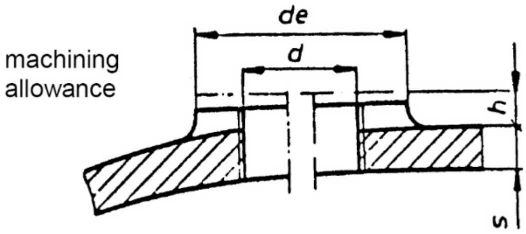
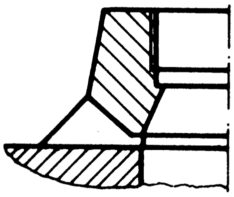
Item	Drawing (example)	Application
1.6		K = 0.57
2	Dished ends	
2.1		The joint may be used in boilers and pressure vessels of Class I, II and III (see Notes 2 and 17)
2.2		The joint may be used in boilers and pressure vessels of Class II and III
2.3		Not recommendable joint – it may be used only for pressure vessels of Class II not exposed to corrosion $s_1 \leq$ 16 mm $D \leq$ 600 mm
2.4		The joint may only be used for pressure vessels of Class III $s_1 \leq$ 16 mm $D \leq$ 600 mm
3	Tube plates	
3.1		K = 0.45 e = 0.7 s_1 $s_1 \leq$ 16 mm (see Notes 3 and 4)

Item	Drawing (example)	Application
3.2		$K = 0.45$ $e = \frac{1}{3} s_1$ $e > 6$ mm $s_1 > 16$ mm (see Notes 5 and 6)
3.3		$K = 0.45$ $r \geq 0.2\ s$, however not less than 5 mm
3.4		$k = 0.45$ $e \geq 0.7\ s_1$; if $L > 13$ mm variant 2, where $L = \frac{1}{3} s_1$ and $L \geq 6$ mm is recommendable (see Note 7)
3.5		$K = 0.45$ $r \geq 0.2\ s$, however not less than 5 mm
4	Tubes	
4.1		$e = s_k$ $e \geq 5$ mm $s_k \geq 2.5$ mm (see Notes 8, 9 and 10)
4.2		$d = s_r$; $l_1 = s_r$ $1.5\ s_r < l < 2\ s_r$ variant 1: $s_r \geq 5$ mm; $l = s_r$ variant 2: $s_r < 5$ mm (see Note 12)

Item	Drawing (example)	Application
4.3		$e = 0.7\ s_k$ $s_k \geq 3$ mm (see Note 12)
5	Branch pieces and joints	
5.1	Welded not penetrating branch pieces	
5.1.1		$s_k \leq 16$ mm $L_1 = \frac{1}{3} s_k$, however not less than 6 mm
5.1.2		$L_1 = \frac{1}{3} s_k$, however not less than 6 mm (see Note 13)
5.1.3		$L_2 = 1.5 \div 2.5$ mm $L_1 \geq \frac{1}{3} s_k$, however not less than 6 mm (see Note 14)
5.1.4		$L_1 \geq \frac{1}{3} s_k$, however not less than 6 mm (see Notes 15 and 16)
5.1.5		$L_1 = 10 \div 13$ mm (see Note 15)

Item	Drawing (example)	Application
5.2	Welded penetrating branch pieces	
5.2.1		Generally, used where $s_k < \frac{1}{2}s$ $e = s_k$
5.2.2		Generally, used where $s_k \cong \frac{1}{2}s$ $e = 6 \div 13$ mm $e + l = s_k$
5.2.3		Generally, used where $s_k > \frac{1}{2}s$ $e \geq \frac{1}{10}s$, however not less than 6 mm
5.3	Offset branch pieces	
5.3.1		
5.3.2		(see Note 17)
5.4	Branch pieces with strengthening ring pads	
5.4.1		$l \geq \frac{1}{3}s_k$, however not less than 6 mm

Item	Drawing (example)	Application
5.4.2		$l \geq \frac{1}{3} s_k$, however not less than 6 mm $L_1 \geq 10$ mm
5.4.3		$e + l = s_k$ or s_{br} (whichever is lesser) $L_1 \geq 10$ mm
5.4.4		$e_2 + l \geq s_k$ $L_1 \geq 10$ mm $2s_k \leq (e_2 + l)$ plus $(s_{br} + e_1)$ or L_1 whichever is lesser
5.5	Pads and branch pieces with threaded holes	
5.5.1		$d_2 \leq d_1 + 2s_{min}$ (see Note 18)
5.5.2		$s \leq 10$ mm (see Notes 19 and 20)
5.5.3		$L \geq 6$ mm $s \leq 20$ mm

Item	Drawing (example)	Application
5.5.4		$s \geq 20$ mm
5.6	Branch pieces and pads for screw joints	
5.6.1		
5.6.2		
5.6.3		$d \leq s$ $d_e = 2\ d$ $h \leq 10$ mm $h \leq 0.5\ s$ (see Note 21)
5.6.4		

Notes:

1. Joint may be used in pressure vessels made of materials with $R_m \leq 470$ MPa or $R_e \leq 370$ MPa.
2. Reduction of the shell thickness or of the thickness of flanged portion of the end plate may be effected in the inside or on the outside.
3. Joint used where welding can be done at both sides of the shell.
4. Shells with more than 16 mm in thickness shall have the edges for fillet welds bevelled in accordance with drawing 3.2.
5. Joints used when welding is possible on the outside of the shell only.
6. In shells with no more than 16 mm in thickness, joints may be single-side welded. The ring breadth shall not be less than 40 mm.
7. The distance between the internal shell diameter and the external tube plate-diameter shall be as little as practicable.
8. The end of the tube projecting beyond the weld shall be milled or ground.
9. The spacing of the tubes shall not be less than 2.5 s_k , however not less than 8 mm.
10. In the case of manual electrical welding, dimension s_k shall not be less than 2.5 mm.
11. Recommended where maximum reduction of the tube plate deformation due to the welding process is necessary.
12. Tubes shall be joined by arc welding manually.

13. The backing ring shall adhere to the parent material and shall be removed after welding.
14. Joint used where welding can be performed inside the branch piece.
15. Joint used where the branch piece dimensions are significantly smaller than those of the vessel.
16. After welding, the branch piece shall be machined to the final dimension.
17. Ring shaped portions, *l*, shall be such as to enable X- ray examination of the joints where necessary.
18. The distance between the ring pad and shell shall not be greater than 3 mm.
19. The distance between the diameter of the opening in the shell and the outside diameter of the ring shall be as little as practicable and shall not be greater than 3 mm.
20. Upper and lower bolt holes in the pad shall be shifted relative to each other
21. Combined thickness of the vessel's shell and deposited weld metal shall be sufficient for the necessary number of thread turns.

List of amendments effective as of 1 July 2019

Item	*Title/Subject*	*Source*
Page 2	Reference to PUB 102/P added, new Publication 122/P added	*PRS*
Definitions	EST -TRIN added	Directive (EU) 2016/1629
1.11.10	PN-W-47058:1988 standard withdrawn	PRS
2.5.2	High pressure fuel pipelines for engines	Art.8.02.5 ES-TRIN
2.11	Emission of gaseous and particulate pollutants from diesel engines	Art.9 ES-TRIN
3.6.1	Ice excitation torsional vibration	PUB 122/ P and experience from ice breakers under PRS survey
4.1.1	Ice excitation torsional vibration	PUB 122/ P and experience from ice breakers under PRS survey
5.2.3.5	ISO 6336 standard updated	PRS
7.2.4	Tests on Board Ship added	Art. 6.09 ES-TRIN
9.1.8	Elevating wheelhouses added	Art.7.12.8 i 7.12.7 ES-TRIN
9.1.9	Elevating wheelhouses added	Art.7.12.5 ES-TRIN
9.1.12	Elevating wheelhouses added	Art.7.12.10 ES-TRIN
15.3.4	Mechanical Joints	PRS
16.3.2	Branch pipes connections to bilge main	Art.8.08.8 ES-TRIN
16.4.5	Closures on oily bilge water bottom drainage pipes	Art.8.08.8 ES-TRIN
17.1.2	Oily water store in engine room bilge	Art.8.09.1 ES-TRIN
17.3.3, 26.3.2	PN_EN 1305:2018-05 updated	PRS
19.4.10	Fuel oil level indicators	Art.8.05.9 ES-TRIN
20.1.3	Exhaust gas pipelines	Art.8.04.2 ES-TRIN
20.1.8 - 20.1.13	Exhaust gas after-treatment system added	Art. 9.09.1 – 9.09.5 ES-TRIN
21.4	Ventilation of battery rooms and lockers	Art.10.11 ES-TRIN
22.2.3	Fuel oil system	Art.8.05.7 ES-TRIN
23.3.2	LO tanks arrangement added	Art.8.06.2 ES-TRIN
23.3.3	LO tanks filling added	Art.8.06.5 ES-TRIN
23.3.4	LO level indicators added	Art.8.06.7 ES-TRIN
22.2.4	Fuel oil system	Art.8.05.8 ES-TRIN
22.5.1	Bunkering ; PN-EN 12827 standard updated	Art.8.05.6 and 8.05.10a) ES-TRIN; PRS
22.5.2	Bunkering	Art.8.05.11 ES-TRIN
22.6.7	Fuel tanks openings added	Art.8.05.12 ES-TRIN
26.4.1	Sewage treatment plant	Art.18 ES - TRIN
28.1.3	Additional requirements for vessels with ice class L1	PUB 122/ P and experience from ice breakers under PRS survey
28.1.4	Additional requirements for vessels with ice class L1	PUB 122 /P and experience from ice breakers under PRS survey
29.7	Waste water collection and disposal facilities added	Art. 19.14 ES -TRIN