PART VII. MACHINERY INSTALLATIONS

1. GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to ship machinery installations, equipment of machinery spaces, shafting lines, propellers, machinery condition monitoring systems, spare parts and active means of the ship's steering (AMSS) as they are defined in 1.2.8 of Part III "Equipment, Arrangements and Outfit".

Machinery installations and machinery space equipment of ships of gross tonnage less than 500, unless otherwise indicated, as well as those of berth-connected ships shall comply with the requirements of Sections 1 to 4 and 9 of the present Part and Part IX "Machinery" in so much as applicable and sufficient.

1.1.2 The requirements of the present Part are set forth proceeding from the condition that the flash point of fuel oil (refer to 1.2, Part VI "Fire Protection") used in ships of unrestricted service for the engines and boilers is not below 60 °C and the flash point of fuel for emergency generator engines, not below 43 °C.

In ships certified for restricted service within areas having a climate ensuring that ambient temperature of spaces where such fuel oil is stored will not rise to within 10 °C below its flash point may use fuel oil with flash point not less than 43 °C. In this case, measures shall be taken to ensure checking and maintenance of the above condition.

The use of fuel having a flash point of less than 43 °C may be permitted for cargo ships only subject to the approval by the Register of the complete installation.

Such fuel shall not be stored in any machinery space.

Crude oil and slops may be used as boiler fuel in oil tankers. The conditions of such use are stated under 13.11, Part VIII "Systems and Piping".

On gas carriers for gas turbine engines and dual fuel internal combustion engines it is allowed to use the natural gas (methane) carried as fuel.
Conditions of application of natural gas as fuel are set out in 4.7 of this Part and 13.12, Part VIII "Systems and Piping" and in 8.10 and Section 9, Part IX "Machinery".

1.1.3 Compliance of a passenger ship having marks **A**, **A-R1, A-R2**, **A-R2-RS**, **A-R2-S**, **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS**, **D-R3-S**, **D-R3-RS** in its class notation with the provisions of the Directive 2009/45/EC of the European Parliament and of the Council on safety rules and standards for passenger ships of May 6, 2009, which came into force on July 15, 2009 (revised version amended by Commission Directive 2010/36/EU of June 1, 2010), hereinafter referred to as the Directive 2009/45/EC, shall be confirmed in accordance with the requirements of Section 2.6.1 of the General Regulations for the Classification and Other Activity by applying these Rules and/or special requirements of these Rules to the ship, depending on the mark in ship class notation, as for new or existing ships (see 2.6.1.1.4.2 or 2.6.1.1.4.3 of the General Regulations for the Classification and Other Activity, respectively) specified in certain paragraphs with or without reference to the mark in ship class notation, specifically, compliance with the following requirements:

— new ships marked **A**, **A-R1, A-R2**, **A-R2-RS**, **or A-R2-S** — with all relevant requirements of this Part, with regard to, where specific requirements apply to the above marks, the reference to the mark in the ship's class notation;

— new ships with mark **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS**, **D-R3-S**, **D-R3-RS**, and existing ships with mark **B-R3-S**, **B-R3-RS** — 1.1.2, 2.1.3, 2.1.4, 2.1.6, 3.2.1.6, 3.3.1, 4.3.1, 4.3.2, 4.3.3;

— all new and existing ships with mark **B-R3-S**, **B-R3-RS** and new ships with mark **C-R3-S**, **C-R3-RS**, **D-R3-S**, **D-R3-RS**, 24 m long and longer — 3.3.1;

— new ships with mark **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS**, **D-R3-S**, **D-R3-RS** — 2.1.9, 3.1.1, 3.1.8, 3.1.10, 3.1.11, 3.2.1.1, 3.2.1.2, 3.2.1.6, 3.2.1.10, 3.2.6, 3.2.7, 3.2.8, 3.2.14, 4.1.4, 4.6.1;

— new ships with mark **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS —** 2.3.1;

— ships with mark **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS**, **D-R3-S**, **D-R3-RS** built not earlier of January 1, 2003 — 3.1.10, 3.1.11, 3.2.7, 4.5.7, 4.5.8.

1.2 DEFINITIONS AND EXPLANATIONS

The definitions and explanations relating to the general terminology of the Rules are given in the General Regulations for the Classification and Other Activity and in Part I "Classification" of the Rules for the Classification and Construction of Sea-Going Ships[1].

The following definitions, as adopted in the present Part, are equally applicable for the purpose of Part VIII "Systems and Piping" and Part IX "Machinery".

Alternative propulsion plant is a combination of machineries, systems and devices that can produce reverse or direct thrust for ship propulsion in emergency situations in case of failure of the main propulsion plant. The following items can be used as alternative propulsion plant: standby emergency engine, electrical motor or shaft generator, which can be used as a propulsion electrical motor.

The total power output of the alternative propulsion plant engines shall be at least 1/8 of the total power output of the main propulsion plant.

Alternative liquid fuel is a liquid fuel that can substitute the appropriate conventional fuels, is produced (mined) from non-conventional sources and kinds of energy materials or is a combination of alternative and conventional fuels and may differ from conventional fuel due to its properties.

Safe atmosphere is an atmospheric environment, gas concentration in which is lower than the appropriate alarm level set for the gas alarm system.

Open space is an area that is open at one or more sides, provided that in all parts of such area efficient natural ventilation through constant openings in side enclosures and in above-located deck is arranged.

Exit is an opening in a bulkhead or a deck equipped with a closure and purposed for people to pass through it.

[1] Hereinafter — Part I "Classification".

E x i t p a t h is a path leading from the lowest level of engine room floor to the exit from this room.

G a s f u e l is any hydrocarbon fuel with Reid vapour pressure (absolute) of at least 0.28 MPa at 37.8 °C.

G a s a r e a is an area where gas-confining systems and equipment are located, including open deck spaces above them.

G a s - h a z a r d o u s s p a c e is a space in gas area, which is not equipped with a certified device constantly providing safe atmosphere. It is classified into hazardous areas 0, 1 and 2, limits of which are specified in 19.12.2 of Part XI "Electrical Equipment".

G a s - s a f e s p a c e is a space that is not gas-hazardous.

G a s - h a z a r d o u s e n g i n e r o o m is a closed gas-hazardous space accommodating gas fuel consumers, provided that, in case of gas fuel leakage, its explosion safety is ensured by Emergency Shut Down (ESD) of all machineries and equipment that can serve as ignition source.

G a s - s a f e e n g i n e r o o m is a closed gas-safe space accommodating gas fuel consumers, its explosion safety is ensured by installing gas-confining equipment in leak-tight shells (pipes, ventilation ducts, enclosures) for removing gas fuel leakage, provided that the inner spaces of enclosures and ventilation ducts are considered gas-hazardous.

G a s - c o n f i n i n g s y s t e m s are systems intended for storing gas, supplying and feeding it to and removing it from on-board consumers.

M a i n g a s v a l v e is an automatic valve installed in gas feeding pipeline at each engine and located outside the engine room, in which the gas fuel combustion equipment is used.

M a i n p r o p u l s i o n p l a n t is a combination of machineries, systems and devices that can produce reverse or direct thrust for ship propulsion and is comprised of propulsion machineries of roughly equal power output, auxiliary machineries and systems supporting their operation, propellers and all necessary monitoring, control and alarm systems. In case several engines comprise the main propulsion plant, each of the propulsion engines comprising it is be considered as the main engine. In case each propulsion plant in multi-shaft propulsion plant is completely independent, each such plant is to be considered as the main propulsion plant.

M a i n a c t i v e m e a n s o f t h e s h i p ' s s t e e r i n g is a propulsion and steering unit being part of the propulsion plant.

M a i n m a c h i n e r y is the machinery being part of the propulsion plant.

D u a l - f u e l e n g i n e is an internal combustion engine that can utilize, due to its design, gas and liquid fuels simultaneously or separately.

R e m o t e c o n t r o l is the changing of the speed and direction of rotation as well as starting and stopping of the machinery from a remote position.

T e c h n i c a l c o n d i t i o n d i a g n o s i s is a process of determining the causes of deviation of diagnostic parameters during technical condition monitoring and/or identification of defects, mostly, by means of non-disassembly methods, with the purpose of technical maintenance and repair on actual condition basis.

A u x i l i a r y a c t i v e m e a n s o f t h e s h i p ' s s t e e r i n g is a propulsion and steering unit providing ship's movement and ensuring its controllability at low speed or allowing controlling the ship without propulsion in case of available main means of propulsion and steering and used in combination with the latter or with main means of propulsion and steering disabled.

Auxiliary machinery is the machinery necessary for the operation of main engines, supply of the ship with electric power and other kinds of energy, as well as functioning of the systems and arrangements subject to survey by the Register.

Essential auxiliary machinery include:

generating set, which serves as a main source of electrical power;

steam supply source;

condensate pump and arrangements used for maintaining vacuum in condensers;

the mechanical air supply for boilers;

an air compressor and receiver for starting or control purposes,

as well as machinery ensuring operation or functioning of:

boiler feed water systems;

the fuel oil supply systems for boilers or engines;

the sources of water pressure;

the hydraulic, pneumatic or electrical means for control in main propulsion machinery including controllable pitch propellers (CPP).

Auxiliary machinery and systems of propulsion plant are all support systems (including machinery and equipment, see, also, "Auxiliary machinery") that are necessary for operation of propulsion machinery and propeller.

Gas Fuel Storage Vessel (GFSV) is a vessel designed as a primary reservoir for storing gas fuel aboard in liquefied or compressed state.

LGF Vessel is a vessel for storing liquefied gas fuel.

CGF Vessel is a vessel for storing compressed gas fuel.

Vessel of A, B and C type is an free standing GFSV that complies with the requirements for insertable cargo vessels of A, B and C type for gas-carrying ships specified in the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

Closed space is any space, within which mechanical ventilation is unavailable and natural ventilation is limited so that any explosion-hazardous atmosphere cannot be dissipated.

Common control station is a control station intended for simultaneous control of two or more main machinery equipped with indicating instruments, alarm devices and means of communication.

Active means of the ship's steering (AMSS) are special propulsion-and-steering machinery and any combinations of them with each other or with the main propellers, that can produce reverse or direct thrust, directed at fixed angle in respect to the centre line of the ship or at variable angle, either at all speeds (main AMSS) or at some speeds including low speeds, as well as at no speed (auxiliary AMSS) (see 7.1.1).

Engine room is a machinery space intended for the main engines and, in the case of ships with electric propulsion plants, the main generators.

M a c h i n e r y s p a c e s are all machinery spaces of category A and all other spaces containing main machinery, shafting, boilers, fuel oil units, steam and internal combustion engines, generators and other major electrical machinery, fuel oil filling stations, ventilation and air-conditioning installations, refrigerating plants, steering engines, stabilizing equipment and similar spaces, and trunks to such spaces.

M a c h i n e r y s p a c e s o f c a t e g o r y A are those spaces and trunks to such spaces, which contain:

internal combustion machinery used for main propulsion; or

internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or

oil-fired boilers or fuel oil units.

L o c a l c o n t r o l s t a t i o n is a control station fitted with controls, indicators, means of communication (if necessary), located in proximity to, or directly on, the engine.

S e m i - c l o s e d s p a c e is a space enveloped by decks and bulkheads, within which natural ventilation is available but its efficiency differs much from usual ventilation at an open deck.

T o r s i o n a l v i b r a t i o n s t r e s s e s are stresses resulting from the alternating torque, which is superimposed on the mean torque.

D e a d s h i p c o n d i t i o n (a s w e l l a s b l a c k o u t) is a condition, under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliaries shall be assumed available. Also, no energy for starting the main engines is available. At the same time, it is assumed that operable main source of electrical power and other essential auxiliary machinery are available.

E q u i p m e n t comprises all types of filters, heat exchangers, tanks and other arrangements ensuring normal operation of a machinery installation.

S i n g l e f a i l u r e o f p r o p u l s i o n p l a n t is a failure either of one active element (main engine, generator, their local control system, remote-controlled valve, etc.) or of one passive element (pipeline, power cable, manual-controlled valve, etc.) that does not cause failures of other elements.

C a r g o c o n t r o l r o o m (C C R) is a room or part thereof where the control, monitoring means and alarm devices, related to performance of cargo handling operations are located; and onboard the tankers, in addition, means for monitoring and alarm of cargo, ballast, atmosphere parameters of cargo and ballast tanks and cargo pump rooms as well as discharge of oil containing and flushing water.

P r o p u l s i o n p l a n t p o w e r o u t p u t is a total power output of all propulsion machinery onboard. If not otherwise specified, propulsion plant power output does not include power output produced by propulsion machinery but utilized in normal operation conditions for the purposes other than ship propulsion (e. g., shaft generator power output).

F u e l s t o r a g e r o o m (F S R) is closed room, in which vessels for storing gas fuel are located.

T e c h n i c a l c o n d i t i o n p r e d i c t i o n is a process of determining causes for the changes in control item for the forthcoming time period, based on the trend of the diagnostic parameter values during the preceding time period.

Propulsion plant is the totality of machinery and arrangements intended for generating, converting and transmitting power ensuring propulsion of the ship at all specified rates of speed and comprising propellers, shafting, main gearing and main machinery, including electric propulsion motors.

Propulsion machinery is a machinery (internal combustion engine, turbine, electrical motor, etc.) that produces mechanical energy for driving a propeller.

Propulsion plant redundancy is a single or multiple duplication of its elements, provided that the propulsion plant is designed so that a single failure of one of its active or passive elements does not cause a loss of ship propulsion and controllability in external conditions specified in the Rules.

Rated power means the maximum continuous (not time-limited) power adopted in calculations under the Rules and stated in documents issued by the Register.

Rated speed means the speed corresponding to the rated power.

Propeller is a mechanism (propeller, steerable propeller, water jet, etc.) that converts the mechanical energy of the propulsion machinery into reverse or direct thrust for ship's propulsion.

Technical condition monitoring system is a complex of inspection facilities and actuators interacting with the control item on demand set forth by the appropriate documentation.

The condition monitoring system provides for the identification of the type of the item technical condition and systematic observation (tracing) of its change on the basis of measurement of the controlled (diagnostic) parameters and comparison of these values with the set standards.

Gas fuel consumer is any onboard equipment or machinery (engine, boiler, inert gas generator, galley range, etc.) that utilizes gas fuel for energy generation or production of combustion products.

Onboard power plant is a combination of machinery, systems and devices that provides a ship with all types of energy and may include the following items: main propulsion plant, alternative propulsion plant, onboard electrical power plant, auxiliary systems and machinery.

Trend of the diagnostic parameter change (parameter trend) is a law of diagnostic parameter variation with time represented in graphical or other form (prehistory of parameter change).

Fuel oil unit is any equipment used for the preparation and delivery of fuel oil (heated or unheated) to boiler, inert gas generator or engine (including gas turbines) and includes any fuel oil pumps, separators, filters and heaters at a pressure of more than 0.18 MPa.

Fuel oil transfer pumps are not considered as fuel oil units.

Main machinery control (MMC) room is a space containing the remote controls of main and auxiliary machinery, CP-propellers, main and auxiliary AMSS, indicating instruments, alarm devices and means of communication.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions covering the procedure of classification and surveys during construction and in service are stated in the General Regulations for the Classification and Other Activity and in Part I "Classification".

1.3.2 Survey by the Register, including the approval of technical documentation according to 4.1, Part I "Classification", shall cover the following parts and components:

.1 shafting as assembled, including propeller shafts with liners and waterproof coatings, shaft bearings, thrust blocks and sterntube bearings, couplings, sterntube seals;

.2 propellers, including vertical-axis propellers and jets, steerable propellers; athwartship thrusters and propulsive systems of active rudders; pitch control units, oil distribution boxes and control systems of propellers;

.3 parts indicated in Table 1.3.2.3 and the corresponding spare parts specified in 10.2.

1.3.3 Subject to survey by the Register is the assembling of the machinery space equipment and testing of the following components of the machinery installation:

.1 main engines with reduction gears and couplings;

.2 boilers, heat exchangers and pressure vessels;

.3 auxiliary machinery;

.4 control, monitoring and alarm systems of the machinery installation;

.5 shafting and propellers;

.6 active means of the ship's steering.

1.3.4 After assembling of machinery, equipment, systems and piping arrangements on board the ship, the machinery installation shall be tested in operation under load according to the program approved by the Register.

Table 1.3.2.3 **Parts to be supervised**

Ser. No.	Item	Material	Chapter of Part XIII "Materials"
1	2	3	4
1	Shafting		
1.1	Intermediate, thrust and propeller shafts	Forged steel	3.7
1.2	Propeller shaft liners	Copper alloy Corrosion-resistant steel	4.1 On agreement with the Register
1.3	Half-couplings	Forged steel Cast steel	3.7 3.8

End of Table 1.3.2.3

1	2	3	4
1.4	Coupling bolts	Forged steel	3.7
1.5	Sterntubes	Rolled steel Cast steel Forged steel Cast iron	3.2 3.8 3.7 3.9

1	2	3	4
1.6	Sterntube and strut bushes	Cast steel Copper alloy Forged steel Cast iron	3.8 4.2 3.7 3.9, 3.10
1.7	Lining of sternbush bearing	Non-metallic materials Metal alloys	On agreement with the Register
1.8	Thrust block casing	Rolled steel Cast steel Cast iron	3.2 3.8 3.9
2	Propellers		
2.1	Solid propellers	Cast steel Copper alloy	3.12 4.2
2.2	Built propellers		
2.2.1	Blades	Cast steel Copper alloy	3.12 4.2
2.2.2	Boss	Cast steel Copper alloy	3.12 4.2
2.2.3	Bolts (studs) for securing of blades, hub cones and seals	Copper alloy Forged steel	4.1 3.7
2.3	Hub cones	Cast steel Copper alloy	3.12 4.1, 4.2
2.4	CPP sliding shoes in ice ships of ice categories **Ice4** to **Ice6** and icebreakers	Forged steel Cast steel	3.7 3.8
2.5	Casings of main AMSS in ice ships of ice categories **Ice4** to **Ice6** and icebreakers	Forged steel Cast steel	3.7 3.8

Notes: 1. The materials shall be selected in accordance with 2.4.

2. All shafts (propeller, thrust, intermediate), propeller blades shall be subjected to non-destructive testing when manufactured. The methods, standards and scope of such tests shall be agreed with the Register.

3. The nomenclature and material of the CPP components: crank pin rings, sliding shoes (other than those given under item 2.4), push-pull rods; hydraulic cylinders, etc., as well as the AMSS parts (other than those given under item 2.5) are subject to special consideration of the Register in each case.

2. GENERAL REQUIREMENTS

2.1 POWER OF MAIN MACHINERY

2.1.1 The requirements to the minimum required power P_{min} (kW) delivered to the propeller shaft of icebreakers and ice ships are given in 2.1.1.1–2.1.1.4 depending on their category.

2.1.1.1 The minimum required power delivered to the propeller shaft of icebreakers shall be consistent with their category according to 2.2.3, Part I “Classification”.

2.1.1.2 The minimum required power P_{min} (kW) delivered to the propeller shaft of ice ships of categories **Ice2** and **Ice3** shall not be less than any of the values determined according to 2.1.1.3 and 2.1.1.4.

The minimum required power P_{min} (kW) delivered to the propeller shaft of ice ships of category **Ice4** shall not be less than the lesser of values determined according to 2.1.1.3 and 2.1.1.4.

The minimum required power P_{min} (kW) delivered to the propeller shaft of ice ships of categories **Ice5–Ice6** shall be determined according to 2.1.1.3.

2.1.13 Power P_{min}, in kW, shall be determined by the formula

$$P_{min} = f_1 f_2 f_3 (f_4 \Delta + P_0), \quad (2.1.1.3)$$

where f_1 = 1.0 for fixed pitch propellers;

f_1 = 0.9 = for propulsion plants with controllable pitch propellers or electric drive;

$f_2 = \varphi / 200 + 0.675$ but not more than 1.1;

φ = slope of stem (refer to 3.10.1.2, Part II "Hull");

f_2 = 1.1 — for a bulbous stem; the product $f_1 \cdot f_2$ shall be taken in all cases not less than 0.85;

$f_3 = 1.2B / \Delta^{1/3}$, but at least 1.0;

B = breadth of the ship, m;

Δ — ship's displacement to the summer load waterline (refer to 1.2.1, Part III "Equipment, Arrangements and Outfit"), tons. When calculating for the ice ships of **Ice2** and **Ice3** categories, Δ need not be taken more than 80,000 t;

f_4 and P_o are given in Table 2.1.1.3 in accordance with respective category of ice strengthening.

Irrespective of the results obtained in calculating the power as per Formula (2.1.1.3), the minimum power, in kW, shall not be less than:

5000 kW for ice category **Ice6**;

2600 kW for ice category **Ice5**;

1000 kW for ice category **Ice4**;

740 kW for ice categories **Ice3** and **Ice2**.

2.1.1.4 The power P_{min}, in kW, shall be determined as the maximum value calculated for the upper (UIWL) and lower ice waterlines (LIWL) as per the formula

$$P_{min} = K_e \frac{(R_{CH}/1000)^{3/2}}{D_p} \quad (2.1.1.4\text{-}1)$$

where K_e = coefficient given in Table 2.1.1.4;

RCH = parameter determined as per the formula

$$R_{CH} = 845 C_\mu (H_F + H_m)^2 (B + C_\psi H_F) + 42 L_{PAR} H_F^2 + 825 (LT/B^2)^3 \frac{A_{wf}}{L}$$

, (2.1.1.4-2)

where $C_\mu = 0.15 \cos \varphi_2 + (\sin \psi / \sin \alpha)$, but at least 0.45;

$H_F = 0.26 + (H_M \cdot B)^{0.5}$;

H_M = 1.0 for category **Ice4**;

H_M = 0.8 for category **Ice3**;

H_M = 0.6 for category **Ice2**;

B — breadth of the ship, m;

$C_\psi = 0.047\ \psi$ — 2.115;

$C_\psi = 0.0$ if $\psi < 45°$;

L_{PAR} — length of the parallel midship body, m;

L — length of the ship between the perpendiculars, m;

T — draught at UIWL or LIWL, m;

A_{wf} — area of the waterline of the bow, m^2;

α — angle of the waterline at B/4, degree;

φ_1 — rake of the stem at the centreline, degree;

φ_1 — 90° for a ship with a bulbous bow;

φ_2 — rake of the bow at B/4, degree;

χ — buttock plane at distance B/4 from the ship centre line;

$\psi = \arctan(\sin \psi / \sin \alpha)$;

D_p — diameter of the propeller, m;

L_{BOW} — length of the bow, m.

The value $(L \cdot T/B^2)^3$ shall be taken within the range $5 < (L \cdot T/B^2)^3 < 20$.

Note:

Upper ice waterline (UIWL) is determined by the maximum draught in fore, middle and aft parts of a ship.

Lower ice waterline (LIWL) is determined by the minimum draught in fore, middle and aft parts of a ship.

Lower ice waterline (LIWL) is determined taking into account ballast condition when cruising in ice environment (e. g., taking into account submersion of the propeller).

Formula (2.1.1.4-1) may be used when the conditions given in Table 2.1.1.4-2 are fulfilled.

Table 2.1.1.4-1 **Values of the coefficient** K_e

Number of propellers	Propulsion plant with CPP or electric drive	Propulsion plant with fixed pitch propeller
1	2.03	2.26
2	1.44	1.60
3	1.18	1.31

Table 2.1.1.4-2 **Application conditions of Formula 2.1.1.4-1**

Parameter	Minimum value	Maximum value
1	2	3
α, degree	15	55
φ_1, degree	25	90
φ_2, degree	10	90
L, m	65.0	250.0

End of Table 2.1.1.4-2

1	2	3
B, m	11.0	40.0
T, m	4.0	15.0
L_{BOW} / L	0.15	0.40
L_{PAR} / L	0.25	0.75
D_p / T	0.45	0.75
$A_{wf} / (L{\cdot}B)$	0.09	0.27

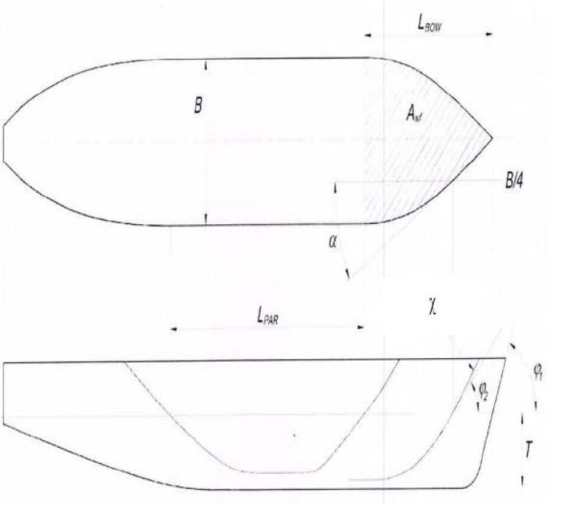

Fig. 2.1.1.4 Geometrical features of the ship for determination of the power delivered to the propeller shaft of ice ships

2.1.1.5 In well-grounded cases the minimum power values may be reduced. These cases are subject to special consideration by the Register.

Table 2.1.1.3 **Values of** f_4 **and** P_0

Displacement Δ, tons	Value	Ice strengthening category				
		Ice2	**Ice3**	**Ice4**	**Ice5**	**Ice6**
< 30,000	f_4	0.18	0.22	0.26	0.3	0.42
	P_0, kW	0	370	740	2200	4000
≥ 30,000	f_4	0.11	0.13	0.15	0.20	0.24
	P_0, kW	2100	3070	4040	5200	9400

2.1.2 In icebreakers and ships with ice strengthening of category **Ice6**, turbines and internal combustion engines with mechanical transmission of power to the propeller may be utilized as main engines, provided use is made of the devices to protect turbines, reduction gears of gas-turbine geared sets and diesel-engine geared sets against the loads exceeding the design torque. This torque is determined with regard to operation of such ships under ice conditions in compliance with the requirements of 4.2.3.2, Part IX "Machinery".

2.1.3 Propulsion plant shall provide sufficient astern power to maintain manoeuvring of the ship in all normal service conditions, at the ship with several propellers it shall provide sufficient power to propel the ship and manoeuvre in case of one or more propellers out of service.

2.1.4 Propulsion plant shall be capable of maintaining in free route astern at least 70% of rated ahead speed for a period of at least 30 min.

By the rated ahead speed is meant a speed corresponding to the maximum continuous power of the main machinery.

The astern power shall be sufficient to take way off a ship making a full ahead speed on an agreeable length, which must be confirmed during trials.

At a passenger ship with several propellers the astern power shall be sufficient (besides taking way off the ship) for propulsion and manoeuvring in case of one or more propellers out of service; it must be confirmed during trials.

2.1.5 In propulsion plants with reversing gears or CP-propellers as well as in electric propulsion plants, precautions shall be taken against possible overload of main engines in excess of permissible values.

2.1.6 Means shall be provided to ensure that the machinery may be brought into operation from the dead ship condition without external aid (refer to 16.2.3, Part VIII "Systems and Piping").

On ships where internal combustion engines are started by compressed air, the set of equipment for starting shall ensure the supply of air in quantity sufficient for the initial start without external aid.

Where the ship is not fitted with an emergency generator, or an emergency generator does not comply with the requirements specified under 2.9.4, Part IX "Machinery", the means for bringing main and auxiliary machinery into operation shall be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board ship without external aid.

If for this purpose an emergency air compressor or an electric generator is required, they shall be powered by a hand-starting internal combustion engine or a hand-operated compressor.

The emergency generator and other means needed to restore the propulsion shall have a capacity such that the necessary propulsion starting energy is available within 30 min of black out/dead ship condition (refer to 1.2).

Emergency generator stored starting energy shall not be directly used for starting the propulsion plant, the main source of electrical power and/or other essential auxiliaries (emergency generator excluded).

For steam ships, the 30 min time limit may be interpreted as time from black out/dead ship condition to light-off of the first boiler.

2.1.7 In the event of failure of one or all turbochargers (refer to 2.5.1, Part IX "Machinery") the machinery installation with one main internal combustion engine shall provide the ship speed at which the steerability of the ship is maintained.

The main engine shall provide not less than 10% of the rated power.

2.1.8 The power of main machinery in ships of river-sea navigation shall provide the ahead speed in load condition of at least 10 knots in calm water.

2.1.9 Supercharged high-speed engines (over 750 rpm), which increased noise level makes direct local control difficult, may be admitted by the Register for use as main engines in sea-going ships, if provision is made for remote control and monitoring so that constant presence of the attending personnel in the engine room will not be necessary.

The control and monitoring facilities shall comply with the requirements of Part XV "Automation".

2.1.10 In the case of ships with twin hulls, the failure of the machinery installation of one hull will not put the machinery installation of the other huh out of action.

2.1.11 Long run of the propulsion plant at all specified rates during its operation under the conditions corresponding to the assigned class shall not lead to the overload.

The substantiation of the required power is subject to special consideration by the Register.

2.1.12 Propulsion plants and auxiliary machinery of passenger ships having length, as defined in 1.2.1 of the Load Line Rules for Sea-Going Ships, of 120 m or more or having three or more main vertical zones, shall comply with the requirements of 2.2.6.7.1 and 2.2.6.8, Part VI "Fire Protection".

2.1.13 For passenger ships the means shall be provided for maintaining or recovery of normal operation of the main engines in case one of the essential auxiliary machinery is out of service.

2.2 NUMBER OF MAIN BOILERS

2.2.1 In general, not less than two main boilers shall be fitted in ships of unrestricted service. The possibility of using a steam power plant with one main boiler shall be considered by the Register in each case.

2.3 ENVIRONMENTAL CONDITIONS

2.3.1 The machinery, equipment and systems installed in the ship shall remain operative under environmental conditions stated in Tables 2.3.1-1 and 2.3.1-2, unless provided otherwise in the other parts of the Rules.

Sea water temperature is assumed to be equal to +32 °C. For ships designed for geographically restricted service other temperatures may be adopted on agreement with the Register.

Table 2.3.1-1 **List, motions and trim[1, 2], deg.**

Machinery and equipment	Steady list either way under static conditions	List either way under dynamic conditions (rolling)	Steady trim by bow or stern	Dynamic trim by bow or stern (pitching)
Main and auxiliary machinery	15.0	22.5	5.0[4]	7.5
Emergency machinery and equipment (emergency power installations, emergency fire pumps and their devices)	22.5[3]	22.5[3]	10.0	10.0

[1] Steady list and trim shall be taken into account simultaneously. Rolling and pitching are also to

be considered simultaneously.

[2] On agreement with the Register, the values of inclinations may be altered depending on the type and dimensions of the ship and its service conditions as well.

[3] In gas carriers and chemical tankers emergency power sources shall remain operative when the ship is listed up to 30 deg.

[4] Where the length of the ship exceeds 100 m, the static trim by bow or stem may be taken as $(500/L)^0$, where L is the length of the ship, in metres, as defined in 1.1.3, Part II "Hull".

Table 2.3.1-2 **Air temperature**

Installed location	Temperature range
Closed spaces	0 to +45 °C
Spaces at machinery and boilers subject to temperatures above 45 °C and below 0 °C	According to specific local conditions
Open decks	−25 to +45 °C

Note. For ships intended for geographically restricted service other temperatures may be adopted on agreement with the Register.

2.4 MATERIALS AND WELDING

2.4.1 Materials for the manufacture of parts of the shaftings and propellers shall comply with the requirements given in the relevant chapters of Part XIII "Materials", as indicated in column 4, Table 1.3.2.3.

The materials used for the components of shafting stated in item 1.7, Table 1.3.2.3 are chosen in accordance with the standards.

The materials used for the components of shafting and propellers stated in items 1.2 to 1.6, 1.8, 2.2.3 and 2.3, Table 1.3.2.3 may also be chosen in accordance with the relevant standards.

In such case, the application of materials shall be agreed with the Register when examining the technical documentation.

Materials used for the components (semi-finished products) indicated in items 1.1, 2.1, 2.2.1 and 2.2.2, Table 1.3.2.3 shall be surveyed by the Register during manufacture; survey of materials used for other components in said Table may be required at the option of the Register.

2.4.2 Intermediate, thrust and propeller shafts shall generally be made of steel with tensile strength R_m between 400 and 800 MPa.

2.4.3 The mechanical properties and chemical composition of materials used for the manufacture of propellers shall be in compliance with 3.12 and 4.2, Part XIII "Materials". Whereas steel of martensitic grade is permitted for the manufacture of propellers for ships of all types, steel of austenitic grade is permitted for the manufacture of propellers for ships without ice strengthening.

The possibility to use carbon steel for the manufacture of propellers is subject to special consideration by the Register considering the requirements of 3.8, Part XIII "Materials".

Copper alloys of categories CU3 and CU4 are admitted for propellers in all ships, except icebreakers and ships with ice strengthening of category **Ice6**; copper alloys of categories CU1 and CU2 may be used exclusively for propellers in ships without ice strengthening and in ships with ice strengthening of categories **Ice1** to **Ice3**.

2.4.4 Where it is intended to make shafting and propellers of alloy steels, including corrosion-resistant and high strength steels, data on chemical composition, mechanical and special properties, confirming suitability of the steel for intended application, shall be submitted to the Register.

2.4.5 Intermediate, thrust and propeller shafts as well as coupling bolts (studs) may be made of rolled steel in accordance with 3.7.1, Part XIII "Materials".

2.4.6 Securing and locking items of propeller blades, hub cones, sterntubes, sternbushes and seals shall be made of corrosion-resistant materials.

2.4.7 Welding procedure and non-destructive testing of welded joints shall comply with the requirements of Part XIV "Welding".

2.4.8 For all ships, new installation of materials which contain asbestos shall be prohibited in machinery installations, machinery and equipment covered by the requirements of Part VI "Fire Protection", Part VII "Machinery Installations", Part VIII "Systems and Piping", Part IX "Machinery", Part X "Boilers, Heat Exchangers and Pressure Vessels" and Part XII "Refrigerating Plants".

2.5 INDICATING INSTRUMENTS

2.5.1 All the indicating instruments, with the exception of liquid-filled thermometers, shall be checked by competent bodies.

Pressure gauges fitted on boilers, heat exchangers, pressure vessels and refrigerating plants shall meet the requirements of 3.3.5 and 6.3.8, Part X "Boilers, Heat Exchangers and Pressure Vessels" and 7.1, Part XII "Refrigerating Plants", respectively.

2.5.2 The tachometer accuracy shall be within ± 2.5%.

With restricted speed ranges, the accuracy shall not be below 2%, and the ranges shall be marked with bright colour on the scales of tachometers or in another way.

2.6 APPLICATION OF THE RELIABILITY MEASURES OF THE MACHINERY INSTALLATIONS

2.6.1 The reliability measures are established and specified during design and/or order of the machinery installation components by agreement of the appropriate technical documentation between the customer (shipowner) and the designer or supplier.

The specific list of the reliability measures to be determined shall be established for each type of products with regard to the peculiarities of its application, failure effects, maintenance and repair system adopted.

2.7 REQUIREMENTS FOR PROPULSION PLANT REDUNDANCY

2.7.1 General provisions.

2.7.1.1 The requirements of this Subsection apply to propulsion plant and steering gear in passenger ships built not earlier than on July 1, 2010, at least 120 m long (the length is determined in accordance with paragraph 1.2 of the Load-Line Rules for Sea-Going Ships) or those having at least three main fireproof vertical zones (refer to 2.2.6.1, Part VI, "Fire Protection"), in accordance with the revised SOLAS Chapter II-2, Regulation 21 (IMO resolution MSC 216(82), Annex 3).

2.7.1.2 The requirements of the present Subsection are mandatory for ships with the class notation supplemented with one of the following marks in accordance with the requirements of 2.2.26, Part I "Classification": **RP-1, RP-1A, RP-1AS, RP-2** or **RP-2S.**

2.7.2 Marks in ship's class notation for propulsion plant elements redundancy.

2.7.2.1 If ship's propulsion plant is provided with redundancy of its elements, the main class notation is supplemented with one of the following marks:

.1 RP-1 — if ship's propulsion plant has redundancy for all its elements, except of main engine, reduction gear, shafting and propeller; a single failure of any of the elements of the systems and equipment supporting the above-mentioned elements shall not result in loss of speed, electric power supply and steerability;

.2 RP-1A — if ship's propulsion plant has redundancy for all its elements, except of reduction gear, shafting and propeller; a single failure of any of the elements of the propulsion plant, its auxiliary machinery and systems or monitoring and control systems shall not result in loss of speed and steerability;

.3 RP-1AS — if ship's propulsion plant has redundancy for all its elements as required for **RP-1A** mark, and main engines or alternative propulsion plant engines are located in independent machinery spaces, so that the loss of one of the compartments due to fire or flooding shall not result in loss of speed, electric power supply and steerability;

.4 RP-2 — if ship's propulsion plant has redundancy for all its elements and consists of several main propulsion plants; a single failure of any of the elements of the propulsion plant and steering gear shall not result in loss of speed, electric power supply and steerability;

.5 RP-2S — if ship's propulsion plant has redundancy for all its elements as required for **RP-2** mark and is located in independent machinery spaces, so that the loss of one of the compartments due to fire or flooding shall not result in loss of speed, electric power supply and steerability.

2.7.2.2 Additional marks **RP-1**, **RP-1A**, **RP-1AS**, **RP-2** or **RP-2S** can be assigned to the ships under construction or in service.

2.7.3 Technical documentation.

2.7.3.1 For assigning additional marks **RP-1**, **RP-1A**, **RP-1AS**, **RP-2** or **RP-2S** in Register class notation to the ship the following technical documentation shall be submitted for approval in addition to the requirements of Section 4, Part I, "Classification" (as applicable):

.1 calculations indicating that in case of a single failure the ship maintains its speed and steerability in accordance with the requirements of **2.7.5.3** (for ships with additional marks **RP-1A**, **RP-1AS**, **RP-2** or **RP-2S**).

The results of model or full-scale testing are allowed for submission as an alternative;

.2 qualitative failure analysis for propulsion plant and steering gear (in accordance with Section 12) or Failure Mode and Effect Analysis (FMEA) for propulsion plant elements based on a failure tree, or equivalent risk assessment method coordinated with the Register;

.3 calculation of torsional vibrations, in which the possibility of continuous operation of the alternative propulsion system shall be considered separately;

.4 programs for mooring and sea trials.

2.7.4 Requirements for ships with additional mark RP-1 in class notation.

2.7.4.1 All elements of the following auxiliary machinery and systems of the main propulsion plant are to be redundant:

.1 fuel system, including slop tanks, but except of fuel reception, transfer and separation system;

.2 lubrication system of propulsion machinery, reduction gears, shafting bearings, sternbush bearings, etc., except of oil reception, transfer and separation system;

.3 hydraulic systems that support the operation of propulsion plant couplings, controllable pitch propellers, reverse deflectors of water jet propellers, etc.;

.4 fresh water and sea water cooling systems that support the main propulsion plant;

.5 fuel heating systems in service tanks that support the main propulsion plant;

.6 starting systems (pneumatic, electric, hydraulic) that support the main propulsion plant;

.7 electric power sources;

.8 ventilation installations, if required, e. g. for air supply for cooling the primary engines;

.9 monitoring, alarm and control systems.

2.7.4.2 A single failure of auxiliary machinery and elements of the systems specified in **2.7.4.1**, including damages to stationary pipelines, shall not result in halt of the ship or loss of its steerability. In order to fulfil this requirement, necessary by-passes and equipment redundancy (pumps, heaters, etc.) shall be provided in the systems. A loss of power output of the main engine is allowed as a result of a single failure by at most 50%.

2.7.4.3 The parts of the systems and pipelines where a failure has occurred shall be able to be disconnected from the operable parts.

2.7.4.4 The ship shall be equipped with main and auxiliary steering gears in accordance with 2.9, Part III, “Equipment, Arrangements and Outfit”.

The main and auxiliary steering gears shall be controlled independently from the navigation bridge and from the steering gear room.

2.7.5 Requirements for ships with additional mark RP-1A in class notation.

2.7.5.1 In addition to the requirements of **2.7.4** the ships with additional mark **RP-1A** shall meet the requirements of **2.7.5**.

2.7.5.2 The main propulsion plant shall consists of at least two propulsion machinery, one reduction gear, one propulsion electric motor, one shafting line and one propeller are sufficient. One of the propulsion machinery may be an alternative propulsion plant. In addition, the independent systems that support the redundant machinery are not subject to the requirements of **2.7.4.2** regarding redundancy of each of the elements of the system.

2.7.5.3 In case of a single failure of the main propulsion plant the operable propulsion machinery or alternative propulsion plant shall ensure the following capabilities in any ship loading condition:

.1 ship propulsion at 6 knots or 50% of specification speed according to 1.1.3, Part II, “Hull”, the lesser of two, at Beaufort 5;

.2 ship steerability sufficient for taking the safest position in respect to stability and maintaining this position at Beaufort 8;

.3 fulfilment of the requirements of **2.7.5.3.1** and **2.7.5.3.2** for at least 72 hours; for ships with the maximum voyage duration less than 72 hours the time specified above may be limited at the maximum voyage duration.

2.7.5.4 The alternative propulsion plant shall be started at most in 5 min after the main propulsion plant fails.

2.7.5.5 A single failure resulting in the loss of at least one generator may be accepted provided that the FMEA performed shows that after failure the ship has enough electric power output to continue propulsion and maintain steerability according to the requirements of **2.7.5.3** without starting the stand-by generator.

After failure the electric power output shall be sufficient for starting the most high-powered consumer without imbalance of the electric loading. Stand-by electric pumps may not be included in electric loading balance during alternative propulsion plant operation.

2.7.5.6 The main switchboard shall consist of two sections. In case one of the sections fails, the remaining section shall be capable of powering the following consumers:

.1 driving motors of the alternative propulsion plant and steering gears, including attached equipment;

.2 equipment for transmission of propulsion thrust;

.3 propulsion electric motor, if any;

.4 propeller;

.5 auxiliary machinery and systems of the propulsion plant;

.6 monitoring, alarm and control systems.

2.7.5.7 The monitoring, alarm and control systems of the alternative propulsion plant shall be independent from the systems of the main propulsion plant.

2.7.6 Requirements for ships with additional mark RP-1AS in class notation.

2.7.6.1 In addition to the requirements of **2.7.5** the ships with additional mark **RP-1AS** shall meet the requirements of **2.7.6**.

2.7.6.2 The main propulsion plant shall be equipped with at least two main engines located in at least two independent machinery spaces according to the requirements of **2.7.6.3** and **2.7.6.4**.

Non-redundant elements of the main propulsion plant (reduction gear, propeller, shafting line, propulsion electric motor) that are common for several main engines shall be located in a separate room separated with watertight bulkhead of A-0 fire resistance from machinery spaces with the main engines according to 2.7.1.2.1, Part II, “Hull”.

2.7.6.3 The bulkhead between the machinery spaces mentioned in **2.7.6.2** shall be watertight according to 2.7.1.2.1, Part II, “Hull” and have fire resistance of A-60.

If the machinery spaces are separated from each other with cofferdams, tanks or other compartments the bulkheads shall have fire resistance at least A-0 but not less than required for adjacent rooms and compartments according to Section 2, Part VI, “Fire Protection”.

2.7.6.4 If closures are provided in the bulkheads specified in **2.7.6.3** and **2.7.6.4** they shall meet the requirements of 7.12, Part III, "Equipment, Arrangements and Outfit".

This closures may not be considered as emergency exits from machinery spaces.

2.7.7 Requirements for ships with additional mark RP-2 in class notation.

2.7.7.1 In addition to the requirements of **2.7.4** and applicable requirements of **2.7.5**, the ship shall meet the requirements of **2.7.7**.

2.7.7.2 The ship shall be equipped with at least two independent main propulsion plants.

In case of a single failure of one of the propulsion plants the propulsion plant shall maintain at least 50% of its power output, which ensures propulsion and steerability in any loading condition.

2.7.7.3 In case of a single failure of one of the propulsion plants the following requirements shall be fulfilled:

.1 the failure shall not affect the operable propulsion plant if it has been in operation when the failure occurred (in particular, no significant change of driving engine power output and rotational speed shall occur);

.2 the operable propulsion plant that has not been in operation when the failure occurred shall be warm stand-by in order to be ready for starting within 45 s after the failure occurs;

.3 safety measures shall be provided for the failed propulsion plant, in particular, shafting block.

2.7.7.4 The ship shall be equipped with at least two independent steering gears in accordance with 2.9, Part III, "Equipment, Arrangements and Outfit". In case of any single failure of one of the steering gears the remaining steering gear shall maintain its operability, including synchronization system failure.

Ship steerability shall be maintained in case of external influences specified in **2.7.5.3**, even in case one of the rudders is blocked at the maximum rudder angle, there shall be a possibility of changing the rudder angle in position parallel to the ship's centreline and fixing it in this position.

2.7.7.5 If only steerable propellers are provided as the means of propulsion and steering, at least two propulsion plants with independent steering shall be provided.

Ship steerability shall be maintained in case of external influences specified in **2.7.5.3**, even in case one of the steerable propellers is blocked or disconnected, there shall be a possibility of changing the angle of the failed steerable propeller into position parallel to the ship's centreline and fixing it in this position.

2.7.8 Requirements for ships with additional mark RP-2S in class notation.

2.7.8.1 In addition to the requirements of **2.7.4**, applicable requirements of **2.7.5** and requirements of **2.7.7**, the ship shall meet the requirements of **2.7.8**.

2.7.8.2 The ship shall be equipped with at least two independent propulsion plants (including reduction gear, propeller and shafting line) according to **2.7.7.2** and **2.7.7.3** located in at least two independent machinery spaces.

2.7.8.3 The longitudinal bulkhead between the machinery spaces mentioned in **2.7.8.2** shall be watertight according to 2.7.1.2.1, Part II, "Hull" and have fire resistance of A-60.

If the machinery spaces are separated from each other with cofferdams, tanks or other compartments the bulkheads shall have fire resistance at least A-0 but not less than required for adjacent rooms and compartments according to Section 2, Part VI, "Fire Protection".

2.7.8.4 If closures are provided in the longitudinal bulkhead specified in **2.7.8.4.2** they shall meet the requirements of 7.12, Part III, "Equipment, Arrangements and Outfit".

This closures may not be considered as emergency exits from machinery spaces.

2.7.8.5 The ship shall be equipped with at least two independent steering gears in accordance with the requirements of **2.7.7.4** located in at least two independent steering gear rooms.

2.7.8.6 The longitudinal bulkhead between the steering gear rooms shall be watertight according to 2.7.1.2.1, Part II, "Hull" and have fire resistance of at least A-0.

2.7.8.7 The main electric power sources shall be located in separate compartments in accordance with **2.7.8.3** and **2.7.8.4** so that in case of fire or flooding in one of the compartments electric power supply to the consumers specified in **2.7.5.6** can be maintained.

2.7.8.8 The main switchboard shall consist of two sections in accordance with **2.7.5.6**.

Each of the sections shall be located in separate room. The bulkhead separating the rooms accommodating the main switchboard shall meet the requirements of **2.7.8.3** and **2.7.8.4**.

2.7.8.9 Automation systems, monitoring and control systems of propulsion plants and steering gears shall be located in such a manner that in case of loss of one of the machinery spaces as a result of fire or flooding only one propulsion plant or steering gear is out of service.

Control stations shall be located so that in case of fire or flooding in one of the machinery spaces or steering gear rooms control functions are maintained.

3. CONTROL DEVICES AND STATIONS. MEANS OF COMMUNICATION

3.1 CONTROL DEVICES

3.1.1 Main and auxiliary machinery essential for the propulsion, control and safety of the ship shall be provided with effective means for its operation and control. All control systems essential for the propulsion, control and safety of the ship shall be independent or so designed that failure of one of them does not degrade the performance of another.

3.1.2 The starting and reversing arrangements shall be so designed and placed that each engine can be started or reversed by one operator.

3.1.3 Proper working direction of control handles or handwheels shall be clearly indicated by arrows and relevant inscriptions.

3.1.4 The setting of manoeuvring handle in the direction from, or to the right of, the operator, or turning the handwheel clockwise, when controlling the main engines from the navigation bridge, shall correspond to the ahead speed direction of the ship.

In the case of control stations, from which only the stem is visible, such a setting shall correspond to the direction of astern speed of the ship.

3.1.5 Control arrangements shall be so designed as to eliminate the possibility of spontaneously changing the positions prescribed.

3.1.6 The control devices of main engines shall have an interlocking system to preclude starting of the main engine, with a mechanical shaft-turning gear engaged.

3.1.7 It is recommended to provide an interlocking system between the engine-room telegraph and the reversing and starting arrangements so as to prevent the engine from running in the direction opposite to the prescribed one.

3.1.8 The main engine remote control system, with control from the bridge, shall be designed so as to provide an alarm in the event of failure.

As far as practicable, the present propeller speed and thrust direction shall remain unchanged until control is transferred to a local station.

Among other factors, the loss of power supply (electric, pneumatic or hydraulic power) shall not substantially affect the power of main engines or change the direction of propeller rotation.

3.1.9 The propulsion machinery remote control system with control from the wheel house shall be independent from the other order transmission system; however, one manoeuvring handle for systems may be accepted.

3.1.10 It shall be possible to control the propulsion machinery from the local control station, in the event of a failure of any unit of the remote control system.

3.1.11 For ships of river-sea navigation the duration of reversing (a period of time from the reversing of a steering control to the beginning of propeller operation with a thrust opposite in direction) shall not exceed:

25 s at full speed;

15 s at low speed.

3.1.12 Possibility shall be provided for controlling the auxiliary machinery required for ship propulsion and safety and the means located at or near such machinery.

3.2 CONTROL STATIONS

3.2.1 The bridge control stations of main engines and propellers, as well as the main machinery control room, with any type of remote control, shall be equipped with:

.1 controls for the operation of main engines and propellers. For installations comprising CP-propellers, vertical axis and similar type propellers, the navigation bridge may be equipped with means for remote control of propellers only. In such case, the alarm for low pressure of starting air, prescribed by 3.2.1.10, need not be provided;

.2 shaft speed and direction indicators if a fixed pitch propeller is installed; shaft speed and blade position indicators if the controllable pitch propeller is installed; main engines speed indicator if the disengaging coupling is provided;

.3 indicating means to show that the main machinery and remote control systems are ready for operation;

.4 indicating means to show which station is in control of the main propulsion machinery;

.5 means of communication (refer to 3.3);

.6 main engine emergency stop device, independent of the control system.

If disengaging couplings are provided for disconnection of main machinery from propellers, it is permissible that emergency shut-off of these couplings only is effected from the navigation bridge;

.7 device to override the automatic protection covering full range of parameters except those parameters which being exceeded, may result in serious damage, complete failure or explosion;

.8 indication for the override operation, alarms for activation of protection devices and the emergency stop;

.9 alarm for minimum oil pressure in pitch control system; overload alarm where the main engine operates with a CPP, unless the recommendation of 6.5.3 is fulfilled;

.10 alarm for low starting air pressure, set at a level which still permits three starting attempts of reversible main engines duly prepared for operation.

In case the main engine remote control system is capable of automated starting the number of consecutive automated tries that have not resulted in a start shall be limited in order to save air pressure for starting at the local control station;

.11 device to remote shut-off fuel oil supply to each engine for multi-engine installations in case where the fuel oil is supplied to all the engines from a single supply source (refer to 13.8.3.2, Part VIII "Systems and Piping");

.12 speed repeater.

3.2.2 The control stations on the wings of navigation bridge shall be equipped with devices of waterproof construction with controlled illumination. The control stations provided on the wings of the navigation bridge need not meet the requirements of 3.2.1.3, 3.2.1.5, 3.2.1.7 to 3.2.1.10.

3.2.3 The emergency stop devices of main engine and the overrides of automatic controls shall be so constructed that inadvertent operation of such devices is not possible.

3.2.4 For the installations which consist of several main engines driving a single shafting, there shall be provided a common control station.

3.2.5 With a remote control system in use, provision shall also be made for local control stations of main machinery and propellers. Where, however, mechanical linkage is fitted for remote-controlling the main engine, the local control stations may be dispensed with an agreement with the Register.

3.2.6 Remote control of main machinery and propellers shall be performed only from one location. The transfer of control between the navigation bridge and engine room shall be possible only in the engine room and the main machinery control room. The means of transfer shall be so designed as to prevent the propelling thrust from altering significantly.

Where the control stations are arranged on the wings of navigation bridge, the remote control of the main machinery shall be possible from one control station only. Such control stations may be equipped with interconnected controls.

3.2.7 Main engines shall be remotely operated from the wheelhouse by means of a single control element per propeller.

In case simultaneous operation of several propellers is provided they may be operated by means of one control with automatic execution of all accompanying functions, including, if required, overload prevention devices.

In installations with CP-propellers, systems with two control elements may be used.

3.2.8 The sequence of the main engine operation modes assigned from the wheelhouse, including reversal from the full ahead speed in case of emergency, shall be controlled with the time intervals admissible for main engines. The modes assigned shall be indicated at the main machinery control room and at the local control stations of the main machinery.

3.2.9 Main machinery control rooms of floating docks shall comprise the following equipment:

.1 controls of the pumps, including the suction and overboard discharge valves of ballast system;

.2 recording devices for heel, trim and deflection control of the dock;

.3 signals indicating the operation of pumps and the position (“open”, “closed”) of suction and discharge valves of the ballast system;

.4 alarms on limit values of list and trim;

.5 water level indicators of ballast compartments;

.6 dock’s communication facilities.

3.2.10 CCR shall be located as far from the machinery spaces as practicable.

Onboard the tankers the CCR shall be arranged according to 2.4.9, Part VI “Fire Protection”.

Furthermore, arrangement of CCR onboard chemical tankers shall comply with the requirements of Section 3, Part II “Structure of Chemical Tanker” of the Rules for the Classification and Construction of Chemical Tankers, and for gas carriers — the requirements of Section 9, Part VI “Systems and Pipelines” of the Rules for the Classification and Construction of Gas Carriers.

3.2.11 If CCR is provided on board the ship with assigning the distinguishing mark **CCO** (refer to 2.2.19, Part I “Classification”) added to the character of classification, besides compliance with the requirements of 3.2.10, CCR shall be equipped with:

.1 means of communication (refer to 3.3.2);

.2 control means of:

.2.1 cargo, stripping and ballast pumps;

.2.2 fans servicing cargo area spaces or cargo holds;

.2.3 remotely controlled valves of cargo and ballast systems;

.2.4 hydraulic system pumps (if provided);

.2.5 inert gas system;

.2.6 pumps and valves of heeling system (if provided);

.3 means for monitoring of:

.3.1 pressure in cargo manifolds;

.3.2 pressure in the manifold for vapour emission system (if provided);

.3.3 temperature in cargo and settling tanks;

.3.4 temperature and pressure of warming medium in the cargo heating system;

.3.5 actual value of ship’s heel, trim and draught;

.3.6 actual value of level in the cargo and ballast tanks;

.4 alarm devices on:

.4.1 fire alarm;

.4.2 exceeding of cargo temperature in cargo holds;

.4.3 high and low levels in cargo, ballast and settling tanks;

.4.4 extreme high level in cargo tanks;

.4.5 exceeding of permissible pressure in cargo manifolds of vapour emission system (80% of pressure for actuating of high-velocity devices);

.4.6 exceeding the permissible fuel oil content in the discharge ballast and flushing water;

.4.7 exceeding the permissible temperature of pump casing according to 5.2.6, Part IX "Machinery";

.4.8 increasing of gland and bearing temperature at bulkhead penetrations of pump shafts as per 4.2.5;

.4.9 availability of cargo in segregated ballast tanks (for chemical tankers);

.4.10 increasing of level in the bilgeways of cargo pump rooms;

.4.11 parameters of inert gas system in compliance with 9.16.7.6, Part VIII "Systems and Piping";

.4.12 status of technical aids stipulated in 3.2.10;

.4.13 low water level in deck water seal (refer to 9.16.5, Part VIII "Systems and Piping").

3.2.12 In ships carrying liquid gas in bulk, means for monitoring and alarm shall be additionally provided in CCR to meet the requirement of Part VIII "Instrumentation" of the Rules for the Classification and Construction of Gas Carriers.

3.2.13 In ships carrying dangerous chemical cargo in bulk, the signalling shall be additionally provided in CCR to meet the requirements of 6.6, Part VIII "Instrumentation" of the Rules for the Classification and Construction of Chemical Tankers.

3.2.14 In case the main engines and other machinery associated with them, including the main electric power sources, have different levels of automatic or remote control and are constantly watched from the central control station, controls shall be designed, equipped and installed so that the operation of machinery is as safe and reliable as in case of direct control. Particular consideration shall be given to protect such spaces against fire and flooding.

3.3 MEANS OF COMMUNICATION

3.3.1 At least two independent means shall be provided for communicating orders from the navigation bridge to the position in the machinery space or in the control room, from which the speed and direction of thrust of the propellers are normally controlled.

One of these shall be an engine-room telegraph, which provides visual indication of the orders and responses both in the machinery spaces and on the navigation bridge and which is fitted with a sound signal clearly audible in any part of the engine room while the machinery is at work, and distinct in tone from all other signals in the machinery space (refer also to 7.1, Part XI "Electrical Equipment").

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

A single voice-communication device serving two control stations located in close proximity is permissible.

3.3.2 Two-way communication shall be provided between the engine room, auxiliary machinery spaces and boiler room.

Onboard the ships equipped with CCR, two-way communication between CCR and navigation bridge, between CCR and the spaces, where cargo and ballast pumps are located, shall be additionally provided.

3.3.3 When installing a voice-communication device, measures shall be taken to ensure clear audibility, with the machinery at work.

3.3.4 Main machinery control rooms of floating docks shall have means of communication in accordance with 19.8, Part XI "Electrical Equipment".

3.3.5 In the case of ships with twin hulls, provision shall be made for voice communication between local control stations of the hulls in addition to communication between local control stations and the common control station in the wheelhouse and the main machinery control room.

4. MACHINERY SPACES, ARRANGEMENT OF MACHINERY AND EQUIPMENT

4.1 GENERAL

4.1.1 Ventilation of machinery spaces shall comply with the requirements of 12.5, Part VIII "Systems and Piping".

4.1.2 Machinery spaces with dual-fuel engines shall be fitted with gas concentration sensors and the ultimate concentration level alarm system (refer to 7.23, Part XI, "Electrical Equipment").

4.1.3 The ventilation of machinery spaces shall be sufficient under normal conditions of ship operation to prevent accumulation of oil product vapour.

4.1.4 All moving parts of machinery, units, equipment and drives that can cause harm to service personnel and other persons onboard shall be fenced with handrails or enclosures.

Internal combustion engines equipped with safety valves of appropriate type for prevention of explosion in crankcase shall be equipped with appropriate means that direct the exhaust through the valves, which ensures minimum possibility of injuries to personnel.

4.1.5 Appropriate means shall be provided in ships for reducing noise down to the acceptable level in accordance with 8.9, Part III, "Equipment, Arrangements and Outfit".

4.2 ARRANGEMENT OF MACHINERY AND EQUIPMENT

4.2.1 Engines, boilers, equipment, pipes and valves shall be so arranged as to provide easy access for servicing and repair; the requirements stated in 4.5.3 shall also be met.

4.2.2 The arrangement of boilers shall be such that the distance between boilers and fuel tanks is sufficient for a free circulation of air necessary to keep the temperature of the fuel in the tanks below its flash point except as mentioned in 13.3.5, Part VIII "Systems and Piping".

4.2.3 Where auxiliary boilers are installed in the same space with the internal combustion engines, their furnaces shall have metallic screens or other arrangements to protect the equipment of that space if flame is accidentally blown out from the furnace.

4.2.4 The auxiliary oil-fired boilers installed on platforms or on 'tween decks in non-watertight enclosures shall be protected by oil-tight coamings at least 200 mm in height.

4.2.5 Driving machinery of the pumps and fans in the cargo pump rooms of oil tankers, combination carriers designed for the carriage of oil products with a flash point 60 °C or less and of oil recovery vessels shall be installed in spaces fitted with mechanical ventilation and having no exits leading to the cargo pump rooms.

Driving machinery of the submerged pumps are allowed to be installed in the open deck, provided their design and location comply with the requirements of 19.2.4.1.4 and 19.2.4.9, Part XI "Electrical Equipment".

Steam engines with working temperatures not exceeding 220 °C and hydraulic motors may be installed in cargo pump rooms.

Drive shafts of pumps and fans shall be carried through bulkheads or decks in gas-tight sealing glands supplied with effective lubrication from outside the pump room. As far as practicable, the construction of sealing gland shall protect it against being overheated.

Those parts of gland, which may come in contact in case of eventual disalignment of drive shaft, or damage to the bearings, shall be made of such materials, which will not initiate sparks.

If bellows are incorporated in the design, they shall be subjected to test pressure before fitting.

Cargo pumps, ballast pumps and stripping pumps, installed in cargo pump-rooms, as well as in ballast pump-rooms where cargo containing equipment is fitted, and driven by shafts passing through pump-room bulkheads shall be fitted with temperature sensing devices for bulkhead shaft glands, bearings and pump casings.

Alarm shall be initiated in the cargo control room or the pump control station.

4.2.6 Air compressors shall be installed in such places where air is least contaminated by vapours of combustible liquids.

4.2.7 Fuel oil units (refer to 1.2) as well as hydraulic units containing flammable liquids with working pressure above 1.5 MPa and not being a part of main and auxiliary engines, boilers, etc., shall be placed in a separate rooms with self-closing steel doors.

If it is impracticable to locate the main components of such units and systems in a separate space, special consideration shall be given with regard to shielding of the components and location, containment of possible leakages.

4.2.8 Requirements for the arrangement of emergency diesel-generators are outlined in 9.2, Part XI "Electrical Equipment".

4.2.9 In oil recovery ships, the internal combustion engines, boilers and equipment containing sources of ignition as well as relevant air inlets shall be installed in intrinsically safe spaces (refer to 19.2, Part XI "Electrical Equipment").

4.2.10 A blowdown gas caps fitted with gas fuel leakage detectors shall be installed above the dual-fuel internal combustion engines (refer to 9.1, Part IX, "Machinery").

4.3 ARRANGEMENT OF FUEL OIL TANKS

4.3.1 In general, fuel oil tanks shall be part of the ship's structure and shall be located outside machinery spaces of category A.

Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, their surfaces in machinery spaces shall be kept to a minimum and shall preferably have a common boundary with the double bottom tanks.

Where such tanks are situated within the boundaries of machinery spaces of category A, they shall not contain fuel oil having flash point less than 60 °C.

In general, the use of free standing fuel oil tanks shall be avoided.

Service fuel oil tanks shall comply with the requirements of 13.8.1, Part VIII "Systems and Piping".

4.3.2 Where the use of free standing fuel oil tanks is permitted by the Register, they shall be placed in oil-tight spill trays, and on passenger ships and special purpose ships carrying more than 60 special personnel, outside machinery spaces of category A as well.

4.3.3 Fuel oil tanks shall not be located immediately above the machinery and equipment with surface temperature under insulation over 220 °C, boilers, internal combustion engines, electrical equipment and, as far as practicable, shall be arranged far apart therefrom.

4.3.4 The arrangement of fuel oil and lubricating oil tanks in way of accommodation, service and refrigerated spaces is permitted, provided they are separated by cofferdams. Dimensions and structure of cofferdams — refer to 2.7.5.2, Part II "Hull".

On the agreement with the Register and providing the initiation of special measures, it may be permitted to separate the above compartments and spaces from the tanks without cofferdams.

Arrangement of cofferdam manholes in way of accommodation and service spaces is not permitted.

4.4 INSTALLATION OF MACHINERY AND EQUIPMENT

4.4.1 The machinery and equipment constituting the propulsion plant shall be installed on strong and rigid searings and securely attached thereto. The construction of the searings shall comply with the requirements of 2.11, Part II "Hull".

4.4.2 Boilers shall be installed on bearers in such a way that their welded joints do not rest on the bearer supports.

4.4.3 To prevent shifting of boilers, provision shall be made for efficient stops and securing for rough sea; thermal expansion of boiler structures shall be taken into account.

4.4.4 The main engines, their gears, thrust bearings of shafts shall be secured to searings with fitted bolts throughout or in part. The bolts may be omitted, if appropriate stops are provided.

Where necessary, fitted bolts shall be used to fasten auxiliary machinery to searings.

4.4.5 The bolts securing the main and auxiliary machinery and shaft bearings to their searings, end nuts of shafts as well as bolts connecting the lengths of shafting shall be fitted with appropriate lockers against spontaneous loosening.

4.4.6 Where the machinery shall be mounted on shock absorbers, the design of the latter shall be approved by the Register.

Shock absorbing fastenings of the machinery and equipment shall:

maintain vibration-proof insulation properties when the absorbed machinery and equipment are operated in the environmental conditions as per the requirement of 2.3.1;

be resistant to the corrosive mediums, temperature and various kinds of radiation;

be equipped with the yielding grounding jumper of sufficient length to prevent radio reception interference and comply with the requirements of safety engineering;

eliminate the interference for operation of other equipment, devices and systems.

4.4.7 Installation of machinery, mechanical equipment, ship arrangements and their components on plastic pads or their assembly with the use of polymeric materials is subject to special consideration by the Register.

Polymeric materials used for the pads and assembly shall be agreed with the Register (refer to Section 6, Part XIII "Materials").

4.4.8 The machinery with horizontal arrangement of the shaft shall be installed parallel to the centre line of the ship. Installing such machinery in any other direction is permitted if the construction of machinery provides for operation under the conditions specified in 2.3.

4.4.9 The machinery for driving generators shall be mounted on the same searings as the generators.

4.5 MEANS OF ESCAPE FROM MACHINERY SPACES

4.5.1 Means of escape from machinery spaces, including ladders, corridors, doors and hatches, shall, if not expressly provided otherwise, provide safe escape to the lifeboat and liferaft embarkation decks.

4.5.2 All the doors as well as the covers of companionways and skylights, which may serve as means of escape from machinery spaces, shall permit of opening and closing both from inside and outside.

The covers of companionways and skylights shall be marked, as appropriate, and bear a clear inscription prohibiting to stow any loads on them.

Lifts shall not be considered as forming one of the means of escape.

4.5.3 The main and auxiliary machinery shall be so arranged as to provide passageways from the control stations and servicing flats to the means of escape from the machinery spaces.

The width of passageways shall not be less than 600 mm over the whole length. In ships of less than 1000 gross tonnage the width of passageways may be reduced to 500 mm.

The width of passageways along the switchboards shall comply with the requirements of 4.6.7, Part XI "Electrical Equipment".

4.5.4 The width of ladders serving as escape routes and the width of doors providing access to embarkation decks shall be at least 600 mm. The width of ladders in ships of less than 1000 gross tonnage may be reduced to 500 mm.

4.5.5 In a passenger ship, each machinery space located below the bulkhead deck shall be provided with at least two means of escape, which shall comply with the requirements of either 4.5.5.1 or 4.5.5.2, as follows:

.1 the means of escape shall consist of two sets of steel ladders as widely separated as possible, leading to doors (hatches) in the upper part of the space similarly separated and satisfying the requirements of 4.5.1.

One of these ladders shall be located within a protected enclosure that satisfies the requirements of 2.1.4.5, Part VI "Fire Protection", from the lower part of the space to a safe position outside the space. Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that the heat is not transferred into the enclosure through non-insulated fixing points.

The protected enclosure shall have minimum internal dimensions of at least 800 x 800 mm, and shall have emergency lighting provisions and vertical stairway in accordance with the requirements of 8.5.4.4, Part III, "Equipment, Arrangements and Outfit".

.2 the means of escape shall consist of one steel ladder leading to a door (hatch) in the upper part of the space and satisfying the requirements of 4.5.1 and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space in accordance with 4.5.1.

4.5.6 Where the machinery spaces in passenger ships are above the bulkhead deck, two means of escape shall be provided, which shall be as widely separated as possible, and the doors (hatches) leading from such means of escape shall be in a position satisfying the requirements of 4.5.1. Where such means of escape require the use of ladders, these shall be of steel.

4.5.7 In passenger ships of less than 1000 gross tonnage, the Register may dispense with one of the means of escape from the spaces specified in 4.5.5 and 4.5.6, due regard being paid to the width and disposition of the upper part of the space.

In ships of 1000 gross tonnage and above, the Register may dispense with one means of escape from the above mentioned (in 4.5.5 and 4.5.6) spaces, including a normally unattended auxiliary machinery space, so long as the provisions of 4.5.1 are satisfied, due regard being paid to the nature of the space and whether persons are normally absent in that space.

In ships of restricted areas of navigation **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS** the Register allows only one mean of escape from machinery spaces:

in ships less than 24 m long taking into account the width and location of the upper part of the space;

in ships at least 24 m long — in case a door or a steel stairway provides a safe path to the deck where boarding life-saving appliances is performed, and taking into account the number of people usually working in this space.

4.5.8 The second means of escape shall be provided from the steering gear space in passenger ships when the emergency steering position is located in that space unless there is a direct access to the open deck.

Note: The local steering position located in the steering gear space is considered to be an emergency steering position if a separate emergency steering position is not provided.

4.5.9 In passenger ships, two means of escape shall be provided from the main machinery control room enclosure located within the machinery space, at least one of which will provide continuous fire shelter to a safe position outside the machinery space.

4.5.10 In a cargo ship, at least two means of escape shall be provided from each machinery space of category A, which shall comply with the requirements of either 4.5.10.1 or 4.5.10.2, as follows:

.1 the means of escape shall consist of two sets of steel ladders as widely separated as possible leading to doors (hatches), from which access is provided to the open deck. One of these means of escape shall be located within a protected enclosure that satisfies the requirements of 2.1.4.5, Part VI "Fire Protection", from the lower part of the space to a safe position outside the space.

Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points.

The protected enclosure shall have minimum internal dimensions of at least 800 x 800 mm, and shall have emergency lighting provisions and vertical stairway in accordance with the requirements of 8.5.4.4, Part III, "Equipment, Arrangements and Outfit".

.2 the means of escape shall consist of one steel ladder leading to a door (hatch) in the upper part of the space, from which access is provided to the open deck and, additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the open deck.

4.5.11 In cargo ships of less than 1000 gross tonnage, the Register may dispense with one of the means of escape from machinery spaces of category A, due regard being paid to the dimension and disposition of the upper part of the space. In addition, the means of escape in these ships need not comply with the requirements for an enclosure listed in 4.5.10.1.

4.5.12 From the steering gear space in cargo ships, the second means of escape shall be provided when the emergency steering position is located in that space unless there is a direct access to the open deck.

Note: The local steering position located in the steering gear space is considered to be an emergency steering position if a separate emergency steering position is not provided.

4.5.13 From each machinery space other than that of category A, at least two escape routes shall be provided except for spaces that are entered only occasionally, and for spaces where the maximum travel distance to the door (hatch) is 5 m or less.

4.5.14 The escape routes from shaft tunnels and pipe ducts shall be enclosed in watertight trunks carried to above the bulkhead deck or the uppermost waterline.

Doors from shaft tunnels and pipe ducts leading in the machinery spaces and cargo pump rooms shall comply with the requirements of 7.12, Part III "Equipment, Arrangements and Outfit".

4.5.15 In oil tankers and combination carriers, one of the escape routes from pipe ducts situated below the cargo tanks may lead in the cargo pump room.

Exit in the machinery space is not permitted.

4.5.16 The doors and hatch covers of cargo pump rooms in oil tankers shall be capable of being opened and closed both from inside and from outside; their design shall preclude the possibility of sparking.

4.5.17 Escape routes from cargo pump rooms shall lead directly to the open deck. Exit to other machinery spaces is not permitted.

4.5.18 If two adjacent machinery spaces communicate through a door and each of them has only one means of escape through the casing, these means of escape shall be located at the opposite sides.

4.6 INSULATION OF HEATED SURFACES

4.6.1 Surfaces of machinery, equipment and piping with temperatures above 220 °C, which may be impinged as a result of a fuel system failure, shall be properly insulated.

4.6.2 The insulating materials and surface of insulation shall be in accordance with the requirements of 2.1.1.5 and 2.1.6, Part VI "Fire Protection".

4.6.3 Structural measures shall be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

4.7 REQUIREMENTS FOR MACHINERY SPACES AND ARRANGEMENT OF MACHINERY AND EQUIPMENT IN SHIPS UTILIZING GAS AS FUEL FOR PROPULSION PLANT

4.7.1 General provisions.

4.7.1.1 Requirements of this Subsection apply to ships that utilize a mix of various hydrocarbon gases in compressed or liquefied state as a fuel.

Utilization of hydrocarbon gases containing less than 85% of methane is subject to special consideration by the Register.

In addition, utilization of gas fuel with methane content of less than 85% shall be agreed with the Administration of the country of flag.

If the ship is gas carrier then, in addition to these requirements, it shall meet the requirements of the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk and the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk.

If the ship is not a gas carrier then a special agreement with the Administration of the country of flag is required for utilization of gas fuel.

Besides sea-going ships, the requirements of this Subsection may be applied to other offshore objects under Register's technical supervision, offshore production platforms and other offshore structures.

Applicability of specific provisions of these requirements to such objects is subject to special consideration by the Register accounting for national requirements applied to such objects.

4.7.1.2 The requirements of this Subsection are based on the requirements of IMO resolution MSC.285(86) "Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships".

4.7.1.3 The class notation of gas-fuelled ships equipped in accordance with this Subsection is supplemented with additional mark **GFS** (gas fuelled ship).

4.7.1.4 All dimensions of hull structural elements, except of those specified in this Subsection, are determined in accordance with the requirements of Part II, "Hull", depending on purpose and structural type of the ship.

4.7.2 Technical documentation.

4.7.2.1 For assigning additional mark **GFS** in Register class notation to the ship, in addition to the requirements of Section 4, Part I, "Classification" the technical documentation shall be submitted for approval that confirms fulfilment of the Rules in accordance with the requirements of 4.2.2.2, 4.2.2.15, 4.2.10.13, 4.2.11.5, 4.2.12.2.4, 4.2.13.9, 4.2.13.10, 4.2.13.28, 4.2.13.32 of Part I, "Classification".

4.7.3 Gas fuel consumers in ship.

4.7.3.1 The following items may be gas fuel consumers in ship:

.1 internal combustion engines (DF-engines);

.2 gas-turbines;

.3 steam and water-heating boilers;

.4 other consumers such as:

.4.1 galley equipment and flow-through heaters for domestic purposes;

.4.2 inert gas production equipment, etc.

4.7.3.2 Internal combustion engines shall be dual-fuel internal combustion engines that utilize gas and liquid fuels or only gas fuel in constant operation modes, in accordance with Section 9, Part IX, "Machinery".

4.7.3.3 Gas turbines shall be dual-fuel engines that utilize gas and liquid fuels, in accordance with Subsection 8.10, Part IX, "Machinery".

4.7.3.4 Boiler installations shall meet the requirements of Subsection 3.6, Part X, "Boilers, Heat Exchangers and Pressure Vessels".

4.7.3.5 Gas fuel for domestic purposes may be utilized only as an independent liquefied gas system that meets the requirements of 13.14, Part VIII, "Systems and Piping".

4.7.3.6 Utilization of gas fuel for purposes other than those specified in **4.7.3.1.1÷4.7.3.1.4.1**, e. g., for inert gas production, is subject to special consideration by the Register in each case.

4.7.4 General requirements for gas fuel utilization.

4.7.4.1 A mix of hydrocarbon gases in compressed or liquefied state is utilized as fuel in ships.

4.7.4.2 Gas fuel storage vessels (GFSV) for storing in liquefied (LGF) or compressed (CGF) state may be located on an open deck or in special closed spaces in ship hull.

In closed spaces gas fuel in liquefied state shall not be stored at the pressure of more than 1 MPa.

In case GFSV crosses the open upper deck, membranes shall be provided in this place as a seal between the deck and GFSV. In this case the space below the membrane is considered as closed gas-hazardous space and the space above the membrane — as an open space.

4.7.4.3 In case GFSVs are located on the open deck they shall be located at least at *B*/5 (one fifth of ship breadth) from the shell plating.

In non-passenger ships the distance from the shell plating may be reduced to less than *B*/5 upon special consideration of the Register, but it shall be at least 760 mm.

In case of location on an open deck the GFSV shall be installed in a special enclosure made as a semi-closed space with sufficient natural ventilation preventing gas accumulation in any of its parts.

Under the LGF storage vessel a stainless steel tray shall be provided preventing the liquefied gas from dropping onto the deck in case of the pipeline connected to the vessel below the possible level of liquefied gas is damaged.

Direct contact between the tray and the hull shall be eliminated.

The insulation shall be sufficient to provide strength of hull structures in case of leakage.

4.7.4.4 An access to gas-hazardous spaces shall be provided for inspecting them.

An access shall be provided to:

.1 the spaces located inside the ship’s hull — directly from the open deck via openings, hatches and manholes with opening size of at least 800 x 800 mm;

.2 the spaces on the open deck — via openings or manholes in vertical walls with opening size at least 800 x 800 mm.

4.7.5 GFSV spaces.

4.7.5.1 In case vessel of type **C** for storing gas fuel are located in a special closed space, these vessels shall be located at least 1/5 of ship’s breadth or 11.5 m, the lesser of last two, distant from the side shell plating. In addition, vessels for storing gas fuel shall be located at least 1/15 of ship’s breadth or 2 m, the lesser of last two, distant from the bottom shell plating.

In non-passenger ships the distance from the shell plating may be reduced to less than *B*/5 upon special consideration of the Register, but it shall be at least 760 mm.

4.7.5.2 If vessels of types other than **C** are used for storing gas fuel then the ship shall have double side and bottom shells in areas where GFSVs are located. The height of the double bottom shall be at least 1/15 of ship’s breadth or 2 m, the lesser of the two.

The width of the double side shall be at least 1/5 of ship’s breadth or 11.5 m, the lesser of the two.

In case the height of the double bottom and the width of the double side are different, the structure in the transition area shall be as shown in Figures 2.6-1 and 2.6-2, Part II, “Structure of Gas Carriers”, the Rules for the Classification and Construction of Gas Carriers.

4.7.5.3 GFSV spaces shall be gas-tight, the entrances into them shall lead from gas-safe space on the open deck. In case the latter requirement is not met, then the entrance into the GFSV space shall be equipped with air lock comprised of two gas-tight self-closing steel doors located at least 1.5 m and at most 2.5 m from each other.

The height of the coamings of air lock doors shall be at least 300 mm.

4.7.5.4 GFSV spaces shall not be adjacent to machinery spaces of A category. In case machinery spaces are separated from GFSV spaces with cofferdams, then one of the bulkheads shall be equipped with fire-resistant insulation of A-60 class.

4.7.5.5 In case the GFSVs have double shells, then the GFSV space may be made as a leak-tight enclosure covering all openings in GFSV and all pipeline valves installed on it.

The enclosure shall be joined with the outer shell of the GFSV leak-tightly by means of welding.

4.7.5.6 The drying system in gas fuel storage spaces shall be independent and shall not be connected to other drying systems onboard (refer to **7.12.8**. Part VIII, “Systems and Piping”).

4.7.6 Machinery spaces.

4.7.6.1 One of the following methods for ensuring the safety in machinery space is accepted:

— machinery space is assumed as gas-safe space. In this case a single failure of gas-confining equipment located in it does not result in creation of explosion-hazardous concentration, the requirements of **4.7.6.2** shall be met.

— machinery space is assumed as gas-hazardous space, in this case a single failure of gas-confining equipment located in it results in creation of explosion-hazardous concentration, the safety is ensured by emergency shut-down of any ignition sources, the requirements of **4.7.6.3** shall be met.

4.7.6.2 The following requirements shall be met for the machinery space to be assumed as gas-safe space:

— pipes and equipment containing gas fuel are placed into pipes with inert gas (pipe in pipe) or into constantly ventilated duct in accordance with the requirements of 13.12.2 or 13.12.3, Part VIII, "Systems and Piping";

— electric equipment inside the duct shall be explosion-proof;

— in case leakage is detected gas fuel supply to the equipment is to be stopped and the pipe is to be purged by means of valves specified in 13.12.5, Part VIII, "Systems and Piping". In this case a second pipeline shall be provided for supplying the fuel (liquid or gas) or, in installation with several main engines, a separate pipeline shall be provided for supplying the fuel to another main engine.

4.7.6.3 In case the machinery space is assumed as gas-hazardous space, then the following requirements shall be met to ensure its safety:

— pipes and equipment containing gas fuel are located directly in the machinery space, gas-hazardous and gas-safe parts of the machinery space are separated with a ventilated air lock;

— gas-hazardous part of the machinery space is continuously ventilated in accordance with 12.14.12, Part VIII, "Systems and Piping";

— all electric equipment inside gas-hazardous part of machinery space is explosion-proof;

— gas concentration is constantly monitored inside the machinery space in accordance with 7.23, Part XI, "Electrical Equipment", in case leakage is detected the main gas valve is closed gas supply to the machinery space is stopped, all ignition sources are shut-down (including the main engine).

4.7.6.4 The use of gas-hazardous machinery spaces specified in **4.7.6.3** is accepted only if at least one other main engine is available in the ship and is located outside the machinery space protected in this way, the power output of this engine shall be approximately equal to the that of the engines located in gas-hazardous machinery space.

It is acceptable to locate the engines in two completely independent gas-hazardous spaces.

4.7.6.5 Boilers, incinerators and other equipment with fuel nozzles are not allowed to be located in gas-hazardous machinery spaces.

4.7.6.6 The use of gas-hazardous machinery spaces specified in **4.7.6.3** is accepted only if the specific gravity of the gas fuel in normal conditions is lower than that of the air, and the pressure in the gas fuel pipelines shall not exceed 1 MPa.

4.7.6.7 In gas carriers the use of gas hazardous machinery spaces is accepted only upon agreement with the Administration of the country of flag.

4.7.7 Gas fuel vessel structures.

4.7.7.1 General requirements for the structure of gas fuel storage vessels (GFSV).

4.7.7.1.1 GFSVs shall be joined to the ship's hull in such a manner that their dislocation due to dynamic or static loads is prevented.

The GFSV structure shall be able to stretch and shrink due to temperature variations without excessive stresses in its elements and hull structure.

GFSV and its supports shall be calculated accounting for static list of 30º.

The supports shall be calculated for the most probable maximum resulting acceleration determined in accordance with 3.5, Part IV of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk.

4.7.7.1.2 The design of the joints between the GFSV and the hull shall provide special stoppers capable of taking horizontal loads caused by collision with level of 0.5 of the weight of vessel with fuel towards the bow and 0.25 of the weight of vessel with fuel towards the stern, respectively; the damage to any element of GFSV structure shall be eliminated.

4.7.7.1.3 In strength calculation for GFSV structural elements and supports the loads specified in **4.7.7.1.2** and the loads caused by list according to **4.7.7.1.1** shall be considered independently, also these loads shall not be superimposed on the loads caused by hull deformations due to wave influence.

4.7.7.1.4 Measures shall be provided to prevent GFSV dislocation in respect to ship's hull due to inertial loads caused by rolling.

4.7.7.1.5 The design of free standing vessels shall provide some fixtures (wedges, stoppers, etc.) that prevent the vessels from coming to surface due to buoyancy of an empty vessel in case of GFSV space flooding to full load draught. The stress in ship's hull structural elements shall not exceed the yield stress.

4.7.7.1.6 Each GFSV (LGF or CGF) shall be equipped with remote-controlled shut-off valve located as close to the GFSV as possible on each pipeline connected to the GFSV or directly on it.

4.7.7.1.7 In case the main engines are fuelled only with gas fuel at least two vessels of approximately equal capacity shall be provided for storing the gas fuel, and they shall be located in separate spaces.

4.7.7.2 Fuel vessels for liquefied gas.

4.7.7.2.1 Fuel vessels for liquefied gas shall be designed in accordance with the requirements of Part IV "Cargo vessels" of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk for LGF cargo vessels.

4.7.7.2.2 Each vessel for storing the liquefied gas fuel shall be equipped with safety valves in accordance with the requirements for cargo tanks per 3.3, Part VI, "Systems and Piping" of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk.

4.7.7.2.3 Fuel vessels for liquefied gas shall be equipped with safety valves that comply with the requirements for safety valves of LFG cargo vessels of gas carriers specified in Part VI, "Systems and Piping" of the Rules for the Classification and Construction of Gas Carriers.

4.7.7.2.4 The exhaust openings of gas-exhausting pipes from the safety valves shall be located above the open upper deck at the height of at least *B*/3 or 6 m, the greatest of two, and 6 m above working area and bow and stern flying bridges.

The gas-exhausting system shall be designed so that the exhaust is directed upwards, water and snow are prevented from getting into the system as much as possible.

4.7.7.2.5 All exhaust openings shall be located at least 10 m distant from:

— the nearest air intake or openings in domestic and service spaces and control stations, or from other gas-safe spaces;

— exit openings in machinery space.

4.7.7.3 Fuel vessels for compressed gas.

4.7.7.3.1 Fuel vessels for compressed gas shall be designed in accordance with the requirements of Part X, “Boilers, Heat Exchangers and Pressure Vessels”.

Standard cylinders may be used as CGF vessels, the allowable pressure shall be calculated for them; or specially designed pressure vessels may be used.

4.7.7.3.2 Each CGF vessel shall be equipped with safety valves that comply with the requirements for safety valves of cargo tanks in accordance with Section 2, Part VI, “Systems and Piping” of the Rules for the Classification and Construction of Ships Carrying Compressed Natural Gas.

4.7.7.3.3 The safety valves of CGF vessels located in the hull or on the open deck shall be connected to the gas-exhausting pipes.

The exhaust openings of gas-exhausting pipes from the safety valves shall meet the requirements of **4.7.7.2.4** and **4.7.7.2.5**.

4.7.8 Spaces of gas fuel compressors and pumps.

4.7.8.1 If spaces of gas fuel compressors and pumps are provided in the ship, then the requirements of **4.7.5.3** and **4.7.5.4** for GFSV spaces are applicable.

4.7.8.2 In case compressors are driven by the shafts crossing a bulkhead or a deck, then the passages for these shafts shall be leak-tight.

5. SHAFTING

5.1 GENERAL

5.1.1 Shafting is a solid unit connecting the engine with the propeller.

Optimum location of the shafting within the ship space shall be provided to ensure rational combination of loads of the shafting components, its supports and the engine.

For this a number of design, scientific, technical and engineering measures shall be taken which are unified by a concept “Shafting alignment” and approved by the Register.

5.1.2 The minimum shaft diameters without allowance for subsequent turning on lathe during service life shall be determined by formulae given in this Section. It is assumed that additional stresses from torsional vibration will not exceed permissible values stipulated in Section 8.

Tensile strength of the shaft material shall be not less than 400 MPa and for shafts which may experience vibratory stresses close to the permissible stresses for transient operation — not less than 500 MPa.

Alternative calculation methods are permitted. These methods shall take into account criteria of static and fatigue strength and include all the relevant loads under all permissible operating conditions.

The shaft diameters determined for ships of restricted navigation areas **R2**, **R2-**

S, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** and **A-R2**, **A-R2-S**, **A-R2-RS**, **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS, D-R3-S**, and **D-R3-RS** according to 5.2.1–5.2.3 may be reduced by 5%.

5.1.3 In icebreakers and ships strengthened for navigation in ice, the propeller shafts shall be protected from ice effects.

5.1.4 In ships with no obstruction for the propeller shaft to slip out of the stemtube, means shall be provided which, in the event of the propeller shaft breaking, will prevent its slipping out of the stemtube; alternative arrangements shall be made to preclude flooding of the engine room, should the propeller shaft be lost.

5.1.5 The areas between the stemtube, strut bearing (if any) and propeller boss shall be protected by a strong casing.

5.1.6 Arrangement of the sterntubes shall comply with the requirements of 1.1.6.1.8, 1.1.6.2.8 or 1.1.6.3.11 of Part II, "Hull", depending on the specific case.

5.2 CONSTRUCTION AND DIAMETERS OF SHAFTS

5.2.1 The design diameter of the intermediate shaft, in mm, shall not be less than that determined by the following formula:

$$d_{int} = F\sqrt[3]{P/n} \quad , \qquad (5.2.1)$$

where F — is factor taken depending on the type of machinery installation as follows:

F = 95 for installations with main machinery of rotary type or main internal combustion engines fitted with hydraulic or electromagnetic couplings;

F = 100 for other machinery installations with internal combustion engines;

P — rated power of intermediate shaft, kW;

n — rated speed of intermediate shaft, rpm.

5.2.2 The diameter of thrust shaft in external bearing on a length equal to thrust shaft diameter on either side of the thrust collar and, where roller thrust bearings are used, on a length inside the housing of thrust bearing, shall not be less than 1.1 times the intermediate shaft diameter determined by Formulas (5.2.1), (5.2.4).

Beyond the said lengths the diameter of the thrust shaft may be tapered to that of the intermediate shaft.

5.2.3 The design diameter of the propeller shaft, in mm, shall not be less than that determined by the following formula:

$$d_p = 100k\sqrt[3]{P/n} \qquad (5.2.3)$$

where k = is factor assumed as follows proceeding from the shaft design features:

for the portion of propeller shaft between the propeller shaft cone base or the aft face of the propeller shaft flange and the forward edge of the aftermost shaft bearing, subject to a minimum of 2.5 d_p:

1.22, where the propeller is keyless fitted onto the propeller shaft taper or is attached to an integral propeller shaft flange;

1.26, where the propeller is keyed onto the propeller shaft taper;

for the portion of propeller shaft between the forward edge of the aftermost shaft bearing, or aft strut bush, and the forward edge of the forward sterntube seal k = 1.15, for all types of design.

Other terms are as defined in 5.2.1.

On the portion of propeller shaft forward of the forward edge of the forward sterntube seal the diameter of the propeller shaft may be tapered to the actual diameter of the intermediate shaft.

Where surface hardening is used, the diameters of propeller shafts may be reduced on agreement with the Register.

5.2.4 The diameter of the shaft made of steel with tensile strength of more than 400 MPa may be determined by the following formula:

$$d_{red} = d\sqrt[3]{560/(R_{msh}+160)} \qquad (5.2.4)$$

where d_{red} — reduced diameter of the shaft, mm;
d — design diameter of the shaft, mm;
R_{msh} — tensile strength of the shaft material.

In all cases the tensile strength in the Formula shall be assumed not exceeding 760 MPa (for carbon and carbon-manganese steel)/800 MPa (for alloyed steel) for intermediate and thrust shafts and 600 MPa for propeller shaft.

5.2.5 The diameters of shafts in icebreakers and ships provided with ice strengthening shall exceed the design diameters by value indicated in Table 5.2.5.

The diameter d of propeller shafts, in mm, for icebreakers and ships provided with ice strengthening (except for category **Ice1**) shall, besides, meet the following condition in way of aft bearings:

$$d \geqslant a\sqrt[3]{bs^2 R_{mbl}/R_e} \quad , \qquad (5.2.5)$$

where a = is factor equal to:
10.8, with propeller boss diameter equal to or less than 0.25D;
11.5, with propeller boss diameter greater than 0.25 D (D is the propeller diameter);
b= actual width of expanded cylindrical section of the blade on the radius of 0.25R for unit-cast propellers and of 0.35R for CPP, m;
s = maximum thickness of expanded cylindrical section of the blade on the radii given for b, mm;
R_{mb1} = tensile strength of the blade material, MPa;
R_e = yield stress of propeller shaft material, MPa.

Table 5.2.5 **Increase of shaft diameter, %**

Shafts	Icebreakers		Ships with ice strengthening categories				
	side shaft	centre shaft	**Ice6**	**Ice5**	**Ice4**	**Ice3**	**Ice2, Ice1**
Intermediate and thrust	20	18	15	12	8	4	0
Propeller	50	45	30	20	15	8	5

5.2.6 If the shaft has a central hole, its bore shall not exceed 0.4 of the design diameter of the shaft.

If considered necessary, the diameter of central hole may be increased to the value obtained from the formula

$$d_c \le (d_a^4 - 0{,}97\,d^3\,d_a)^{1/4}\,, \qquad (5.2.6)$$

where d_c = diameter of central hole;
d_a = actual shaft diameter;
d = design diameter of the shaft without regard for central hole.

5.2.7 Where the shaft has a radial hole, the shaft diameter shall be increased over a length of at least seven diameters of the hole. The hole shall be located at mid-length of the bossed portion of the shaft, and its diameter shall not exceed 0.3 of the shaft design diameter. In all cases, irrespective of the hole diameter, the diameter of the shaft shall be increased by not less than 0.1 times the design diameter. The edges of the hole shall be rounded to a radius not less than 0.35 times its diameter and the inside surface shall have a smooth finish.

The influence of intersection between a radial and an eccentric axial bore is subject to special consideration by the Register.

5.2.8 The diameter of a shaft having a longitudinal slot shall be increased by at least 0.2 of the design diameter of that shaft. The slot length shall not exceed 0.8 and slot width shall be at least 0.1 of the design shaft diameter. Up to three slots are permitted, with consideration for their equally-spaced location.

The bossed portion of the shaft shall be of such length as to extend beyond the slot for not less than 0.25 of the design diameter of the shaft. The transition from one diameter to another shall be smooth. The ends of the slot shall be rounded to a radius of half the width of the slot and the edges — to a radius of at least 0.35 times the width; the surface of the slot shall have a smooth finish.

5.2.9 The diameter of a shaft having a keyway shall be increased by at least 0.1 of its design diameter. After a length of not less than 0.2 of the design diameter from the ends of the keyway, no increase of the shaft diameter is required.

Keyways are not recommended in the shafts with a barred speed range.

If the keyway is made on the outer end of the propeller shaft the increase of propeller shaft diameter is not mandatory.

5.2.10 For intermediate shafts, thrust shafts and inboard end of propeller shafts the coupling flange shall have a minimum thickness of 0.2 times the required diameter of the intermediate shaft, or the thickness of the coupling bolt diameter (refer to Formula (5.3.2)) calculated for the material having the same tensile strength as the corresponding shaft, whichever is the greater.

The thickness of coupling flange of the outboard end of propeller shaft under the bolt heads shall not be less than 0.25 times the required diameter of the shaft at the flange.

5.2.11 The fillet radius at the base of aft flange of the propeller shaft shall not be less than 0.125 and for other flanges of shafts — shall not be less than 0.08 of the required diameter at the flange.

The fillet may be of variable radius. In this case stress concentration factor shall not be more than in case of constant fillet radius.

The fillet shall be smooth. The fillets shall have a smooth finish and shall not be recessed in way of nuts and bolt heads.

5.2.12 Fillet radii in the transverse section of the bottom of the key way shall not be less than 0.0125 of the diameter of the shaft, but at least 1 mm.

5.2.13 Where keys are used to fit the propeller on the propeller shaft cone, the latter shall have a taper not in excess of 1:12, in case of keyless fitting — according to 5.4.1.

5.2.14 On the cone base side, the keyways in shaft cones shall be spoon-shaped, while in propeller shaft cones they shall be ski-shaped in addition.

Where the outboard end of a propeller shaft having the diameter in excess of 100 mm is concerned, the distance between the cone base and the spoon-shaped keyway end shall be at least 0.2 of the shaft diameter required, with the ratio of the keyway depth to the shaft diameter less than 0.1 and 0.5 at least of the shaft diameter required, with the ratio of the keyway depth to the shaft diameter exceeding 0.1.

In coupling shaft cones, the ski-shaped keyway end shall not extend beyond the cone base.

Where the key is secured with screws in the keyway, the first screw shall be positioned at least 1/3 of the shaft cone length from the shaft cone base. The bore length shall not exceed the propeller diameter. The bore edges shall be rounded off. Where the shaft has blind axial bores, the bore edges and end shall also be rounded off. The fillet radius shall not be less than specified in 5.2.12.

5.2.15 Propeller shafts shall be effectively protected against exposure to sea water.

5.2.16 Propeller shaft liners shall be made of such alloys, which possess sufficient corrosion resistance in sea water.

5.2.17 The thickness s of a bronze liner, in mm, shall not be less than

$$s = 0{,}03d_p' + 7{,}5, \qquad (5.2.17)$$

where d'_p = diameter of the propeller shaft under the liner, mm.

The thickness of the liner between the bearings may be reduced to 0,75*s*.

5.2.18 Continuous liners are recommended to be used.

Liners consisting of two or more lengths shall be joined by welding or by other methods approved by the Register. The butt welded joints of the liner shall be arranged outside the region of bearings. In case of non-continuous liners the portion of the shaft between the liners shall be protected against the action of sea water by a method approved by the Register.

5.2.19 To prevent water from reaching the propeller shaft cone, appropriate sealing shall be provided.

Structural provision shall be made for hydraulic testing of the sealing.

5.2.20 The liners shall be shrunk on the shaft in such a way as to provide tight interference between mating surfaces. The use of pins or other parts for securing of liners to the shaft is not permitted.

5.3 SHAFT COUPLINGS

5.3.1 The shaft flanges shall be coupled with tightly fitted bolts.

The possibility of using coupling flanges without fitted bolts shall be specially considered by the Register in each case.

5.3.2 The coupling bolt diameter, in mm, shall not be less than

$$d_b = 0{,}65\sqrt{\frac{d_{int}^3\ (R_{msh} + 160)}{iDR_{m_b}}}, \qquad (5.3.2)$$

where d_{int} = diameter of intermediate shaft determined by Formula (5.2.1) taking into account the ice strengthening requirements under 5.2.5, mm.

If the shaft diameter is increased to account for torsional vibration, d_{int} will be taken as the increased diameter of intermediate shaft;

R_{msh} = tensile strength of the shaft material, MPa;

R_{mb} = tensile strength of the fitted coupling bolt material, MPa, taken: $R_{msh} \le R_{mb} \le 1.7R_{msh}$, but not higher than 1000 MPa;

i = number of fitted coupling bolts;

D = pitch circle diameter of coupling bolts, mm.

The diameter of bolts, with which the propeller is secured to the propeller shaft flange, is subject to special consideration by the Register in each particular case.

5.4 KEYLESS FITTING OF PROPELLERS AND SHAFT COUPLINGS

5.4.1 In case of keyless fitted propellers and shaft couplings, the taper of the shaft cone shall not exceed 1:15. Provided the taper does not exceed 1:50, the shafts may be assembled with the couplings without the use of an end nut or other means of securing the coupling.

The stoppers of the end nuts shall be secured to the shaft.

5.4.2 A keyless assembly shall generally be constructed without a sleeve between the propeller boss and the shaft.

Constructions with intermediate sleeves are subject to special consideration by the Register in each particular case.

5.4.3 When fitting the keyless shrunk assembly, the axial pull-up of the boss in relation to the shaft or intermediate sleeve, as soon as the contact area between mating surfaces is checked after eliminating the clearance, shall be determined by the following formula:

$$\Delta h = \left[\frac{80B}{hz}\sqrt{\left(\frac{1910PL^3}{nD_w}\right)^2 + T^2} + \frac{D_w(\alpha_y - \alpha_w)(t_e - t_m)}{z}\right]k \qquad (5.4.3)$$

where Δh = axial pull-up of the boss in the course of fitting, cm;

B = material and shape factor of the assembly, MPa^{-1} determined by the formula

$$B = \frac{1}{E_y}\left(\frac{y^2+1}{y^2-1} + \nu_y\right) + \frac{1}{E_\omega}\left(\frac{1+\omega^2}{1-\omega^2} - \nu_\omega\right).$$

For assemblies with a steel shaft having no axial bore, the factor B may be obtained from Table 5.4.3-1 using linear interpolation;

E_y, E_ω = modules of elasticity of the boss and shaft material, respectively, MPa;

ν_y = Poisson's ratio for the boss material;

ν_ω = Poisson's ratio for the shaft material; for steel $\nu_\omega = 0.3$;

y = mean factor of outside boss diameter;

ω = mean factor of shaft bore;

D_ω = mean outside shaft diameter in way of contact with the boss or intermediate sleeve (refer to Fig. 5.4.3).

Without intermediate sleeve:

$D_{\omega1} = D_{y1}$; $D_{\omega2} = D_{y2}$, $D_{\omega3} = D_{y3}$, $D_\omega = D_y$.

With intermediate sleeve:

$D_{\omega1} \neq D_{y1}$; $D_{\omega2} \neq D_{y2}$, $D_{\omega3} \neq D_{y3}$, $D_\omega \neq D_y$.

$$y = \frac{D_{z1} + D_{z2} + D_{z3}}{D_{y1} + D_{y2} + D_{y3}}$$ — for the boss;

$$\omega = \frac{D_{01} + D_{02} + D_{03}}{D_{\omega1} + D_{\omega2} + D_{\omega3}}$$ — for the shaft;

$D_\omega = (D_{\omega1} + D_{\omega2} + D_{\omega3}) / 3$;

$D_y = (D_{y1} + D_{y2} + D_{y3}) / 3$;

D_y = mean internal boss diameter in way of contact with the shaft or intermediate sleeve, cm;

h = active length of the shaft cone or sleeve at the contact with the boss, cm;

z = taper of the boss;

P = power transmitted by the assembly, kW;

n = speed, rpm;

L = factor for ice strengthening according to Table 5.4.3-2;

T = propeller thrust at ahead speed, in kN (where data is unavailable, refer to 2.2.2.6, Part III, "Equipment, Arrangements and Outfit");

α_y, α_ω = thermal coefficients of linear expansion of the boss and shaft materials, 1/°C;

t_e, t_m = temperature of the assembly in service conditions and in the course of fitting, °C;

k = 1 for assemblies without intermediate sleeve;

k = 1.1 for assemblies with the use of intermediate sleeve.

For ships provided with ice strengthening, the value Δh shall be chosen as the greater of the results obtained from calculations for extreme service temperatures, i. e.:

t_e = 35 °C for L = 1;

t_e = 0 °C for L > 1.

In the absence of ice strengthening the calculation shall be made solely for the maximum service temperature t_e = 35 °C for L = 1.

5.4.4 When assembling steel couplings and shafts with cylindrical mating surfaces, the interference fit shall be determined by the following formula:

$$\Delta D = \frac{80B}{h}\sqrt{\left(\frac{1910PL^3}{nD_\omega}\right)^2 + T^2}, \qquad (5.4.4)$$

where ΔD is interference fit for D_ω, cm.

Other terms are as defined in 5.4.3.

5.4.5 For propeller bosses and half-couplings in keyless assemblies with the shafts, the following condition shall be met:

$$\frac{A}{B}\left[\frac{C}{D_y}+(\alpha_y-\alpha_\omega)t_m\right]\le 0{,}75R_{eH}\qquad(5.4.5)$$

where *A* is shape factor of the boss determined by the formula:

$$A=\frac{1}{y^2-1}\sqrt{1+3y^4};$$

$C = \Delta h_r z$ — for assemblies with conical mating surfaces;

$C = \Delta D_r$ — for assemblies with cylindrical mating surfaces;

Δh_r — actual pull-up of the boss in the course of fitting at a temperature t_m, cm,

$\Delta h_r \ge \Delta h$;

ΔD_r — actual interference fit of the assembly with cylindrical mating surfaces, in cm $\Delta D_r \ge \Delta D$;

R_{eH} is yield stress of the boss material, MPa.

The factor *A* may be obtained from Table 5.4.5 by linear interpolation.

Other terms are as defined in 5.4.3.

Table 5.4.3-1 **Factor $B\cdot10^5$, MPa^{-1}, steel shaft ω = 0, $E_\omega = 2.059\cdot10^5$ MPa, ν_ω = 0.3**

Factor *y*	Copper alloy boss ν_y = 0.34 with E_y, MPa:							Steel boss ν_y = 0.3 with $E_y = 2.05\cdot10^5$, MPa
	$0.98\cdot10^5$	$1.078\cdot10^5$	$1.176\cdot10^5$	$1.274\cdot10^5$	$1.373\cdot10^5$	$1.471\cdot10^5$	$1.569\cdot10^5$	
1.2	6.34	5.79	5.34	4.96	4.63	4.34	4.09	3.18
1.3	4.66	4.26	3.95	3.66	3.43	3.22	3.04	2.38
1.4	3.83	3.52	3.25	3.03	2.83	2.67	2.52	1.98
1.5	3.33	3.07	2.83	2.64	2.48	2.34	2.21	1.74
1.6	3.01	2.77	2.57	2.40	2.24	2.12	2.01	1.59
1.7	2.78	2.48	2.38	2.22	2.09	1.97	1.87	1.49
1.8	2.62	2.38	2.23	2.09	1.97	1.86	1.76	1.41
1.9	2.49	2.29	2.13	1.99	1.88	11.77	1.68	1.35
2.0	2.39	2.20	2.05	1.92	1.80	1.70	1.62	1.29
2.1	2.30	2.13	1.98	1.86	1.74	1.65	1.57	1.25
2.2	2.23	2.06	1.92	1.79	1.69	1.60	1.53	1.22
2.3	2.18	2.01	1.88	1.75	1.65	1.57	1.49	1.19
2.4	2.13	1.97	1.84	1.72	1.62	1.54	1.46	1.17

Table 5.4.3-2 **Factor *L***

Assembly	Ships with ice strengthening categories					Icebreakers	
	Ice1, Ice2	**Ice3**	**Ice4**	**Ice5**	**Ice6**	Centre shaft	Side shaft
Propeller with shaft	1.05	1.08	1.15	1.20	1.30	1.45	1.50
Coupling with shaft	1.0	1.04	1.08	1.12	1.15	1.18	1.20

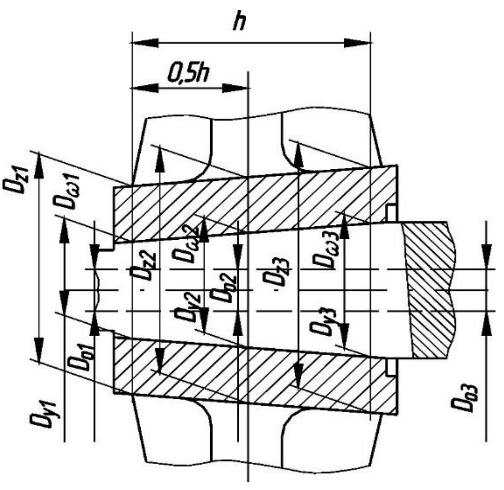

Fig. 5.4.3

Table 5.4.5 **Factor *A***

y	*A*	*y*	*A*
1.2	6.11	1.9	2.42
1.3	4.48	2.0	2.33
1.4	3.69	2.1	2.26
1.5	3.22	2.2	2.20
1.6	2.92	2.3	2.15
1.7	2.70	2.4	2.11
1.8	2.54	–	–

5.5 ARRANGEMENT OF SHAFTING SUPPORTS

5.5.1 The number of the shaftline supports, their position along the axis and in the vertical plane as well as the loads carried shall be determined on the basis of calculation made by a proven procedure agreed with the Register.

5.5.2 The distance between the reaction forces of the adjacent shaftline bearings with no concentrated masses in span shall meet the following condition:

$$5{,}5a\sqrt{d} \le l \le a\lambda\sqrt{d} \quad (5.5.2)$$

where: l is span length (distance between the reactions of adjacent supports), m;

d is minimum outside shaft diameter in span, m;

λ is factor taken equal to:

$\lambda = 14$ — for $n \le 500$ rpm, or $\lambda = 300 / \sqrt{n}$ — for $n > 500$ rpm;

n is shaft speed, in rpm;

α — factor for bored shafts taken equal to:

$$\alpha = \sqrt[4]{1 + b^2}$$

$b = d_0 / d$ — ratio of the diameters: bore diameter d_0 *and* the outside shaft diameter *d.*

N o t e . Restriction on the minimum length (the left part of equation (5.5.2)) is used for all spans except for that nearest to the propeller.

5.5.3 It is recommended to seek the minimum number of shaftline supports and the maximum possible length of the spans between them.

5.5.4 The lengths of the spans between the shaft supports shall be checked by the bending vibration calculation.

5.5.5 The shaftline supports shall be so installed that the engine or reduction gear components (bearings, gear wheels) take up loads within the permissible limits.

5.5.6 The reactions of all shaftline supports shall be positive.

5.6 SHAFT BEARINGS

5.6.1 The propeller shaft bearing nearest to the propeller shall meet the requirements of Table 5.6.1.

Those propeller shaft bearings, which are located forward of the bearing mentioned above, shall meet the condition:

$$l \ge R / qd \quad (5.6.1)$$

where the symbols and values for q are taken from Table 5.6.1.

Table 5.6.1

Bearing material	l / d^1, at least	q^2, MPa, at most
White metal (babbit)	2^4	1.0
Lignum vitae	4	0.25
Rubber or other synthetic water-lubricated materials approved by the Register	4^3	0.25^3
Rubber or other synthetic oil- or environment-friendly oily liquid-lubricated materials approved by the Register	2^4	1.0

[1] l = length of bearing;
d = design shaft journal diameter in way of bearing.
[2] q is contact pressure taken up by the bearing:
$q = R / (l \times d)$, where R is reaction of support.
[3] Length of the bearing may be reduced to twice the design shaft diameter in way of the aft bearing, provided the results of the operational check are satisfactory.
[4] Length of the bearing may be reduced if the contact pressure does not exceed 0.8 MPa and if the results of the operational check are satisfactory. In all cases, the length of the bearing shall not be less than 1.5 of the actual shaft diameter in way of the bearing.

5.6.2 The water cooling of sterntube bearings shall be of forced type (refer to 15.1, Part VIII "Systems and Piping").

The water supply system shall be provided with a flow indicator and with alarms for the minimum flow of water.

Where an open system of seawater lubrication is applied for the sternbush bearings of ships operating in shallow waters, and of specialized vessels, such as wet dredgers, suction dredgers, it is recommended that an efficient seawater cleaning device (filter, cyclone filter, etc.) shall be incorporated in the circulation system of the sternbush bearing, or sternbush bearings with mud collectors to be washed subsequently shall be fitted.

The shut-off valve controlling the supply of water to sterntube bearings shall be fitted on the sterntube or the after peak bulkhead.

5.6.3 The oil-lubricated sternbush bearings shall be provided with forced cooling arrangements unless the after peak tank is permanently filled with water.

Indication of temperature of oil or bearing bush shall be provided.

5.6.4 If a gravity system of lubrication is used for sternbush bearings, the lubricating oil tanks shall be fitted with oil level indicators and low level alarms.

5.7 STERNTUBE SEALING ARRANGEMENTS

5.7.1 Stemtube arrangements shall be fitted with stemtube sealing arrangements providing the efficient protection against emergency intrusion of sea water inside the hull, and the environmental safety of stemtube arrangement.

5.7.2 The minimum and the maximum permissible volumes of the refrigerant leakage into the ambient space and inside the hull shall be technically substantiated.

5.8 BRAKING DEVICES

5.8.1 The shaftline shall comprise appropriate braking devices. Such devices may be a brake, a stopping or a shaft turning gear preventing rotation of the shaft in the event the main engine goes out of action.

5.9 HYDRAULIC TESTS

5.9.1 Propeller shaft liners and cast sterntubes shall be hydraulically tested to a pressure of 0.2 MPa upon completion of machining.

Hydraulic tests of welded and forged-and-welded sterntubes may be omitted, providing non-destructive testing of 100% of welds.

5.9.2 After assembling, the seals of the sterntube when the closed lubrication system is used shall be tested for tightness by a pressure head up to the working level of liquid in gravity tanks. In general, the test shall be carried out while the propeller shaft is turning.

6. PROPELLERS

6.1 GENERAL

6.1.1 The requirements of this Section apply to metal fixed-pitch propellers, both solid and detachable-blade propellers, as well as to controllable-pitch propellers.

6.1.2 The design and size of propellers of the main active means of the ship's steering shall meet the requirements of the present Section.

The design of vertical-axis and jet propellers is subject to special consideration by the Register.

The scope of requirements for the design and size of propellers of the auxiliary AMSS may be reduced, subject to agreement with the Register.

6.2 BLADE THICKNESS

6.2.1 Propeller blade thickness is checked in the design root section and in the blade section at the radius $r = 0.6R$ where R is propeller radius.

The location of the design root section is adopted as follows:

for solid propellers — at the radius $0.2R$ where the propeller boss radius is smaller than $0.2R$, and at the radius $0.25R$, where the propeller boss radius is greater than or equal to $0.2R$;

for detachable-blade propellers — at the radius $0.3R$, the values of the factors A and c are adopted as in the case of $r = 0.25R$;

for CPP — at the radius $0.35R$.

Note: In the design section, the blade thickness is determined the fillets neglected.

In solid propellers, detachable-blade propellers and CPP, the maximum thickness s, in mm, of an expanded cylindrical section shall not be less than

$$s = 9{,}8\left[A\sqrt{\frac{0{,}14kP}{zb\sigma n}} + c\frac{m}{\sigma}\left(\frac{Dn}{300}\right)^2\right], \quad (6.2.1)$$

where A = coefficient to be determined by Formula 6.2.1 depending on the relative radius r/R of design section and the pitch ratio H/D at this radius (for a CP-propeller, take the pitch ratio of the basic design operating condition);

k = coefficient obtained from Table 6.2.1-1;

P = shaft power at the rated output of the main propulsion engine, kW;

z = number of blades;

b = width of the expanded cylindrical section of the blade on the design radius, m;

$\sigma = 0.6R_{mbl} + 175$ MPa, but not more than 570 MPa for steels and not more than 610 MPa for copper alloys;

R_{mbl} = tensile strength of blade material, MPa;

n = speed at the rated output, rpm;

c = coefficient of centrifugal stresses to be determined by Formula (6.2.1-2);

m = blade rake, mm;

D = propeller diameter, m.

The holes for the items securing the blades of built-up and CPPs shall not reduce the design root section.

For ships of river-sea navigation and of restricted navigation areas **R2, R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** and **A-R2**, **A-R2-S**, **A-R2-RS**, **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS** blade thickness may be reduced by 5%.

Table 6.2.1-1 **Coefficient *k***

Ships without ice strengthening	Ships with ice strengthening categories					Icebreakers	
	Ice1, Ice2	**Ice3**	**Ice4**	**Ice5**	**Ice6**	Centre propeller	Side propeller
8	9	10	11.2	12.5	14	16	$16+\frac{23500}{P^{*}}$

**P* — shaft power, kW.

N o t e s : 1. If reciprocating engines with less than four cylinders are installed in the ship, *k* shall be increased by 7%.

2. For reciprocating engines fitted with hydraulic or electromagnetic couplings, *k* may be reduced by 5%.

3. For side propellers of ships without ice strengthening *k* may be reduced by 7%.

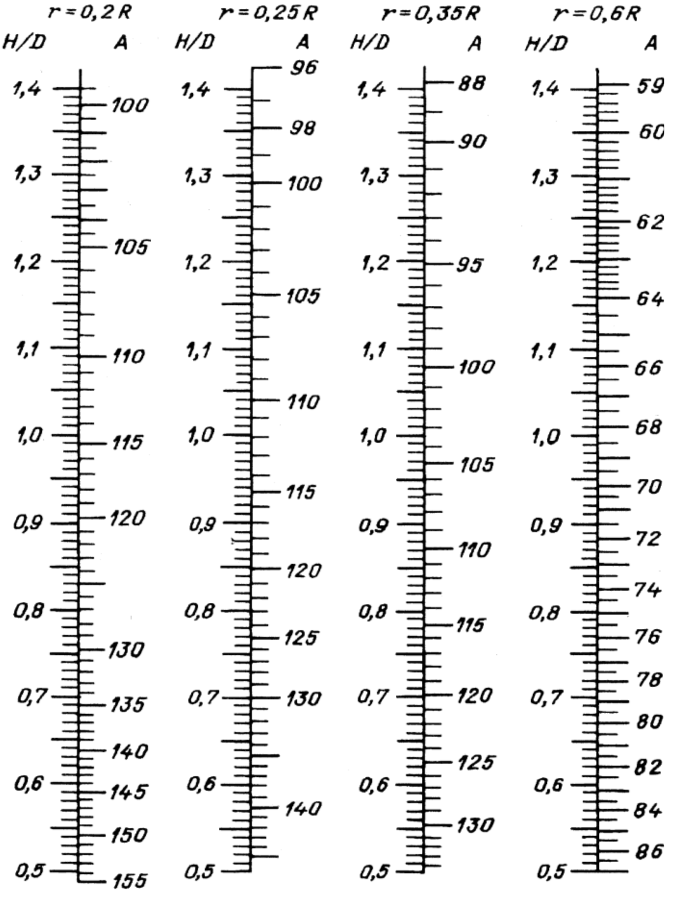

Fig. 6.2.1

Table 6.2.1-2 **Factor *c***

r/R	*c*
0.20	0.50
0.25	0.45
0.35	0.30
0.60	0

6.2.2 The blade tip thickness at the radius *D*/2 shall not be less than provided in Table 6.2.2.

The leading and trailing blade edge thickness measured at 0.05 of the blade width from the edges shall not be less than 50% of blade tip thickness.

Table 6.2.2. **Blade tip thickness**

Ships without ice strengthening	Ships with ice strengthening categories		Icebreakers
	Ice1–Ice5	**Ice6**	
0.0035*D**	0.005*D*	0.006*D*	0.008*D*

**D* — diameter of the propeller.

6.2.3 The blade thickness calculated in accordance with 6.2.1 and 6.2.2 may be reduced (e. g. for blades of particular shape), provided a detailed strength calculation is submitted for consideration to the Register.

6.2.4 The thickness of a high-skewed ($\theta > 25°$) blade with an asymmetrical outline of the normal projection shall be checked in compliance with the requirements of 6.2.1.

Besides, the blade thickness at the radius 0.6*R* at a distance of 0.8 of the width of section *b* shall not be less than determined from the following formula:

$$s_k = 0{,}4s(1 + 0{,}064\sqrt{\theta - 25}), \quad (6.2.4)$$

where *s* is to be determined from Formula (6.2.1) at the radius 0.6*R*;

Θ is angle, in degrees, equal to angle Θ_1 or Θ_2, whichever is the greater (refer to Fig. 6.2.4);

If smoothness of the blade section profile at the radius 0.6*R* under condition of mandatory compliance with the requirements for the minimum thickness close to the trailing edge (on 0.8*b*) is not provided, thickness *s* at the radius 0.6*R* is increased.

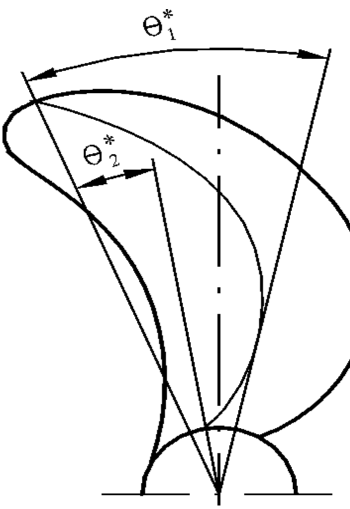

Fig. 6.2.4

θ_1^* is angle between the radius drawn through the blade tip and the radius tangent to the mid-chord;

θ_2^* is angle between radii drawn through the blade tip and root section centre of the blade.

6.2.5 In icebreakers and ships provided with ice strengthening, the stresses in the most loaded parts of pitch control gear shall not exceed yield stress of the material, if the blade is broken in direction of the weakest section by a force applied along the blade axis over ⅔ of its length from the boss and laterally over ⅔ from the blade spindle axis to the leading edge.

6.3 PROPELLER BOSS AND BLADE FASTENING PARTS

6.3.1 Fillet radii of the transition from the root of a blade to the boss shall not be less than 0.04D on the suction side of the blade and shall not be less than 0.03D on the pressure side.

If the blade has no rake, the fillet radius on both sides shall be at least 0.03D.

Smooth transition from the blade to the boss using a variable radius may be permitted.

6.3.2 The propeller boss shall be provided with holes through which the empty spaces between the boss and shaft cone are filled with non-corrosive mass; the latter shall also fill the space inside the propeller cap.

6.3.3 The diameter of the bolts (studs), by which the blades are secured to the propeller boss or the internal diameter of the thread of such bolts (studs) d_b, in mm, whichever is less, shall not be less than that determined by the following formula:

$$D_b = ks\sqrt{\frac{bR_{mbl}}{dR_{m_b}}}, \quad (6.3.3)$$

where k = 0.33 in case of three bolts in blade flange, at thrust surface;

0.30 in case of four bolts in blade flange, at thrust surface;

0.28 in case of five bolts in blade flange, at thrust surface;

s = the maximum actual thickness of the blade at design root section (refer to 6.2.1), mm;

b = width of expanded cylindrical section of the blade at the design root section, m;

R_{mbl} = tensile strength of blade material, MPa;

R_{mb} = tensile strength of bolt/stud material, MPa;

d = diameter of bolt (stud) pitch circle; with other arrangement of bolts, d = 0.85l (l is the distance between the most distant bolts), m.

6.3.4 The securing devices of the bolts (studs), by which the blades are fastened to the detachable-blade propellers of ice-strengthened ships, shall be recessed in the blade flange.

6.4 PROPELLER BALANCING

6.4.1 The completely finished propeller shall be statically balanced.

The extent of balancing shall be checked by a test load, which when suspended from the tip of every blade in horizontal position, shall cause the propeller to rotate. The mass of the test load shall not be more than determined by the following formula:

$$m \leqslant km_p/R \quad (6.4.1)$$

where m = mass of test load, kg;

m_p = mass of propeller, tons;

R = propeller radius, m;

k = 0.75 for $n \le 200$;

0.5 for $200 < n \le 500$;

0.25 for $n > 500$;

n = rated speed of propeller, rpm.

Where the propeller mass exceeds 10 tons, the coefficient k shall not be greater than 0.5, irrespective of the propeller speed.

6.5 CONTROLLABLE PITCH PROPELLERS

6.5.1 The hydraulic power system of the controllable pitch propeller shall be supplied by two pumps of equal capacity, basic and standby, one of which may be driven from the main engine. The main engine driven pump shall provide turning of the blades under any operating mode of the main engines.

Where more than two pumps are available, their capacity shall be selected on the assumption that, if any of the pumps fails, the aggregate capacity of the rest would be sufficient to ensure the blade turning-over time not longer than stipulated by 6.5.5.

In ships with two CPPs one independent standby pump may be fitted for both CPPs.

6.5.2 The pitch control unit shall be designed so as to enable turning the blades into ahead speed position, shall the hydraulic power system fail.

In multi-screw ships, except icebreakers and ships with ice strengthening of categories **Ice5** and **Ice6**, this requirement need not be satisfied.

6.5.3 In ships with a CPP, in which the main engine may become overloaded due to particular service conditions, it is recommended that automatic protection against overloading be used for the main engine.

6.5.4 The hydraulic power system of pitch control unit shall be constructed according to the requirements of Section 7, Part IX "Machinery", and the pipes shall be tested according to Section 21, Part VIII "Systems and Piping".

6.5.5 The time required for the blades to be turned over from full ahead to full astern speed position with main machinery inoperative shall not exceed 20 s for CPPs up to 2 m in diameter including, and 30 s for CPPs with diameters over 2 m.

6.5.6 In the gravity lubrication systems of CPPs, the gravity tanks shall be installed above the deepest load waterline and be provided with level indicators and low level alarms.

6.6 HYDRAULIC TESTS

6.6.1 The sealings fitted to the cone and flange casing of the propeller shaft (if such method of connection with the propeller boss is used) shall be tested to a pressure of at least 0.2 MPa after the propeller is fitted in place. If the above sealings are under pressure of oil from the sterntube or the propeller boss, they shall be tested in conjunction with testing of the sterntubes or propeller boss.

6.6.2 After being assembled with the blades the boss of a CPP shall be tested by internal pressure equal to a head up to the working level of oil in gravity tank, or by a pressure created by the lubricating pump of the boss.

In general, the test shall be made during blade adjustment.

7. ACTIVE MEANS OF THE SHIP'S STEERING

7.1 GENERAL

7.1.1 The requirements of the present Section apply to steerable propellers with podded drives or with mechanical transmission of power to the propeller including retractable units of all types, water-jets, vertical-axis propellers, propellers in transverse tunnel (athwartship thrusters) and other devices of similar purpose (AMSS, as defined in 1.2.8, Part III "Equipment, Arrangements and Outfit").

7.1.2 Where AMSS is intended for main propulsion and steering of a ship, a minimum of two AMSS shall be provided.

Provision in this case shall be made for control stations equipped with necessary devices and means of communication as indicated in 2.5, 3.1 to 3.3.

Where a single AMSS installation is proposed as the main propulsion and steering, it will be subject to the special consideration by the Register.

7.1.3 The type and structure of main AMSS shall be selected during ship design considering the ship purpose and area of navigation, as well as operational peculiarities.

7.1.4 The requirements for installation of AMSS machinery and equipment, materials and welding are given in 1.3, 2.4, 4.4.

7.1.5 For AMSS intended for the main propulsion and for the dynamic positioning, size and materials of shafts, couplings, connection bolts, propellers, gearing as well as electrical equipment shall meet the requirements of relevant parts and sections of the Rules.

Moreover, the main AMSS shall comply with the applicable requirements for the steering gears, set forth in the relevant sections of the Rules.

All essential components used in steering arrangements for ship directional control shall be of sound reliable construction proved by appropriate calculations.

All essential components used in steering arrangements for ship directional control shall be duplicated. When not duplicated possibility of using them is subject to special consideration by the Register in each particular case.

Any such essential component shall, where appropriate, utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

When the Rules contain no requirements for particular AMSS components, possibility of using them is subject to special consideration by the Register in each particular case.

7.1.6 Calculations of the AMSS gearing shall be made following the procedure outlined in 4.2, Part IX "Machinery" or by other methods recognized by the Register.

The safety factors of gearing shall not be less than those specified in 4.2, Part IX "Machinery". The values of these factors for the AMSS gearing intended for dynamic positioning duty shall be taken as for the main AMSS.

7.1.7 To support operating capacity of AMSS till special survey the service life of the rolling bearings shall be at least:

30,000 h for the main AMSS;

10,000 h for the AMSS used for dynamic positioning duty;

5000 h for the auxiliary AMSS.

7.1.8 Spaces containing the AMSS machinery shall be equipped with appropriate ventilating, fire extinguishing, drainage, heating and lighting arrangements.

7.2 CONSTRUCTION REQUIREMENTS

7.2.1 Steerable propellers shall be capable to be locked in all angular positions.

7.2.2 The main AMSS shall be provided with an emergency turning mechanism. The main AMSS angle indicator shall be provided.

The difference between the indicated and actual positions shall comply with 2.9.15, Part III "Equipment, Arrangements and Outfit".

7.2.3 The steerable propeller designed for reversing the thrust by turning the unit shall provide an acceptable reversing time depending on the purpose of the ship. The time required for turning the unit through 180° shall not then exceed 20 s for the units with a propeller of 2 m and less in diameter and shall not exceed 30 s for the units with a propeller of more than 2 m in diameter.

The ability of the machinery to reverse the direction of thrust in sufficient time, and so to bring the ship to rest within a reasonable distance from maximum ahead service speed, shall be demonstrated and recorded.

The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propulsion/steering arrangements to navigate and manoeuvre with one or more of these devices inoperative, shall be available on board for the use of the master or designated personnel.

7.2.4 Sealing boxes of a type approved by the Register shall be installed to prevent sea water from gaining access to internal parts of the AMSS. For the main and for the dynamic positioning AMSS such sealing arrangement shall contain at least two separate, closely effective sealing elements.

7.2.5 An easy access shall be provided to component parts of the AMSS to allow their maintenance within the scope stipulated by the Service Manual.

7.2.6 Where the design of the main AMSS does not insure against free rotation of the propeller and shafting in case of failure of the prime mover, provision shall be made for a braking device in accordance with the requirements of 5.8.

On agreement with the Register, braking devices for the AMSS intended for the dynamic positioning and for the auxiliary AMSS may be not provided.

7.2.7 The strength of the parts of the main AMSS turning mechanism, casing components and securing items of the component parts, shafts, gearings, CPP components shall be so calculated that they can withstand without damage a load, which may cause breakdown of the propeller blade.

7.2.8 Main AMSS of icebreakers and ships with ice categories **Ice4** to **Ice6** shall be provided with a device to prevent the ice overload of turning mechanism.

7.2.9 Strength of the parts of main AMSS turning mechanism, components for securing to ship's hull shall be so calculated that they can withstand hydrodynamic and ice loads acting upon the propeller, nozzle and AMSS casing without damage.

The procedure for design loads determination shall be agreed with the Register. It is permitted to determine hydrodynamic and ice loads on the AMSS components according to the results of hydrodynamic tests and testing of self-propelled models in the ice model basin according to the procedures approved by the Register.

7.2.10 For technical condition monitoring of the main AMSS in service, they shall be fitted with control facilities considering the requirements of Section 9 and Section 11.

The technical condition monitoring system shall combine functions of built-in (stationary) systems and portable control facilities.

A list of the technical condition monitoring system equipment, controlled parameters and frequency of their measurements, as well as standards of technical condition of the AMSS control items are developed by manufacturers and/or suppliers of the equipment.

The substantiation of required control of the main AMSS is subject to special consideration by the Register in each particular case.

7.2.11 In a ship fitted with multiple steering systems, such as but not limited to steerable propellers or water jet propulsion systems, each of the steering systems shall be equipped with its own independent steering gear to meet the requirements of 2.9.1, Part III "Equipment, Arrangements and Outfit" and 6.2.1.1, Part IX "Machinery".

7.2.12 The main steering arrangements for ship directional control shall be:

.1 of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated in trial;

.2 capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average rotational speed of not less than 2.3°/s with the ship running ahead at maximum ahead service speed (refer also to 2.9.2, Part III "Equipment, Arrangements and Outfit");

.3 operated by power (for all ships);

.4 so designed that they will not be damaged at maximum astern speed.

Note. Declared steering angle limits (of steerable propeller, thrust angle changing arrangement) are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturer's guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation. The declared steering angle limits shall be declared by the directional control system manufacturer for each AMSS.

Ship's manoeuvrability tests shall be carried out with steering angles not exceeding the declared steering angle limits of AMSS.

7.2.13 In a ship fitted with multiple AMSS, such as but not limited to steerable propellers or water jet propulsion systems, auxiliary AMSS need not be fitted, provided that:

.1 in a passenger ship, each of the AMSS is fitted with two or more identical power units, capable of satisfying the requirements of 7.2.12.2 while any one of the power units is out of operation;

.2 in a cargo ship, each of the AMSS is fitted with one or more identical power units, capable of satisfying the requirements of 7.2.12.2 while operating with all power units;

.3 each of the AMSS is arranged so that after a single failure in its piping or in one of the power units, ship steering capability (but not with an individual AMSS) can be maintained or speedily regained (e. g. by the possibility of positioning the failed AMSS in a neutral position in an emergency, if needed).

7.2.14 The requirements of the this paragraph apply to the AMSS having a certain proven steering capability due to ship speed also in case propulsion power has failed.

Where the propulsion power of an individual AMSS exceeds 2500 kW, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of 7.2.15.2 and also its associated control system and the steering system response indicator, shall be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment.

This independent source of power shall be used only for this purpose.

In each ship of at least 10,000 gross tonnage, the alternative power supply shall have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

7.2.15 The auxiliary turning mechanisms of the main AMSS shall be:

.1 of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;

.2 capable of changing AMSS angle from one side to the other at declared steering angle limits at an average rotational speed of not less than 0.5°/s with the ship running ahead at half the maximum ahead speed or 7 knots, whichever is the greater;

.3 for all ships, operated by power where necessary to meet the requirements of 7.2.15.2 and in any ship having propulsion power of more than 2500 kW per AMSS.

Refer also to the note to 7.2.12.

7.3 ALARMS

7.3.1 The AMSS shall be at least provided with alarms to be operated in the event of the following faults:

.1 overload and emergency stop of prime mover;

.2 power failure in remote control and alarm system;

.3 low level in lubricating oil tank (if provided);

.4 low lubricating oil pressure (if forced lubricating oil system);

.5 low oil level in hydraulic supply system for turning steerable propellers and CPP blades;

.6 low oil level in head tank for sealing arrangements;

.7 high level in bilge wells of the hull and AMSS spaces.

7.3.2 Individual indication units shall be provided on the bridge for:

.1 overload of prime mover AMSS and servo mover for steerable propellers if no automatic protection is provided;

.2 frequency of the propeller rotation, vertical-axis propeller or water jet impeller;

.3 blade turning angle or propeller pitch for CPP plants;

.4 direction of thrust for fixed propeller plants, vertical-axis propeller or water jet;

.5 angular position of steerable propeller, water jet steering and reversing gear or vertical-axis propeller eccentricity;

.6 available power in the alarm system.

7.3.3 For auxiliary AMSS the number of parameters covered by the alarm system and indicator units may be reduced subject to agreement with the Register.

7.4 HYDRAULIC TESTS

7.4.1 Once assembled, the internal parts of the unit casing shall be subjected to test hydraulic pressure corresponding to the maximum operational depth of immersion with an allowance made for the overpressure of the sealing arrangements. For water-jet propellers pressure generated by water head shall be considered in case of reversing.

7.4.2 Once installed, the sealing arrangements shall be subjected to leak testing by pressure equal to the height of a liquid column in head tanks at an operational level.

7.4.3 In addition, it may be necessary to carry out non-destructive testing of welds on the steerable propeller components and other welded structures within the scope of requirements set forth in Part XIV, "Welding".

8. TORSIONAL VIBRATION

8.1 GENERAL

8.1.1 The present Section applies to propulsion plants with the main engines having a power of not less than 75 kW when ICE are used and of not less than 110 kW when using turbo or electric drives, and to auxiliary diesel generators as well as to ICE-driven machinery having a primary engine power of not less than 110 kW.

8.1.2. Torsional vibration calculations shall be prepared both for the basic variant and for other variants and conditions possible in the operation of the installation, as follows:

.1 maximum power take-off and idling speed (with the propeller blades at zero position) for installations comprising CPPs or vertical axis propellers;

.2 individual and simultaneous operation of main engines with a common reduction gear;

.3 reverse gear;

.4 connection of additional power consumers if their moments of inertia are commensurate with the inertia moments of the working cylinder;

.5 running with one cylinder misfiring, for installations containing flexible couplings and reduction gear; to be assumed not firing is the cylinder the disconnection of which accounts to the greatest degree for the increase of stresses and alternating torques;

.6 damper jammed or removed where single main engine installations are concerned;

.7 flexible coupling blocked due to breakage of its elastic components (where single main engine installations are concerned).

8.1.3 For ships of restricted area of navigation **R3**, **R3-IN**, **D-R3-S**, **D-R3-RS** calculations stipulated by 8.1.2.6 and 8.1.2.7 are not necessary.

No calculations shall be submitted if it is documented that the installation is similar to that approved earlier or that its mass inertia moments and torsion stiffness between masses do not differ from the basic ones by 10% and 5%, respectively, or the calculation may be limited to determination of the natural frequencies if at this stage of the calculation it is established that the differences in the mass inertia moments and torsion stiffness between masses do not result in change of the natural frequency of any one of the modes under consideration by more than 5%.

8.1.4 Torsional vibration calculations shall include:

.1 details of all the installation components:

particulars of engine, propeller, damper, flexible coupling, reduction gear, generator, etc.;

speeds corresponding to the principal long-term operating conditions specified for operation under partial loads (half speed, slow speed, dead slow speed, trawling operation, zero-speed operation for installations comprising CPPs, main diesel generator conditions, etc.);

layouts of all installation operating conditions possible;

initial data for the design torsional diagram of the installation;

.2 natural frequency tables for all basic modes of vibration having a resonance up to the 12th order inclusive within the speed range (0–1.2)n_r with relative vibration amplitudes of masses and moments, and with scales of stresses (torques) for all sections of the system (where n_r — refer to 8.2.1);

.3 for each order of all vibration modes under consideration:

resonance vibration amplitudes of the first mass of the system;

resonance stresses (torques) in all the system components (shafts, reduction gear, couplings, generators, compression or compression-key joints, etc.) and temperatures of the rubber components of flexible couplings as compared to relevant permissible values;

.4 total stresses (torques), where it is necessary to consider the simultaneous effect of disturbing moments of several orders, as compared to relevant permissible values;

.5 stress (torque) curves for the principal sections of the system with indication of permissible values for continuous running and rapid passage and of restricted speed ranges where these are assigned;

.6 conclusions based on the results of calculation.

8.1.5 The alternating torsional stress amplitude is understood as ($\tau_{max} - \tau_{min}$)/2 as it can be measured on a shaft in a relevant condition over a repetitive cycle.

8.2 PERMISSIBLE STRESSES FOR CRANKSHAFTS

8.2.1 For main engine crankshafts of icebreakers and of ships with ice categories **Ice4** to **Ice6** within the speed range (0.7–1.05)n_r, and for main engine crankshafts of other types of ships and the crankshafts of engines driving generators and other auxiliary machinery for essential services within the speed range (0.9–1.05)n_r the total stresses due to torsional vibration under conditions of continuous running shall not exceed the values determined by the following formulas:

when calculating a crankshaft in accordance with 2.4.5, Part IX "Machinery"

$$\tau_1 = \pm\tau_N; \quad (8.2.1\text{-}1)$$

when calculating a crankshaft by another method

$$\tau_1 = \pm 0{,}76\frac{R_m + 160}{18}C_d; \quad (8.2.1\text{-}2)$$

within speed ranges lower than indicated

$$\tau_1 = \pm\frac{\tau_N\left[3 - 2(n/n_p)^2\right]}{1{,}38}, \quad (8.2.1\text{-}3)$$

or

$$\tau_1 = \pm 0{,}55 \frac{R_m + 160}{18} C_d \left[3 - 2\left(n / n_p\right)^2\right], \qquad (8.2.1\text{-}4)$$

Where τ_1 is permissible stress, MPa;

τ_N is the maximum alternating torsional stress determined during crankshaft calculation from Formula (2.4.5.1), Part IX "Machinery" for the maximum value of W_p, MPa;

R_m is tensile strength of the shaft material, MPa. When using materials with the tensile strength above 800 MPa, R_m = 800 MPa shall be adopted for calculation purposes.

n is speed under consideration, rpm. For tugs, trawlers and other ships which main engines run continuously under conditions of maximum torque at speeds below the rated speed throughout the speed range, $n = n_p$ shall be adopted and Formulas (8.2.1-1) and (8.2.1-2) shall be used. For the main diesel generators of ships with electric propulsion plants, the value of n shall be adopted so that to consider all possible specification modes of n_p, and in each of the ranges $(0.9–1.05)n_p$, Formulas (8.2.1-3) and (8.2.1-4) shall be used for partial loads;

n_r is rated speed, rpm;

$C_d = 0.35 + 0.93d^{-0.2}$ is scale factor;

d is shaft diameter, mm.

8.2.2 The total stresses due to torsional vibration within speed ranges prohibited for continuous running, but which may only be rapidly passed through shall not exceed the values determined by the following formulas:

for the crankshafts of main engines

$$\tau_2 = 2\tau_1, \qquad (8.2.2\text{-}1)$$

for the crankshafts of engines driving generators or other auxiliary machinery for essential services

$$\tau_2 = 5\tau_1, \qquad (8.2.2\text{-}2)$$

where τ_2 is permissible stress for speed ranges to be rapidly passed through, MPa;

τ_1 is permissible stress determined by one of Formulas (8.2.1-1) to (8.2.1-4).

8.3 PERMISSIBLE STRESSES FOR INTERMEDIATE, THRUST, PROPELLER SHAFTS AND GENERATOR SHAFTS

8.3.1 Under conditions of continuous running, the total stresses due to torsional vibration shall not exceed the values determined by the formulas:

for the shafts of icebreakers and ships with ice categories **Ice4–Ice6** within the speed range $(0.7–1.05)n_r$, and for the shafts of all other ships and generator shafts within the speed range $(0.9–1.05)n_r$

$$\tau_1 = \pm 1{,}38 \frac{R_m + 160}{18} C_k\, C_d; \qquad (8.3.1\text{-}1)$$

within speed ranges lower than indicated

$$\tau_1 = \pm \frac{R_m + 160}{18} C_k C_d \left[3 - 2\left(n / n_p\right)^2\right], \qquad (8.3.1\text{-}2)$$

where τ_1 is permissible stress, MPa;

R_m is tensile strength of the shaft material, MPa. When using the material with the tensile strength over 800 MPa (for intermediate and thrust shafts of alloyed steel) and over 600 MPa (for intermediate and thrust shafts of carbon and carbon-manganese steel, as well as for propeller shaft) R_m = 800 MPa and 600 MPa, respectively;

C_k is factor obtained from Table 8.3.1;

for C_d, n, n_r refer to 8.2.1.

8.3.2 The total stresses due to torsional vibration within speed ranges prohibited for continuous running, but which may only be rapidly passed through shall not exceed:

for intermediate, thrust, propeller shafts and shafts of generators driven by the main engine

$$\tau_2 = \frac{1{,}7\tau_1}{\sqrt{C_k}};\quad (8.3.2)$$

for the shafts of generators driven by auxiliary engines, the value determined by Formula (8.2.2-2).

Table 8.3.1 **Factor C_k**

Structural type of the shaft		C_k
Intermediate shaft, thrust shaft in external thrust bearing outside the area of roller bearing or the collar area, generator shaft	with integral coupling flanges or shrink fit couplings[1]	1.0
	with a radial hole (refer to 5.2.7)	0.50
	with a taper joint keyway (refer to 5.2.9)	0.60
	with a cylindrical joint keyway (refer to 5.2.9)	0.45
	with a longitudinal slot (refer to 5.2.8)	0.30[2]
Thrust shaft in way of the collar or the roller thrust bearing (refer to 5.2.2)		0.85
Propeller shaft	forward sections (k = 1.15, refer to 5.2.3)	0.80
	sections in way of the aft sterntube bearing and propeller (k = 1.22; k = 1.26 — refer to 5.2.3)	0.55

[1] When shafts may experience vibratory stresses close to the permissible stresses for continuous operation, the diameter increase in the compression joint shall be provided.

[2] Other C_k value may be substantiate and calculated.

8.4 PERMISSIBLE TORQUE IN REDUCTION GEAR

8.4.1 For the case of continuous running or rapid passage, the alternating torques in any reduction gear step shall not exceed the permissible values established for the operating conditions by the manufacturer.

8.4.2 Where the values mentioned under 8.4.1 are not available, the alternating torque in any reduction gear step for the case of continuous running shall satisfy the following conditions:

within the speed range (0.7–1.05)n_r for the main propulsion plants of icebreakers and ships with ice categories **Ice4–Ice6**, and within the speed range (0.9–1.05)n_r for other ships

$$M_{alt} \leqslant 0{,}3 M_{nom}; \quad (8.4.2\text{-}1)$$

within speed ranges lower than indicated, the permissible value of alternating torque will be specially considered by the Register in each case, but, in any case:

$$M_{alt} \leqslant 1{,}3 M_{nom} - M, \quad (8.4.2\text{-}2)$$

where M_{nom} is average torque in the step under consideration at nominal speed, N·m;

M is average torque at the speed under consideration, N·m.

For the case of rapid passage, the alternating torque value is subject to special consideration by the Register in each case.

8.5 PERMISSIBLE TORQUE AND TEMPERATURE OF FLEXIBLE COUPLINGS

8.5.1 For the case of continuous running or rapid passage, the alternating torque in a coupling, relevant stresses in and temperatures of the flexible component material due to torsional vibration shall not exceed the permissible values established for the operating conditions by the manufacturer.

8.5.2 Where the values mentioned under 8.5.1 are not available, the torque, stress and temperature values permissible for continuous running and rapid passage shall be determined by the procedures approved by the Register.

8.6 OTHER INSTALLATION COMPONENTS

8.6.1 Under conditions of continuous running, the total torque (average torque plus alternating torque) shall not exceed the frictional torque in the keyless fitting of the propeller and shaft or shafting couplings.

8.6.2 Where, for generator rotors, the Manufacturer's permissible values are not available, the alternating torque shall not exceed twice, in the case of continuous running, or six times, in the case of rapid passage, the nominal generator torque.

8.7 TORSIONAL VIBRATION MEASUREMENT

8.7.1 Data obtained from torsional vibration calculations for machinery installations with the main engines shall be confirmed by measurements. The measurements shall cover all the variants and operation conditions of the installation, for which calculations were made in accordance with 8.1.2, except emergency operation conditions listed in 8.1.2.6 and 8.1.2.7.

In substantiated cases, the Register may require torsional vibrations to be measured in auxiliary diesel generators and ICE-driven auxiliary machinery for essential services.

8.7.2 The results of measurement obtained on the first ship (unit) of a series apply to all the ships (units) of that series, provided their engine-shafting-propeller (driven machinery) systems are identical.

8.7.3 The free resonance vibration frequencies obtained as a result of measurement shall not differ from the design values by more than 5%. Otherwise, the calculation shall be corrected accordingly.

8.7.4 The stresses shall be determined proceeding from the greatest vibration or stress amplitudes measured in the respective section of the torsiogram or oscillogram.

When estimating the total stresses due to vibration of several orders, the registered parameters shall undergo harmonic analysis.

8.8 RESTRICTED SPEED RANGES

8.8.1 Where the shaft stresses, torques in some installation components or temperature of the rubber components of flexible couplings arising due to torsional vibration exceed the relevant permissible values for continuous running determined in accordance with 8.2.1, 8.3.1, 8.4 to 8.6, restricted speed ranges are assigned.

8.8.2 No restricted speed ranges are permitted for the following speeds:

$n \geq 0.7n_r$ with respect to icebreakers and ships with ice categories **Ice4–Ice6**;

$n \geq 0.8n_r$ with respect to other ships;

$n = (0.9–1.05)n_r$ with respect to diesel generators and other auxiliary diesel machinery for essential services. Where the main diesel generators of ships with electric propulsion plants are concerned, all the fixed speed values corresponding to the specified conditions of partial loading shall alternately be adopted for n_r.

In icebreakers and ships with ice category **Ice6** fitted with a FPP, blade frequency resonance shall be avoided within the range $(0.5–0.8)n_r$.

Restricted speed range with one cylinder misfiring in case of one main engine on board the ship shall not influence the ship's steerability.

8.8.3 If all the other methods of lowering stresses (torques) due to torsional vibration prove ineffective, a vibration damper or antivibrator may be fitted where the values permitted by 8.2 to 8.6 are exceeded:

in the case of continuous running, within speed ranges where restricted speed range is not permitted or undesirable;

in the case of rapid passage, in any point of the speed range $(0–1.2)n_r$.

8.8.4 The vibration damper or antivibrator shall ensure lowering of stresses (torques) by not less than 85% of the relevant permissible values at the resonance to which it is adjusted.

8.8.5 For icebreakers and ships with ice categories **Ice4–Ice6** within the main engine speed range $(0.7–1.05)n_r$ and for other ships and diesel generators within the speed range $(0.9–1.05)n_r$, vibration dampers or antivibrators may be used to eliminate restricted speed ranges subject to special consideration by the Register in each case.

8.8.6 A restricted speed range is established proceeding from the speed range, in which the stresses (torques, temperature) exceed the permissible values increased by 0.02 of n_{res} on both sides (with regard to tachometer error).

The engine shall be stable in operation at the barred range boundaries.

For CPP with the possibility of individual pitch and speed control, both full and zero pitch conditions shall be considered.

For calculation purposes, the restricted speed range borders may be determined by the following formula:

$$\frac{16n_{res}}{18 - n_{res}/n_r} \leqslant n \leqslant \frac{(18 - n_{res}/n_r)n_{res}}{16}, \quad (8.8.6)$$

where n_{res} = resonance speed, rpm.

8.8.7 Restricted speed ranges shall be marked off on the tachometer in accordance with 2.5.2.

Information on restricted speed ranges and their borders shall be made available on plates fastened at all the stations, from which the installation may be controlled.

8.8.8 For the case of remote control of the main machinery from the wheelhouse, the requirements of 4.2.2.4, Part XV "Automation" shall be complied with.

9. VIBRATION OF MACHINERY AND EQUIPMENT. TECHNICAL STANDARDS

9.1 GENERAL

9.1.1 This Section sets down the limits of vibration levels (vibration standards) for ships machinery and equipment.

The standards are intended to determine whether actual vibration levels in machinery and equipment installed onboard the ships during construction (after repair) and ships in service are permissible proceeding from vibration parameter measurements. The vibration standards provide three categories of technical condition of ship machinery and equipment:

A — condition of machinery and equipment after manufacturing (construction of the ship) or repair at the commissioning;

B — condition of machinery and equipment during normal operation;

C — condition of machinery and equipment when technical maintenance or repair is required.

The standards determine the upper limits of categories A and B.

For machinery and equipment, not mentioned in this section but affecting the safe operation of the ship, if it is required to assess their levels of vibration, one shall be guided by the standards specified by the manufacturer, or applicable national and international standards.

9.1.2 Vibration measurements shall be taken on all the first ships of a series being built at each shipyard, on the first ship of modified design, on the single buildings and on the ships that underwent conversion.

Vibration measurements of machinery and equipment shall be taken during construction of the ship according to the program approved by the Register.

Technical documentation as per the measurement results shall be submitted according to the requirements of 1.5, Part II "Hull".

Vibration measurements of machinery and equipment shall be performed in compliance with the instructions of 18.7, Part V "Technical Supervision during Construction of Ships" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

9.1.3 During construction of the ship (or after repair) the vibration level of the machinery and equipment shall not exceed the upper limit of category A, determined as to ensure sufficient margin for changing of vibration level in operation.

Under conditions of long-term service of the ship the vibration level of the machinery and equipment shall not exceed the upper limit of category B, determined as to ensure vibration strength and reliability of ship machinery and equipment.

9.1.4 The measurement results shall be compared with the permissible vibration levels.

Where vibration exceeds the standards, measures shall be taken to reduce it to permissible level.

9.1.5 Vibration levels of machinery and equipment shall not exceed the standards both when the ships is lying and at specified ahead speeds under different loading conditions.

At non-specification rates of speed vibration exceeding established standards may be permitted, when these rates are not continuous.

9.1.6 Deviation from the present standards is in each case subject to special consideration by the Register.

9.2 STANDARDIZED VIBRATION PARAMETERS

9.2.1 The root-mean square value of vibration rate, measured in 1/3-octave band, is assumed as the basic vibration parameter. Measuring of vibration in octave band is allowed.

9.2.2 Alongside with the vibration rate the root-mean square value of vibration acceleration may also be a parameter measured.

9.2.3 Vibration parameters are measured in absolute units or in decibels relatively to standard limiting values of speed or acceleration being equal to $5 \cdot 10^{-5}$, mm/s, and $3 \cdot 10^{-4}$, m/s^2, respectively.

Conversion of the measured values of vibration rate into relative units shall be made using the formula

$$L = 20\lg \frac{v_e}{v_{eo}}, \quad (9.2.3)$$

where v_e = the measured root-mean square value of vibration rate, mm/s;

$v_{eo} = 5X10^{-5}$, mm/s.

9.2.4 When vibration is measured in octave bands, the permissible values of the parameter measured may be increased by $\sqrt{2} = 1{,}41$ times (3 dB) as compared to those stated in 9.3 to 9.8 for bands with geometric mean frequency values of 2; 4; 8; 16; 31.5; 63; 125; 250 and 500 Hz.

9.2.5 Measurements of vibration of the machinery and equipment shall be taken for each of the three inter-perpendicular direction about the ship axes: vertical, horizontal-transverse and horizontal-longitudinal.

For internal combustion engines, measurements of vibration shall be taken according to direction of axes: X — axial (coincident with the direction of the crankshaft), Y — horizontal-transverse, Z — vertical. Such designation shall be applied for main diesel engines and diesel engines of diesel-generators. The points of vibration measuring are indicated in Fig. 9.2.5.

9.2.6 Vibration standards of machinery are specified in the relative chapters for rigid and yielding supports to which machinery can be attached under shipboard conditions.

Rigid supports are those supports where the first natural frequency of the “support — machinery” system exceeds the basic exciting frequency (working frequency of revolution) in the vibration measurement direction by more than 25%.

Yielding support is a support where the first natural frequency is less than 25% of the machinery working frequency of revolution.

Yielding of the support is ensured by resilient mounting of the machinery or support (vibration insulators of various design — shock absorbers, springs, rubber insulators, etc.).

The vibration standards of categories A and B for machinery installed on rigid supports are specified in the relevant tables and figures. When the machinery is attached to yielding supports, the values of permissible vibration standards are increased.

To determine the values of permissible vibration rate, multiplication factor for the particular type of machinery shall be applied.

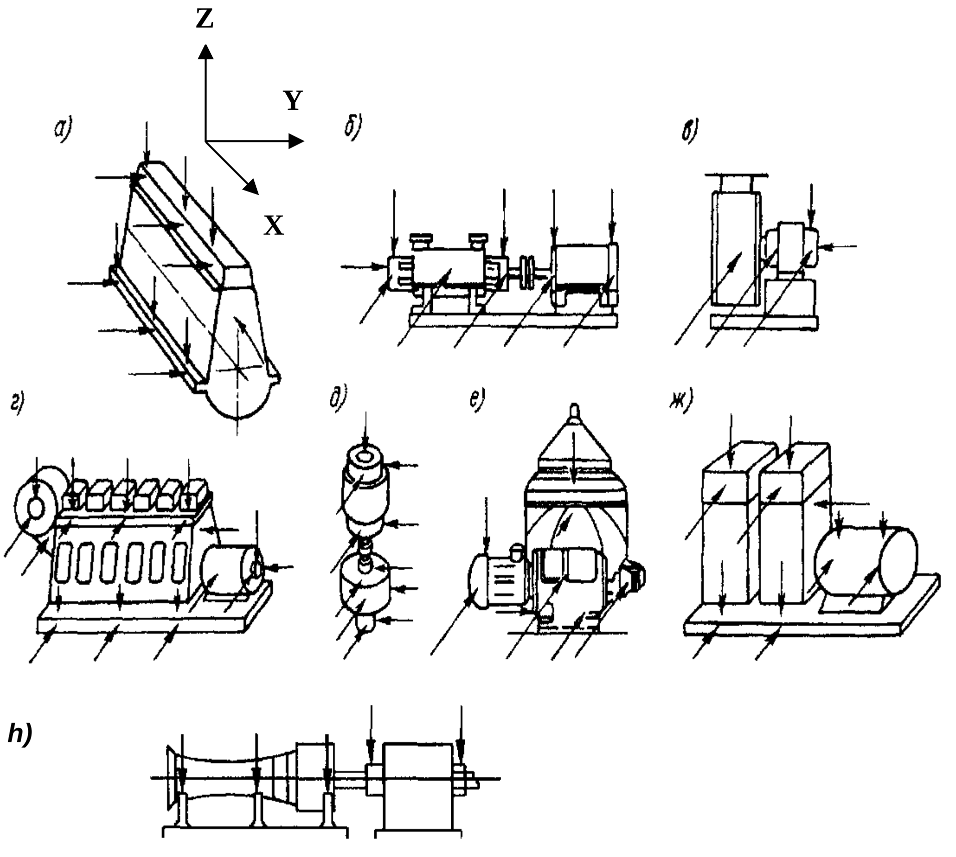

Fig. 9.2.5 Points of vibration measuring:
a — internal combustion engine; *b* — horizontal pump; *c* — fan; *d* — diesel-generator; *e* — vertical pump; *f* — separator; *g* — piston compressor; *h* — gas turbine gear unit.
The points and directions of vibration measurement are shown by arrows.

9.3 VIBRATION STANDARDS FOR INTERNAL COMBUSTION ENGINES

9.3.1 Vibration standards are extended to cover ICE with 55 kW and above in power and rotation frequency ≤ 3000 min^{-1}.

9.3.2 Vibration of low-speed internal combustion engines installed on rigid supports is considered permissible for categories A and B, provided the root-means square values of vibration rate and vibration acceleration measured in the direction of axes X and Z do not exceed the values specified in Table 9.3.2 and Fig. 9.3.2.

When vibration is measured along the axis y (in transverse direction) the permissible vibration rate standards for categories A and B shall be increased 1.4 times.

When the internal combustion engines are installed on yielding supports (main medium-speed diesel engines and diesel engines of diesel-generators) the permissible vibration standards for categories A and B in the direction of axes X, Y and Z specified in Table 9.3.2 and Fig. 9.3.2 shall be increased 1.4 times.

9.3.3 Vibration of machinery and devices hung on ICE shall not exceed the levels given in 9.3.2.

9.3.4 Vibration of turbo-compressors measured on bearing housings is considered permissible for categories A and B, provided the root-mean square values of vibration rate or vibration acceleration do not exceed the values specified in Table 9.3.4 and Fig. 9.3.4.

Table 9.3.2 **Vibration standards for ICEs**

Geometric mean frequencies of 1/3-octave bands, Hz	Engines with piston stroke, cm											
	under 30				30 to 70				71 to 140			
	Permissible values of vibration rate											
	Category A		Category B		Category A		Category B		Category A		Category B	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1.6	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101
2	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101
2.5	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101
3.2	4	98	5.6	101	4	98	5.6	101	4.5	99	6.3	102
4	4	98	5.6	101	4.5	99	6.3	102	5.6	101	8.0	104
5	4.5	99	6.3	102	5.6	101	8.0	104	7.1	103	10	106
6.3	5.6	101	8.0	104	7.1	103	10	106	8.9	105	12.5	108
8	7.1	103	10	106	8.9	105	12.5	108	11	107	16	110
10	8.9	105	12.5	108	11	107	16	110	14	109	20	112
12.5	11	107	16	110	14	109	20	112	16	110	22	113
16	14	109	20	112	16	110	22	113	16	110	22	113
20	16	110	22	113	16	110	22	113	16	110	22	113
25	16	110	22	113	16	110	22	113	16	110	22	113
31.5	16	110	22	113	16	110	22	113	16	110	22	113
40	16	110	22	113	16	110	22	113	12.5	108	18	111

50	16	110	22	113	12.5	108	18	111	10	106	14	109
63	12.5	108	18	111	10	106	14	109	8	104	11	107
80	10	106	14	109	8	104	11	107	6.3	102	8.9	105
100	8	104	11	107	6.3	102	8.9	105	5	100	7.1	103
125	6.3	102	8.9	105	5	100	7.1	103	4	98	5.6	101
160	5	100	7.1	103	4	98	5.6	101	3.2	96	4.5	99

Table 9.3.2 ***Vibration standards for ICEs*** *continued*

Geometric mean frequencies of 1/3-octave bands, Hz	Engines with piston stroke, cm							
	141 to 240				more than 240			
	Permissible values of vibration rate							
	Category A		Category B		Category A		Category B	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1.6	4	98	5.6	101	4	98	5.6	101
2	4	98	5.6	101	4.5	99	6.3	102
2.5	4.6	99	6.3	102	5.6	101	8.0	104
3.2	5.6	101	8.0	104	7.1	103	10	106
4	7.1	103	10	106	8.9	105	12.5	108
5	8.9	105	12.5	108	11	107	16	110
6.3	11	107	16	110	14	109	20	112
8	14	109	20	112	16	110	22	113
10	16	110	22	113	16	110	22	113
12.5	16	110	22	113	16	110	22	113
16	16	110	22	113	16	110	22	113
20	16	110	22	113	16	110	22	113
25	16	110	22	113	12.5	108	18	111
31.5	12.5	108	18	111	10	106	14	109
40	10	106	14	109	8	104	11	107
50	8	104	11	107	6.3	102	8.9	105
63	6.3	102	8.9	105	5	100	7.1	103
80	5	100	7.1	103	4	98	5.6	101
100	4	98	5.6	101	3.2	96	4.5	99
125	3.2	96	4.5	99	2.5	94	3.6	97
160	2.5	94	3.6	97	2	92	2.8	95

9.4 VIBRATION STANDARDS FOR MAIN GEARED TURBINES AND THRUST BEARINGS

9.4.1 The running vibration of 15,000 to 30,000 kW power main geared turbines measured on the bearing housings is considered permissible for categories A and B, provided the root-means square values of vibration rate or vibration acceleration do not exceed the values specified in Table 9.4.1 and Fig. 9.4.1.

The vibration standards specified in Table 9.4.1 and Fig. 9.4.1 shall be applied to the main geared turbines when installed both on rigid and on yielding supports.

9.4.2 For main geared turbines of less than 15,000 kW power the vibration standards are 3 dB lower than the values specified in Table 9.4.1 and Fig. 9.4.1.

9.4.3 Vibration of thrust bearings shall not exceed the standards given in 9.4.1 and 9.4.2.

Table 9.3.4 **Vibration standards for turbo-compressors**

Geometric mean frequencies of 1/3-octave bands, Hz	Permissible values of vibration rate			
	Category A		Category B	
	mm/s	dB	mm/s	dB
1.6	10	106	14	109
2	12.5	108	16	110
2.5	14	109	20	112
3.2	20	112	25.5	114
4	24	114	34	116
5	24	114	34	116
6.3	24	114	34	116
8	24	114	34	116
10	24	114	34	116
12.5	24	114	34	116
16	24	114	34	116
20	24	114	34	116
25	24	114	34	116
31.5	24	114	34	116
40	24	114	34	116
50	24	114	34	116
63	24	114	34	116
80	24	114	34	116
100	24	114	34	116
125	24	114	34	116
160	24	114	34	116
200	24	114	34	116
250	18	111	26	116
320	14	109	20	112
400	11	107	16	110
500	9	106	13	109

9.5 VIBRATION STANDARDS FOR AUXILIARY MACHINERY OF ROTARY TYPE

9.5.1 Vibration of vertical pumps with the capacity of 15 to 75 kW, including their electric drive, is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.5.1 and in Fig. 9.5.1.

For pumps having the capacity of 2 to 15 kW the vibration standards for categories A and B are assumed being 3 dB lower compared with the vibration standards for the pumps hewing the capacity of 15 to 75 kW, and for the pumps with the capacity of 75 to 300 kW such standards shall be raised by 2 dB.

Vibration standards for horizontal pumps for the above mentioned capacity range are assumed being 2 dB lower.

The vibration standards specified in Table 9.5.1 and Fig. 9.5.1 shall be applied to all pumps when installed on rigid supports.

In case when the pumps are installed on yielding support, the permissible vibration standards shall be increased by 1.4 times for categories A and B.

9.5.2 Vibration of centrifugal separators is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.5.1 and in Fig. 9.5.2.

The vibration standards are specified considering the installation of separators on shock absorbers.

9.5.3 Vibration of fans and gas blowers of the inert gas systems is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.5.1 and in Fig. 9.5.3.

The vibration standards are specified considering the installation of fans and gas blowers on shock absorbers.

In case of rigid fixing, these standards shall also be applied.

9.5.4 Vibration of turbo-drives, turbo-generators and generators of diesel-generators with the capacity of 1000 to 2000 kW, measured on the bearing housings, is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.4.1 and in Fig. 9.5.4.

For the turbo-drives, turbo-generators and generators of diesel-generators with the capacity under 1000 kW the vibration standards for categories A and B are by 4 dB lower than the values stated in Table 9.4.1 and in Fig. 9.5.4.

The vibration standards for turbo-drives and turbo-generators specified in Table 9.4.1 and Fig. 9.5.4 shall be applied when these are installed both on rigid and on yielding supports.

The vibration standards for generators of diesel-generators when installed on yielding supports shall be doubled.

Table 9.4.1 **Vibration standards for main geared turbines, thrust bearings, boilers, heat exchangers, ICE-driven generators, shaft-generators, turbo-drives, turbo-generators and piston compressors**

Geometric mean frequencies of 1/3-octave bands, Hz	Main geared turbines and trust bearings				Boilers and heat exchangers			
	Permissible values of vibration rate							
	Category A		Category B		Category A		Category B	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1.6	1.5	90	2.5	94	3.5	97	5.6	101
2	1.9	92	3.1	96	3.5	97	5.6	101
2.5	2.4	94	3.8	98	3.5	97	5.6	101
3.2	3	96	4.8	100	4.4	99	7.1	103
4	3.7	97	6	102	5.6	101	8.9	105
5	4.6	99	7.5	104	7	103	11	107
6.3	5.7	101	9.3	105	8.8	105	14	109
8	7	103	11.5	107	10	106	16	110
10	8.8	105	14.5	109	10	106	16	110
12.5	11	107	18	111	10	106	16	110
16	11	107	18	111	10	106	16	110
20	11	107	18	111	10	106	16	110
25	11	107	18	111	10	106	16	110
31.5	11	107	18	111	10	106	16	110
40	11	107	18	111	10	106	16	110
50	8.8	105	14.5	109	8	104	12.5	106
63	7	103	11.5	107	6.3	102	10	106
80	5.7	101	9.3	105	5.2	100	8	104
100	4.6	99	7.5	104	–	–	–	–
125	–	–	–	–	–	–	–	–

160	–	–	–	–	–	–	–	–
200	–	–	–	–	–	–	–	–
250	–	–	–	–	–	–	–	–

Table 9.4.1 continued

Geometric mean frequencies of 1/3-octave bands, Hz	ICE-driven generators, turbo-drives and turbo-generators[1]				Piston compressors			
	Permissible values of vibration rate							
	Category A		Category B		Category A		Category B	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1.6	1	86	1.6	90	2	92	3.2	96
2	1.3	88	1.9	92	2.5	94	4	98
2.5	1.5	90	2.4	94	3.1	96	5.1	100
3.2	1.9	92	3	96	4	98	6.4	102
4	2.3	93	3.7	97	5	100	8	104
5	2.9	95	4.6	99	6.2	102	10	106
6.3	3.6	97	5.7	101	7.9	104	12.5	108
8	4.5	99	7.1	103	10	106	16	110
10	5.6	101	8.9	105	10	106	16	110
12.5	7	103	11	107	10	106	16	110
16	7	103	11	107	10	106	16	110
20	7	103	11	107	10	106	16	110
25	7	103	11	107	10	106	16	110
31.5	7	103	11	107	10	106	16	110
40	7	103	11	107	10	106	16	110
50	7	103	11	107	10	106	16	110
63	7	103	11	107	7.9	104	12.5	108
80	7	103	11	107	6.2	102	10	106
100	5.6	101	8.9	105	5	100	8	104
125	4.5	99	7.1	103	4	98	6.4	102
160	3.6	97	5.7	101	3.1	96	5.1	100
200	2.9	95	4.6	99	2.5	94	4	98
250	2.3	93	3.7	97	2	92	3.2	96
320	1.9	92	3	96	1.6	90	2.5	94
400	–	–	–	–	1.3	88	2.1	92
500	–	–	–	–	1	86	1.6	90

[1] Refer to 9.5.4

Table 9.5.1 **Vibration standards for pumps, centrifugal separators and fans**

Geometric mean frequencies of 1/3-octave bands, Hz	Pumps with the capacity of 15–75 kW				Centrifugal separators				Fans			
	Permissible values of vibration rate											
	Category A		Category B		Category A		Category B		Category A		Category B	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**

1.6	1	86	1	86	1	86	1.3	88	1	86	1.3	88
2	1	86	1.2	88	1	86	1.6	90	1	86	1.6	90
2.5	1.1	87	1.4	89	1.3	88	2	92	1.3	88	2	92
3.2	1.4	89	2	92	1.6	90	2.5	94	1.6	90	2.5	94
4	1.7	91	2.5	94	2	92	3.2	96	2	92	3.2	96
5	2.2	93	3.3	96	2.5	94	4	98	2.6	94	4	98

End of Table 9.5.1

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
6.3	2.7	95	4	98	3.2	96	5	100	3.3	96	5	100
8	3.5	97	5	100	4	98	6.4	102	4.1	98	6.4	102
10	4.3	99	6.3	102	5	100	8	104	5.2	100	8	104
12.5	5.5	101	8	104	5	100	8	104	6.7	103	10.3	106
16	7	103	10	106	5	100	8	104	8.5	105	13	108
20	7	103	10	106	5	100	8	104	8.5	105	13	108
25	7	103	10	106	5	100	8	104	8.5	105	13	108
31.5	7	103	10	106	5	100	8	104	8.5	105	13	108
40	7	103	10	106	5	100	8	104	8.5	105	13	108
50	7	103	10	106	5	100	8	104	8.5	105	13	108
63	7	103	10	106	5	100	8	104	6.7	103	10.3	106
80	5.5	101	8	104	5	100	8	104	5.2	100	8	104
100	4.3	99	6.3	102	5	100	8	104	4.1	98	6.4	102
125	3.5	97	5	100	4	98	6.4	102	3.3	96	5	100
160	2.7	95	4	98	3.2	96	5	100	2.6	94	4	98
200	2.2	93	3.3	96	2.5	94	4	98	2	92	3.2	96
250	1.7	91	2.5	94	2	92	3.2	96	1.6	90	2.5	94
320	1.4	89	2	92	1.6	90	2.5	94	1.3	88	2	92
400	–	–	–	–	1.3	88	2	92	1	86	1.6	90
500	–	–	–	–	1	86	1.6	90	1	86	1.3	88

9.6 VIBRATION STANDARDS FOR PISTON AIR COMPRESSORS

9.6.1 Vibration of piston air compressors is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.4.1 and in Fig. 9.6.1. When the compressor is mounted on the shock-absorbers, the vibration standards shall he raised by 4 dB.

9.7 VIBRATION STANDARDS FOR BOILERS AND HEAT EXCHANGERS

9.7.1 Vibration of boilers and heat exchangers is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.4.1 and in Fig. 9.7.1.

9.7.2 Vibration standards for auxiliary machinery and equipments, not covered by 9.5 and 9.6, shall be chosen based on 9.7.1.

9.8 VIBRATION STANDARDS FOR GEARED GAS TURBINES

9.8.1 Vibration of 250 to 25,000 kW main geared gas turbines measured on the gas turbine supports and reduction gear bearings is considered permissible, provided the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.8.1 and shown in Fig. 9.8.1.

9.8.2 Vibration standards for auxiliary gas turbines of less than 250 kW power shall be subject to special consideration by the Register and shall be submitted by the gas turbine manufacturer.

Table 9.8.1 **Vibration standards for geared gas turbines**

Geometric mean frequencies of 1/3-octave bands, Hz	Permissible values of vibration rate			
	Category A		Category B	
	mm/s	dB	mm/s	dB
1	**2**	**3**	**4**	**5**
1.6	1.6	90	2.9	96
2	1.8	91	3.5	97
2.5	2.2	93	4.3	98
3.2	2.7	95	5.3	100
4	3.2	96	7.0	103
5	4	98	9	105
6.3	5	100	11	107
8	6.7	103	13	108
10	8	104	16.5	110
12.5	8	104	16.5	110
16	8	104	16.5	110
20	8	104	16.5	110
25	8	104	16.5	110
31.5	8	104	16.5	110
40	8	104	16.5	110
50	8	104	16.5	110
63	8	104	16.5	110
80	8	104	16.5	110
100	8	104	16.5	110
125	8	104	16.5	110
160	8	104	16.5	110

End of Table 9.8.1

1	**2**	**3**	**4**	**5**
200	8	104	16.5	110
250	8	104	16.5	110
320	8	104	16.5	110
400	8	104	16.5	110
500	8	104	16.5	110
640	6.5	102	12.5	108
800	4.8	100	10	106
1000	4	98	8	104
1280	3	96	7	103
1600	2.6	94	5	100
2000	2.1	92	3.9	98
2560	1.8	91	3	96
3200	1.5	90	2.4	95
4000	1	86	2	92
5120			1.7	91
6400			1.4	89
8000			1	86

9.8.3 Vibration of gas-turbine-driven servo-machinery and devices shall not exceed the levels given in 9.8.1 and 9.8.2.

9.8.4 The gas turbine manufacturer may deviate from the above standards, provided convincing data are available that the gas turbines are capable of operating under different vibration levels.

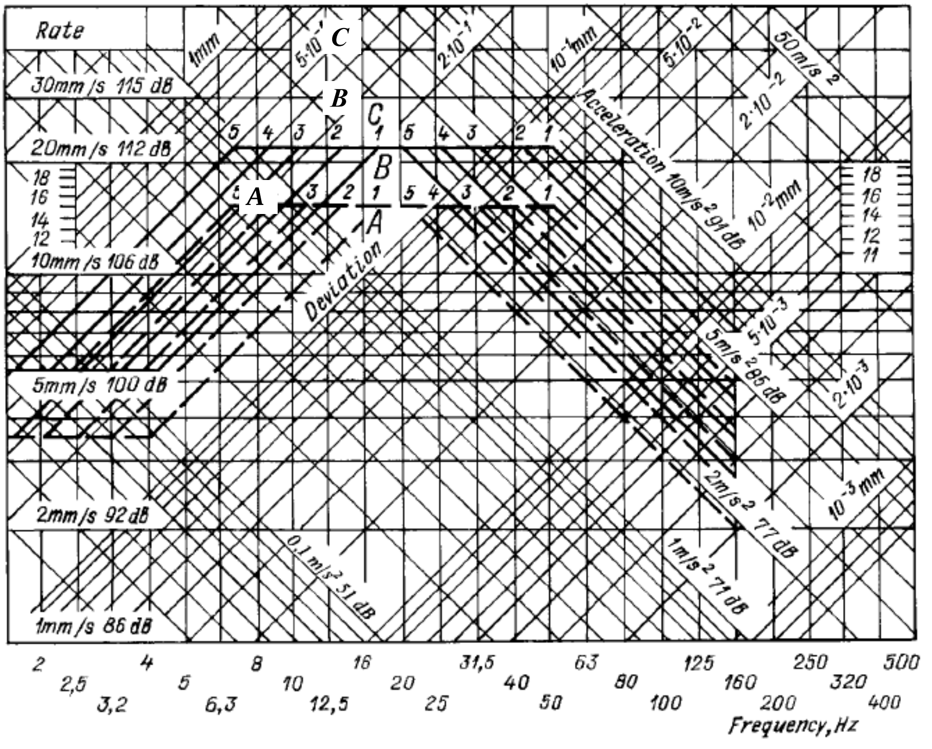

Fig. 9.3.2 Vibration standards for ICEs with piston stroke of:
1 — under 30 cm; 2 — 30 to 70 cm;
3 — 71 to 140 cm; 4 — 141 to 240 cm;
5 — over 240 cm;
- - - - - - - - - - upper limit of category A;
——————— upper limit of category B.

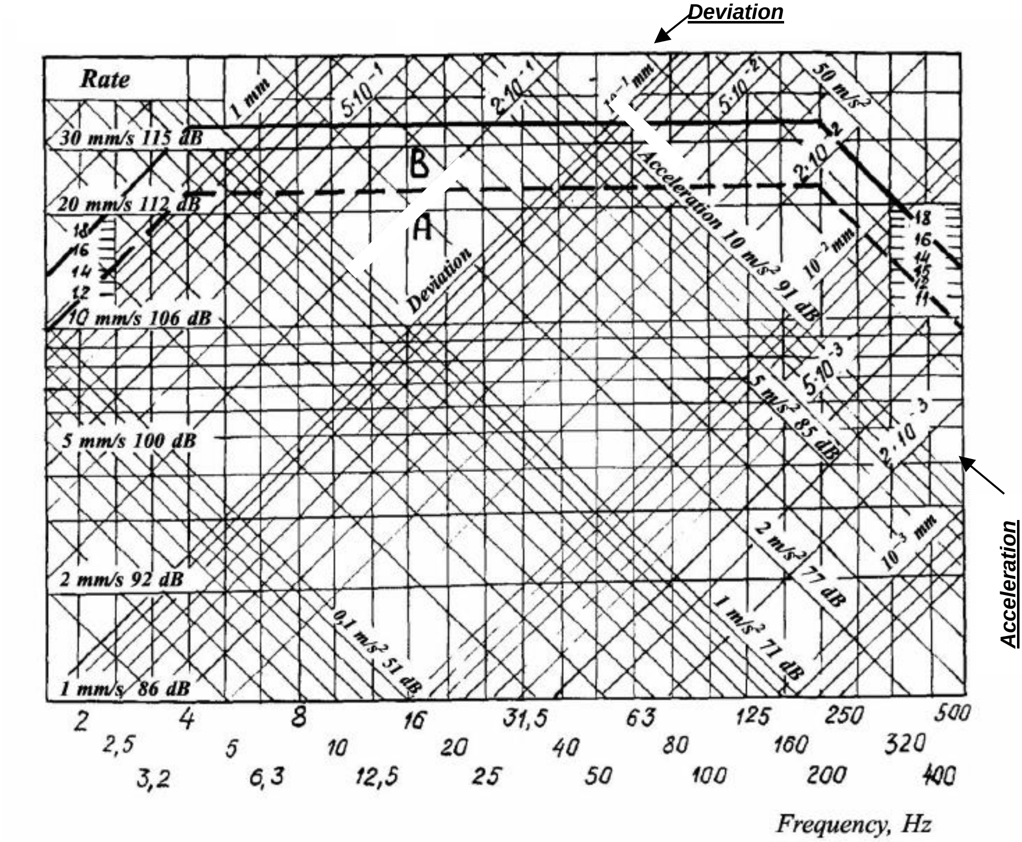

Fig. 9.3.4 Vibration standards for turbo-compressors of ICEs:

- - - - - - - - - - upper limit of category A;

———— upper limit of category B.

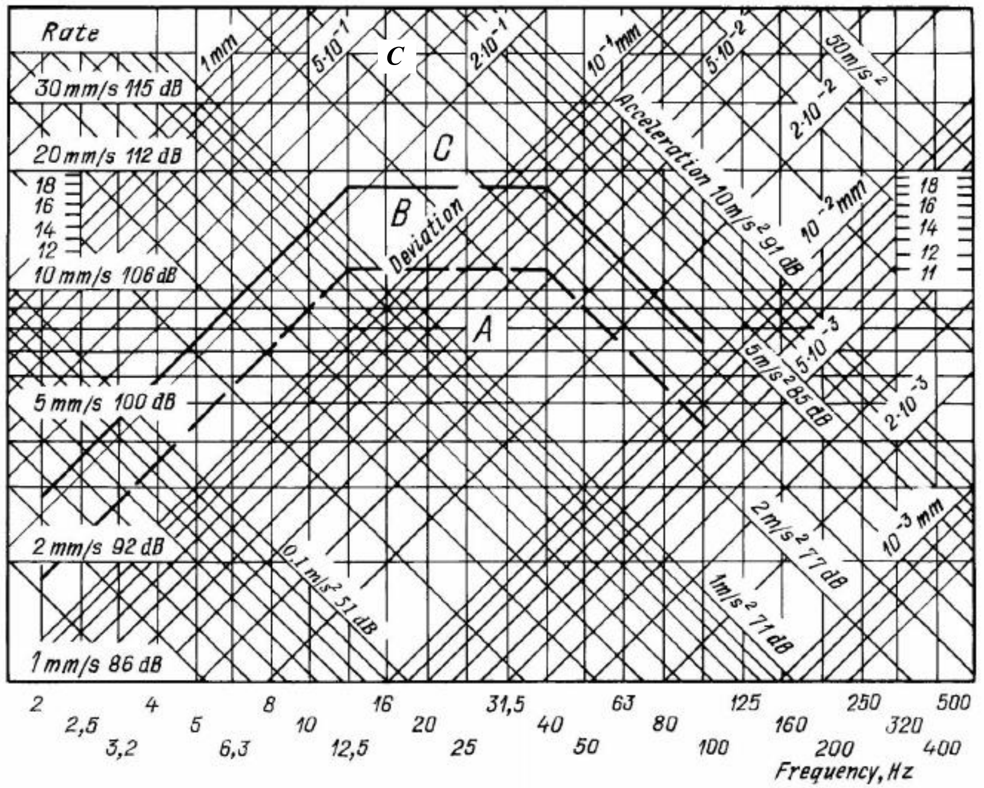

Fig. 9.4.1 Vibration standards for main steam geared turbines of 15,000 to 30,000 kW capacity and thrust bearings

- - - - - - - - - - upper limit of category A;

———————— upper limit of category B.

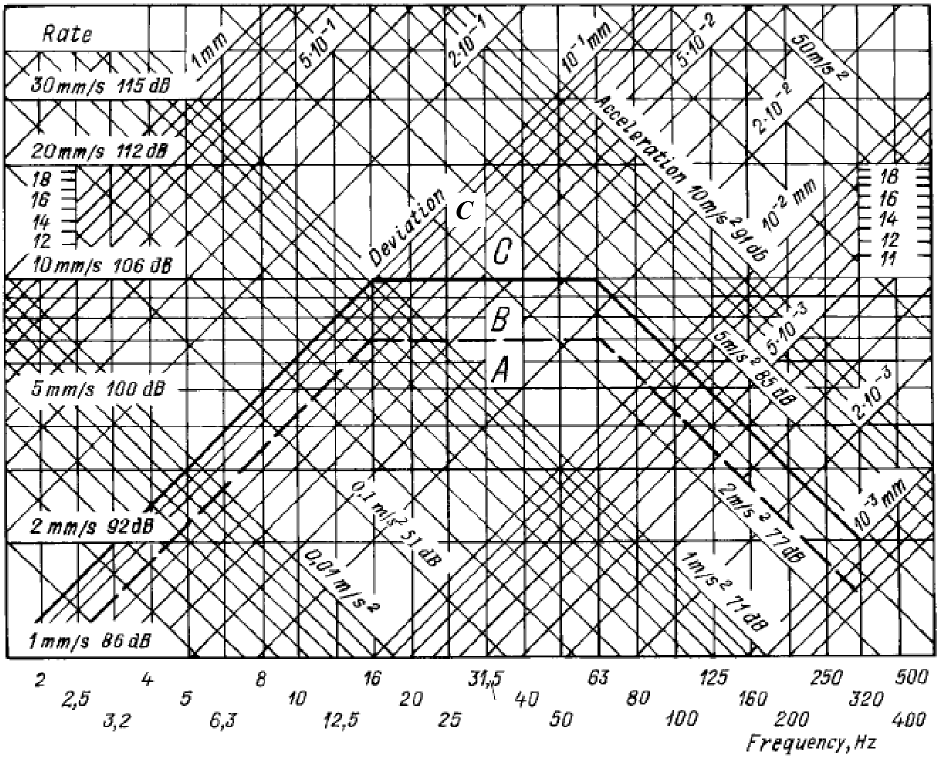

Fig. 9.5.1 Vibration standards for pumps with the capacity of 15 to 75 kW

- - - - - - - - - - upper limit of category A;

———————— upper limit of category B.

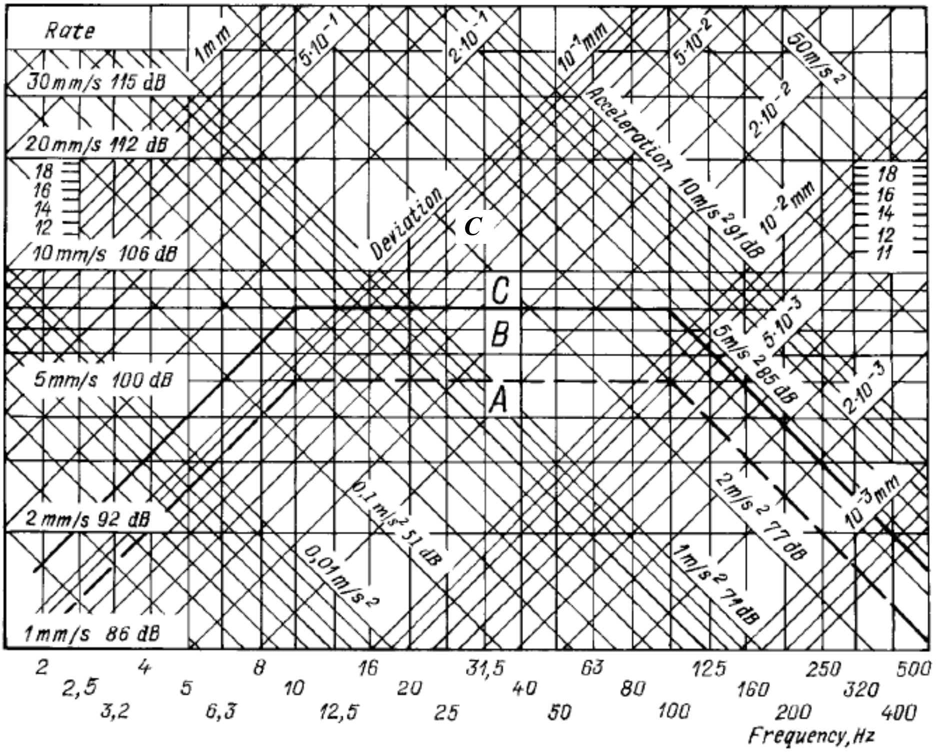

Fig. 9.5.2 Vibration standards for centrifugal separators

- - - - - - - - - - upper limit of category A;

———————— upper limit of category B.

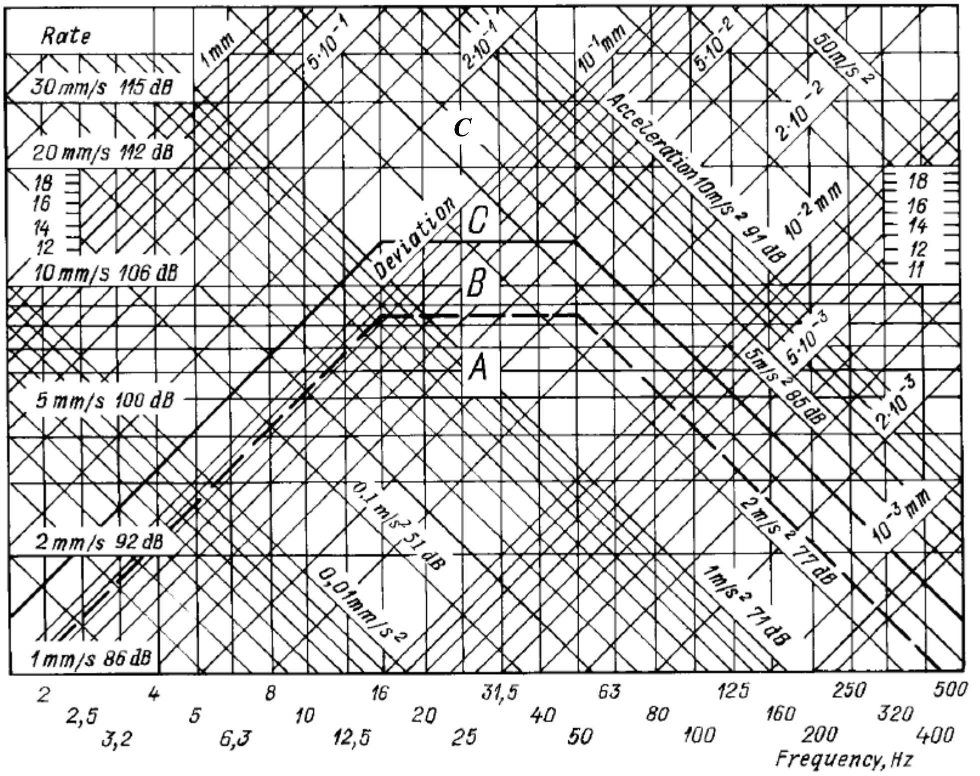

Fig. 9.5.3 Vibration standards for fans

- - - - - - - - - - upper limit of category A;

———— upper limit of category B.

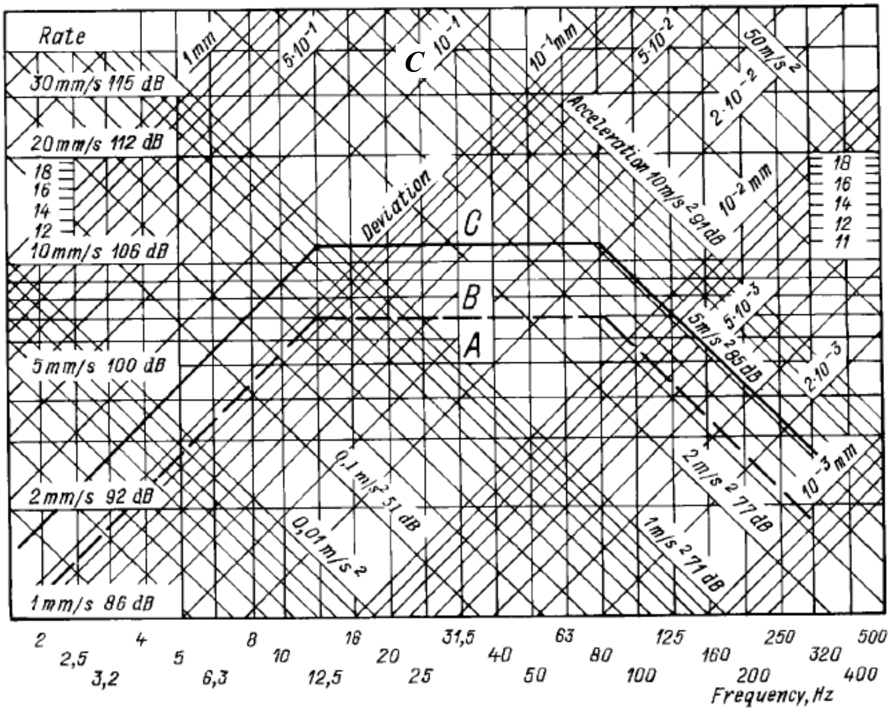

Fig. 9.5.4 Vibration standards for ICE-driven generators, shaft-generators, turbo-drives and turbo-generators of 1000 to 2000 kW capacity

- - - - - - - - - - upper limit of category A;

———————— upper limit of category B.

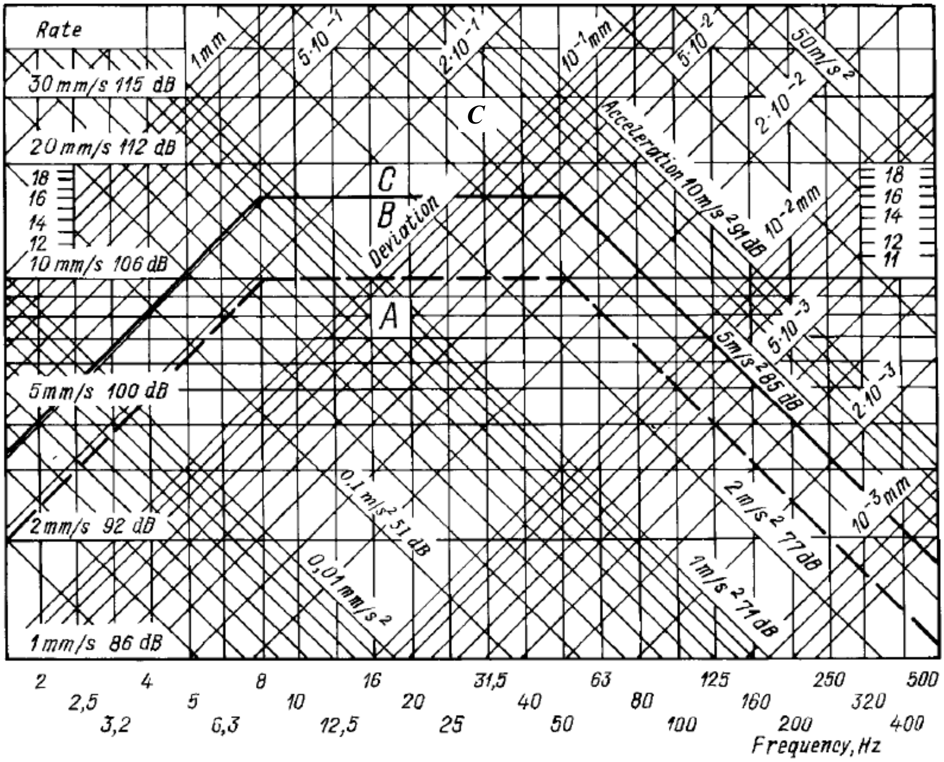

Fig. 9.6.1 Vibration standards for piston compressors
- - - - - - - - - - upper limit of category A;
———————— upper limit of category B.

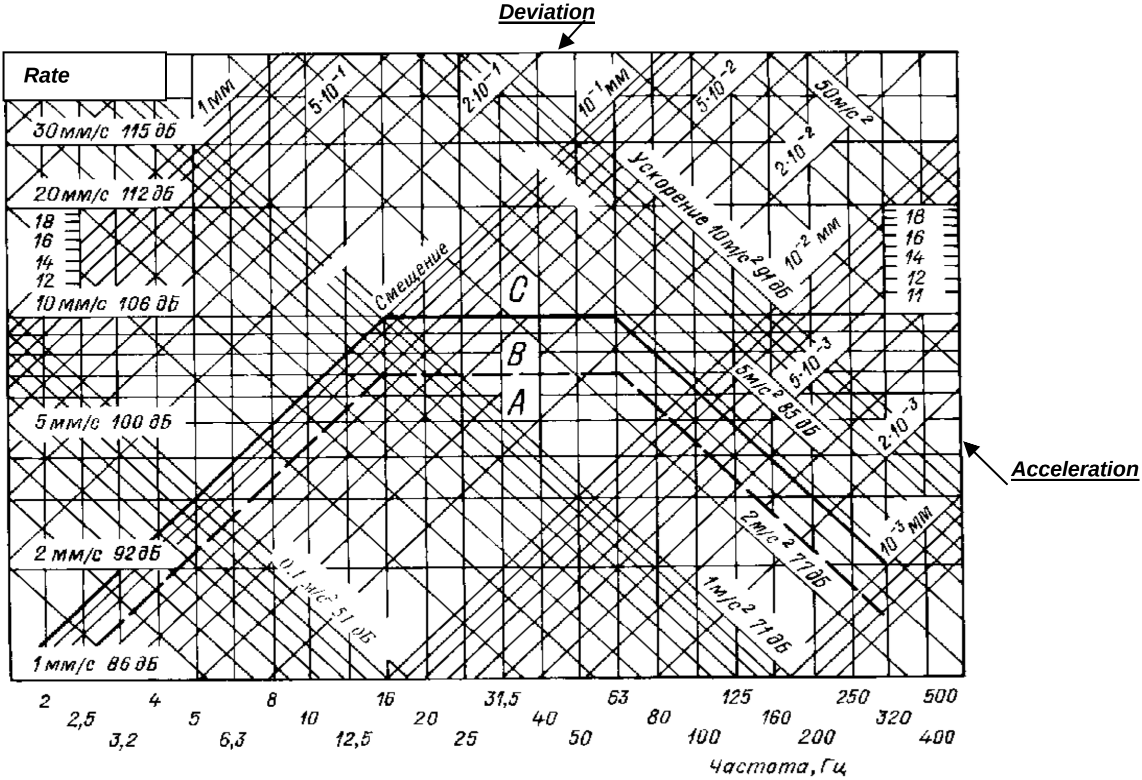

Fig. 9.7.1 Vibration standards for boilers, auxiliary machinery and equipment

- - - - - - - - - - upper limit of category A;

———————— upper limit of category B.

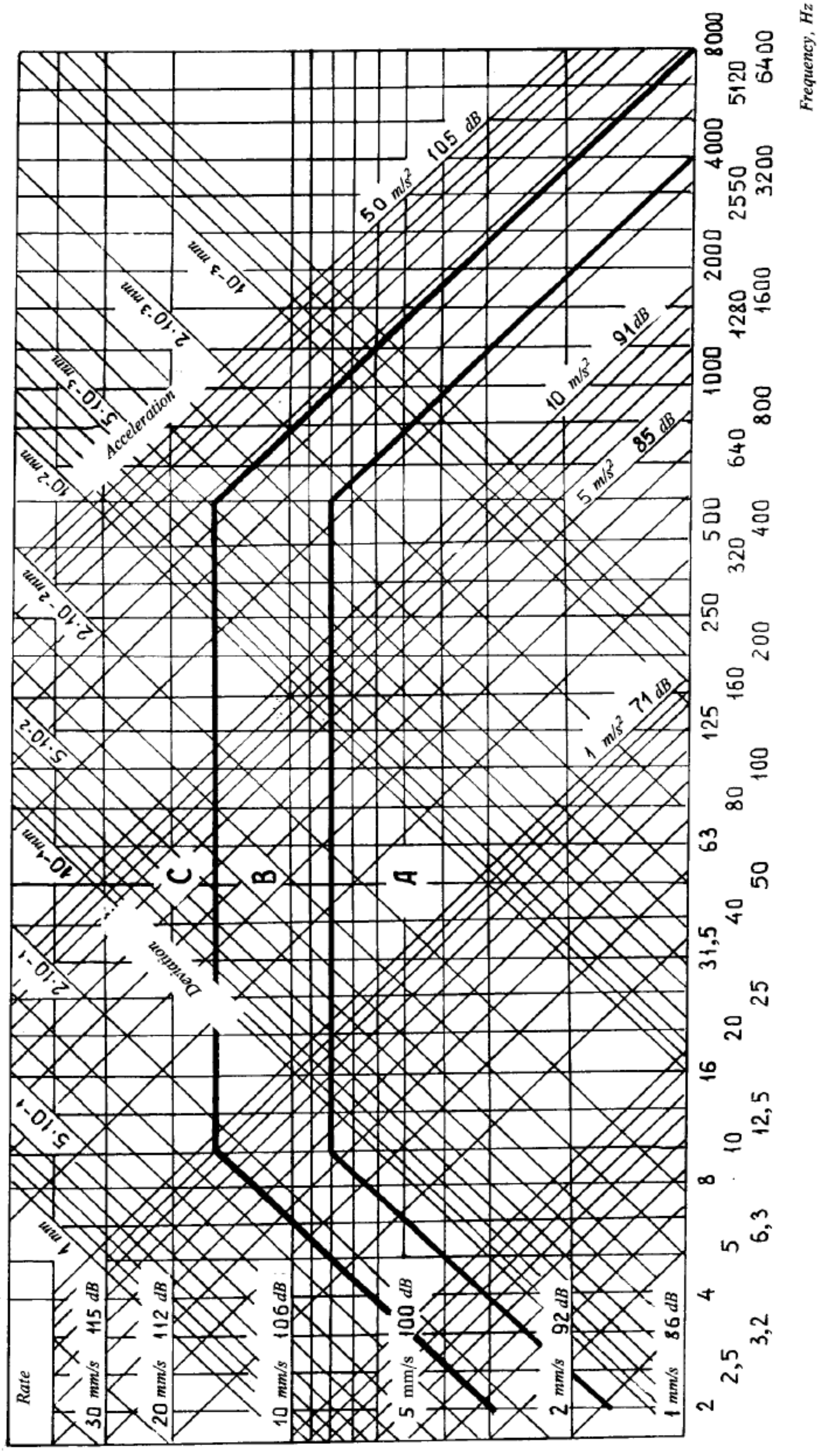

Fig. 9.8.1-1
Vibration standards for geared gas turbines

9.9 VIBRATION STANDARDS FOR POWER-DRIVEN AZIMUTH THRUSTERS

9.9.1 Vibration standards are extended to cover azimuth thrusters ICE-driven up to 3000 kW at rotation speed of an input drive shaft of azimuth thruster up to 2000 rpm.

These standards may be waived like in the case of using on the drive shafts in shafting shall be subject to special consideration by the Register in each case.

9.9.2 The points and directions of vibration measuring are given in Fig. 9.9.2.

9.9.3 Vibration of azimuth thrusters is considered admissible for the categories as follows A and B, if the root-mean square values of vibration rate within the range of 10–1000 Hz determined by ISO 10816-1 does not exceed the values in Table 9.9.3 and in Fig. 9.9.3.

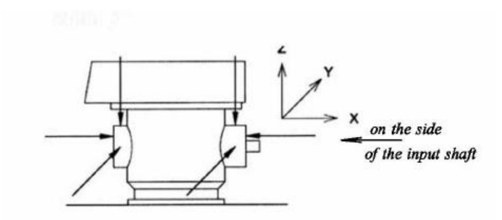

Fig. 9.9.2 Points of vibration measuring of azimuth thrusters

Table 9.9.3 **Vibration standards for azimuth thrusters**

Relative rotation frequency of the driving shaft end, *n*	Admissible root-mean square values of vibration rate[1]			
	Category A		Category B	
	mm/s	dB	mm/s	dB
1	2	3	4	5
0.54	0.83	84	1.06	86
0.61	1.98	92	2.70	95
0.67	3.01	96	4.16	98
0.73	3.92	98	5.44	101
0.79	4.71	99	6.54	102
0.85	5.38	101	7.46	103
0.91	5.91	101	8.20	104
0.97	6.36	102	8.76	105
1.03	6.67	102	9.14	105
1.10	6.86	103	9.34	105

[1] The root-mean square values of vibration rate are determined in the frequency range of 10–1000 Hz in compliance with ISO 10816-1.

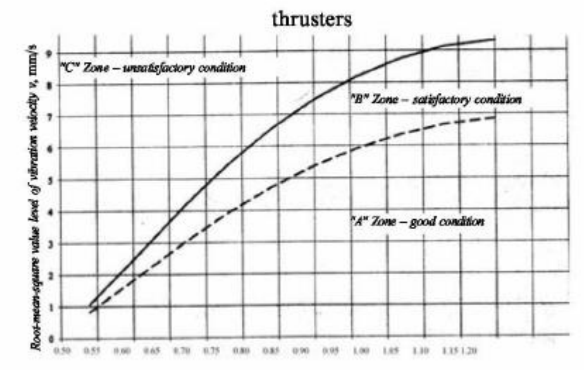

Fig. 9.9.3 Vibration standards for azimuth thrusters

10. SPARE PARTS

10.1 GENERAL

10.1.1 The lists of spare parts given in this Section specify the minimum amount of spare parts to the equipment supervised by the Register and essential to the propulsion and safety of the ship.

10.1.2 The nomenclature and the amount of spare parts for icebreakers and ships equipped with machinery of the types other than those indicated in 10.2 shall, in each case, be submitted for consideration to the Register with regard to the manufacturers' recommendations.

The availability of other spare parts on board the ship in addition to those specified in the Tables 10.2-1 to 10.2-8 is up to the shipowner's discretion.

10.1.3 Each ship shall be supplied with a set of appropriate tools and appliances necessary for dismantling and assembling of the machinery in service conditions.

When dismantling and assembly of machinery can be carried out by the manufacturer's service or dedicated coastal service only, the amount of spare parts on board the ship shall be specially considered by the Register.

10.1.4 Each ship shall be supplied with a set of flexible joints of every type and size used in the ship's systems and machinery.

10.1.5 The spare parts shall be properly secured in easily accessible places, marked and efficiently protected against corrosion.

When using spare parts, it is recommended to replenish them at the earliest opportunity.

10.1.6 If the number of spare parts determined according to the list given below is a fraction, then to define the amount of spares, the nearest greatest whole number shall be taken.

10.1.7 For ships assigned to restricted navigation areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN**, **A-R2**, **A-R2-S**, **A-R2-RS**, **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS**, **D-R3-S**, **D-R3-RS** and for floating docks, the required minimum of spare parts is not regulated. For the definitions of restricted areas of navigation, refer to 2.2.5, Part I "Classification".

10.2 REQUIRED MINIMUM OF SPARE PARTS

Table 10.2-1 **Internal combustion engines**

Ser. No.	Spare parts	Main engines of ships considered with regard to navigation area [1, 2, 3]		Supply of spare parts	Auxiliary engines of ships considered with regard to navigation area [1, 3, 4]		Supply of spare parts
		unrestricted, **A**	restricted **R1, A-R1**		unrestricted, **A**	restricted **R1, A-R1**	
1	2	3	4	5	6	7	8
1	Main bearings or shells of each type and size fitted, complete with shims, studs (bolts) and nuts	1 set		M	1 set	–	–
2	Cylinder liner with valves, joint rings and gaskets	1		M	Joint rings and gaskets only — 1 set		R
3	Cylinder cover with valves, joint rings and gaskets	1		M	Joint rings and gaskets only — 1 set		R
3.1	Cylinder cover bolts and nuts	1/2 set per cover		R	–	–	–
4	Cylinder valves						
4.1	Exhaust valves, complete with casings, seats, springs and other valves, per cylinder	2 sets	1 set	R	2 sets	1 set	R
4.2	Air inlet valves: as for item 4.1	1 set		R	1 set	–	–
4.3	Starting air valve, complete with casing, seats, springs and other valves	1		M	1	–	R
4.4	Overpressure sentinel valve, complete	1		M	1	–	R
4.5[5]	Fuel valves of each type and size fitted, complete with all fittings, per engine	1 set	1/4 of a set	M	1/2 of a set	1/4 of a set	R
5	Connecting rod bearings						
5.1	Connecting-rod bearings or shells of each type and size fitted, complete with shims, bolts and nuts, per cylinder	1 set		M	1 set		R
5.2	Top end bearings or shells of each type and size fitted, complete with shims, bolts and nuts, per cylinder	1 set		M	1 set		R

Table 10.2.-1 continued

1	2	3	4	5	6	7	8
6	Pistons						
6.1	Crosshead type: piston of each type and size fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts	1		M	1		-
6.2	Trunk type: piston of each type and size fitted, complete with skirt, rings, gudgeon pin, connecting rod, studs and nuts	1		M	1		R
7	Piston rings, per cylinder	1 set		M	1 set		R
8	Telescopic cooling pipes of pistons with packings and other fittings, per cylinder	1 set		M	1 set		R
9	Largest size lubricator, complete with drive	1	–	M	–		–
10	Fuel pumps						
10.1	Fuel pump complete or, if parts are replaceable on board, a complete set of parts for one pump (plunger, sleeve, valves, springs, etc.)	1		M			R
10.2	High pressure fuel pipe of each size and shape fitted, complete with unions	1	–	M			R
11[6]	Scavenge blowers including turbo-chargers						
11.1	Rotors, rotor shafts, bearings, gear wheels, nozzle devices, seal parts, suction and discharge valves (proceeding from the type of supercharger)	1 set	–	R	–		–

[1] For an installation comprising several engines of the same type, spare parts stock intended for one engine is sufficient. By engines of the same type, engines are meant the identical parts of which are interchangeable.

[2] For a thrust bearing built in main engine, see the requirements of item 1 of Table 10.2-4.

[3] The necessity of stocking further spares such as gear wheels, camshaft drive chains shall be determined by the shipowner with regard to the recommendations of engine manufacturers.

[4] For emergency engines, spare parts are not compulsory.

[5] For engines with one or two fuel valves per cylinder: one set of complete fuel valves for an engine. For engines with three or more fuel valves per cylinder: two complete fuel valves per cylinder, and for the rest of the fuel valves, all parts except the bodies.

[6] Locking devices shall be provided for the case of turbocharger being damaged. Spare parts may not be provided when the possibility of the internal combustion engine of this type operation without one turbocharger was demonstrated during the type tests with the satisfactory manoeuvring characteristics retained.

Note. For internal combustion engines with electronic control systems spare parts shall be supplied based on the recommendations of designer or manufacturer of the internal combustion engine.

Table 10.2-2 **Steam turbines (main and auxiliary)**[1, 2]

Ser. No.	Spare parts	Number of spare parts depending on the navigation area	
		unrestricted	restricted **R1, A-R1**
1	Carbon sealing rings for each type and size of gland	1 set	
2	Strainer baskets, inserts and other detachable parts for oil filters of special design, each type and size	1 set per filter	

[1] Recommended minimum.

[2] When the installation consists of several turbines of the same type, the recommended minimum is assumed for one turbine only. By turbines of the same type, turbines are meant the identical parts of which are interchangeable.

Table 10.2-3 **Gears and couplings of main machinery**[1, 2, 3]

Ser. No.	Spare parts	Number of spare parts depending on the navigation area	
		unrestricted, **A**	restricted **R1, A-R1**
1	Plain bearing bushes of gears and couplings of each type and size fitted	1 set per bearing	
2	Pads of thrust block with liners or adjusting rings of each type and size fitted, with assorted liners for one face of thrust	1 set	
3	Roller type bearings of each type and size fitted, if used	1 set	

[1] Spare parts are necessary for the case of eventual replacement at sea by the crew.

[2] When several gears and couplings of the same type are used, spare parts are required for one gear or coupling, respectively. By gears and couplings of the same type, those gears and couplings are meant the identical parts of which are interchangeable.

[3] Supply is mandatory.

Table 10.2-4 **Shafting, propellers and active means of the ship's steering**

Ser. No.	Spare parts	Number of spare parts depending on the navigation area		Supply of spare parts
		unrestricted, **A**	restricted **R1, A-R1**	
1	2	3	4	5
1	Shafting			
1.1	Thrust block of shaftline			
1.1.1	Pads for ahead face of Mitchel type thrust block, where used	1 set		M
1.1.2	Inner and outer race with rollers where roller thrust bearings are used	1 set		R
1.2	Coupling bolts with nuts for flanges and shaft couplings, each type and size fitted	1 set of fittings		R

End of Table 10.2-4

1	2	3	4	5
2	Propellers			
2.1[1]	Detachable propeller blades complete with securing items (for icebreakers and ships with ice categories **Ice4–Ice6** only)	2 per propeller	–	M
2.2[1]	CPP blades complete with securing items (for icebreakers and ships with ice categories **Ice4–Ice6** only)	2 per propeller	–	M
2.3	Spare parts for arrangements of CP-propellers, steerable propellers, vertical axis propellers and servicing systems except those mentioned in items 2.1 and 2.2, depending on propeller type	On agreement with the Register	–	M

[1] Detachable blades are necessary for the case of eventual replacement by the crew when afloat.

Table 10.2-5 **Auxiliary machinery[1]**

Ser. No.	Spare parts	Number of spare parts depending on the navigation area	
		unrestricted, **A**	restricted **R1, A-R1**
1	Piston pumps		
1.1	Valves with seats and springs, each type and size fitted	1 set	**–**
1.2	Piston rings of each type and size fitted	1 set	1 set
2	Centrifugal pumps		
2.1	Bearings of each type and size fitted	1	
2.2	Rotor seals of each type and size fitted	1	
3	Rotary pumps (screw and gear pumps)		
3.1	Bearings of each type and size fitted	1	
3.2	Rotor seals of each type and size fitted	1	
4	Compressors		
4.1	Suction and delivery valves, each type and size fitted in one unit	1/2 set	
4.2	Piston rings of each type and size fitted in one piston	1 set	

[1] Supply is recommended.

Table 10.2-6 **Ship equipment and deck machinery[2]**

Ser. No.	Spare parts	Number of spare parts depending on the navigation area	
		unrestricted, **A**	Restricted **R1, A-R1**
1	2	3	4
	Hydraulic steering gears		
1	Cylinder plunger seals, sealing rings for pumps of each type and size fitted	1 set	

End of Table 10.2-6

1	2	3	4
2[1]	Valve springs of each type and size fitted	1	
3[1]	Safety and non-return valves of each type and size fitted	1	–
4	Ball or roller bearings	1 set for 1 pump	
5	Special pipe connections of steering gear	1 set	

[1] The list of spare parts is drawn up on agreement with the Register.
[2] Supply is mandatory.

Table 10.2-7 **Steam boilers, thermal fluid boilers, pressure vessels and heat exchangers**

Ser. No.	Spare parts	Number of spare parts depending on the navigation area	Supply of spare parts
		unrestricted, **A**, restricted **R1, A-R1**	
1	2	3	4
1	Steam boilers (main and auxiliary for essential services), thermal fluid boilers		
1.1	Springs of safety valves of each type and size fitted	1 per boiler	M
1.2	Water gauge glasses, complete	1 per boiler	M
1.3[1]	Oil fuel burners, complete, each type and size fitted	1 per boiler	M
1.4[1]	Fuel atomizers complete with washers	1 per boiler	M
1.5	Tube plugs of each diameter fitted, including superheater plugs	For 4% of tubes but at most 20 pcs.	M
1.6	Boiler pressure gauge of each type and size fitted	1 set for 1 boiler unit	M
1.7	Metal gaskets of special type for superheater and economizer valves	1 set for 1 boiler	R
1.8	Gaskets for manholes and other openings, each type and size fitted	1 set	R
2	Pressure vessels and heat exchangers		
2.1	Level gauge glasses of each type and size fitted	1	R
2.2	Gaskets and glands of special type for covers, manholes, openings and valves of each type and size fitted	1 set for 1 heat exchanger (pressure vessel)	R
2.3	Plugs for heat exchanger tubes	For 5% of tubes	M

[1] For boilers with automated burning units, the list of spare parts as per items 1.3 and 1.4 is drawn up on agreement with the Register.

Table 10.2-8 **Gas turbines (main and auxiliary)**

Ser. No.	Spare parts [1]	Number of spare parts depending on the navigation area		Supply of spare parts
		unrestricted, **A**	restricted **R1, A-R1**	
1	2	3		4
1	Flame tubes	1 set for 1 engine		M
2	Main burners	1 set for 1 engine		M
3	Auxiliary burners	1 set for 1 engine		M
4	Ignition arrangements, complete	1 set for 1 engine		M
5	Plasma igniters or ignition plugs	1 set for 1 engine		M
6	Spare parts for burners	1 set per 1 burner		M

[1] Additional spare parts as well as replaceable units (gas turbine-driven servo-machinery), the lifetime of which is less than the lifetime of the gas turbine, before shop repair shall be supplied by the gas turbine manufacturer on approval by the Register.

Legend for Tables 10.2-1–10.2-8:
M — mandatory, R — recommended.

11 MACHINERY TECHNICAL CONDITION MONITORING SYSTEMS

11.1 GENERAL

11.1.1 The requirements of this Section apply to the machinery technical condition monitoring systems, which have been approved by the Register as the classification survey items on the basis of the Planned Maintenance Scheme (PMS) (refer to 2.7, Part II "Survey Procedure and Scope" of the Rules for the Classification Surveys of Ships in Service) and condition control (CC).

11.1.2 Data of the machinery technical condition monitoring are intended for use:

by the Register Branch Office when carrying out surveys on the basis of PMS and CC;

by the ship crew to establish the terms for performing the machinery maintenance operations, i. e. providing maintenance on the "condition" basis;

by the Shipowner to assess the technical condition and to manage maintenance of ships, to schedule terms and scope of their repairs.

11.1.3 The composition of the equipment of the technical condition monitoring system, controlled parameters and frequency of their measurements, standards of the control item technical condition shall be approved by the Register when the survey system on the basis of PMS and CC is implemented on board the ship.

11.1.4 The organisational and normative and methodical principles of implementing technical condition monitoring systems on board the ship, submitting control data and assessment data of the technical condition of the control item are set out in 2.7, Part II "Survey Procedure and Scope" of the Rules for the Classification Surveys of Ships in Service.

11.2 CONTROL ITEMS AND PARAMETERS

11.2.1 The technical condition monitoring system may cover the following equipment:

main diesel engine, including turbocharger;

main turbine;

AMSS;

reduction gear;

shafting;

sterntube gear;

auxiliary diesel generators (turbogenerators);

systems maintaining operation of the main diesel engine (compressed air, fuel oil, lubricating oil and cooling);

steering gear.

11.2.2 On agreement with the Register, the ship may be equipped with the technical condition monitoring systems exercising control over:

the working process and wear of the cylinder and piston assembly of the main diesel engine;

the working process of the turbine;

the lubricating oil condition;

the vibration condition of the machinery;

the shock pulses of the roller bearings;

the electric values of the electrical equipment.

11.2.3 The conditions for acceptance of the technical condition monitoring results when carrying out surveys of the PMS and CC items are as follows:

the diagnostic parameters define the technical condition of the controlled item and are approved by the Register;

the limiting values of the diagnostic parameters have been determined on the basis of the requirements of the controlled item manufacturers and/or the Register;

the parameters used for the technical condition prediction shall be brought to standard conditions. The measured parameter values are brought to the standard conditions in accordance with 2.2.7, Part IX "Machinery";

the results of measurements, trend analysis and prediction of parameters shall be kept in a form accessible for the Surveyor: in the tabular form, in the form of graphs on paper media or, preferably, on the PC media;

the frequency of the diagnostic parameter measurements shall provide reliability of determination of the control item technical condition;

the measuring instruments used in the technical condition monitoring systems shall have appropriate documents on verification by a competent authority.

11.3 GENERAL REQUIREMENTS FOR TECHNICAL CONDITION MONITORING SYSTEMS

11.3.1 The technical condition monitoring systems may be constructed on the basis of built-in (fixed) condition monitoring systems, portable control facilities or may combine both.

11.3.2 The built-in technical condition monitoring systems of the main engines, as a rule, shall be integrated structurally with the centralized monitoring systems and be capable of using the data obtained from the sensors of the centralized control system. Technical condition monitoring system integrated with the centralized control system shall not affect the centralized monitoring functions.

11.3.3 The technical condition monitoring system integrated with the centralized control system shall incorporate the technical condition diagnosis functions with the aim to perform the maintenance and repair of the control item on the actual condition basis.

11.3.4 The built-in monitoring systems and their elements shall meet the requirements imposed on the ship automation systems (refer to Section 2, Part XV "Automation").

The built-in monitoring systems installed on board the ships under construction or while in service shall be approved by the Register.

The built-in monitoring systems installed on board the ships are subject to the technical supervision with respect to:

check for functioning;

selection of cable cross-section;

protection, insulation and earthing means;

zero influence exerted by these systems on the operation of the equipment related to the items of the technical supervision of the Register.

Failures in the operation of the built-in monitoring system shall not adversely affect the operation of the equipment.

11.3.5 The portable control facilities and procedures for their application may be provided on board the ships under construction (or in service) after agreement with the Register. The basis for the agreement is the attestation thereof and conclusion (on the basis of examination of the necessary materials and/or carrying out of tests) of a competent organization regarding techniques and means for diagnosis of the ship facilities.

11.3.6 The technical condition monitoring system shall provide for recording the diagnostic parameter values, their trend analysis, prediction of the control item technical condition. The condition prediction is performed on the basis of the previous history of diagnostic parameters with sufficient number of their measurements.

11.3.7 The requirements for computers used in the technical condition monitoring systems are similar to the requirements of Section 7, Part XV "Automation".

11.3.8 The basic values of the diagnostic parameters used as initial (reference) data during the technical condition monitoring shall be obtained under the specific conditions of draught and the ship speed (at sea) and under operating conditions of the main engines and auxiliaries.

The basic data may be obtained on acceptance trials or on maiden voyage for a newbuilding or on another operational voyage under steady operating modes of the control items agreed with the Register.

11.4 TECHNICAL DOCUMENTATION

11.4.1 The following types of documentation on the technical condition monitoring system shall be submitted to the Register for review and approval:

.1 functional description with indication of the technical data and operating conditions (no approval stamp is affixed);

.2 methodological guidelines (instructions) for making measurements and control data processing (no approval stamp is affixed);

.3 test program for the built-in monitoring systems.

11.5 REQUIREMENTS FOR WORKING LUBRICATING OIL PARAMETERS

11.5.1 The requirements for the controlled parameters of working lubricating oils shall be consistent with the type of equipment to be surveyed. Oil grades and methods of oil sampling for analysis shall be indicated for each machinery. The oil sampling location shall be clearly described.

11.5.2 The range of the characteristics and rejected parameter values of the oils to be analysed are established by a developer of the monitoring system and agreed with the Register.

11.5.3 The oil sample shall be analysed by a recognized shore-based laboratory. On board the ships the ship rapid analysis attested by a competent organisation shall be used (refer to 11.3.5).

11.5.4 The results of the oil analysis are submitted according to 11.2.3.

11.6 REQUIREMENTS FOR CONTROL OF THE DIESEL ENGINE WORKING PROCESS PARAMETERS

11.6.1 The requirements apply to the equipment for measuring pressure in the engine cylinder and fuel supply parameters.

11.6.2 To process the measurement results of the working process parameters, use is also made of the parameters measured in the alarm system.

In this case, interference shall not be introduced into the operation of the alarm system.

11.6.3 The Register shall be given specifications of sensors, measuring equipment and measurement results processing program (including list of calculated parameters and method of presentation thereof).

11.6.4 The electronic unit used for measurement of the working process parameters shall have dynamic characteristics providing for the measurement of the maximum gas pressure in cylinder.

11.6.5 Measurement of the pressure in cylinder and fuel supply parameters with the use of the sensors presented is allowed to be made not on all cylinders simultaneously, but for all that the steady operating conditions of the diesel engine shall be maintained.

11.6.6 The equipment for measurement, processing and presentation of the cylinder pressure curve (indicator diagram) and the fuel supply characteristics shall provide for the analysis thereof with a resolution of not less than one degree of the crankshaft rotation.

11.6.7 The indicator diagram processing program shall calculate for each cylinder:

mean indicated pressure;

cylinder indicated power;

maximum cylinder combustion pressure;

maximum compression pressure;

pressure on compression line at point 12° before the top dead centre (TDC);

pressure on expansion line at point 36° after the TDC;

the crankshaft rotation angle corresponding to the maximum combustion pressure;

ignition advance angle.

11.6.8 The fuel supply parameters processing program shall determine:

fuel injection beginning;

fuel injection time angle;

maximum fuel pressure.

11.6.9 The processing program shall provide for comparison of the loading in cylinders.

Permissible deviations of the working process parameters from the average over the cylinders:

mean indicated pressure — not more than ± 2.5%;

maximum combustion pressure — not more than ± 3.5%;

compression end pressure — ± 2.5%.

The cited values of the combustion pressure in any cylinder shall not be less than 85% of the value obtained on basic tests.

The results of basic tests are considered to mean the results of the acceptance tests of the diesel engine on board or special tests on operational voyage (refer to 11.3.8).

11.6.10 The measurement data shall be submitted according to 11.2.3.

11.7 REQUIREMENTS FOR CONTROL OF WEAR PARAMETERS OF THE ENGINE CYLINDER AND PISTON ASSEMBLY

11.7.1 The parameter, which defines the engine cylinder and piston assembly condition (its wear), is the tightness of the combustion chamber.

11.7.2 The tightness of the combustion chamber is measured by a special instrument: pneumoindicator, which is a flowmetering device set at a particular cylinder diameter.

11.7.3 The methods for determination of the cylinder tightness and the standards for the cylinder and piston assembly condition shall be presented by the system developer.

11.7.4 The results shall be submitted according to 11.2.3.

11.8 REQUIREMENTS FOR CONTROL OF VIBRATION PARAMETERS

11.8.1 The items of vibration condition monitoring on board the ship are machinery of rotary type listed in 11.2.1 as well as piston compressors.

11.8.2 For the purpose of the machinery vibration condition monitoring, use shall be made of the following equipment, which provides for the measurement and processing of the vibration parameters: root-mean-square values of vibration rate or vibration acceleration in 1/3-octave band and in octave band, and the data analysis in temporal area:

vibrometers-analyzers;

vibration diagnosis systems performing measurement, processing, storage and spectrum analysis of the vibration parameters.

11.8.3 The basic requirements for the equipment used in the vibration condition monitoring system:

the housing of the vibrometer-analyzer shall correspond to the IP54 protection type (refer to 2.4.4.2, Part XI "Electrical Equipment");

frequency range — not less than 4 to 16,000 Hz;

dynamic range — not less than 70 dB.

Special requirements for the vibration diagnosis systems:

the possibility of operating according to a process chart, which ensures performance of at least one complete measurement of the vibration parameters on all the monitoring system objects;

the possibility of transferring data to computer.

11.8.4 The composition of the vibration condition monitoring equipment and organization of the performance thereof shall be agreed upon with the Register when the PMS and CC based survey system is being implemented on board the ship.

11.8.5 When performing the vibration condition monitoring, consideration shall be given to the provisions of 18.7, Part V "Technical Supervision during Construction of Ships" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

11.8.6 The requirements for the installation and attachment of the vibration pickup on the controlled item shall be provided. The preference shall be given to attachment of the pickup by a pin (screw). To realize such attachment method, pins shall be fitted beforehand at all measurement points. The vibration pickups may be installed on a magnet. Where the vibration pickups cannot be installed using a pin or magnet, manual vibration pickups may be used.

11.8.7 For each machinery, points and directions for measuring vibration parameters shall be indicated. The manufacturers' recommendations shall be used. Where no such recommendations are available, type lay-out diagrams of the machinery vibration measurement points shall be taken as a guide (refer to 9.2.5).

For the vibration condition monitoring, measurement may be restricted to one or two directions on one most loaded machinery bearing.

N o t e . For units consisting of a machinery and its driving unit (pump and electric motor, fan and electric motor), measurements are made on one machinery bearing and one motor bearing on the coupling side. When exercising control of the separator vibration condition, measurements shall be made in two radial directions on both motor bearings and in three directions on the separator bowl bearing.

11.8.8 Standardization of the condition on the basis of the controlled parameter vibration levels shall be displayed in the documentation of the technical condition monitoring system submitted to the Register for review (refer to 11.4.1).

It is necessary to use the recommendations of the control item manufacturer or to be guided by the Register standards (refer to Section 9).

11.8.9 The results shall be submitted according to 11.2.3.

11.9 REQUIREMENTS FOR CONTROL OF THE SHOCK PULSE

11.9.1 The condition of the roller bearings is assessed by a shock pulse method. The controlled machinery manufacturer, developer or supplier of the technical condition monitoring system may propose another method of roller bearing condition assessment. In this case, the proposed method shall be approved by the Register.

11.9.2 For the bearing condition control by shock pulse method, special instruments are used: shock pulse meters and/or roller bearing condition indicators, which shall meet the following basic requirements:

.1 range of controlled bearings:
internal diameter — 50 to 1000 mm;
speed — 10 to 30,000 min^{-1};
dynamic range — not less than 90 dB;

.2 as regards dust- and watertightness, the instrument housing shall correspond to IP54 protection type (refer to 2.4.4.2, Part XI "Electrical Equipment");

.3 instrument for control of the roller bearing condition may be combined with the vibrometer (refer to 11.8.2).

11.9.3 The instrument for control of the roller bearing condition shall be fitted with a built-in calibrator to verify precision of readings.

11.9.4 The measurement methods shall make it possible to separate the values of shock pulses arising due to the roller bearing against the background of the signals from other sources. The methods shall establish positions for other measurements to be made on the bearing housing on the basis of the maximum shock pulse value or contemplate special devices — measuring bolts, where there is no direct access to the bearing housing.

11.9.5 The shock pulse standards defining lubrication condition and roller bearing damages shall be presented by the manufacturer of the technical condition monitoring system.

11.9.6 The results of control shall be submitted according to 11.2.3.

11.10 REQUIREMENTS FOR THE TREND ANALYSIS OF THE DIAGNOSTIC PARAMETERS AND FOR THE TECHNICAL CONDITION PREDICTION

11.10.1 The processing program for the diagnostic parameters measured by the built-in condition monitoring systems shall contemplate a trend analysis and prediction of the parameter changing.

The trend analysis of the diagnostic parameters measured by the portable control facilities shall be made after each last measurement.

11.10.2 The parameter trend is based on the measurements made during the period between special surveys with a frequency not less than 4 to 5 measurements at approximately equal time intervals.

11.10.3 The controlled item condition is predicted for the forthcoming time period between annual surveys.

The prediction is made either on the basis of the past history of the parameters defining condition or on the basis of the known rate of the parameter change. On completion of the measurement, the prediction shall be adjusted.

11.10.4 Based on the prediction results, the frequency of the condition control may be changed.

If the prediction results indicates that the limiting values of the controlled parameters can be attained, the intervals between the measurements shall be reduced, the causes of the condition degradation established and the maintenance planned.

11.10.5 If the item condition is described by the several independent parameters, prediction shall be made for each parameter. In this case, maintenance becomes necessary when any of the parameters to be predicted reaches the limiting value.

11.10.6 The monitoring system shall be accompanied by the prediction procedure. Along with that, the Register shall be given data confirming reliability of the procedure.

12 QUALITATIVE FAILURE ANALYSIS FOR PROPULSION AND STEERING ON PASSENGER SHIPS

12.1 APPLICATION

12.1.1 The requirements of the present Section refer to the qualitative failure analysis for propulsion and steering for new passenger ships built not earlier than on July 1, 2010, including those having a length of 120 m or more or having three or more main vertical zones (refer to 2.2.6.1, Part VI “Fire Protection”) in compliance with the revised SOLAS Chapter II-2, Regulation 21 (IMO resolution MSC 216(82), Annex 3).

12.1.2 For ships having at least two independent means of propulsion and steering to comply with SOLAS requirements for a safe return to port, the following shall be provided:

.1 knowledge of the effects of failure in all the equipment and systems due to fire in any space, or flooding of any watertight compartment that could affect the availability of the propulsion and steering;

.2 solutions to ensure the availability of propulsion and steering upon such failures specified in 12.1.2.1.

12.1.3 Ships not required to satisfy the safe return to port concept will require the analysis of failure in single equipment and fire in any space to provide knowledge and possible solutions for enhancing availability of propulsion and steering.

12.2 SYSTEMS TO BE CONSIDERED

12.2.1 The qualitative failure analysis shall consider the propulsion and steering equipment and all its associated systems which might impair the availability of propulsion and steering.

12.2.2 The qualitative failure analysis shall include:

.1 propulsion and electrical power prime movers (diesel engines, electric motors);

.2 power transmission systems (shafting, bearings, power converters, transformers, slip ring systems);

.3 steering gear (rudder actuator or equivalent for azimuthing propulsor, rudder stock with bearings and seals, rudder, power unit and control gear, local control systems and indicators, remote control systems and indicators, communication equipment);

.4 propulsors (propeller, azimuthing thruster, water jet);

.5 main power supply systems (electrical generators and distribution systems, cable runs, hydraulic, pneumatic);

.6 essential auxiliary systems (compressed air, oil fuel, lubricating oil, cooling water, ventilation, fuel storage and supply systems);

.7 control and monitoring systems (electrical auxiliary circuits, power supplies, protective safety systems, power management systems, automation and control systems);

.8 support systems (fighting, ventilation).

To consider the effects of fire or flooding in a single compartment, the analysis shall address the location and layout of equipment and systems.

12.3 FAILURE CRITERIA

12.3.1 Failures are deviations from normal operating conditions such as loss or malfunction of a component or system such that it cannot perform an intended or required function.

12.3.2 The qualitative failure analysis shall be based on single failure criteria (not two independent failures occurring simultaneously).

12.3.3 Where a single failure cause results in failure of more than one component in a system (common cause failure), all the resulting failures shall be considered together.

12.3.4 Where the occurrence of a failure leads directly to further failures, all those failures shall be considered together.

12.4 VERIFICATION OF SOLUTIONS

12.4.1 The shipyard shall submit a report to the Register that identifies how the objectives have been addressed. The report shall include the following information:

.1 the standards used for analysis of the design;

.2 the objectives of the analysis;

.3 any assumptions made in the analysis;

.4 the equipment, system or subsystem, mode of operation of the equipment;

.5 probable failure modes and acceptable deviations from the intended or required function;

.6 evaluation of the local effects (e. g. fuel injection failure) and the effects on the system as a whole (e. g. loss of propulsion power) of each failure mode as applicable;

.7 trials and testing necessary to prove conclusions.

N o t e . All stakeholders (the Register, shipowners, shipyard and manufacturers) shall as far as possible be involved in the development of the report.

12.4.2 The report shall be submitted prior to approval of detail design plans. The report may be submitted in two parts:

.1 a preliminary analysis as soon as the initial arrangements of different compartments and propulsion plant are known which can form the basis of discussion. This shall include a structured assessment of all essential systems supporting the propulsion plant after a failure in equipment, fire or flooding in any compartment casualty;

.2 a final report detailing the final design with a detailed assessment of any critical system identified in the preliminary report.

12.4.3 Verification of the report findings shall be agreed between the Register and the shipyard.