RUSSIAN MARITIME REGISTER OF SHIPPING

RULES

FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING SHIPS

VOLUME

2

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LIST OF CIRCULAR LETTERS AMENDING/SUPPLEMENTING NORMATIVE DOCUMENT

ND 2-020101-047-E

Rules for the Classification and Construction of Sea-Going Ships (2007), Volume 2

(Normative document No. and title)

Item No.	Circular letter No., date of approval	List of amended and supplemented paras
1.	011-6.15.1-277ц dated 26.11.07	Part XV: Section 7.
2.	007-2.1-278ц dated 27.11.07	Part VII: 1.1.1.
3.	009-1.8-281ц dated 29.11.07	Part VIII: 12.2.4.
4.	009-1.9-282ц dated 30.11.07	Part IX: 2.3.5.5.
5.	009-1.8-295ц dated 25.01.08	Part VIII: 4.3.1.2, 5.8.
6.	009-1.8-317ц dated 23.04.08	Part VIII: 2.5.3.1.

Rules for the Classification and Construction of Sea-Going Ships of Russian Maritime Register of Shipping have been approved in accordance with the established approval procedure. The date of coming into force of the present Rules is 1 October 2007.

The Rules are based on the tenth edition taking into account additions and amendments of Notice (2006) and those developed immediately before publication.

The unified requirements, interpretations and recommendations of the International Association of Classification Societies (IACS) and the relevant resolutions of the International Maritime Organization (IMO) have been taken into consideration in the Rules.

The Rules are published in four volumes. General Regulations for the Classification and Other Activity, Part I "Classification", Part II "Hull", Part III "Equipment, Arrangements and Outfit", Part IV "Stability", Part V "Subdivision", Part VI " Fire Protection" are included in Volume 1.

Part VII "Machinery Installations", Part VIII "Systems and Piping", Part IX "Machinery", Part X "Boilers, Heat Exchangers and Pressure Vessels", Part XI "Electrical Equipment", Part XII "Refrigerating Plants", Part XIII "Materials", Part XIV " Welding", Part XV "Automation", Part XVI "Hull Structure and Strength of Glass-Reinforced Plastic Ships and Boats" are included in Volume 2.

The text of the Rules in the Russian language published in 2007 shall be considered as the original.

Part XVII "Common Structural Rules for Double Hull Oil Tankers" is included in Volume 3. Common Structural Rules for Double Hull Oil Tankers of Russian Maritime Register of Shipping have been approved in accordance with the established approval procedure. The present Rules entered into force 1 April 2006. The Rules contain two parts, one part that is for information and does not constitute specific requirements and one part giving structural rules for double hull oil tankers of 150 m and greater. Subjects for information are given in Section 1 "Introduction" and Section 2 "Rule Principles". Specific rule requirements are given in Sections 3 to 12 and the Appendices. Editorial amendments to the Rules entered into force 1 April 2006 are included into the electronic version of the Rules as separate documents:

"Corrigenda 1. Rule Editorials and Clarifications (April 2006)";

"Corrigenda 2. Rule Editorials and Clarifications.

They are also available at the Register internal web site.

In case of contradictions in the texts the English text shall be considered as the original.

Part XVIII "Common Structural Rules for Bulk Carriers" is included in Volume 4. Common Structural Rules for Bulk Carriers of Russian Maritime Register of Shipping have been approved in accordance with the established approval procedure. The present Rules entered into force 1 April 2006. The Rules contain structural requirements for the classification of bulk carriers of 90 m in length or greater. The Rules contain 13 chapters. Editorial amendments to the Rules entered into force 1 April 2006 are included into the electronic version of the Rules as a separate document:

"Bulk Carriers CSR Corrigenda 1 (May 2006)".

They are also available at the Register internal web site.

In case of contradictions in the texts the English text shall be considered as the original.

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The present eleventh edition of the Rules, as compared with the previous edition of 2005, contains the following amendments:

NEW CLASSIFICATION SYMBOLS FOR SHIPS IN THE RS RULES

The distinguishing feature of the present edition of the Rules is the use of Latin alphabet for all the Register classification symbols instead of formerly applied Cyrillic. At that letters **KM**, **KE** and **K** in the character of classification remain unchanged.

Rules, edition 2005	Present Rules
КМ	**KM**
КЕ	**KE**
К	**K**

Distinguishing marks added to the character of classification have been changed as follows:

Ice category marks:

Rules, edition 2005	Present Rules
ЛЛ9	**Icebreaker9**
ЛЛ8	**Icebreaker8**
ЛЛ7	**Icebreaker7**
ЛЛ6	**Icebreaker6**
ЛУ9	**Arc9**
ЛУ8	**Arc8**
ЛУ7	**Arc7**
ЛУ6	**Arc6**
ЛУ5	**Arc5**
ЛУ4	**Arc4**
ЛУ3	**Ice3**
ЛУ2	**Ice2**
ЛУ1	**Ice1**

N o t e s . The first four categories are icebreakers (**Icebreaker6** — **9**), the second six categories are arctic ships (**Arc4** — **9**), the last three categories are non-arctic ships (**Ice1** — **3**).

Distinguishing marks for restricted areas of navigation:

Roman figures have been substituted by Arabic figures with a letter **R** placed in front of them (an abbreviation for «**restricted area**»), namely:

Rules, edition 2005	Present Rules
I	**R1**
II	**R2**
II СП	**R2-RSN**
III СП	**R3-RSN**
III	**R3**
стоечное	**Berth-connected ship**

N o t e s . **RSN** is an abbreviation for «**river-sea navigation**».

Distinguishing automation marks:

Rules, edition 2005	Present Rules
А1 **А2** **А3** **А1К** **А2К** **А3К** **А1И** **А2И** **А3И**	**AUT1** **AUT2** **AUT3** **AUT1-C** **AUT2-C** **AUT3-C** **AUT1-ICS** **AUT2-ICS** **AUT3-ICS**

N o t e.
AUT is an abbreviation for «**automation**»;
C is an abbreviation for «**computer**»;
ICS is an abbreviation for «**integrated computer system**».

Distinguishing mark of one-man bridge operated ship:

Rules, edition 2005	Present Rules
ОВНМ	**OMBO**

N o t e. **OMBO** is an abbreviation for «**one man bridge operation**».

Distinguishing mark for ships carrying equipment for fire fighting aboard other ships:

Rules, edition 2005	Present Rules
П1 **П2** **П1В** **П2В** **П3В**	**FF1** **FF2** **FF1WS** **FF2WS** **FF3WS**

N o t e. **FF** is an abbreviation for «**fire fighting**»,
WS is an abbreviation for «**water-screen system**».

Distinguishing mark for ships fitted with a dynamic positioning system:

Rules, edition 2005	Present Rules
ДИНПОЗ-1 **ДИНПОЗ-2** **ДИНПОЗ-3**	**DYNPOS-1** **DYNPOS-2** **DYNPOS-3**

Distinguishing mark for availability of main electrical propulsion plant:

EPP is an abbreviation for «electrical propulsion plant».

N o t e. This mark has been introduced for the first time.

Distinguishing mark of ships' enhanced survey program:

Rules, edition 2005	Present Rules
(ОРП)	**(ESP)**

Distinguishing mark for a ship intended for carriage of refrigerated cargo:

Rules, edition 2005	Present Rules
РЕФ	**REF**
(РЕФ)	**(REF)**

Descriptive notation in the class notation:
Descriptive notation is written in English, namely:

Rules, edition 2005	Present Rules
буксир	**Tug**
грунтоотвозное	**Hopper**
земснаряд	**Dredger**
катамаран	**Catamaran**
контейнеровоз	**Container ship**
крановое	**Crane vessel**
лесовоз	**Timber carrier**
навалочное	**Bulk carrier**
накатное	**Ro-ro ship**
наливное	**Tanker**
наливное (вода)	**Tanker (water)**
наливное (вино)	**Tanker (wine)**
наплавное	**Docklift ship**
нефтеналивное	**Oil tanker**
нефтесборное	**Oil recovery ship**
нефтенавалочное	**Oil/bulk carrier**
нефтерудонавалочное	**Oil/bulk/ore carrier**
пассажирское	**Passenger ship**
пассажирское накатное	**Ro-ro passenger ship**
плавдок	**Floating dock**
плавкран	**Floating crane**
понтон	**Pontoon**
рудовоз	**Ore carrier**
рыболовное	**Fishing vessel**
сборщик льяльных вод	**Bilge water removing ship**
спасатель	**Salvage ship**
специального назначения	**Special purpose ship**
судно обеспечения	**Supply vessel**
судовая баржа	**Shipborne barge**

and so on.

Examples of new class notations of ships of various types and designations:

KM⍟ Icebreaker7 [2] AUT2 EPP
KM⍟ Arc4 [1] AUT1-ICS OMBO Oil tanker (> 60 °C) (ESP)
KE★Berth-connected ship Floating hotel
K★R3 Floating crane
KM⍟ Ice3 R2-RSN AUT3 Timber carrier
KM⍟ Arc6 [1] AUT1 FF1WS Salvage ship

Distinguishing mark for ship's classed refrigerating plant:
Character of classification:

Rules, edition 2005	Present Rules
X	**REF**

N o t e . **REF** is an abbreviation for «**refrigerating**».
Distinguishing marks for survey have been remained unchanged.

Distinguishing marks:

Rules, edition 2005	Present Rules	Mark meaning
+	**PRECOOLING**	preliminary cooling of cargo
Р	**QUICK FREEZING**	capability for cooling or freezing fishery products
Н	**LG**	maintaining the required mode of liquefied gases carriage in bulk by a gas carrier
Г	**CA**	availability of gaseous medium control system for refrigerated spaces and/or thermal containers
К	**CONTAINERS**	cargo cooling carried in thermal containers

Note. **LG** is an abbreviation for «liquefied gas»;
CA is an abbreviation for «controlled atmosphere».

Examples of new class notations for refrigerating plants of various types and designations:

REF ✪ PRECOOLING
REF ✪ QUICK FREEZING
REF ✪ LG
REF ✪ CA; REF✪PRECOOLING CA
REF ✪ CONTAINERS; REF✪CONTAINERS CA

RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING SHIPS

PART VII. MACHINERY INSTALLATIONS

1. Chapter 1.2: the definition of "Machinery spaces of category A" has been specified in compliance with Regulation II-1/3.17, SOLAS-74 and IACS UI SC16;

the definition of "Fuel oil unit" has been amended in compliance with IACS UI SC16 (Rev. 1, June 2005).

2. Chapter 2.1: editorial amendments have been made.

3. Chapter 2.3: requirements regarding emergency machinery list values have been specified.

4. Chapter 4.2: requirements for entrance doors, air inlets and openings in oil tankers have been amended considering IACS UI SC188 (Rev. 1).

5. Chapter 4.3: requirements for fuel oil tanks arrangement have been specified.

6. Para 4.4.7: requirements for installation and assembly of machinery, equipment and arrangements using polymeric materials have been specified.

7. Chapter 4.5: requirements for means of escape from steering gear spaces have been specified.

8. Para 4.6.2: the reference has been specified.

9. Chapter 5.1: requirements for shafting have been specified (based on the research results).

10. Section 5: IACS UR M68 (Feb. 2005) has been considered – Chapters 5.1, 5.2, 8.1, 8.3, 8.8 have been amended.

11. Chapter 5.9: requirements for seals of the sterntube have been specified.

12. Chapter 7.2: requirements for AMSS construction have been specified (based on the research results).

13. Chapter 10.2: has been amended in compliance with IACS Recommendations 26-30 (Rev. 1, Nov. 2006) – requirements for the required minimum of spare parts have been specified.

14. Chapter 11.2: the applicability of requirements for AMSS has been extended.

PART VIII. SYSTEMS AND PIPING

1. Para 1.4.6.2: amendments have been introduced considering IACS UR S27 (Rev. 4, Nov. 2004).

2. A new Chapter 2.5 "Flexible hoses" has been introduced considering UR P2.12 (Jan. 2005).

3. A new Chapter 8.7 "Ballast systems for ballast water exchange at sea" has been introduced considering IACS UR P5 (May 2004).

4. Para 12.2.4: provisions of IACS UI SC192 (Dec. 2004) have been included.

5. A new Chapter 9.16 "Inert gas system" has been introduced. The requirements contained in this Chapter have been transferred from Chapter 3.9, Part VI "Fire Protection". In this Chapter para 9.16.12.13 has been revised considering amendments to IACS UR F20 (Rev. 5, Nov. 2005).

6. Chapter 12.2: para 12.2.2 has been supplemented in compliance with amendments to IACS UI SC99 (Rev. 1, Nov. 2005);

para 12.2.7 has been supplemented in compliance with amendments to IACS UI SC106 (Rev. 1, Nov. 2005);

the Chapter has been supplemented with the requirements for fire dampers (a new para 12.2.14) in compliance with IACS UI SC118 (Rev. 1 Nov. 2005).

7. Chapter 12.7: has been supplemented with the requirements for mechanical ventilation in open top container holds (a new para 12.7.9) in compliance with IACS UI SC110 (Rev. 1, Nov. 2005).

8. Chapter 13.8: para 13.8.1 has been supplemented with a clarification regarding the schemes on Figs 13.8.1-1, b and 13.8.1-2, b in compliance with IACS UI SC123 (Rev. 3, Dec. 2005).

9. A new Chapter 13.14 "Liquefied gas system for domestic needs" has been introduced.

10. A new Chapter 13.15 "Fuel oil supply system for galley equipment" has been introduced.

11. Section 17: has been revised based on the research results.

12. Chapter 17.2: IACS UR P6 (May 2005) has been included in para 17.2.6.

PART IX. MACHINERY

1. Chapter 1.2: has been amended with regard to IACS UR M10 (Rev. 2, Corr. 1).

2. Chapters 2.1 and 2.2: have been supplemented with the requirements for internal combustion engines with electronic control systems (based on the research results).

3. Chapter 2.3: has been amended in compliance with IACS UR M9 (Rev. 3, Corr. 1) and M10 (Rev. 2, Corr. 1).

4. Chapter 2.4: new requirements for crankshaft design in way of oil bores and fillets have been introduced in compliance with IACS UR M53 (Rev. 1, Dec. 2004) and considering research results.

5. Chapter 2.6: a requirement has been introduced as regards engine overload protection in operation.

6. Chapter 2.9: editorial amendments have been made.

7. Chapter 2.12: the requirement for diesel warning alarms has been specified.

8. Chapter 3.1: requirements for steam turbine design have been specified considering amendments to IACS UR M16 (Rev. 1, Corr. 1).

9. Chapter 4.2: some factor values have been specified, editorial amendments have been made.

10. Chapter 5.3: requirements for the design of fans have been specified in compliance with IACS UR F29 (Rev. 6, June 2005).

11. Chapter 7.1: requirements for hatch cover drives have been specified.

PART X. BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

1. Paras 1.1.1.1, 1.1.1.7 and 3.2.17: editorial amendments have been made.

2. Chapter 3.2: paras 3.2.15, 3.2.16 and 3.2.17 have been amended with regard to requirements for the design of waste-heat boilers with forced circulation aimed at improving their fire safety, based on research results.

3. Chapter 6.4: para 6.4.5.4.4 has been introduced in order to reduce the number of cross references.

PART XI. ELECTRICAL EQUIPMENT

1. Chapter 1.2: definition "Uninterruptible power system (UPS)" has been introduced.

2. Chapter 2.9: has been amended due to introduction of a new Chapter 19.11 "Ships carrying dangerous goods".

3. Chapter 4.1: has been amended in respect of permissible distribution systems of electrical power based on research results.

4. Section 5: has been supplemented with a new Chapter 5.11 "Electric drives for oil burner units of boilers and incinerators".

5. Section 6: has been supplemented with a new Chapter 6.9 "Lighting and illumination means of helidecks".

6. Chapter 7.5: IACS UI SC117 (Rev. 2, Nov. 2005) has been included; the requirements for fire detection system have been transferred from Part VI "Fire Protection".

7. Chapter 7.10: IACS UI SC180 (Rev. 2, Nov. 2005) has been included.

8. Chapter 7.11: the heading of the Chapter has been amended to read "Alarm of ultimate concentration of dangerously explosive and noxious gases"; the text of the Chapter has been amended.

9. Section 8: has been supplemented with a new Chapter 8.9 "Residual-current devices (RCD)" based on the research results.

10. Section 9: IACS UI SC72 (Rev. 1, Nov. 2005) has been included into Chapter 9.3;

a new Chapter 9.7 "Uninterruptible power system (UPS)" has been introduced in compliance with IACS UR E21 (May 2005).

11. Section 15: has been supplemented with a new Chapter 15.4 "Systems utilising heating cables".

12. Chapter 16.8: IACS UI E15 (Rev. 2, Feb. 2006) has been included.

13. Section 17: has been replaced by a new Section based on the research results.

14. Chapter 19.3: IACS UI SC42 (Rev. 1, Nov. 2005) has been included.

15. Section 19: has been supplemented with a new Chapter 19.11 "Ships carrying dangerous goods" considering IACS UI SC79 (Rev. 2, Sept. 2005).

PART XII. REFRIGERATING PLANTS

1. Para 3.1.1: has been specified.

PART XIII. MATERIALS

1. Chapters 1.1, 1.3, 3.1, 3.3, 3.4, 3.6, 3.7, 3.8: have been amended due to transfer of the main issues of technical supervision from Part XIII "Materials" of the Rules for the Classification and Construction of Sea-Going Ships to the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

2. Chapter 1.4: has been revised to unify requirements for marking and identification of materials. IACS UR W11 (Rev. 5, Rev. 6), W7 (Rev. 3), W8 (Rev. 2), W9 (Rev. 2), W10 (Rev. 2) were the basis of the amendments.

3. Paras 3.2.8, 3.3.8, 3.4.8, 3.5.8, 3.8.8, 3.9.8, 3.13.8, 3.14.8, 3.15.8, 3.16.1.9: have been revised due to unification of requirements for marking and identification of materials in Chapter 1.4.

4. Section 6: para 6.1.3 has been deleted due to transfer of its contents to the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships;

para 6.5 has been revised and replaced by a new para 6.5 "Corrosion-resistant coatings".

PART XIV. WELDING

1. Has been amended in compliance with IACS UR W17 (Rev. 3, 2004), W26 (Rev. 1, 2004) and W32 (2005).

PART XV. AUTOMATION

1. Table 2.4.1.5: has been amended due to introduction of aerosol fire extinguishing systems (Chapter 3.11, Part VI " Fire Protection").

2. Para 4.3.3: has been amended on the research results.

3. Para 6.1.1: has been amended to bring the text in compliance with 2.2.6.3, Part I "Classification".

4. Paras 8.5.4 and 8.5.6: references have been revised.

5. A new Section 9 "Anchoring positioning systems" has been introduced on the basis of the IMO "Code for the Construction and Equipment of Mobile Offshore Drilling Units, Consolidated Edition, 2001" (IMO Resolution A.649(16) as amended) and IEC 61892-5, Mobile and Fixed Offshore Units – Electrical Installations, Part 5: Mobile Units.

PART XVI. HULL STRUCTURE AND STRENGTH OF GLASS-REINFORCED PLASTIC SHIPS AND BOATS

1. No amendments have been introduced.

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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 defined in 1.2.8, 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 flashpoint 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".

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to general terminology of the Rules are given in Part I "Classification".

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

Auxiliary active means of the ship's steering is a propulsion and steering unit ensuring propulsion and steering of a ship at low speed or steering of a ship at zero speed when the ship is equipped with main means of propulsion and steering, and is used either in combination with the latter or when the main means of propulsion and steering are inoperative.

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

Among the essential auxiliary machinery are:

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

steam supply source;

condensate pump and arrangements used for maintaining vacuum in condensers;

the mechanical air supply for boilers;

an air compressor and receiver for starting or control purposes;

as well as machinery ensuring operation or functioning of:

boiler feed water systems;

the fuel oil supply systems for boilers or engines;

the sources of water pressure;

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

Exit is an opening in bulkhead or deck provided with closing means and intended for the passage of persons.

Means of escape comprise the escape routes leading from the lowest part of the machinery space floor plates to the exit from that space.

Main active means of the ship's steering is a propulsion and steering unit being part of the propulsion plant.

Main machinery is the machinery being part of the propulsion plant.

Technical condition diagnosis is a process of establishing causes for the deviation of diagnostic parameters when performing condition monitoring and/or detecting malfunctions, as a rules, by stripless methods in order to provide maintenance and repair on the actual condition basis.

Remote control is the changing of the speed and direction of rotation as well as starting and stopping of the machinery from a remote position.

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

Machinery spaces are all machinery spaces of category A and all other spaces containing main machinery, shafting, boilers, fuel oil units, steam and internal combustion engines, generators and other major electrical machinery, fuel oil filling stations, ventilation and air-conditioning installations, refrigerating plants, steering engines, stabilizing equipment and similar spaces, and trunks to such spaces.

Machinery spaces of category A are those spaces and trunks to such spaces, which contain:

internal combustion machinery used for main propulsion; or

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

oil-fired boilers or fuel oil units.

Local control station is a control station fitted with controls, indicators, means of communication (if necessary), located in proximity to, or directly on, the engine.

Torsional vibration stresses are stresses resulting from the alternating torque, which is superimposed on the mean torque.

Dead ship condition (as well as black out) is a condition, under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliaries shall be assumed available. It is assumed that means are available to start the emergency generator at all times.

Equipment comprises all types of filters, heat exchangers, tanks and other arrangements ensuring normal operation of a machinery installation.

Common control station is a control station intended for simultaneous control of two or several main engines and fitted with indicating instruments, alarm devices and means of communication.

Cargo control room (CCR) is a room or part thereof where the control, monitoring means and alarm devices, related to performance of cargo handling operations are located; and onboard the tankers, in addition, means for monitoring and alarm of cargo, ballast, atmosphere parameters of cargo and ballast tanks and cargo pump rooms as well as discharge of oil containing and flushing water.

Technical condition prediction is a process of determining causes for the changes in control item for the forthcoming time period, based on the trend of the diagnostic parameter values during the preceding time period.

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

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.

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.

Fuel oil unit is any equipment used for the preparation and delivery of fuel oil (heated or unheated) to boiler, inert gas generator or engine (including gas turbines) and includes any fuel oil pumps, separators, filters and heaters at a pressure of more than 0,18 MPa.

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

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

Trend in diagnostic parameter (parameter trend) is a time history of the diagnostic parameter shown graphically or in other form (previous history of the parameter change).

1.3 SCOPE OF SURVEYS

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

1.3.2 Survey by the Register, including the approval of technical documentation according to 3.2.8, Part I "Classification", shall cover the following parts and components:

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

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

Table 1.3.2.3

Parts to be supervised

Nos	Item	Material	Chapter of Part XIII "Materials"
1	**Shafting**		
1.1	Intermediate, thrust and propeller shafts	Forged steel	3.7
1.2	Propeller shaft liners	Copper alloy Corrosion-resistant steel	4.1 On agreement with the Register
1.3	Half-couplings	Forged steel Cast steel	3.7 3.8
1.4	Coupling bolts	Forged steel	3.7
1.5	Sterntubes	Rolled steel Cast steel Forged steel Cast iron	3.2 3.8 3.7 3.9
1.6	Sterntube and strut bushes	Cast steel Copper alloy Forged steel Cast iron	3.8 4.2 3.7 3.9 3.10
1.7	Lining of sternbush bearing	Non-metallic materials Metal alloys	On agreement with the Register
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 **Arc4** to **Arc9** and icebreakers	Forged steel Cast steel	3.7 3.8
2.5	Casings of main AMSS in ice ships of ice categories **Arc4** to **Arc9** and icebreakers		

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 tests 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.

.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.

2 GENERAL REQUIREMENTS

2.1 POWER OF MAIN MACHINERY

2.1.1 The power of main machinery in ice-breakers shall be consistent with their category according to 2.2.3, Part I "Classification".

In ships strengthened for navigation in ice of categories **Ice2** to **Arc9** the power delivered to the propeller shaft P_{min}, in kW, shall not be less than

$$P_{min} = f_1 f_2 f_3 (f_4 \Delta + P_0) \qquad (2.1.1)$$

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 $f_1 f_2$ shall be taken in all cases not less than 0,85;
f_3 = $1{,}2\ B/\sqrt[3]{\Delta}$, but not less than 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"), t;
calculating P_{min} for ships strengthened for navigation in ice of **Ice2** and **Ice3** categories Δ need not be taken more than 80000 t;
f_4 and P_0 are given in Table 2.1.1.

Irrespective of the results obtained in calculating shaft power by Formula (2.1.1), it shall not be less than:

10000 kW for ice category **Arc9**;
7200 kW for ice category **Arc8**;
5000 kW for ice category **Arc7**;
3500 kW for ice category **Arc6**;
2600 kW for ice category **Arc5**;
1000 kW for ice category **Arc4**;
740 kW for ice categories **Ice3**, **Ice2**.

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

2.1.2 In icebreakers and ships with ice strengthening of categories **Arc6** to **Arc9**, turbines and internal combustion engines with mechanical transmission of power to the propeller may be utilized as main engines, provided use is made of the devices to protect turbines, reduction gears of gas-turbine geared sets and diesel-engine geared sets against the loads exceeding the design torque determined with regard to operation of such ships under ice conditions in compliance with the requirements of 4.2.3.2, Part IX "Machinery".

2.1.3 Propulsion plant shall provide sufficient astern power to maintain manoeuvring of the ship in all normal service conditions.

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

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

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

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

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

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

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

Table 2.1.1

Displacement Δ, t	Value	Ice strengthening category							
		Ice2	**Ice3**	**Arc4**	**Arc5**	**Arc6**	**Arc7**	**Arc8**	**Arc9**
$\Delta < 30000$	f_4	0,18	0,22	0,26	0,3	0,36	0,42	0,47	0,5
	P_0, kW	0	370	740	2200	3100	4000	5300	7500
$\Delta \geqslant 30000$	f_4	0,11	0,13	0,15	0,2	0,22	0,24	0,25	0,26
	P_0, kW	2100	3070	4040	5200	7300	9400	11600	14700

Table 2.3.1-1

List, motions and trim[1,2]

Machinery and equipment	Steady list either way under static conditions	List either way under dynamic conditions (rolling)	Steady trim by bow or stern	Dynamic inclination by bow or stern (pitching)
Main and auxiliary machinery	15,0	22,5	5,0[4]	7,5
Emergency machinery and equipment (emergency power installations, emergency fire pumps and their devices)	22,5[3]	22,5[3]	10,0	10,0

[1] Steady list and trim shall be taken into account simultaneously. Rolling and pitching are also to be considered simultaneously.
[2] On agreement with the Register, the values of inclinations may be altered depending on the type and dimensions of the ship and its service conditions as well.
[3] In gas carriers and chemical tankers emergency power sources shall remian operative when the ship is listed up to 30 deg.
[4] Where the length of the ship exceeds 100 m, the static trim by bow or stern may be taken as $(500/L)°$ where L is the length of the ship, in m, as defined in 1.1.3, Part II "Hull".

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

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

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

2.1.7 In the event of failure of one or all turbochargers (refer to 2.5.1, Part IX "Machinery") the machinery installation with one main internal combustion engine shall provide the ship speed at which the steerability of the ship is maintained. The main engine shall provide not less than 10 per cent of the rated power.

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

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 hull out of action.

2.1.11 Long run of the propulsion plant at all specified rates shall not lead to the overload of the main engine. The substantiation of the main engines required power is subject to special consideration by the Register in each particular case.

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 2.3.1-2

Air temperature

Installed location	Temperature range, °C
In enclosed spaces	0 to + 45
Machinery or boilers in spaces subject to temperatures exceeding 45°C and below 0°C	According to specific local conditions
On the open deck	−25 to + 45

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 use of grades 1 and 2 steel is subject to special consideration by the Register.

Copper alloys of Type CU3 and Type CU4 are admitted for propellers in all ships, except icebreakers and ships with ice categories **Arc7** to **Arc9**; copper alloys of Type CU1 and Type 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 sealings shall be made of corrosion-resistant materials.

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

2.5 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 $\pm 2,5$ per cent. With restricted speed ranges, the accuracy shall not be below 2 per cent, and the ranges shall be marked with bright colour on the scales of tachometers or in another way.

2.6 APPLICATION OF THE RELIABILITY MEASURES OF THE MACHINERY INSTALLATIONS

2.6.1 The reliability measures are established and specified during design and/or order of the machinery installation components by agreement of the appropriate technical documentation between the customer (shipowner) and the designer or supplier. The specific list of the reliability measures to be determined shall be established for each type of products with regard to the peculiarities of its application, failure effects, maintenance and repair system adopted.

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 navigating bridge, shall correspond to the ahead speed direction of the ship.

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

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

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

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

3.1.8 The main engine remote control system, with control from the bridge, shall be designed so as to provide an alarm in the event of failure. As far as practicable, the present propeller speed and thrust direction shall remain unchanged until control is transferred to a local station. Among other factors, the loss of power supply (electric, pneumatic or hydraulic power) shall not substantially affect the power of main engines or change the direction of propeller rotation.

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

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

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

25 s at full speed,

15 s at slow speed,

depending on the ship's speed.

3.2 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 navigating 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 navigating bridge;

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

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

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

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

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

.12 speed repeater.

3.2.2 The control stations on the wings of navigating bridge shall be equipped with devices of waterproof construction with controlled illumination. The control stations provided on the wings of the navigating 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 of main engines and propellers. Where, however, mechnaical linkage is fitted for remote-controlling the main engine, the local controls may be dispensed with on agreement with the Register.

3.2.6 Remote control of main machinery and propellers shall be performed only from one location. The transfer of control between the navigating 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 navigating bridge, the remote control of the main machinery shall be possible from one control station only. Such control stations may be equipped with interconnected controls.

3.2.7 Main engines shall be remotely operated from the wheelhouse by means of a single control element per propeller. In installations with CP-propellers, systems with two control elements may be used.

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

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 fittings 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 CCR shall be equipped with:

.1 means of communication according to 3.3.2;

.2 control means of:

.2.1 cargo, stripping and ballast pumps;

.2.2 fans servicing cargo area spaces or cargo holds;

.2.3 remotely controlled fittings of cargo and ballast systems;

.2.4 hydraulic system pumps (if provided);

.2.5 inert gas system;

.2.6 pumps and fittings 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 per cent of pressure for actuating of high-velocity devices);

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

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

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

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

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

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

.4.12 status of technical aids stipulated in 3.2.10;

.4.13 low water level in deck water seal (refer to 3.9.16.5, 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.

3.3 MEANS OF COMMUNICATION

3.3.1 At least two independent means shall be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room, from which the speed and 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 navigating 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 navigating 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 navigating 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 vocal 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 EUIPMENT

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.

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

4.2 ARRANGEMENT OF MACHINERY AND EQUIPMENT

4.2.1 Engines, boilers, equipment, pipes and fittings 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 gastight sealing glands supplied with effective lubrication from outside the pump room. As far as practicable, the construction of sealing gland shall protect it against being overheated.

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

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

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

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

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

4.2.7 Fuel oil units (refer to 1.2) as well as hydraulic units containing flammable liquids with working pressure above 1,5 MPa and not being a part of main and auxiliary engines, boilers, etc., shall be placed in a separate rooms with self-closing steel doors.

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

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

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

4.2.10 A blowdown gas caps fitted with gas fuel leakage detectors shall be installed above the 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 50 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 seatings and securely attached thereto. The construction of the seatings shall comply with the requirements of 2.11, Part II "Hull".

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

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

4.4.4 The main engines, their gears, thrust bearings of shafts shall be secured to seatings with fitted bolts throughout or in part. The bolts may be omitted, if appropriate stops are provided. Where necessary, fitted bolts shall be used to fasten auxiliary machinery to seatings.

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

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

Shock absorbing fastenings of the machinery and equipment shall:

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

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

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

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

4.4.7 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.

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

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

4.5 MEANS OF ESCAPE FROM MACHINERY SPACES

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

4.5.2 All the doors as well as the covers of companionways and skylights, which may serve as means of escape from machinery spaces, shall permit of opening and closing both from inside and outside. The covers of companionways and skylights shall be marked, as appropriate, and bear a clear inscription prohibiting to stow any loads on them.

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

4.5.3 The main and auxiliary machinery shall be so arranged as to provide passageways from the control stations and servicing flats to the means of escape from the machinery spaces. The width of passageways shall not be less than 600 mm over the whole length. In ships of less than 1000 gross tonnage the width of passageways may be reduced to 500 mm. The width of passageways along the switchboards shall comply with the requirements of 4.6.7, Part XI "Electrical Equipment".

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

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

.1 the means of escape shall consist of two sets of steel ladders as widely separated as possible, leading to doors (hatches) in the upper part of the space similarly separated and satisfying the requirements of 4.5.1. One of these ladders shall be located within a protected enclosure that satisfies the requirements of 2.1.4.5, Part VI "Fire Protection", from the lower part of the space to a safe position outside the space. Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that the heat is not transferred into the enclosure through non-insulated fixing points. The protected enclosure shall have minimum internal dimensions of at least 800×800 mm, and shall have emergency lighting provisions;

.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 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.

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 800×800 mm, and shall have emergency lighting provisions;

.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 paragraph 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, Part VI "Fire Protection".

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

5 SHAFTING

5.1 GENERAL

5.1.1 Shafting is a solid unit connecting the engine with the propeller. Optimum location of the shafting within the ship space shall be provided to ensure rational combination of loads of the shafting components, its supports and the engine. For this a number of design, scientific, technical and engineering measures shall be taken which are unified by a concept "Shafting alignment" and approved by the Register.

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

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

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

The shaft diameters determined for ships of restricted navigation areas **R2** and **R3** according to 5.2.1, 5.2.2 and 5.2.3 may be reduced by 5 per cent.

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 sterntube, means shall be provided which, in the event of the propeller shaft breaking, will prevent its slipping out of the sterntube; alternative arrangements shall be made to preclude flooding of the engine room, should the propeller shaft be lost.

5.1.5 The area between the sterntube and propeller boss shall be protected by a strong casing.

5.2 CONSTRUCTION AND DIAMETERS OF SHAFTS

5.2.1 The design diameter of the intermediate shaft d_{int}, in mm, shall not be less than

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

where F = factor taken depending on the type of machinery installation as follows:
95 for installations with main machinery of rotary type or main internal combustion engines fitted with hydraulic or electromagnetic couplings;
100 for other machinery installations with internal combustion engines;
P = rated power of intermediate shaft, kW;
n = rated speed of intermediate shaft, rpm.

5.2.2 The diameter of thrust shaft in external bearing on a length equal to thrust shaft diameter on either side of the thrust collar and, where roller thrust bearings are used, on a length inside the housing of thrust bearing, shall not be less than 1,1 times the intermediate shaft diameter determined by Formulas (5.2.1), (5.2.4). Beyond the said lengths the diameter of the thrust shaft may be tapered to that of the intermediate shaft.

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

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

where k = factor assumed as follows proceeding from the shaft design features:
for the portion of propeller shaft between the propeller shaft cone base or the aft face of the propeller shaft flange and the forward edge of the aftermost shaft bearing, subject to a minimum of 2,5 d_p:
k = 1,22, where the propeller is keyless fitted onto the propeller shaft taper or is attached to an integral propeller shaft flange;
k = 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:

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

where d_{red} = reduced diameter of the shaft, mm;
d = design diameter of the shaft, mm;
$R_{m_{sh}}$ = 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:

$$d \geqslant a\sqrt[3]{bs^2 R_{m_{bl}}/R_{eH}} \qquad (5.2.5)$$

where a = factor equal to:
10,8, with propeller boss diameter equal to, or less than 0,25D (D is the propeller diameter);
11,5, with propeller boss diameter greater than 0,25D;
b = actual width of expanded cylindrical section of the blade on the radius of 0,25R for unit-cast propellers and of 0,35R for CPP, m;
s = maximum thickness of expanded cylindrical section of the blade on the radii given for b, mm;
$R_{m_{b1}}$ = tensile strength of the blade material, MPa;
R_{eH} = yield stress of propeller shaft material, MPa.

5.2.6 If the shaft has a central hole, its bore shall not exceed 0,4 of the design diameter of the shaft.

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

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

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.

Table 5.2.5

Increase of shaft diameter, %

Shafts	Ships with ice categories							Icebreakers	
	Ice1, **Ice2**	**Ice3**	**Arc4**	**Arc5**	**Arc6**	**Arc7**	**Arc8**, **Arc9**	Centre shaft	Side shaft
Intermediate and thrust	0	4	8	12	13,5	15	*	18	20
Propeller	5	8	15	20	25	30	*	45	50

* Subject to special consideration by the Register in each particular case.

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.

If the keyway is made on the outboard end of the propeller shaft, the diameter need not be increased.

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

5.2.10 For intermediate shafts, thrust shafts and inboard end of propeller shafts the coupling flange shall have a minimum thickness of 0,2 times the required diameter of the intermediate shaft, or the thickness of the coupling bolt diameter (refer to Formula (5.3.2)) calculated for the material having the same tensile strength as the corresponding shaft, whichever is the greater.

The thickness of coupling flange of the outboard end of propeller shaft under the bolt heads shall not be less than 0,25 times the required diameter of the shaft at the flange.

5.2.11 The fillet radius at the base of aft flange of the propeller shaft shall not be less than 0,125 and for other flanges of shafts — shall not be less than 0,08 of the required diameter at the flange. The fillet may be formed by multiradii in such a way that the stress concentration factor will not be greater than that for a constant fillet radius.

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

5.2.12 Fillet radii in the transverse section of the bottom of the keyway shall not be less than 0,0125 of the diameter of the shaft, but at least 1 mm.

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

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

Where the outboard end of a propeller shaft having the diameter in excess of 100 mm is concerned, the distance between the cone base and the spoon-shaped keyway end shall be at least 0,2 of the shaft diameter required, with the ratio of the keyway depth to the shaft diameter less than 0,1 and 0,5 at least of the shaft diameter required, with the ratio of the keyway depth to the shaft diameter exceeding 0,1.

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

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

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

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

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

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

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

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

5.2.18 Continuous liners are recommended to be used.

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

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

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

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

5.3 SHAFT COUPLINGS

5.3.1 The bolts used at the coupling flanges of shafts shall be all fitted bolts of cylindrical section.

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

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

where d_{int} = diameter of intermediate shaft determined by Formula (5.2.1) taking into account the ice 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;
$R_{m_{sh}}$ = tensile strength of the shaft material, MPa;
R_{m_b} = tensile strength of the fitted coupling bolt material, MPa, taken:
$R_{m_{sh}} \leqslant R_{m_b} \leqslant 1{,}7R_{m_{sh}}$
but not higher than 1000 MPa;
i = number of fitted coupling bolts;
D = pitch circle diameter of coupling bolts, mm.

The diameter of bolts, by 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
$B = \frac{1}{E_y}\left(\frac{y^2+1}{y^2-1} + \nu_y\right) + \frac{1}{E_w}\left(\frac{1+w^2}{1-w^2} - \nu_w\right).$
For assemblies with a steel shaft having no axial bore, the factor B may be obtained from Table 5.4.3-1 using linear interpolation;
E_y = modulus of elasticity of the boss material, MPa;
E_w = modulus of elasticity of shaft material, MPa;
ν_y = Poisson's ratio for the boss material;
ν_w = Poisson's ratio for the shaft material; for steel $\nu_w = 0{,}3$;
y = mean factor of outside boss diameter;
w = mean factor of shaft bore;
D_w = mean outside shaft diameter in way of contact with the boss or intermediate sleeve (refer to Fig. 5.4.3):
without intermediate sleeve:

$D_{w1} = D_{y1}$; $D_{w2} = D_{y2}$; $D_{w3} = D_{y3}$;

$D_w = D_y$;

Table 5.4.3-1

Factor $B \times 10^5$, MPa^{-1}. Steel shaft $w = 0$, $E_w = 2{,}059 \times 10^5$ MPa, $\nu_w = 0{,}3$

Factor y	Copper alloy boss, $\nu_y = 0{,}34$ with E_y, MPa							Steel boss, $\nu_y = 0{,}3$ with $E_y = 2{,}059 \times 10^5$, MPa
	$0{,}98 \times 10^5$	$1{,}078 \times 10^5$	$1{,}176 \times 10^5$	$1{,}274 \times 10^5$	$1{,}373 \times 10^5$	$1{,}471 \times 10^5$	$1{,}569 \times 10^5$	
1,2	6,34	5,79	5,34	4,96	4,63	4,34	4,09	3,18
1,3	4,66	4,26	3,95	3,66	3,43	3,22	3,04	2,38
1,4	3,83	3,52	3,25	3,03	2,83	2,67	2,52	1,98
1,5	3,33	3,07	2,83	2,64	2,48	2,34	2,21	1,74
1,6	3,01	2,77	2,57	2,40	2,24	2,12	2,01	1,59
1,7	2,78	2,48	2,38	2,22	2,09	1,97	1,87	1,49
1,8	2,62	2,38	2,23	2,09	1,97	1,86	1,76	1,41
1,9	2,49	2,29	2,13	1,99	1,88	1,77	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**	**Arc4**	**Arc5**	**Arc6**	**Arc7**	**Arc8, Arc9**	Centre shaft	Side shaft
Propeller with shaft	1,05	1,08	1,15	1,20	1,25	1,30	*	1,45	1,50
Coupling with shaft	1,0	1,04	1,08	1,12	1,135	1,15	*	1,18	1,20

* Subject to special consideration by the Register in each particular case.

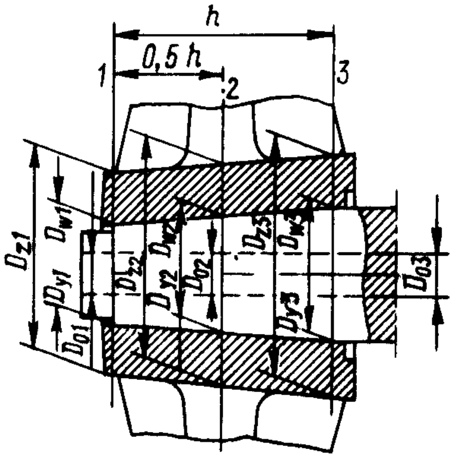


Fig. 5.4.3

with intermediate sleeve:

$D_{w1} \neq D_{y1}$; $D_{w2} \neq D_{y2}$; $D_{w3} \neq D_{y3}$;

$D_w \neq D_y$;

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

$$w = \frac{D_{01} + D_{02} + D_{03}}{D_{w1} + D_{w2} + D_{w3}} \text{ for the shaft;}$$

$$D_w = (D_{w1} + D_{w2} + D_{w3})/3;$$

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

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 are unavailable, refer to 2.2.2.6, Part III "Equipment, Arrangements and Outfit");
α_y = thermal coefficient of linear expansion of the boss material, 1/°C;
α_w = thermal coefficient of linear expansion of the shaft material, 1/°C;
t_e = temperature of the assembly in service conditions, °C;
t_m = temperature of the assembly 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:

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

where ΔD = interference fit for D_w, 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:

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

where A = shape factor of the boss determined by the formula

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

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

$C = \Delta h_r z$ 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; $\Delta h_r \geqslant \Delta h$;
ΔD_r = actual interference fit of the assembly with cylindrical mating surfaces, in cm; $\Delta D_r \geqslant \Delta D$;
R_{eH} = yield stress of the boss material, MPa.

Other terms are as defined in 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:

$$5{,}5a\sqrt{d} \leqslant l \leqslant a\lambda\sqrt{d} \qquad (5.5.2)$$

where l = span length (distance between the reactions of adjacent supports), m;
d = minimum outside shaft diameter in span, m;
n = shaft speed, in rpm;
λ = factor taken equal to:
14 when $n \leqslant 500$ rpm
or $300/\sqrt{n}$ when $n > 500$ rpm;
a = factor for bored shafts taken equal to $\sqrt[4]{1+b^2}$;
$b = d_o/d$ = ratio of the bore diameter d_o to 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

$$l \geqslant R/qd \qquad (5.6.1)$$

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

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

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

T a b l e 5.6.1

Bearing material	l/d[1], not less than	q[2], in MPa, not more than
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 = contact pressure taken up by the bearing, $q = R/(l \times d)$, where R = 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.

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

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

5.8 BRAKING DEVICES

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

5.9 HYDRAULIC TESTS

5.9.1 Propeller shaft liners and cast sterntubes shall be hydraulically tested to a pressure of 0,2 MPa upon completion of machining. Hydraulic tests of welded and forged-and-welded sterntubes may be omitted, provided non-destructive tests are carried out on 100 per cent of welds.

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

6 PROPELLERS

6.1 GENERAL

6.1.1 The requirements of this Section apply to metal fixed-pitch propellers, 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 being adopted as in the case of $r = 0{,}25R$;

for CPP — at the radius $0{,}35R$.

N o t e. In the design section, the blade thickness is determined the fillets neglected.

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

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

where A = coefficient to be determined from the nomograph in Fig. 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;
σ = $0{,}6R_{m_{bl}}$ + 175 MPa, but not more than 570 MPa for steels and not more than 610 MPa for copper alloys;
$R_{m_{bl}}$ = tensile strength of blade material, MPa;
n = speed at the rated output, rpm;
c = coefficient of centrifugal stresses to be determined from Table 6.2.1-2;
m = blade rake, mm;
D = propeller diameter, m.

T a b l e 6.2.1-1

Coefficient *k*

Ships without ice strengthening	Ships with ice strengthening categories							Icebreakers	
	Ice1, **Ice2**	**Ice3**	**Arc4**	**Arc5**	**Arc6**	**Arc7**	**Arc8**, **Arc9**	Centre propeller	Side propeller
8	9	10	11,2	12,5	13,2	14	**	16	$16 + \frac{23500}{P^*}$

*P = shaft power, kW.
** Subject to special consideration by the Register in each case.
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 per cent.
2. For reciprocating engines fitted with hydraulic or electromagnetic couplings, k may be reduced by 5 per cent.
3. For side propellers of ships without ice strengthening and with ice strengthening of categories **Ice1** and **Ice2**, k may be reduced by 7 per cent.

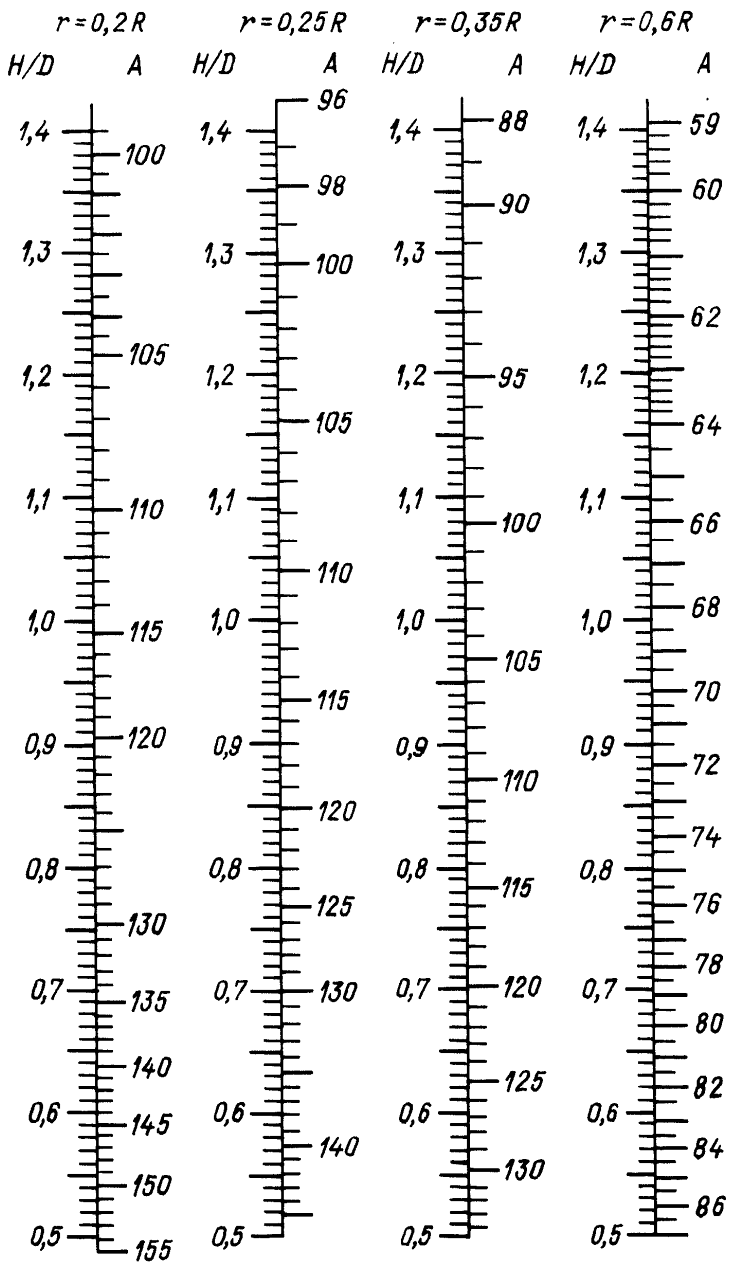


Fig. 6.2.1

Table 6.2.1-2

Coefficient *c*

r/R	*c*
0,20 0,25 0,35 0,60	0,50 0,45 0,30 0

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

The thickness of propeller blades in ships of river-sea navigation and in ships of restricted areas of navigation **R2** and **R3** may be reduced by 5 per cent.

Table 6.2.2

Ships without ice strengthening	Ships with ice strengthening categories				Icebreakers
	Ice1 to **Arc5**	**Arc6**	**Arc7**	**Arc8, Arc9**	
0,0035*D**	0,005*D*	0,0055*D*	0,006*D*	**	0,008*D*

*D = diameter of the propeller.
** Subject to special consideration by the Register in each case.

6.2.2 The blade tip thickness at the radius $D/2$ shall not be less than provided in Table 6.2.2. The leading and trailing blade edge thickness measured at

0,05 of the blade width from the edges shall not be less than 50 per cent of blade tip thickness.

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

6.2.4 The thickness of a high-skewed ($\theta > 25°$) blade with an asymmetrical outline of the normal projection shall be checked in compliance with the requirements of 6.2.1. Besides, the blade thickness at the radius 0,6*R* at a distance of 0,8 of the width of section *b* shall not be less than determined from the following formula:

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

where s = to be determined from Formula (6.2.1) at the radius 0,6*R*;
θ = angle, in degrees, equal to angle θ_1 or θ_2, whichever is the greater (refer to Fig. 6.2.4).

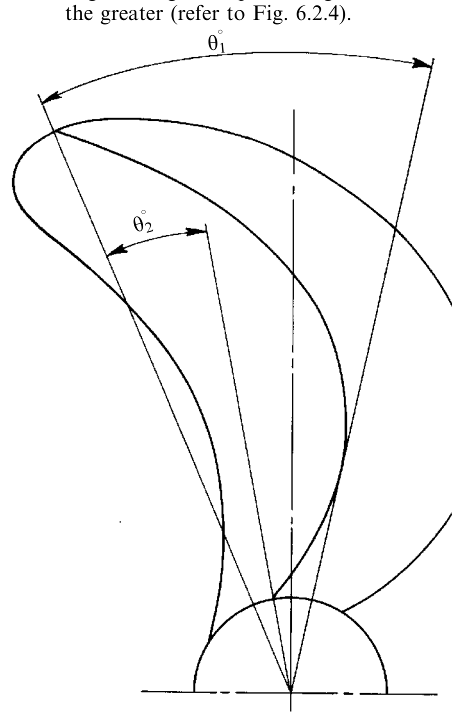


Fig. 6.2.4:
θ_1° = angle between the radius drawn through the blade tip and the radius tangent to the mid-chord;
θ_2° = angle between radii drawn through the blade tip and root section centre of the blade

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.

6.2.5 In icebreakers and ships provided with ice strengthening, the stresses in the most loaded parts of pitch control gear shall not exceed yield stress of the material, if the blade is broken in direction of the weakest section by a force applied along the blade axis over 2/3 of its length from the boss and laterally over 2/3 from the blade spindle axis to the leading edge.

6.3 PROPELLER BOSS AND BLADE FASTENING PARTS

6.3.1 Fillet radii of the transition from the root of a blade to the boss shall not be less than 0,04*D* on the suction side of the blade and shall not be less than 0,03*D* on the pressure side.

If the blade has no rake, the fillet radius on both sides shall be at least 0,03*D*.

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

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

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

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

where k = 0,33 in case of three bolts in blade flange, at thrust surface;
0,30 in case of four bolts in blade flange, at thrust surface;
0,28 in case of five bolts in blade flange, at thrust surface;
s = the maximum actual thickness of the blade at design root section (refer to 6.2.1), mm;
b = width of expanded cylindrical section of the blade at the design root section, m;
$R_{m_{bl}}$ = tensile strength of blade material, MPa;
R_{m_b} = tensile strength of bolt/stud material, MPa;
d = diameter of bolt pitch circle; with other arrangement of bolts, $d = 0{,}85l$ where l = the distance between the most distant bolts, m.

6.3.4 The securing devices of the bolts (studs), by which the blades are fastened to the 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

$$m \leqslant k m_p / R \qquad (6.4.1)$$

where m = mass of test load, kg;
m_p = mass of propeller, t;
R = propeller radius, m;
k = 0,75 for $n \leqslant 200$;
0,5 for $200 < n \leqslant 500$;
0,25 for $n > 500$.
n = rated speed of propeller, rpm.

Where the propeller mass exceeds 10 t, the coefficient k shall not be greater than 0,5, irrespective of the propeller speed.

6.5 CONTROLLABLE PITCH PROPELLERS

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

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

In ships with two CP-propellers one independent standby pump may be fitted for both CP-propellers.

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

In multi-screw ships, except icebreakers and ships with ice strengthening of categories **Arc5** to **Arc9**, this requirement need not be satisfied.

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

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

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

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

6.6 HYDRAULIC TESTS

6.6.1 The sealings fitted to the cone and flange casing of the propeller shaft (if such method of connection with the propeller boss is used) shall be tested to a pressure of at least 0,2 MPa after the propeller is fitted in place. If the above sealings are under pressure of oil from the sterntube or the propeller boss, they shall be tested in conjunction with testing of the sterntubes or propeller boss.

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

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

7 ACTIVE MEANS OF THE SHIP'S STEERING

7.1 GENERAL

7.1.1 The requirements of this Section apply to the 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 requirements for installation of AMSS machinery and equipment, materials and welding are given in 1.3, 2.4, 4.4.

7.1.4 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.

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

7.1.5 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.

7.1.6 The minimum service life of the rolling bearings shall be at least:

30000 hrs for the main AMSS,

10000 hrs for the AMSS used for dynamic positioning duty,

5000 hrs for the auxiliary AMSS.

7.1.7 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 Main AMSS shall be provided with an emergency turning mechanism.

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.

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 5.7.

On agreement with the Register, braking devices for the AMSS intended for the dynamic positioning and for the auxiliary AMSS may be dispensed with.

7.2.7 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 **Arc4** to **Arc9** 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.

7.3 ALARMS

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

.1 overload and emergency stop of prime mover;

.2 power failure in remote control and alarm system;

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

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

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

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

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

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

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

.2 frequency of the propeller rotation;

.3 blade turning angle or propeller pitch for CP-propeller plants;

.4 direction of thrust for fixed propeller plants;

.5 angular position of steerable propeller;

.6 power failure of 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.

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 diesel generators as well as to ICE-driven auxiliary machinery having a primary engine power of not less than 110 kW.

8.1.2 Torsional vibration calculations shall be prepared both for the basic variant and for other variants and conditions possible in the operation of the installation, as follows:

.1 maximum power take-off and idling speed (with the propeller blades at zero position) for installations comprising CP-propellers or vertical axis propellers;

.2 individual and simultaneous operation of main engines with a common reduction gear;

.3 reverse gear;

.4 connection of additional power consumers if their moments of inertia are commensurate with the inertia moments of the working cylinder;

.5 running with one cylinder missfiring, for installations containing flexible couplings and reduction gear; to be assumed not firing is the cylinder the disconnection of which accounts to the greatest degree for the increase of stresses and alternating torques;

.6 damper jammed or removed where single main engine installations are concerned;

.7 flexible coupling blocked due to breakage of its elastic components (where single main engine installations are concerned).

8.1.3 For ships of restricted area of navigation **R3**, calculations stipulated by 8.1.2.6 and 8.1.2.7 are not necessary.

No calculations shall be submitted if it is documented that the installation is similar to that approved earlier or that its mass inertia moments and torsion stiffness between masses do not differ from the basic ones by 10 per cent and 5 per cent accordingly or the calculation may be limited to determination of the natural frequencies if at this stage of the calculation it is established that the differences in the mass inertia moments and torsion stiffness between masses do not result in change of the natural frequency of any one of the modes under consideration by more than 5 per cent.

8.1.4 Torsional vibration calculations shall include:

.1 details of all the installation components: particulars of engine, propeller, damper, flexible coupling, reduction gear, generator, etc.;

speeds corresponding to the principal long-term operating conditions specified for operation under partial loads (half speed, slow speed, dead slow speed, trawling operation, zero-speed operation for installations comprising CP-propellers, main diesel generator conditions, etc.);

layouts of all installation operating conditions possible;

initial data for the design torsional diagram of the installation;

.2 natural frequency tables for all basic modes of vibration having a resonance up to the 12th order inclusive within the speed range (0 — 1,2)n_r with relative vibration amplitudes of masses and moments, and with scales of stresses (torques) for all sections of the system;

.3 for each order of all vibration modes under consideration:

resonance vibration amplitudes of the first mass of the system;

resonance stresses (torques) in all the system components (shafts, reduction gear, couplings, generators, compression or compression-key joints, etc.) and temperatures of the rubber components of flexible couplings as compared to relevant permissible values;

.4 total stresses (torques), where it is necessary to consider the simultaneous effect of disturbing moments of several orders, as compared to relevant permissible values;

.5 stress (torque) curves for the principal sections of the system with indication of permissible values for continuous running and rapid passage and of restricted speed ranges where these are assigned;

.6 conclusions based on the results of calculation.

8.1.5 The alternating torsional stress amplitude is understood as $(\tau_{max} - \tau_{min})/2$ as it can be measured on a shaft in a relevant condition over a repetitive cycle.

8.2 PERMISSIBLE STRESSES FOR CRANKSHAFTS

8.2.1 For main engine crankshafts of icebreakers and of ships with ice categories **Arc4** to **Arc9** 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",

$$\tau_C = \pm \tau_N ; \qquad (8.2.1\text{-}1)$$

when calculating a crankshaft by another method,

$$\tau_C = \pm 0{,}76 \frac{R_m + 160}{18} C_d ; \qquad (8.2.1\text{-}2)$$

within speed ranges lower than indicated

$$\tau_C = \pm \frac{\tau_N[3 - 2(n/n_r)^2]}{1{,}38} ; \qquad (8.2.1\text{-}3)$$

or

$$\tau_C = \pm 0{,}55 \frac{R_m + 160}{18} C_d[3 - 2(n/n_r)^2] \qquad (8.2.1\text{-}4)$$

where τ_C = permissible stresses, MPa;
τ_N = the maximum alternating torsional stress determined during crankshaft calculation from Formula (2.4.5.1), Part IX "Machinery" for the maximum value of W_P;
R_m = tensile strength of shaft material, MPa. When using materials with the tensile strength above 800 MPa, R_m = 800 MPa shall be adopted for calculation purposes;
n = speed under consideration, rpm. For tugs, trawlers and other ships which main engines run continuously under conditions of maximum torque at speeds below the rated speed throughout the speed range, $n = n_r$ shall be adopted and Formulas (8.2.1-1) and (8.2.1-2) shall be used. For the main diesel generators of ships with electric propulsion plants, all the specified values of n_r shall, by turn, be adopted as n, and in each of the ranges (0,9 — 1,05)n_r, Formulas (8.2.1-3) and (8.2.1-4) shall be used for partial loads;
n_r = rated speed, rpm;
C_d = 0,35 + 0,93$d^{-0,2}$ — scale factor;
d = shaft diameter, mm.

8.2.2 The total stresses due to torsional vibration within speed ranges prohibited for continuous running, but which may only be rapidly passed through shall not exceed the values determined by the following formulas:

for the crankshafts of main engines

$$\tau_T = 2\tau_C; \qquad (8.2.2\text{-}1)$$

for the crankshafts of engines driving generators or other auxiliary machinery for essential services

$$\tau_T = 5\tau_C \qquad (8.2.2\text{-}2)$$

where τ_T = permissible stresses for speed ranges to be rapidly passed through, MPa;
τ_C = permissible stresses determined by one of Formulas (8.2.1-1) to (8.2.1-4).

8.3 PERMISSIBLE STRESSES FOR INTERMEDIATE, THRUST, PROPELLER SHAFTS AND GENERATOR SHAFTS

8.3.1 Under conditions of continuous running, the total stresses due to torsional vibration shall not exceed the values determined by the formulas:

for the shafts of icebreakers and ships with ice categories **Arc4** to **Arc9** 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 $(0{,}9 — 1{,}05)n_r$

$$\tau_C = \pm 1{,}38\ \frac{R_m + 160}{18}\ C_k\, C_d\,; \qquad (8.3.1\text{-}1)$$

within speed ranges lower than indicated

$$\tau_C = \pm\ \frac{R_m + 160}{18}\ C_k\, C_d [3 — 2(n/n_r)^2] \qquad (8.3.1\text{-}2)$$

where R_m = tensile strength of the shaft material, MPa. When using the material with the tensile strength over 800 MPa (for intermediate and thrust shafts of alloyed steel) and over 600 MPa (for intermediate and thrust shafts of carbon and carbon-manganese steel, as well as for propeller shaft) $R_m = 800$ MPa and $R_m = 600$ MPa shall be assumed in the calculations accordingly;
C_k = factor obtained from Table 8.3.1;
for C_d, refer to 8.2.1.

Table 8.3.1

Coefficient C_k

Structural shaft type		C_k
Intermediate shaft, thrust shaft in external thrust bearing outside the area of roller bearing or the collar area, generator shaft	with integral coupling flanges or shrink fit couplings*	1,0
	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 5.8.9)	0,45
	with a longitudinal slot (refer to 5.2.8)	0,30**
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 stern-tube bearing and propeller ($k = 1{,}22$, $k = 1{,}26$, refer to 5.2.3)	0,55

* — when shafts may experience vibratory stresses close to the permissible stresses for continuous operation, the diameter increase in the compression joint shall be provided.
** — other C_k value may be substantiated and calculated.

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

$$\tau_T = \frac{1{,}7\tau_C}{\sqrt{C_k}}\,; \qquad (8.3.2)$$

for the shafts of generators driven by auxiliary engines, the value determined by Formula (8.2.2-2).

8.4 PERMISSIBLE TORQUE IN REDUCTION GEAR

8.4.1 For the case of continuous running or rapid passage, the alternating torques in any reduction gear step shall not exceed the permissible values established for the operating conditions by the manufacturer.

8.4.2 Where the values mentioned under 8.4.1 are not available, the alternating torque in any reduction gear step for the case of continuous running shall satisfy the following conditions:

within the speed range $(0{,}7 — 1{,}05)n_r$ for the main propulsion plants of icebreakers and ships with ice categories **Arc4** to **Arc9**, and within the speed range $(0{,}9-1{,}05)n_r$ for other ships,

$$M_{alt} \leqslant 0{,}3 M_{nom}; \qquad (8.4.2\text{-}1)$$

within speed ranges lower than indicated, the permissible value of alternating torque will be specially considered by the Register in each case, but, in any case:

$$M_{alt} \leqslant 1{,}3 M_{nom} — M \qquad (8.4.2\text{-}2)$$

where M_{nom} = average torque in the step under consideration at nominal speed, N/m;
M = average torque at the speed under consideration, N/m.

For the case of rapid passage, the alternating torque value 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 well-grounded cases, the Register may require torsional vibrations to be measured in auxiliary diesel generators and ICE-driven auxiliary machinery for essential services.

8.7.2 The results of measurement obtained on the first ship (unit) of a series apply to all the ships (units) of that series, provided their engine-shafting-propeller (driven machinery) systems are identical.

8.7.3 The free resonance vibration frequencies obtained as a result of measurement shall not differ from the design values by more than 5 per cent. Otherwise, the calculation shall be corrected accordingly.

8.7.4 The stresses shall be determined proceeding from the greatest vibration or stress amplitudes measured in the respective section of the torsiogram or oscillogram.

When estimating the total stresses due to vibration of several orders, the registered parameters shall undergo harmonic analysis.

8.8 RESTRICTED SPEED RANGES

8.8.1 Where the shaft stresses, torques in some installation components or temperature of the rubber componenets of flexible couplings arising due to torsional vibration exceed the relevant permissible values for continuous running determined in accordance with 8.2.1, 8.3.1, 8.4 to 8.6, restricted speed ranges are assigned.

8.8.2 No restricted speed ranges are permitted for the following speeds:

$n \geqslant 0{,}7n_r$ with respect to icebreakers and ships with ice categories **Arc4** to **Arc9**;

$n \geqslant 0{,}8n_r$ 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 categories **Arc7** to **Arc9** fitted with a FPP, blade frequency resonance shall be avoided within the range $(0{,}5 - 0{,}8)n_r$.

Barred speed range with one cylinder misfiring in case of one main engine on board the ship shall not influence the ship's steerability.

8.8.3 If all the other methods of lowering stresses (torques) due to torsional vibration prove ineffective, a vibration damper or antivibrator may be fitted where the values permitted by 8.2 to 8.6 are exceeded:

in the case of continuous running, within speed ranges where restricted speed range is not permitted or undesirable;

in the case of rapid passage, in any point of the speed range $(0 - 1{,}2)n_r$.

8.8.4 The vibration damper or antivibrator shall ensure lowering of stresses (torques) by not less than 85 per cent of the relevant permissible values at the resonance to which it is adjusted.

8.8.5 For icebreakers and ships with ice categories **Arc4** to **Arc9** 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 tolerance). The engine shall be stable in operation at the barred range boundaries.

For calculation purposes, the restricted speed range borders may be determined by the following formula:

$$\frac{16n_{res}}{18 - n_{res}/n_r} \leqslant n \leqslant \frac{(18 - n_{res}/n_r)n_{res}}{16} \qquad (8.8.6)$$

where n_{res} = resonance speed, rpm.

For CPP with the possibility of individual pitch and speed control, both full and zero pitch conditions shall be considered.

8.8.7 Restricted speed ranges shall be marked off on the tachometer in accordance with 2.5.2.

Information on restricted speed ranges and their borders shall be made available on plates fastened at all the stations, from which the installation may be controlled.

8.8.8 For the case of remote control of the main machinery from the wheelhouse, the requirements of 4.2.2.4 , Part XV "Automation" shall be complied with.

9 VIBRATION OF MACHINERY AND EQUIPMENT. VIBRATION STANDARDS

9.1 GENERAL

9.1.1 This Chapter 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*.

9.1.2 Vibration measurements shall be taken on all the first ships of a series being built at each shipyard, on the first ship of modified design, on the single buildings and on the ships undergone conversion.

Vibration measurements of machinery and equipment shall be taken during construction of the ship according to the program approved by the Register. Technical documentation as per the measurement results shall be submitted according to the requirements of 1.5.4, 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-specified rates of speed vibration exceeding established standards may be permitted, when these rates are not continuous.

9.1.6 Withdrawal 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 5×10^{-5}, mm/s, and 3×10^{-4}, m/s^2, accordingly.

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 root-mean-square 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. The points of vibration measuring are indicated in Fig. 9.2.5.

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 $\leqslant 3000$ min^{-1}.

9.3.2 Vibration of internal combustion engines and units including ICE 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 stated in Table 9.3.2 and shown in Fig. 9.3.2.

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 stated in Table 9.3.4 and shown in Fig. 9.3.4.

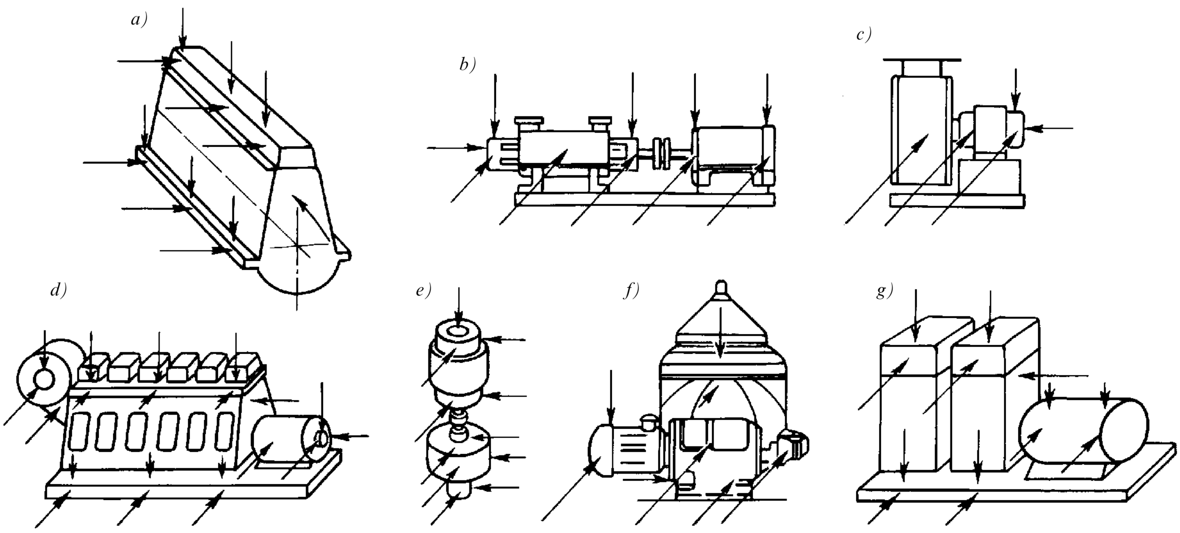


Fig. 9.2.5 Points of vibration measuring:
a) internal combustion engine; *b)* horizontal pump; *c)* fan; *d)* diesel-generator;
e) vertical pump; *f)* separator; *g)* piston compressor.
The points and directions of vibration measurement are shown by arrows

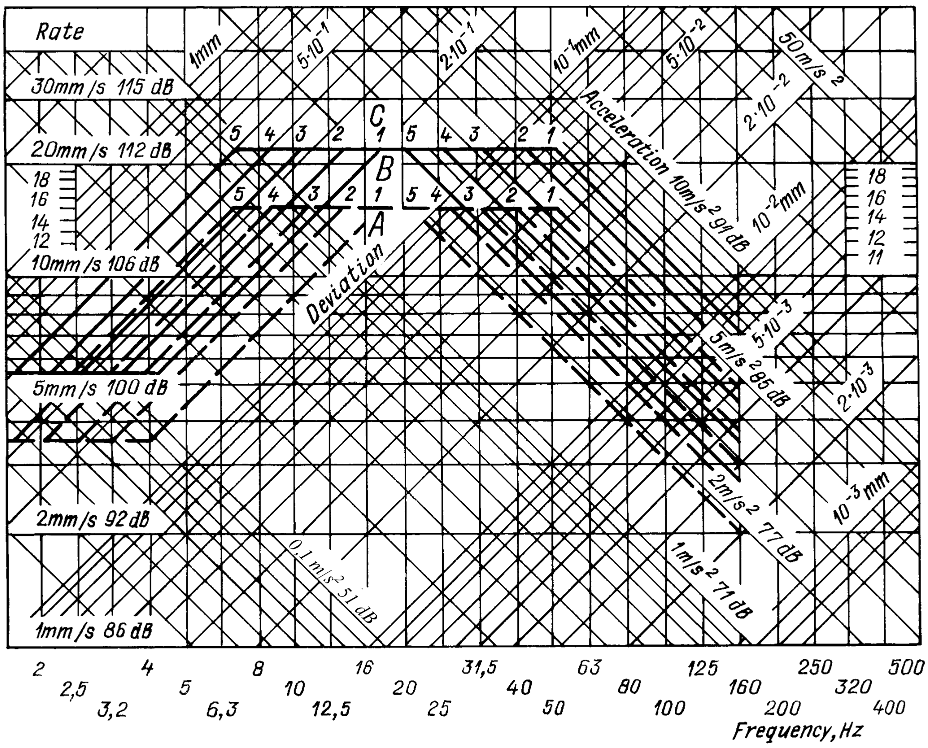


Fig. 9.3.2 Vibration standards for internal combustion engines with a piston stroke:
1 — under 30 cm; *2* — 30 to 70 cm; *3* — 71 to 140 cm; *4* — 141 to 240 cm; *5* — over 240 cm.
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

9.4 VIBRATION STANDARDS FOR MAIN GEARED TURBINES AND THRUST BEARINGS

9.4.1 The running vibration of 15000 to 3000 kW horse power main geared turbines measured on the bearing housings is considered permissible for Categories *A* and *B*, provided the root-mean-square values of vibration rate or vibration acceleration do not exceed the values stated in Table 9.4.1 and shown in Fig. 9.4.1.

9.4.2 For main geared turbines of less than 15000 kW power the vibration standards are 3 dB lower than the values stated in Table 9.4.1 and shown in 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 9.3.2

Vibration standards for internal combustion engines

Root-mean square frequencies of 1/3-octave bands, Hz	Engines with piston stroke, cm																			
	under 30				30 to 70				71 to 140				141 to 240				over 240			
	Permissible values of vibration rate																			
	Category *A*		Category *B*		Category *A*		Category *B*		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	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	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	4	98	5,6	101	4,5	99	6,3	102
2,5	4	98	5,6	101	4	98	5,6	101	4	98	5,6	101	4,6	99	6,3	102	5,6	101	8,0	104
3,2	4	98	5,6	101	4	98	5,6	101	4,5	99	6,3	102	5,6	101	8,0	104	7,1	103	10	106
4	4	98	5,6	101	4,5	99	6,3	102	5,6	101	8,0	104	7,1	103	10	106	8,9	105	12,5	108
5	4,5	99	6,3	102	5,6	101	8,0	104	7,1	103	10	106	8,9	105	12,5	108	11	107	16	110
6,3	5,6	101	8,0	104	7,1	103	10	106	8,9	105	12,5	108	11	107	16	110	14	109	20	112
8	7,1	103	10	106	8,9	105	12,5	108	11	107	16	110	14	109	20	112	16	110	22	113
10	8,9	105	12,5	108	11	107	16	110	14	109	20	112	16	110	22	113	16	110	22	113
12,5	11	107	16	110	14	109	20	112	16	110	22	113	16	110	22	113	16	110	22	113
16	14	109	20	112	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
20	16	110	22	113	16	110	22	113	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	16	110	22	113	12,5	108	18	111
31,5	16	110	22	113	16	110	22	113	16	110	22	113	12,5	108	18	111	10	106	14	109
40	16	110	22	113	16	110	22	113	12,5	108	18	111	10	106	14	109	8	104	11	107
50	16	110	22	113	12,5	108	18	111	10	106	14	109	8	104	11	107	6,3	102	8,9	105
63	12,5	108	18	111	10	106	14	109	8	104	11	107	6,3	102	8,9	105	5	100	7,1	103
80	10	106	14	109	8	104	11	107	6,3	102	8,9	105	5	100	7,1	103	4	98	5,6	101
100	8	104	11	107	6,3	102	8,9	105	5	100	7,1	103	4	98	5,6	101	3,2	96	4,5	99
125	6,3	102	8,9	105	5	100	7,1	103	4	98	5,6	101	3,2	96	4,5	99	2,5	94	3,6	97
160	5	100	7,1	103	4	98	5,6	101	3,2	96	4,5	99	2,5	94	3,6	97	2	92	2,8	95

Table 9.3.4

Vibration standards for turbo-compressors of internal combustion engines

Root-mean square frequencies of 1/3-octave bands, Hz	Engine turbo-compressors with piston stroke, cm																			
	under 30				30 to 70				71 to 140				141 to 240				over 240			
	Permissible values of vibration rate																			
	Category *A*		Category *B*		Category *A*		Category *B*		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	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	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	4	98	5,6	101	4,5	99	6,3	102
2,5	4	98	5,6	101	4	98	5,6	101	4	98	5,6	101	4,5	99	6,3	102	5,6	101	8,0	104
3,2	4	98	5,6	101	4	98	5,6	101	4,5	99	6,3	102	5,6	101	8,0	104	7,1	103	10	106
4	4	98	5,6	101	4,5	99	6,3	102	5,6	101	8,0	104	7,1	103	10	106	8,9	105	12,5	108
5	4,5	99	6,3	102	5,6	101	8,0	104	7,1	103	10	106	8,9	105	12,5	108	11	107	16	110
6,3	5,6	101	8,0	104	7,1	103	10	106	8,9	105	12,5	108	11	107	16	110	14	109	20	112
8	7,1	103	10	106	8,9	105	12,5	108	11	107	16	110	14	109	20	112	16	110	22	113
10	8,9	105	12,5	108	11	107	16	110	14	109	20	112	16	110	22	113	16	110	22	113
12,5	11	107	16	110	14	109	20	112	16	110	22	113	16	110	22	113	16	110	22	113
16	14	109	20	112	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
20	16	110	20	112	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
25	16	110	20	112	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
31,5	16	110	20	112	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
40	16	110	20	112	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
50	16	110	20	112	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
63	12,5	108	18	111	12,5	108	18	111	12,5	108	18	111	12,5	108	18	111	12,5	108	18	111
80	10	106	14	109	10	106	14	109	10	106	14	109	10	106	14	109	10	106	14	109
100	8	104	11	107	8	104	11	107	8	104	11	107	8	104	11	107	8	104	11	107
125	6,3	102	8,9	105	6,3	102	8,9	105	6,3	102	8,9	105	6,3	102	8,9	105	6,3	102	8,9	105
160	5	100	7,1	103	5	100	7,1	103	5	100	7,1	103	5	100	7,1	103	5	100	7,1	103
200	4,1	98	5,8	101	4,1	98	5,8	101	4,1	98	5,8	101	4,1	98	5,8	101	4,1	98	5,8	101
250	3,3	96	4,5	99	3,3	96	4,5	99	3,3	96	4,5	99	3,3	96	4,5	99	3,3	96	4,5	99
320	2,6	94	3,7	97	2,6	94	3,7	97	2,6	94	3,7	97	2,6	94	3,7	97	2,6	94	3,7	97
400	2,1	92	2,9	95	2,1	92	2,9	95	2,1	92	2,9	95	2,1	92	2,9	95	2,1	92	2,9	95
500	1,7	91	2,3	93	1,7	91	2,3	93	1,7	91	2,3	93	1,7	91	2,3	93	1,7	91	2,3	93

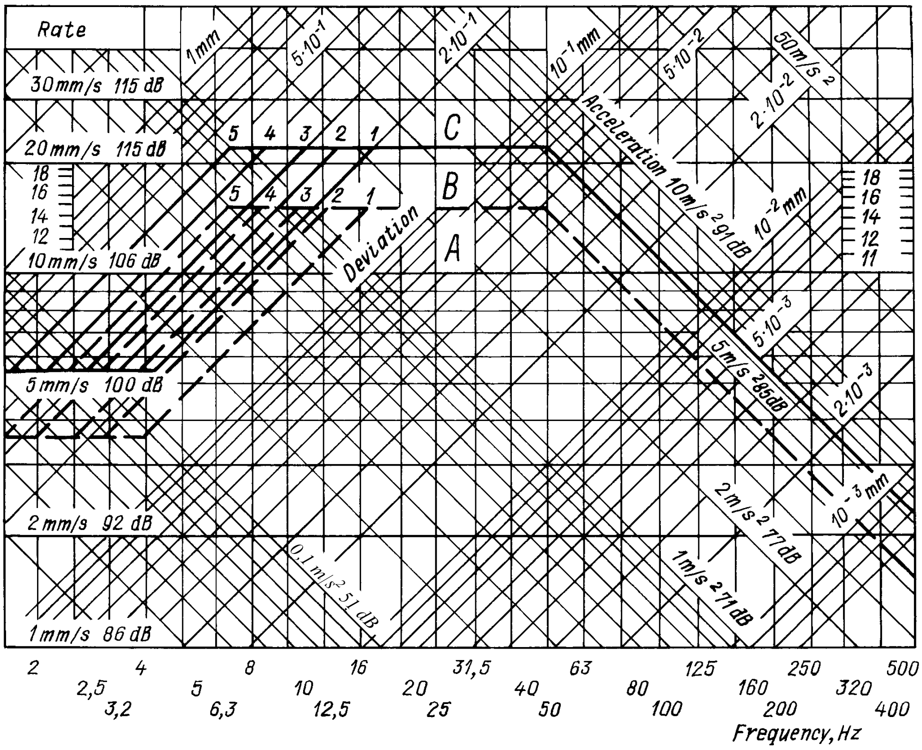


Fig. 9.3.4 Vibration standards for turbo-compressors of internal combustion engines: for *1, 2, 3, 4* and *5* — refer to Fig. 9.3.2;
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

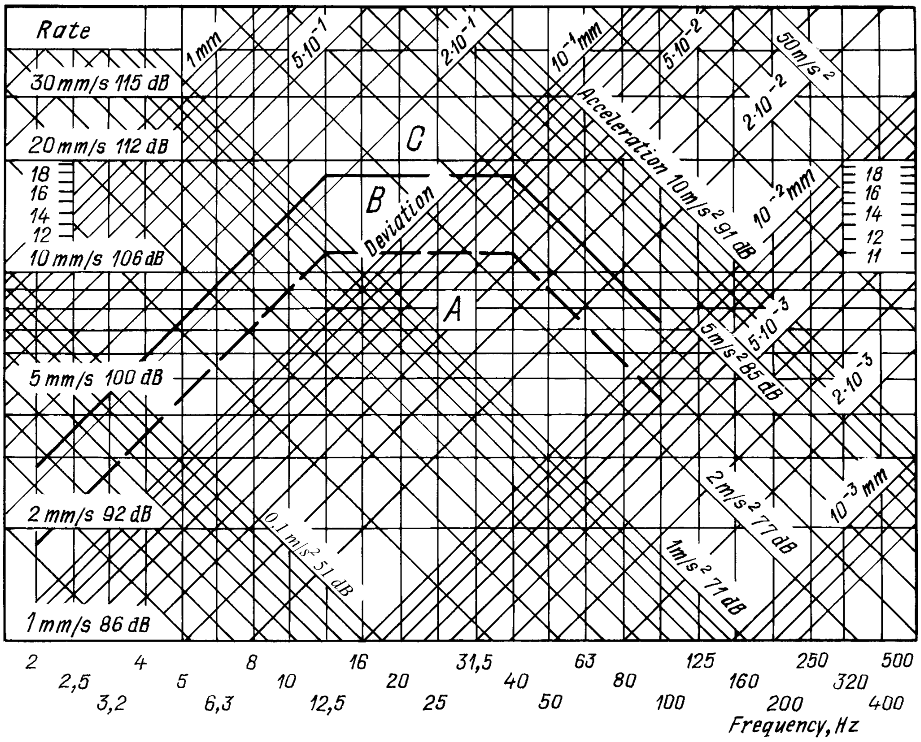


Fig. 9.4.1 Vibration standards for main steam geared turbines of 15000 to 30000 kW capacity and thrust bearings:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

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

Root-mean square frequencies of 1/3-octave bands, Hz	Main geared turbines and trust bearings				Boilers and heat exchangers				ICE-driven generators, turbo-drives and turbo-generators[1]				Piston compressors			
	Permissible values of vibration rate															
	Category *A*		Category *B*		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	mm/s	dB	mm/s	dB
1,6	1,5	90	2,5	94	3,5	97	5,6	101	1	86	1,6	90	2	92	3,2	96
2	1,9	92	3,1	96	3,5	97	5,6	101	1,3	88	1,9	92	2,5	94	4	98
2,5	2,4	94	3,8	98	3,5	97	5,6	101	1,5	90	2,4	94	3,1	96	5,1	100
3,2	3	96	4,8	100	4,4	99	7,1	103	1,9	92	3	96	4	98	6,4	102
4	3,7	97	6	102	5,6	101	8,9	105	2,3	93	3,7	97	5	100	38	104
5	4,6	99	7,5	104	7	103	11	107	2,9	95	4,6	99	6,2	102	10	106
6,3	5,7	101	9,3	105	8,8	105	14	109	3,6	97	5,7	101	7,9	104	12,5	108
8	7	103	11,5	107	10	106	16	110	4,5	99	7,1	103	10	106	16	110
10	8,8	105	14,5	109	10	106	16	110	5,6	101	8,9	105	10	106	16	110
12,5	11	107	18	111	10	106	16	110	7	103	11	107	10	106	16	110
16	11	107	18	111	10	106	16	110	7	103	11	107	10	106	16	110
20	11	107	18	111	10	106	16	110	7	103	11	107	10	106	16	110
25	11	107	18	111	10	106	16	110	7	103	11	107	10	106	16	110
31,5	11	107	18	111	10	106	16	110	7	103	11	107	10	106	16	110
40	11	107	18	111	10	106	16	110	7	103	11	107	10	106	16	110
50	8,8	105	14,5	109	8	104	12,5	108	7	103	11	107	10	106	16	110
63	7	103	11,5	107	6,3	102	10	106	7	103	11	107	7,9	104	12,5	108
80	5,7	101	9,3	105	5,2	100	8	104	7	103	11	107	6,2	102	10	106
100	4,6	99	7,5	104	—	—	—	—	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.

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.

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.

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.

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.

Table 9.5.1

Vibration standards for pumps, centrifugal separators and fans

Root-mean square frequencies of 1/3-octave bands, Hz	Pumps with the capacity of 15 to 75 kW				Centrifugal separators				Fans			
	Permissible values of vibration rate											
	Category *A*		Category *B*		Category *A*		Category *B*		Category *A*		Category *B*	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1,6	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
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

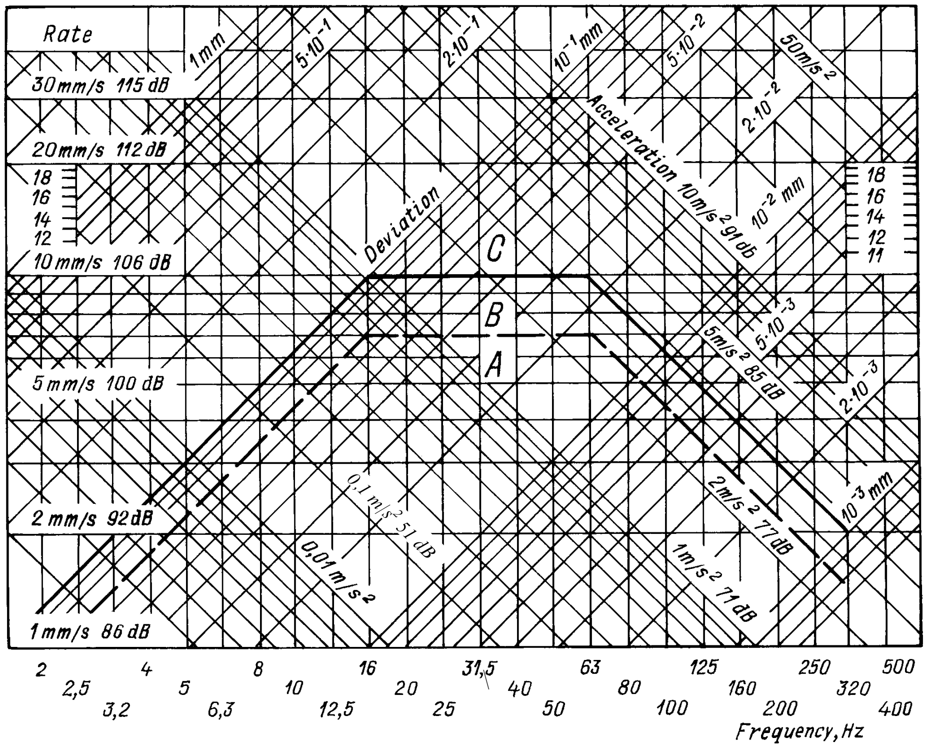


Fig. 9.5.1 Vibration standards for pumps with the capacity of 15 to 75 kW:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

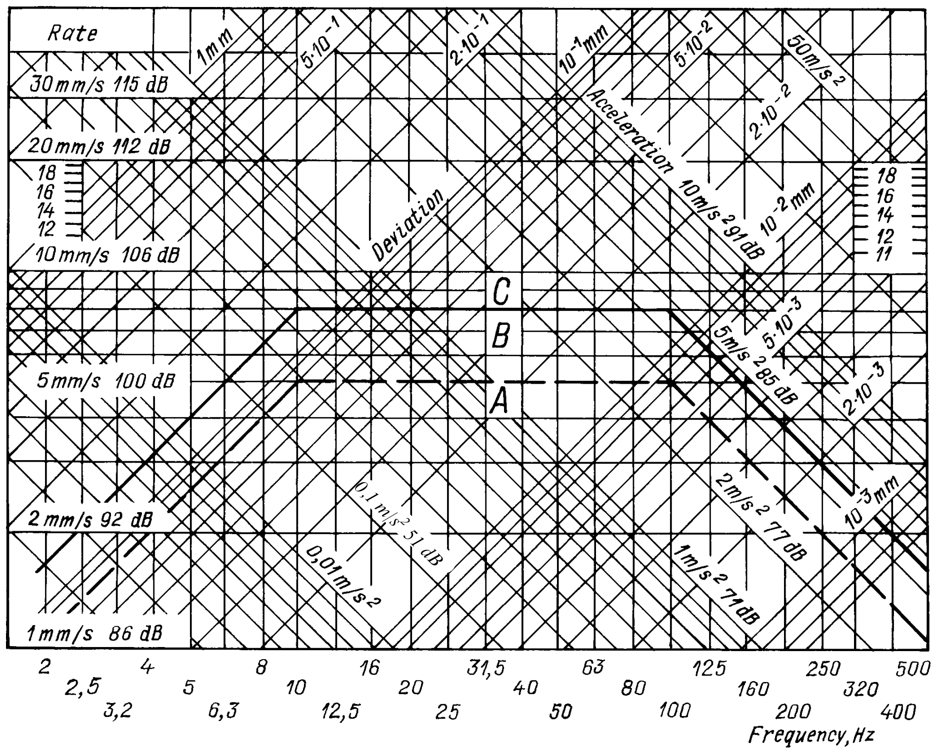


Fig. 9.5.2 Vibration standards for centrifugal separators:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

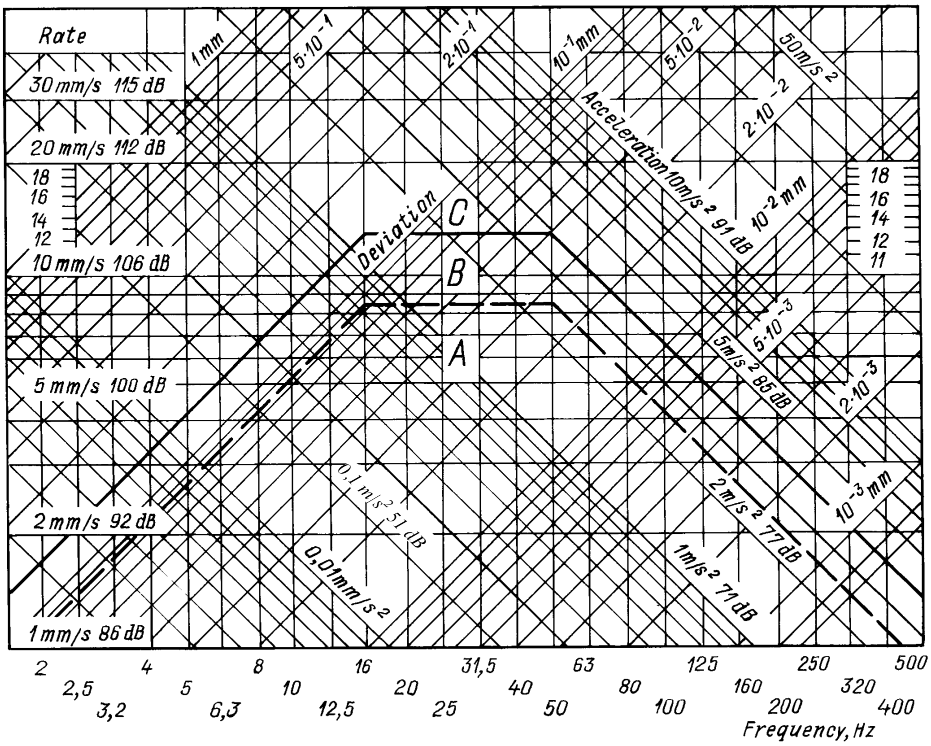


Fig. 9.5.3 Vibration standards for fans:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

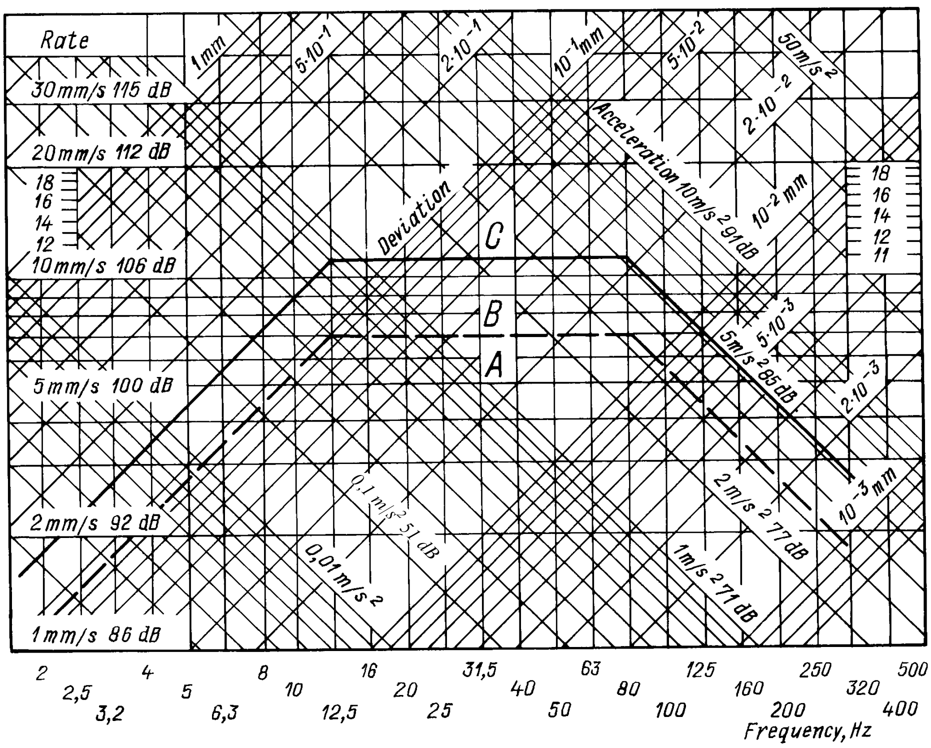


Fig. 9.5.4 Vibration standards for ICE-driven generators, shaft-generators, turbo-drives and turbo-generators of 1000 to 2000 kW capacity:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

9.6 VIBRATION STANDARDS FOR PISTON AIR COMPRESSORS

9.6.1 Vibration of piston air compressors is assumed permissible for Categories *A* and *B*, when the 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 be 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 25000 kW main geared gas turbines measured on the gas turbine supports and reduction gear bearings is considered permissible, provided the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.8.1 and shown in Fig. 9.8.1-1.

Points of vibration measuring are shown in Fig. 9.8.1-2.

9.8.2 Vibration standards for auxiliary gas turbines of less than 250 kW power shall be subject to special consideration by the Register and shall be submitted by the gas turbine manufacturer.

9.8.3 Vibration of gas-turbine-driven servo-machinery and devices shall not exceed the levels given in 9.8.1 and 9.8.2.

9.8.4 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.

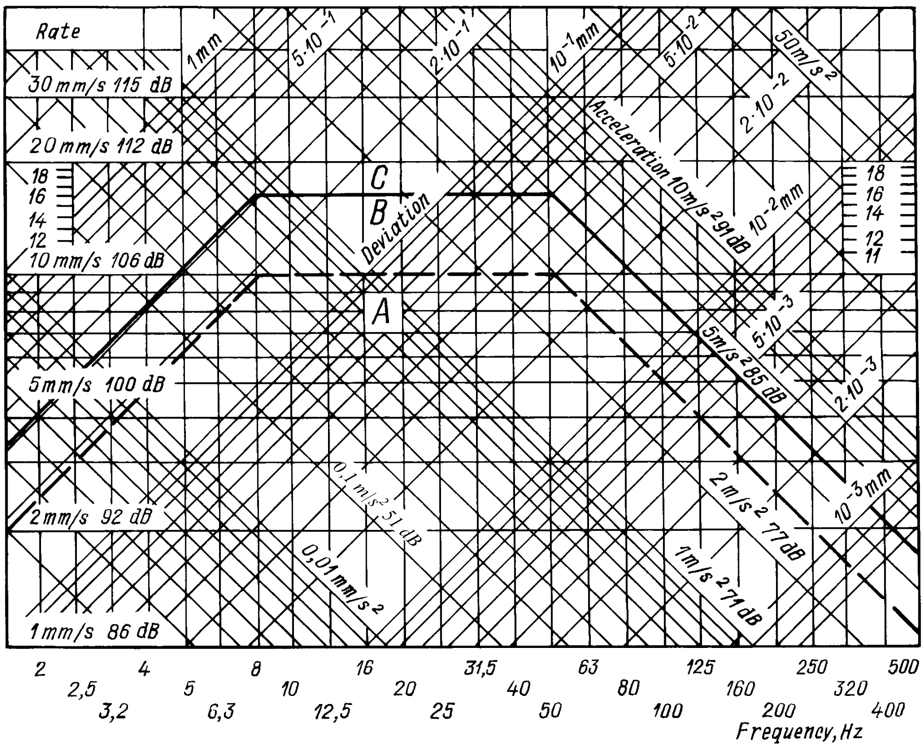


Fig. 9.6.1 Vibration standards for piston compressors:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

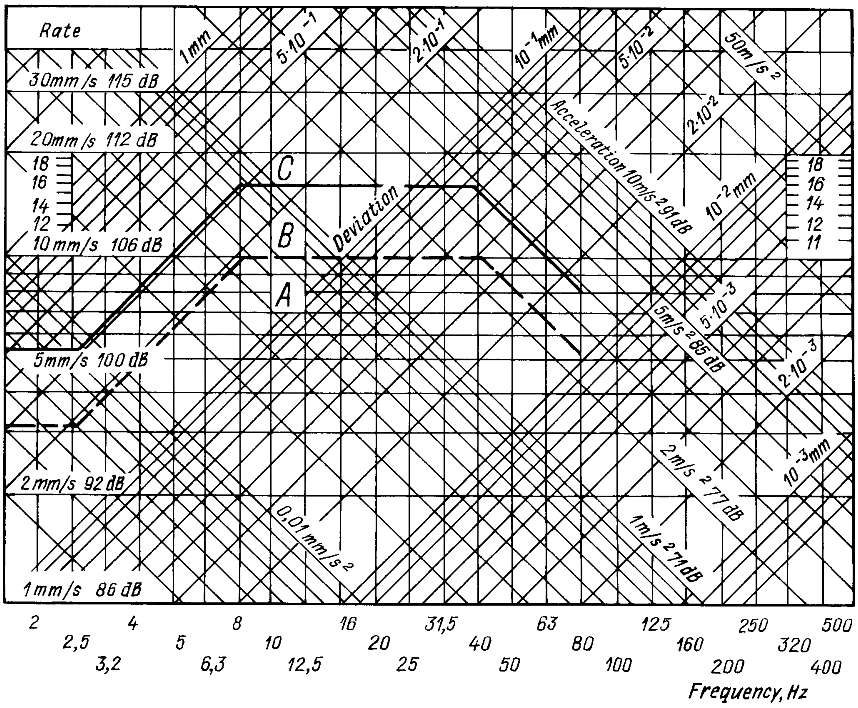


Fig. 9.7.1 Vibration standards for boilers, auxiliary machinery and equipment:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

Table 9.8.1

Vibration standards for geared gas turbines

Root-mean square frequencies of 1/3-octave	bands, Hz				Root-mean square frequencies of 1/3-octave	bands, Hz			
	Permissible values of		Category A			Permissible values of		Category A	
	vibration	rate	mm/s	dB		vibration	rate	mm/s	dB
1,6	1,6	90	2,9	96	125	8	104	16,5	110
2	1,8	91	3,5	97	160	8	104	16,5	110
2,5	2,2	93	4,3	98	200	8	104	16,5	110
3,2	2,7	95	5,3	100	250	8	104	16,5	110
4	3,2	96	7,0	103	320	8	104	16,5	110
5	4	98	9	105	400	8	104	16,5	110
6,3	5	100	11	107	500	8	104	16,5	110
8	6,7	103	13	108	640	6,5	102	12,5	108
10	8	104	16,5	110	800	4,8	100	10	106
12,5	8	104	16,5	110	1000	4	98	8	104
16	8	104	16,5	110	1280	3	96	7	103
20	8	104	16,5	110	1600	2,6	94	5	100
25	8	104	16,5	110	2000	2,1	92	3,9	98
31,5	8	104	16,5	110	2560	1,8	91	3	96
40	8	104	16,5	110	3200	1,5	90	2,4	95
50	8	104	16,5	110	4000	1	86	2	92
63	8	104	16,5	110	5120	—	—	1,7	91
80	8	104	16,5	110	6400	—	—	1,4	89
100	8	104	16,5	110	8000	—	—	1	86

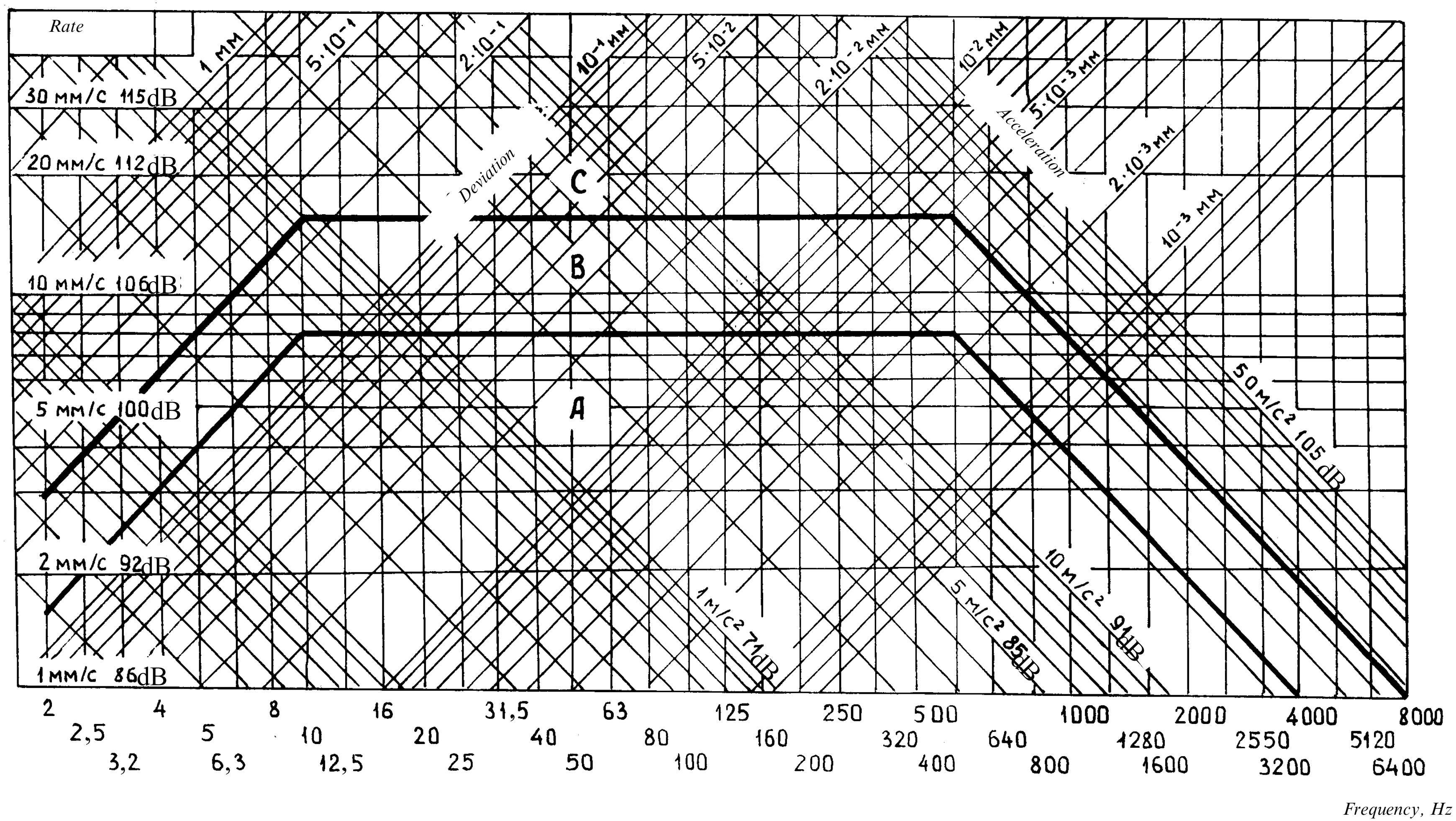


Fig. 9.8.1-1
Vibration standards for geared gas turbines

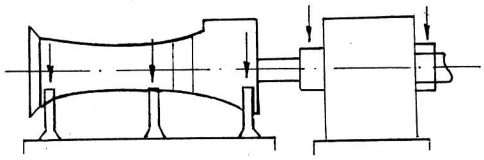


Fig. 9.8.1-2 Points of vibration measuring
(the points and directions of vibration measurement are shown by arrows)

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.

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**, **R3**, **R2-RSN**, **R3-RSN** and for floating docks, the required minimum of spare parts is not regulated.

For the definitions of restricted areas of navigation, refer to 2.2.5.1, Part I "Classification".

10.2 REQUIRED MINIMUM OF SPARE PARTS

Table 10.2-1

Internal combustion engines

Symbols:
O — required;
R — recommended.

Nos.	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	restricted **R1**		unrestricted	restricted **R1**	
1	Main bearings or shells of each type and size fitted, complete with shims, studs (bolts) and nuts	1 set		O	1 set	—	—
2	Cylinder liner complete with valves, joint rings and gaskets	1		O	Joint rings and gaskets only, 1 set		P
3	Cylinder cover, complete with valves, joint rings and gaskets	1		O	Joint rings and gaskets only, 1 set		P
3.1	Cylinder cover bolts and nuts	1/2 set per cover		P	—		—
4	Cylinder valves						
4.1	Exhaust valves, complete with casings, seats, springs and other fittings, per cylinder	1 set	1 set	P	1 set	1 set	P
4.2	Air inlet valves, complete with casings, seats, springs and other fittings, per cylinder	1 set		P	1 set	—	—
4.3	Starting air valve, complete with casing, seats, springs and other fittings	1		O	1	—	P
4.4	Overpressure sentinel valve, complete	1		O	1	—	P
4.5[5]	Fuel valves of each type and size fitted, complete with all fittings, per engine	1 set	1/4 set	O	1/2 set	1/4 set	P
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		O	1 set		P
5.2	Top end bearings or shells of each type and size fitted, complete with shims, bolts and nuts, per cylinder	1 set		O	1 set		P
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		O	1		—
6.2	Trunk type: piston of each type and size fitted, complete with skirt, rings, gudgeon pin, connecting rod, studs and nuts	Ditto		O	Ditto		P
7	Piston rings, per cylinder	1 set		O	1 set		P
8	Telescopic cooling pipes of pistons with packings and other fittings, per cylinder	Ditto		O	Ditto		P
9	Largest size lubricator, complete with drive	1	—	O	—		—
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		O	1	—	P

Nos.	Spare parts	Main engines of ships considered with regard for navigation area[1,2,3]		Supply of spare parts	Auxiliary engines of ships considered with regard for navigation area[1,3,4]		Supply of spare parts
		unrestricted	restricted **R1**		unrestricted	restricted **R1**	
10.2	High pressure fuel pipe of each size and shape fitted, complete with unions	1	—	O	1	—	P
11[6]	Scavenge blowers including turbochargers						
11.1	Rotors, rotor shafts, bearings, gear wheels, nozzle devices, seal parts, suction and discharge valves (proceeding from the type of supercharger)	1 set	—	P	—		—

[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 maneuvering characteristics retained.
N o t e. 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)

Nos.	Spare parts	Number of spare parts on board depending on the navigation area		Supply of spare parts
		unrestricted	restricted **R1**	
1	Carbon sealing rings for each type and size of gland	1 set		P
2	Strainer baskets, inserts and other detachable parts for oil filters of special design, each type and size	1 set for filter		P

N o t e. When the installation consists of several turbines of the same type, the recommended minimum is assumed for one turbine only.

Table 10.2-3

Gears and couplings of main machinery[1,2]

Nos.	Spare parts	Number of spare parts on board depending on the navigation area		Supply of spare parts
		unrestricted	restricted **R1**	
1	Plain bearing bushes of gears and couplings of each type and size fitted	1 set per bearing		O
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		O
3	Roller type bearings of each type and size fitted, if used	Ditto		O

[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 accordingly (by gears and couplings of the same type, those gears and couplings are meant the identical parts of which are interchangeable).

Table 10.2-4

Shafting, propellers and active means of the ship's steering

Nos.	Spare parts	Number of spare parts on board depending on the navigation area: unrestricted	restricted **R1**	Supply of spare parts
1	**Shafting**			
1.1	Thrust block of shaftline			
1.1.1	Pads for ahead face of Mitchel type thrust block, where used	1 set		O
1.1.2	Inner and outer race with rollers where roller thrust bearings are used	Ditto		O
1.2	Coupling bolts with nuts for flanges and shaft couplings, each type and size fitted	1 coupling set		P
2	**Propellers**			
2.1[1]	Detachable propeller blades complete with securing items (for icebreakers and ships with ice categories **Arc4** to **Arc9** only)	2 per propeller	—	O
2.2[1]	CP-propeller blades complete with securing items (for icebreakers and ships with ice categories **Arc4** to **Arc9** only)	Ditto	—	O
2.3	Spare parts for arrangements of CP-propellers, propulsion units, vertical axis propellers and servicing systems except those mentioned in items 3 and 4	On agreement with the Register	—	O

[1] Detachable blades are necessary for the case of eventual replacement by the crew when afloat.

Table 10.2-5

Auxiliary machinery

Nos.	Spare parts	Number of spare parts on board depending on the navigation area: unrestricted	restricted **R1**	Supply of spare parts
1	**Piston pumps**			
1.1	Valves with seats and springs, each type and size fitted	1 set	—	P
1.2	Piston rings of each type and size fitted	Ditto	1 set	P
2	**Centrifugal pumps**			
2.1	Bearings of each type and size fitted	1		P
2.2	Rotor seals of each type and size fitted	1		P
3	**Rotary pumps (screw and gear pumps)**			
3.1	Bearings of each type and size fitted	1		P
3.2	Rotor seals of each type and size fitted	1		P
4	**Compressors**			
4.1	Suction and delivery valves, each type and size fitted in one unit	1/2 set		P
4.2	Piston rings of each type and size fitted in one piston	1 set		P

Table 10.2-6

Ship equipment and deck machinery

Nos.	Spare parts	Number of spare parts on board depending on the navigation area: unrestricted	restricted **R1**	Supply of spare parts
	Hydraulic steering gears			
1	Cylinder plunger seals, sealing rings for pumps of each type and size fitted	1 set		O
2[1]	Valve springs of each type and size fitted	1		O
3[1]	Safety and non-return valves of each type and size fitted	1	—	O
4	Ball or roller bearings	1 set for 1 pump		O
5	Special pipe connections of steering gear	1 set		O

[1] The list of spare parts as per items 2 and 3 is drawn up on agreement with the Register.

Table 10.2-7

Steam boilers, thermal fluid boilers, pressure vessels and heat exchangers

Nos.	Spare parts	Number of spare parts on board depending on the navigation area		Supply of spare parts
		unrestricted	restricted **R1**	
1	**Steam boilers (main and auxiliary for essential services), thermal fluid boilers**			
1.1	Springs of safety valves	1 per boiler		O
1.2	Water gauge glasses, complete	Ditto		O
1.3[1]	Oil fuel burners, complete, each type and size fitted	- " -		O
1.4[1]	Fuel atomizers complete with washers	- " -		O
1.5	Tube plugs of each diameter fitted, including superheater plugs	For 4 per cent of tubes (but not more than 20 pcs)		O
1.6	Boiler pressure gauge of each type and size fitted	1 set of boiler unit		O
1.7	Metal gaskets of special type for superheater and economizer fittings	1 set for 1 boiler		P
1.8	Gaskets for manholes and other openings, each type and size fitted	1 set		P
2	**Pressure vessels and heat exchangers**			
2.1	Level gauge glasses of each type and size fitted	1		P
2.2	Gaskets and glands of special type for covers, manholes, openings and fittings of each type and size fitted	1 set for 1 heat exchanger (pressure vessel)		P
2.3	Plugs for heat exchanger tubes	For 5 per cent of tubes		O

[1] For boilers with automated burning units, the list of spare parts as per items 3 and 4 is drawn up on agreement with the Register.

Table 10.2-8

Gas turbines (main and auxiliary)

Nos.	Spare parts[1]	Number of spare parts on board depending on the navigation area		Supply of spare parts
		unrestricted	restricted **R1**	
1	Flame tubes	1 set per engine		O
2	Main burners	Ditto		O
3	Auxiliary burners	— " —		O
4	Ignition arrangements, complete	— " —		O
5	Plasma igniters or ignition plugs	— " —		O
6	Spare parts for burners	1 set per each burner		O

[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.

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 Inspectorate 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 analyzed are established by a developer of the monitoring system and agreed with the Register.

11.5.3 The oil sample shall be analyzed 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 per cent;

maximum combustion pressure – not more than ±3,5 per cent;

compression end pressure – ±2,5 per cent.

The cited values of the combustion pressure in any cylinder shall not be less than 85 per cent 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 flow-metering device set at a particular cylinder diameter.

11.7.3 The methods for determination of the cylinder tightness and the standards for the cylinder and piston assembly condition shall be presented by the system developer.

11.7.4 The 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 16000 Hz;

dynamic range — not less than 70 dB.

Special requirements for the vibration diagnosis systems:

the possibility of operating according to a process chart, which ensures performance of at least one complete measurement of the vibration parameters on all the monitoring system objects;

the possibility of transferring data to computer.

11.8.4 The composition of the vibration condition monitoring equipment and organization of the performance thereof shall be agreed upon with the Register when the PMS and CC based survey system is being implemented on board the ship.

11.8.5 When performing the vibration condition monitoring, consideration shall be given to the provisions of 18.7, Part V "Technical Supervision during Construction of Ships" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

11.8.6 The requirements for the installation and attachment of the vibration pickup on the controlled item shall be provided. The preference shall be given to attachment of the pickup by a pin (screw). To realize such attachment method, pins shall be fitted beforehand at all measurement points. The vibration pickups may be installed on a magnet. Where the vibration pickups cannot be installed using a pin or magnet, manual vibration pickups may be used.

11.8.7 For each machinery, points and directions for measuring vibration parameters shall be indicated. The manufacturers' recommendations shall be used. Where no such recommendations are available, type lay-out diagrams of the machinery vibration measurement points shall be taken as a guide (refer to 9.2.5).

For the vibration condition monitoring, measurement may be restricted to one or two directions on one most loaded machinery bearing.

Note. For units consisting of a machinery and its driving unit (pump and electric motor, fan and electric motor), measurements are made on one machinery bearing and one motor bearing on the coupling side. When exercising control of the separator vibration condition, measurements shall be made in two radial directions on both motor bearings and in three directions on the separator bowl bearing.

11.8.8 Standardization of the condition on the basis of the controlled parameter vibration levels shall be displayed in the documentation of the technical condition monitoring system submitted to the Register for review (refer to 11.4.1). It is necessary to use the recommendations of the control item manufacturer or to be guided by the Register standards (refer to Section 9).

11.8.9 The results shall be submitted according to 11.2.3.

11.9 REQUIREMENTS FOR CONTROL OF THE SHOCK PULSE

11.9.1 The condition of the roller bearings is assessed by a shock pulse method. The controlled machinery manufacturer, developer or supplier of the technical condition monitoring system may propose another method of roller bearing condition assessment. In this case, the proposed method shall be approved by the Register.

11.9.2 For the bearing condition control by shock pulse method, special instruments are used: shock pulse meters and/or roller bearing condition indicators, which shall meet the following basic requirements:

.1 range of controlled bearings:

internal diameter – 50 to 1000 mm;

speed – 10 to 30000 min^{-1};

dynamic range – not less than 90 dB;

.2 as regards dust- and water tightness, 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.

PART VIII. SYSTEMS AND PIPING

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to the following pumping and piping arrangements used in ships:

.1 bilge and drain;

.2 ballast, heel and trim;

.3 special systems of tankers and combination carriers;

.4 liquefied gas;

.5 toxic media;

.6 steam and blow-down pipelines;

.7 feed water and condensate;

.8 fuel oil;

.9 lubricating oil;

.10 water cooling;

.11 compressed air;

.12 air, venting, overflow and sounding pipes;

.13 exhaust gas;

.14 ventilation;

.15 open-ended steam pipes from safety valves;

.16 cleaning and washing of tanks;

.17 hydraulic drives;

.18 containing organic coolants.

Special requirements for systems other than stated above are set out in the relevant Parts of the Rules.

Pumping and piping of berth-connected ships shall comply with the requirements of the present Part in so much as applicable and sufficient unless expressly provided otherwise below.

1.1.2 The fuel oil used in ships shall comply with the requirements of 1.1.2, Part VII "Machinery Installations".

1.1.3 Machinery and other elements of the systems indicated in 1.1.1 shall remain operative under environmental conditions set out in 2.3, Part VII "Machinery Installations".

1.1.4 Pumps, fans, compressors and their electric drives used in systems covered by the requirements of the present Part shall also comply with the requirements of Part IX "Machinery" and Part XI "Electrical Equipment".

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 In the present Part the following definitions have been adopted.

Fittings are stop, regulating and safety devices, intended for motion control, consumption distribution and regulation and other parameters of the conveying medium by means of entire or partial opening or closing of flow section.

Pipeline fire resistance is the ability of pipeline to maintain strength and functional properties within the set period of time at flame exposure.

System is a combination of pipelines, machinery, apparatus, devices, appliances and reservoirs, intended for performance of certain functions providing ship's operation.

Pipeline is a combination of pipes, fittings, formed components, pipe joints, any internal and external linings, insulation coatings, fastening elements and components for protection of pipes, intended for conveying of liquid, gaseous and compound media, as well as for transmission of pressure and sound waves.

Essential pipeline is a pipeline, which damage may result in a combustible medium spillage in the machinery spaces, flooding, toxic media leakage, failure of system ensuring the operation of main and auxiliary engines, loss of run or control.

Pipelines formed components are bends, t-pieces, bulkhead and deck penetrations and other elements of pipelines, intended for pipelines branching, changing of conveying medium direction and ensuring of hull structures tightness.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions relating to classification procedure, surveys during construction and in service, as well as requirements for technical documentation submitted to the Register for consideration and approval, are set forth in General Regulations for the Classification and Other Activity and in Part I "Classification".

1.3.2 Proceeding from the type and characteristics of the conveyed medium pipes are subdivided into three classes as indicated in Fig. 1.3.2 and Table 1.3.2. Test categories, types of joints, welding procedure and heat treatment are determined proceeding from the pipe class.

1.3.3 Class I and Class II pipes, pipelines fittings, side and bottom fittings, remote-controlled fittings, venting fittings, air pipe covers, flexible joints (including expansion joints), as well as the valves on the forepeak bulkhead, are subject to survey by the Register during manufacture.

1.4 PROTECTION AND INSULATION OF PIPING

1.4.1 Constructional measures on corrosion protection.

1.4.1.1 In order to reduce the corrosion and erosion wear of ship sea water pipelines during their

Table 1.3.2

Piping system for	Class I ($p > p_2$ or $t > t_2$)	Class II	Class III ($p < p_1$ or $t < t_1$)
Toxic and corrosive media	Without special safeguards[1]	With special safeguards[1,2]	—
Inflammable media heated above flash point or having flash point below 60°C[3], liquefied gases	Without special safeguards[1]	With special safeguards[1]	—
Steam[4]	$p > 1,6$ or $t > 300$	Any pressure and temperature combination except the values indicated for Classes I and III	$p \leqslant 0,7$ and $t \leqslant 170$
Organic coolants[4]	$p > 1,6$ or $t > 300$		$p \leqslant 0,7$ and $t \leqslant 150$
Fuel oil, lubricating oil and hydraulic oil[4]	$p > 1,6$ or $t > 300$		$p \leqslant 0,7$ and $t \leqslant 60$
Other media[4,5,6]	$p > 4,0$ or $t > 300$		$p \leqslant 1,6$ and $t \leqslant 200$

[1] Safeguard for reducing leakage possibility and limiting its consequences at the Register satisfaction.
[2] Not applicable to ammonia and other toxic media.
[3] Cargo oil pipes belong to Class III.
[4] p = design pressure, MPa;
t = design temperature, °C (refer to 2.3.1).
[5] Including water, air, gases, non-flammable hydraulic fluids.
[6] For open-ended pipes (drains, overflows, vents, exhaust gas lines, boiler escape pipes) irrespective of the temperature, Class III pipes may be used.

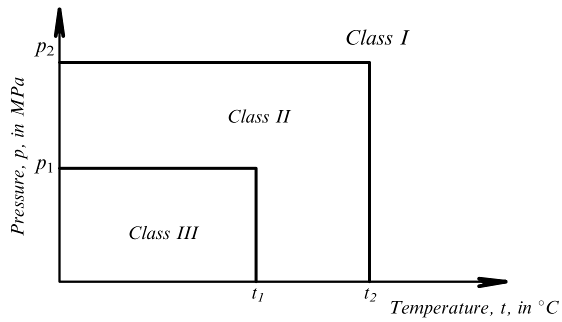


Fig. 1.3.2

design and installation, the following shall be taken into account:

.1 a number of detachable joints shall be kept to a minimum. Detachable joints shall be located in places accessible for inspection, maintenance and repair;

.2 a number of shut-off devices on pipelines shall be kept to a minimum provided the system is functioning properly. Fittings shall be located in places accessible for inspection, maintenance and repair;

.3 pipelines shall have the minimum number of bends. The radii of pipe bends shall be at least 2,5 times of their external diameter. Where the use of bends with less radii is required, the special fittings shall be applied;

.4 the use of welded bends made of segments for pipes of the nominal diameter less than 200 mm is not allowed. A number of segments for the 90° bend shall not be less than three. The use of bent or welded fittings for manufacturing of side or kingston valve branch pipes is not permitted (refer to 4.3.2.10);

.5 the use of tee-pipes, branch pipes, nipples, welded-on pieces and other components shall not result in reduction of open flow area of the main in the places of their installation;

.6 the average design flow velocity determined according to Formula (1.4.1.1.6) shall not exceed the values specified in Table 1.4.1.1.6.

Table 1.4.1.1.6

Pipe material	Permissible average flow velocity, in m/s
Steel including galvanized, nodular graphite iron	2,5
Copper	0,9
Aluminium brass	2,0
Copper-nickel alloys:	
CuNi 5 Fe	2,0
CuNi 10 Fe	2,5
CuNi 30 Fe	3,5
Titanium alloys	10,0

Notes: 1. For pipelines of over 50 mm diameter with shaped elements having the rounding radii in the places of conjuctions with the main being equal to 0,15 diameter of the latter and more, bent with the bending radius in excess of 2,5 external diameters and without welded turns and throttle membranes, the flow velocity may be 30 per cent higher than specified in the Table.

2. In low-activity systems (drenching, water screen, fire sprinkling, ballast, heel, trim) the permissible values of a flow velocity, regardless of the design and technological version of the applied piping components, may be 30 per cent higher than specified in the Table.

3. In systems with titanium pipes and fittings of other materials, when permissible velocities are determined, the decisive components are those made of other materials, and the permissible velocities are subject to special consideration by the Register in each case.

The compliance of the average flow velocity V_{mean} in the above sections of pipelines as well as in kingston connecting channels with these requirements shall be confirmed by the calculation according to the formula

$$V_{mean} = 354Q/d^2 \qquad (1.4.1.1.6)$$

where Q = permissible the maximum consumption at the design section, in m^3/h;
d = the internal diameter of a pipeline, in mm.

1.4.2 Protection against general equal corrosion.

1.4.2.1 Steel pipes of sea water, as well as air and sounding pipes of ballast tanks, shall be protected against corrosion upon completion of bending and welding work by a method approved by the Register.

The following methods may be used as such protection:

.1 zinc coating applied by a hot method. The minimum thickness of zinc coating layer shall not be less than 50µ. Depending on the purpose of piping, the Register may require increasing of the coating thickness;

.2 zinc-filled paint coatings of not less than 120µ in thickness;

.3 effective paint protective coatings (epoxy or equal thereto in water-resisting property).

When selecting the coating type, consideration shall be given to its resistance to the medium conveyed by the system in accordance with the operating conditions of the pipeline.

Aluminium coatings of pipelines are allowed in ballast tanks, in cargo inerted tanks, as well as in hazardous areas on the open deck provided their protection of the accidental impacts. Application of zinc or other metal coating does not relieve of measures for protection of pipelines against contact corrosion.

1.4.3 Protection against contact corrosion.

1.4.3.1 One of the following methods to protect against contact corrosion shall be used when pipes made of different metals are joined in sea water systems: application of protective coating on internal pipelines surfaces, electrical insulation, cathodic protection, use of "sacrificial" branch pipes (refer to 1.4.3.5).

1.4.3.2 The protective water proofing coating (polymeric, paintwork or of other type approved by the Register) is applied to contacting metals surfaces washed by sea water at the length of at least 5 pipe diameters from a contact point (but more than 1 m is not required). The planar oxidation may be used for titanium alloys instead of a water proofing. It is recommended to use coatings along with other methods of protection against contact corrosion.

1.4.3.3 Electrical disconnection of different metals is effected by means of fitting electric insulating joints. In this case the following requirements shall be fulfilled:

.1 to protect heat exchangers, other equipment and pipes hooked up to them against contact corrosion, one electric insulating joint at the contact place of different metals and another one at a distance of at least 5 nominal those pipes diameters shall be fitted;

.2 to protect pipes and fittings connected to them, bellows-shaped expansion joints and other similar pipeline components made of different metals against contact corrosion, electric insulating joints shall be fitted at both sides of those components;

.3 to protect interconnected pipes made of different materials against contact corrosion, the pipe made of any above pipe material and having a length of at least 5 nominal those pipes diameters shall be fitted between pipes using electric insulating joints at both ends;

.4 to protect hull structures from contact with bottom and side fittings of nonferrous metal alloys, electric insulating joints shall be fitted at both ends of the bottom and side fittings, and also on the very pipe and its branch pipes at a distance of at least 5 nominal pipe diameters if the pipe and the ship hull materials form an electric pair. Bottom, side and pipeline fittings shall be electrically insulated from all types of joints (control, heating, blow-off, etc pipelines), which may form a metal contact between the fittings and the ship hull. Where side and bottom fittings are provided with the second shut-off fittings made of the same metal, they shall be electrically insulated as a unified structure;

.5 pipes with two or more electric insulating joints shall be insulated from hangers;

.6 the structure of an electric insulating joint shall be approved by the Register, have the tightness required, be tested by hydraulic pressure in accordance with 21.2 and have an electrical resistance in a dry condition (prior to system filling) not less than 10 kOhm and not less than 1 kOhm following the system filling and hydraulic tests.

1.4.3.4 A cathodic protection shall be applied where sea water system components made of metals specified in Table 1.4.3.4 are in contact.

1.4.3.4.1 Protectors shall be fitted immediately between the surfaces of mating different metals. Where it is impossible, they may be fitted on the surface protected as close to the pipe contact place as possible (at least one diameter).

Table 1.4.3.4

Metal combination		Material subjected to corrosion	Protector material
Carbon, low-alloy steel, cast iron	Copper, brass, bronze, copper-nickel alloys, corrosion-resistant steel, titanium alloys	Carbon, low-alloy steel, cast iron	Zinc alloy
Copper, brass, bronze, copper-nickel alloys	Corrosion-resistant steel of austenitic class, titanium alloys	Copper, brass, bronze, copper-nickel alloys	Carbon steel
Copper, brass	Corrosion-resistant non-austenitc steel	Copper, brass	Carbon steel
Bronze, copper-nickel alloys	Corrosion-resistant non-austenitic steel	Any material specified may be subjected to corrosion	Carbon steel
Corrosion-resistant steel	Titanium alloy	Corrosion-resistant steel	Carbon steel
Corrosion-resistant steel of austenitic class	Corrosion-resistant non-austenitic steel	Any material specified may be subjected to corrosion	Carbon steel
Brass	Bronze, copper, copper-nickel alloys	Brass	Carbon steel

1.4.3.4.2 In pipelines with fittings and pipes of different metals, protectors shall be fitted behind each valve along a flow. For permanently closed valves and in sections with changing flow motion direction, protectors shall be fitted at both valve sides.

1.4.3.4.3 A corrosion-resistant steel, tin brass and manganese bronze, aluminium bronze may be used in sea water if only a cathodic protection is provided.

1.4.3.4.4 When fitting protectors, the reliable electrical contact of a protector with an article protected shall be provided.

1.4.3.4.5 The protector design shall permit its replacement, which is effected after the protector life cycle expires. In this case, joints tightness shall not be broken.

1.4.3.4.6 The protector service period shall be at least 2,5 years (at least 3 years for protection of kingston and side branch pipes) and shall be determined according to the formula

$$T = A\frac{M}{S} \qquad (1.4.3.4.6)$$

where T = protector service period, in years;
M = mass of a protector working metal, in kg;
S = area of protected surface, in m^2; the protected pipe surface therewith is assumed equal to an internal surface area of 5 internal diameters long;
A = coefficient equal to 0,75 for zinc protector and to 1,71 for steel one.

1.4.3.4.7 In addition to the materials specified in Table 1.4.3.3, aluminium alloys may be used as the material for protectors. However, the application of aluminium protectors is, in each case, subject to special consideration by the Register.

1.4.3.5 Where other methods of protection against contact corrosion can not be used, it is permitted to apply "sacrificial" branch pipes.

1.4.3.5.1 The "sacrificial" branch pipe is the thick-walled cylindrical section of a carbon steel pipe intended for displacement of a contact zone of pipelines components made of nonferrous metals and alloys from essential steel structures and equipment. The "sacrificial" branch pipe shall not be internally coated.

1.4.3.5.2 "Sacrificial" branch pipes shall be machined of forgings or rolled products. The length of a "sacrificial" branch pipe shall be at least 1,5 of the internal pipe diameter. The sealing flange surface of the "sacrificial" branch pipe being in contact with a different metal shall be protected against contact corrosion by facing or by another approved method of cladding metal on the contacting item.

1.4.3.5.3 The wear margin of a "sacrificial" branch pipe wall shall provide a pipeline service period of at least 10 years on a basis of the total wall corrosion rate of 1,5 mm/year.

1.4.3.5.4 The "sacrificial" branch pipe shall be located in place accessible for inspection and replacement. The spare "sacrificial" branch pipe shall be on the ship.

1.4.3.5.5 Dismantling, inspection of contact surfaces and measurements of "sacrificial" branch pipe wall thicknesses shall be carried out at least once in 5 years.

1.4.4 Protection against excessive pressure.

1.4.4.1 Pipelines, in which pressure in excess of the design pressure is possible, shall be equipped with safety devices so that the pressure would not exceed the design value for the pipes.

The liquid diversion from relief valves of pumps transferring flammable liquids shall be effected into the suction side of the pump or to the suction pipeline. This requirement does not apply to centrifugal pumps.

1.4.4.2 Where provision is made for a reducing valve on the pipeline, a pressure gauge and a safety valve shall be installed after the reducing valve.

An arrangement for by-passing the reducing valve is allowed for use.

1.4.5 Insulation of piping.

Insulation of piping shall comply with 4.6, Part VII "Machinery Installations" and 8.2, Part XII "Refrigerating Plants".

1.4.6 Protection against green sea forces.

1.4.6.1 The requirements of 1.4.6 are applicable to all ship types of sea-going service of length 80 m or more, where the height of the exposed deck over the forward 0,25L is less than 0,1L or 22 m above the summer load waterline, whichever is the lesser.

1.4.6.2 Air pipes of tanks, ventilator pipes and their closing devices located within the forward quarter length shall have strength sufficient to resist green sea forces at open sea. The requirements of 1.4.6 do not apply to cargo tank venting systems.

1.4.6.3 Applied loading.

1.4.6.3.1 The wave pressure P, kN/m^2, acting on air pipes, ventilator pipes and their closing devices may be determined by the formula

$$P = 0{,}5\rho V^2 C_d C_s C_p \qquad (1.4.6.3.1)$$

where ρ = density of sea water (1,025 t/m^3);
V = velocity of water infrusion over the fore deck (13,5 m/sec);
C_d = shape coefficient, which is assumed:
0,5 – for pipes;
1,3 – for air pipes or ventilator heads;
0,8 – for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction;
C_s = slamming coefficient, which is assumed 3,2;
C_p = protection coefficient, which is assumed:
0,7 – for pipes and ventilator heads located immediately behind a breakwater or forecastle,
1,0 – elsewhere and immediately behind a bulwark.

1.4.6.3.2 Forces acting in horizontal direction on the pipes and their closing devices may be determined by Formula (1.4.6.3.1) using the largest projected area of each component.

1.4.6.4 Strength requirements.

1.4.6.4.1 Bending stresses and loads in air and ventilator pipes shall be determined at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses shall not exceed $0,8\sigma_y$ where σ_y is the yield stress or proof stress of steel at 0,2 per cent elongation at room temperature. Irrespective of corrosion protection, a corrosion addition to the net section of 2 mm shall be then applied.

1.4.6.4.2 For standard pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1.4.6.4.2. Where brackets are required, three or more radial brackets shall be fitted.

Brackets shall be of gross thickness 8 mm or more, of minimum length not less than 100 mm, and height according to Table 1.4.6.4.2 but shall not extend over the joint flange for the head. Bracket toes at the deck shall be suitably supported.

1.4.6.4.3 For other configurations, loads and means of support shall be determined in accordance with 1.4.6.3 and 1.4.6.4. Brackets, where fitted, shall be of suitable thickness and length according to their height. Pipe thickness shall not be taken less than as indicated in 10.1.4.

1.4.6.4.4 For standard ventilators of 900 mm height, pipe thicknesses and bracket heights are specified in Table 1.4.6.4.4. Brackets, where required shall be as specified in 1.4.6.4.2.

1.4.6.4.5 For ventilators of height greater than 900 mm, brackets or alternative means of support are subject to special consideration by the Register in each case.

1.4.6.4.6 All component parts and connections of the air pipe or ventilator shall be capable of withstanding the loads defined in 1.4.6.3.

1.4.6.5 Rotating type mushroom ventilator heads are not permitted for installation in the areas defined in 1.4.6.2.

1.5 WELDING AND NON-DESTRUCTIVE TESTING OF WELDS

1.5.1 Welding and non-destructive testing of welds in pipes shall be effected in compliance with 2.5 and 3, Part XIV "Welding".

Table 1.4.6.4.2

760 mm air pipe thickness and bracket standards

Nominal pipe diameter, mm	Minimum pipe thickness, mm	Maximum projection area of head, cm^2	Height of bracket, mm
50A	6,0	—	520
65A	6,0	—	480
80A	6,3	—	460
100A	7,0	—	380
125A	7,8	—	300
150A	8,5	—	300
175A	8,5	—	300
200A	8,5[1]	1900	300[2]
250A	8,5[1]	2500	300[2]
300A	8,5[1]	3200	300[2]
350A	8,5[1]	3800	300[2]
400A	8,5[1]	4500	300[2]

[1] Brackets shall be fitted where the pipe thickness is less than 10,5 mm, or where the tabulated projected head area is exceeded.
[2] For other air pipe heights, the relevant requirements of 1.4.6.4.3 shall be applied.

Table 1.4.6.4.4

900 mm ventilator pipe thickness and bracket standards

Nominal pipe diameter, mm	Minimum pipe thickness, mm	Minimum projection area of head, cm^2	Height of bracket[1], mm
80A	6,3	—	460
100A	7,0	—	380
150A	8,5	—	300
175A	8,5	55	—
200A	8,5	880	—
250A	8,5	1200	—
300A	8,5	2000	—
350A	8,5	2700	—
400A	8,5	3300	—
500A	8,5	4000	—

[1] For other ventilator heights the relevant requirements of 1.4.6.4.5 shall be applied.

1.6 MACHINERY, APPARATUS AND CONTROL DEVICES

1.6.1 Pumps, fans, compressors and the electric drives used in systems covered by the requirements of the present Part shall also comply with the requirements of Part IX "Machinery" and Part XI "Electrical Equipment".

1.6.2 Control and monitoring devices of piping systems shall comply with the requirements of Part XV "Automation".

1.6.3 Heat exchangers and pressure vessels used in ships systems shall comply with the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels".

2 METAL PIPING

2.1 MATERIAL, MANUFACTURE AND APPLICATION

2.1.1 The materials, used for pipes and fittings, as well as the methods of testing the materials shall comply with the requirements of Part XIII "Materials".

The fuel oil pipes shall be manufactured of steel or other material meeting the Register requirements as to its strength and fire-resistance. These requirements apply to lubricating oil pipes in machinery spaces and to pipes conveying other flammable oil products including hydraulic and thermal liquids if they are in spaces with sources of ignition.

2.1.2 In general, pipes and fittings of carbon steel and carbon-manganese steel shall be used for media with temperature not exceeding 400 °C, of low-alloy steel — with temperature not exceeding 500 °C.

These steels may be admitted for temperatures higher than the above mentioned, if their mechanical properties and the average stress to produce rupture in 100 000 hours at the design temperature comply with the effective standards and are guaranteed by the steel maker as suitable for high temperature service.

Pipes and fittings for media with temperature above 500 °C shall be manufactured of alloy steel. Exhaust gas pipes are excluded from this requirement.

2.1.3 Copper and copper alloy pipes shall be seamless drawn pipes or other type approved by the Register.

Copper pipes for Classes I and II shall be seamless.

Pipes and fittings of copper and copper alloys shall generally be used for media having temperature not in excess of 200 °C, and those of copper-nickel alloys, for temperature not over 300 °C. Bronze fittings may be admitted for media having temperatures up to 260 °C.

2.1.4 Grey cast iron may be admitted for pipes and fittings of piping in Class III used at ambient temperature not lower than -15 °C. In this case, the ultimate strength of the grey cast iron shall not be less than 200 MPa, and that of the fitting casings and shaped components — not less than 300 MPa. Apart from cargo pipelines, the permissible working pressure in the pipelines of grey cast iron shall not exceed 1 MPa and for steam pipelines — 0,3 MPa.

Pipes and fittings of grey cast iron may be also used for cargo lines with pressures up to 1,6 MPa on the weather deck, inside cargo and slop tanks, except for the manifolds, their valves and fittings for connection to the cargo hoses.

The grey cast iron shall not be used for:

.1 pipes and fittings handling media with temperatures above 220 °C;

.2 pipes and fittings subject to water hammer, excessive strains and vibration;

.3 pipes directly connected to the shell plating;

.4 fittings fitted directly on the shell plating and collision bulkhead;

.5 valves under static head, fitted directly on fuel and lubricating oil tanks, unless protected against mechanical damage by a method approved by the Register;

.6 fire smothering systems;

.7 ballast lines inside cargo and slop tanks.

2.1.5 Spheroidal or nodular graphite cast iron may be admitted for pipes and fittings of piping in Classes II and III including ballast, bilge and cargo lines, if the elongation of this cast iron is not less than 12 per cent. Where the elongation is less than that required, the area of application of the pipes and fittings of spheroidal or nodular graphite cast iron shall be the same as specified in 2.1.4 for the grey cast iron.

The working temperature for piping components made of spheroidal graphite cast iron of perlitic or ferritic-perlitic structure shall not exceed 300 °C and for the cast iron of ferritic structure 350 °C.

The impact toughness of the spheroidal graphite cast iron for pipes and fittings used at the temperature lower than — 15 °C shall not be less than 20 J/cm^2.

Ship side-and-bottom fittings as well as the valves and fittings referred to in 4.3.2.4, 4.3.2.6 to 4.3.2.7 and the valves on the collision bulkhead, fuel and lube oil tanks may be admitted to be of spheroidal graphite cast iron of fully ferritic structure in accordance with Table 3.9.3.1, Part XIII "Materials".

2.1.6 Pipes up to 50 mm in diameter and fittings of ductile cast iron of ferritic structure with elongation more than 12 per cent may be used for services mentioned in 2.1.5 at the working temperature not lower than — 15 °C and not higher than 350 °C and under working pressure up to 2 MPa.

The area of application of pipes and fittings made of ductile cast iron with elongation less than 12 per cent shall be the same as specified in 2.1.4 for products made of grey cast iron.

2.1.7 The application of pipes and other pipeline components made of aluminium alloys in systems mentioned under 1.1.1 is subject to special consideration of the Register.

2.1.8 The plugs and threaded portion of deck bushes of sounding pipes, terminating on the open decks, shall be of bronze or brass. The use of other materials shall be specially considered by the Register.

2.1.9 Sight-glasses on fuel oil and oil pipes shall be refractory.

2.2 RADII OF PIPE BENDS, HEAT TREATMENT AFTER BENDING

2.2.1 The inner radius of pipe bend of the boiler blow off pipes shall be at least 3,5 d_1 (d_1 = pipe inside diameter).

The inner radius of bend of the steel and copper pipes subjected to a pressure exceeding 0,49 MPa or a working medium temperature exceeding 60 °C, as well as bending radius of pipes with allowance for thermal expansion, shall be at least 2,5d (d = pipe outside diameter).

On agreement with the Register, bending to a lesser radius may be permitted, provided no thinning of pipe wall below the values stated in 2.3 would occur during the bending.

2.2.2 Hot bending of stell pipes shall be generally carried out in the temperature range 1000 to 850 °C; however, the temperature may decrease to 750 °C during the bending process.

For pipes, the bending of which is carried out within this temperature range, the following applies:

.1 for C, C-Mn and C-Mo steels, no subsequent heat treatment is required;

.2 for 1 Cr — 0,5 Mo steel with a wall thickness greater than 8 mm, a subsequent stress relieving heat treatment in the temperature range 620 to 680 °C is required;

.3 for 2,25 Cr — 1 Mo and 0,5 Cr — 0,5 Mo — 0,25 V steels of all thickness, a subsequent stress relieving heat treatment in the temperature range 650 to 720 °C is required except for pipes with a wall thickness ⩽8 mm, diameter ⩽100 mm and the maximum service temperature up to 450 °C, for which no subsequent heat treatment may be carried out.

2.2.3 When the hot bending is carried out outside the temperature range stated in 2.2.2, a subsequent new heat treatment in accordance with Table 2.2.3 is generally required.

Table 2.2.3

Type of steel	Heat-treatment and temperature (°C)
C and C — Mn	Normalizing 880 to 940
0,3 Mo	Normalizing 900 to 940
1 Cr — 0,5 Mo	Normalizing 900 to 960 Tempering 640 to 720
2,25 Cr — 1 Mo	Normalizing 900 to 960 Tempering 650 to 780
0,5 Cr — 0,5 Mo — 0,25 V	Normalizing 930 to 980 Tempering 670 to 720

2.2.4 After cold bending when $r = 4d$, a complete heat treatment in accordance with Table 2.2.3 is generally required in any case, a stress relieving heat treatment is required for 0,3 Mo steel with a wall thickness ⩾15 mm at 580 to 640 °C, 1 Cr — 0,5 Mo steel with a wall thickness ⩾8 mm at 620 to 680 °C and for 2,25 Cr — 1 Mo and 0,5 Cr — 0,5 Mo — 0,25 V steel with a wall thickness ⩾8 mm, diameter ⩾100 mm and service temperature above 450 °C at 650 to 720 °C.

2.2.5 Copper and copper-alloy pipes, except for the pipes of measuring instruments, shall be annealed before hydraulic testing.

2.2.6 Preheating before welding and postweld heat treatment shall be effected in accordance with 2.5.5 to 2.5.7, Part XIV "Welding".

2.3 METAL PIPE WALL THICKNESS

2.3.1 The wall thickness of metal pipes (except cast iron pipes) operating under the internal pressure shall correspond to the greater of the values determined from Table 2.3.8 or by the following formula:

$$S = \frac{S_0 + b + c}{1 - (a/100)} \qquad (2.3.1)$$

where: $S_0 = dp/(2\sigma\varphi + p)$;
S_0 = theoretical wall thickness, mm;
d = outside diameter of the pipe, mm;
p = design pressure determined in accordance with 2.3.2, MPa;
φ = weld efficiency factor taken in accordance with 2.3.3;
b = allowance for a reduction of pipe wall thickness because of bending taken in accordance with 2.3.4, mm;
σ = permissible (normal) stress determined in accordance with 2.3.5 to 2.3.7, MPa;
c = corrosion addition taken in accordance with Table 2.3.1-1 for steel pipes and Table 2.3.1-2 for pipes of nonferrous metals, mm;

Table 2.3.1-1

Allowance *c* for corrosion for steel pipes

Working medium, piping service	*c*, mm
Superheated steam	0,3
Saturated steam	0,8
Heating steam coils for water and fuel oil products in tanks and cargo tanks	2,0
Feed water in open circuit systems	1,5
Feed water in closed circuit systems	0,5
Blow-down of boilers	1,5
Compressed air	1,0
Hydraulic oil systems	0,3
Lubricating oil	0,3
Fuel oil	1,0
Cargo pipelines	2,0
Liquefied gas	0,3
Refrigerant piping	0,3
Fresh water	0,8
Sea water	3,0

Notes: 1. On agreement with the Register, the allowance for corrosion may be reduced for pipes protected against corrosion by special coatings, linings, etc.

2. Where pipes of steel with sufficient corrosion resistance are used, the allowance for corrosion may be reduced to zero.

3. For pipes passing through tanks and on the open decks the table values shall be increased by the allowance for the influence of the external medium, which is assumed for the appropriate medium in accordance with the present Table.

Table 2.3.1-2

Allowance *c* for corrosion for pipes of nonferrous metals and alloys

Pipe material	*c*, mm
Copper, brass, copper-tin alloys and similar alloys, except those with lead content	0,8
Copper-nickel alloys (with Ni content $\geqslant$ 10 %)	0,5

Note. Where pipes of special alloys with sufficient corrosion resistance are used, the allowance for corrosion may be reduced to zero.

a = negative manufacturing tolerance for pipe wall thickness, % (when pipes without negative allowance are used, $a = 0$).

2.3.2 The design pressure, on the basis of which pipe strength calculations are made, shall be assumed equal to the maximum working pressure of the system. Where safety relief valves are fitted, the design pressure shall be their highest set pressure. Pipelines and components of piping systems not protected by safety valves or may be disconnected from their safety valves, shall be calculated for the maximum possible pressure at the outlet of the pumps connected.

For pipelines containing heated fuel oil, the design pressure shall be taken according to Table 2.3.2.

Table 2.3.2

Determination of design pressure for fuel oil systems

Working pressure P, MPa	Working temperature T, °C	
	No more than 60	More than 60
No more than 0,7	0,3MPa or P_{max} (the greater of two values)	0,3MPa or P_{max} (the greater of two values)
More than 0,7	P_{max}	1,4MPa or P_{max} (the greater value)

For pipelines of steering gear the design pressure shall be assumed in compliance with 6.2.8.1, Part IX "Machinery".

In particular cases not provided by the Rules the design pressure is subject to special consideration by the Register.

2.3.3 The strength factor φ in strength calculations shall be taken as 1 for seamless pipes and approved welded pipes, which are considered to be equal to seamless pipes.

For other welded pipes the strength factor φ is subject to special consideration by the Register in each case.

2.3.4 The allowance for an actual reduction of pipe wall thickness because of bending shall be chosen in such a way that the stresses in the bent part of the pipe because of internal pressure do not exceed the permissible stresses.

Where precise values of thickness reduction while bending are not known, the allowance b, mm, may be obtained by the formula

$$b = 0{,}4 S_0 d / R \qquad (2.3.4)$$

where R = mean radius of pipe bend, mm.

2.3.5 In strength calculations the permissible stresses are taken considering the following properties of material and working conditions:

$R_{m/20}$ = ultimate resistance at room temperature, MPa;

$R_{eL/t}$ = the minimum yield strength at the design temperature, MPa;

$R_{0,2/t}$ = conventional yield strength at the design temperature, MPa;

$R_{m/t}^{100\,000}$ = ultimate long-term strength for 100 000 hours at the design temperature, MPa;

$R_{p1\%/t}^{100\,000}$ = 1 per cent of creep limit for 100 000 hours at the design temperature, MPa.

The design temperature t for determining permissible stresses is taken as the maximum temperature of the medium inside the pipes. In particular cases the design temperature is specially considered by the Register.

2.3.5.1 For carbon or alloy steel pipes the permissible design stresses are chosen equal to the lowest of the following values:

$R_{m/20}/2{,}7$; $R_{eL/t}/1{,}8$ or $R_{0,2/t}/1{,}8$; $R_{\mathrm{m}/t}^{100\ 000}/1{,}8$; $R_{p1\%/t}^{100\,000}/1{,}0$.

The possibility of safety factor reduction shall be a matter of special consideration by the Register in each case.

When the design temperature is not included in the creep limit of the material, the permissible stresses on the creep limit are not compulsory for examination.

2.3.5.2 The permissible stresses for high-alloyed steels are subject to special consideration by the Register in each case.

2.3.5.3 For copper and copper alloys pipes the permissible stresses shall be determined in accordance with Table 2.3.5.3.

2.3.5.4 The permissible stresses for aluminium and titanium pipes in the strength calculations are assumed equal to the minimum of the following values:

$$R_{m/20}/4{,}0;\ R_{0{,}2/t}/1{,}6;\ R_{m/t}^{100\ 000}/1{,}6.$$

When the design temperature is not included in the creep limit of the material, the permissible stresses on the creep limit are not compulsory for examination.

2.3.6 Steam pipes with an external diameter of 80 mm and over for superheated steam at a temperature of 350 °C and over shall be calculated for stresses caused by thermal expansion, and flanged joints — for strength and tightness.

The calculations of stresses in pipes because of thermal expansion shall comply with the requirements of 18.3.

2.3.7 The wall thickness $t_{\min}$, in mm, of cast iron pipeline components shall not be less than that obtained from the formula

$$t_{\min} = k(0{,}5 + 0{,}001D_{nom}) \qquad (2.3.7)$$

where D_{nom} = nominal diameter, in mm;
k = factor taken equal to:
9 — for pipes;
14 — for T-joints and valve bodies;
12 — for joints.

Moreover, the wall thickness of cast iron pipes and fittings under internal pressure shall not be less than that obtained from Formula (2.3.1), and the allowance for a reduction of pipe wall thickness because of bending in this case is $b = 0$;

weld efficiency factor φ taken equal to:

1 — for pipes and couplings;

0,4 — for bends, T-joints and four-way unions;

0,25 — for fitting bodies;

permissible stress σ determined with regard to 2.1.4.3, 2.1.4.6, and 2.1.5.5, Part X "Boilers, Heat Exchangers and Pressure Vessels";

corrosion addition c due to sea water is:

4 mm — for cast iron of ferritic and ferritic-perlitic structure;

3 mm — for cast iron of perlitic structure;

for media with low corrosivity, corrosion addition c may be reduced on agreement with the Register.

2.3.8 The wall thickness of steel, copper, copper and titanium alloys pipes shall not be less than indicated in Table 2.3.8.

2.4 PIPE JOINTS

2.4.1 Use of welded, flanged, threaded and mechanical joints, made in accordance with the standards approved by the Register, is allowed.

2.4.2 Welded joints.

2.4.2.1 Welded butt joints may be accomplished with or without special provisions for full root penetration. Welded butt joints of full penetration type with special provisions for root side quality, for instance, performed with the use of double-sided welds, backing strap or other equivalent methods, are allowed for piping of any class and diameter.

Welded butt joints of full penetration type without special provisions for root side quality are allowed for Class II and III pipelines without diameter restrictions.

2.4.2.2 Slip-on and socket welded joints shall have sleeves and sockets of adequate dimensions, meeting the requirements of the standards approved by the Register. Slip-on sleeve and faucet welded joints may be used for Class III pipelines regardless of pipe diameter.

In some cases such joints may be used for Class I and II pipelines with outside diameter up to 88,9 mm except the pipelines conveying toxic or corrosive media and for operation under heavy fatigue loads, excessive corrosion and erosion.

2.4.2.3 Welding and non-destructive testing shall be carried out in accordance with 2.5 and 3.2, Part XIV "Welding".

2.4.3 Flange connections.

2.4.3.1 Dimensions and shape of flanges and connecting bolts shall comply with the standards approved by the Register.

Table 2.3.5.3

Permissible stresses σ_{perm} for pipes of copper and copper alloys

Pipe material	Heat treatment	Minimum tensile strength, MPa	σ_{perm}, MPa, at working medium temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealing	220	41	41	40	40	34	27	19	—	—	—	—
Aluminium brass	Ditto	320	78	78	78	78	78	51	25	—	—	—	—
Copper-nickel	Ditto	270	69	69	68	66	64	62	59	56	52	48	44
95/5 and 90/10											5,3		
Copper-nickel 70/30	Ditto	360	81	79	77	76	74	72	70	68	66	64	62

Notes: 1. Intermediate values shall be determined by linear interpolation.
2. For materials, which are not included in the Table, the permissible stresses will be subject to special consideration by the Register in each case.

Table 2.3.8

Minimum wall thickness of metal pipes, mm

External diameter, mm	Pipes									
	Steel						Copper	Copper alloys	Corro-sion-resistant steel	Tita-nium-based alloys
	Pipes of systems other than stated in columns 3 — 7	Venting, overflow and sounding pipes of structural tanks, except for those stated in column 5 of the Table and in 10.1.4.	Sea water pipes (bilge, ballast, cooling water, fire extingui-shing systems, etc.)	Bilge, air, overflow and sounding pipes passing through ballast and fuel tanks; ballast pipes passing through fuel tanks; fuel pipings passing through ballast tanks (refer also to 9.2.3)	Pipings of CO_2 fire extinguishing system					
					from cylinders to starting valves	from starting valves to discharge nozzles				
1	2	3	4	5	6	7	8	9	10	11
< 8	1,0	—	—	—	—	—	—	—	1,0	0,7
8,0	1,2	—	—	—	—	—	1,0	0,8	1,0	0,8
10,2	1,6	—	—	—	—	—	1,0	0,8	1,0	0,8
12,0	1,6	—	—	—	—	—	1,2	1,0	1,0	1,0
13,5	1,8	—	—	—	—	—	1,2	1,0	1,0	1,0
16,0	1,8	—	—	—	—	—	1,2	1,0	1,0	1,0
17,2	1,8	—	—	—	—	—	1,2	1,0	1,0	1,0
19,3	1,8	—	—	—	—	—	1,2	1,0	1,0	1,0
20,0	2,0	—	—	—	—	—	1,2	1,0	1,0	1,0
21,3	2,0	—	3,2	—	3,2	2,6	1,2	1,0	1,6	1,0
25,0	2,0	—	3,2	—	3,2	2,6	1,5	1,2	1,6	1,0
26,9	2,0	—	3,2	—	3,2	2,6	1,5	1,2	1,6	1,0
30,0	2,0	—	3,2	—	4,0	3,2	1,5	1,2	1,6	1,0
33,7	2,0	—	3,2	—	4,0	3,2	1,5	1,2	1,6	1,0
38,0	2,0	4,5	3,6	6,3	4,0	3,2	1,5	1,2	1,6	1,0
42,4	2,0	4,5	3,6	6,3	4,0	3,2	1,5	1,2	1,6	1,0
44,5	2,0	4,5	3,6	6,3	4,0	3,2	1,5	1,2	1,6	1,0
48,3	2,3	4,5	3,6	6,3	4,0	3,2	2,0	1,5	1,6	1,5
51,0	2,3	4,5	4,0	6,3	4,5	3,6	2,0	1,5	1,6	1,5
54,0	2,3	4,5	4,0	6,3	4,5	3,6	2,0	1,5	1,6	1,5
57,0	2,3	4,5	4,0	6,3	4,5	3,6	2,0	1,5	1,6	1,5
60,3	2,3	4,5	4,0	6,3	4,5	3,6	2,0	1,5	2,0	1,5
63,5	2,3	4,5	4,0	6,3	5,0	3,6	2,0	1,5	2,0	1,5
70,0	2,6	4,5	4,0	6,3	5,0	3,6	2,0	1,5	2,0	1,5
76,1	2,6	4,5	4,5	6,3	5,0	3,6	2,0	1,5	2,0	1,5
82,5	2,6	4,5	4,5	6,3	5,6	4,0	2,0	1,5	2,0	1,5
88,9	2,9	4,5	4,5	7,1	5,6	4,0	2,5	2,0	2,0	2,0
101,6	2,9	4,5	4,5	7,1	6,3	4,0	2,5	2,0	2,0	2,0
108,0	2,9	4,5	4,5	7,1	7,1	4,5	2,5	2,0	2,0	2,0
114,3	3,2	4,5	4,5	8,0	7,1	4,5	2,5	2,0	2,3	2,0
127,0	3,2	4,5	4,5	8,0	8,0	4,5	2,5	2,0	2,3	2,0
133,0	3,6	4,5	4,5	8,0	8,0	5,0	3,0	2,5	2,3	2,0
139,7	3,6	4,5	4,5	8,0	8,0	5,0	3,0	2,5	2,3	2,0
152,4	4,0	4,5	4,5	8,8	8,8	5,6	3,0	2,5	2,3	2,0
159,0	4,0	4,5	4,5	8,8	8,8	5,6	3,0	2,5	2,3	2,0
168,3	4,0	4,5	4,5	8,8	8,8	5,6	3,0	2,5	2,3	2,0
177,8	4,5	5,0	5,0	8,8	—	—	3,0	2,5	2,3	2,0
193,7	4,5	5,4	5,4	8,8	—	—	3,5	3,0		2,5
219,1	4,5	5,9	5,9	8,8	—	—	3,5	3,0		2,5
244,5	5,0	6,3	6,3	8,8	—	—	3,5	3,0		2,5
267,0	5,0	6,3	6,3	8,8	—	—	3,5	3,0		2,5
273,0	5,0	6,3	6,3	8,8	—	—	4,0	3,5		3,0
298,5	5,6	6,3	6,3	8,8	—	—	4,0	3,5		3,0
323,9	5,6	6,3	6,3	8,8	—	—	4,0	3,5		3,0
355,6	5,6	6,3	6,3	8,8	—	—	4,0	3,5		3,0
368,0	5,6	6,3	6,3	8,8	—	—	4,0	3,5		3,0

Table 2.3.8 — continued

1	2	3	4	5	6	7	8	9	10	11
406,4	6,3	6,3	6,3	8,8	—	—	4,0	3,5	2,3	3,0
419,0	6,3	6,3	6,3	8,8	—	—	4,0	3,5	2,6	3,0
457,2	6,3	6,3	6,3	8,8	—	—	4,0	3,5	2,6	3,0
508,0	—	—	—	—	—	—	4,5	4,0	2,6	3,5

N o t e s : 1. For pipes with thicknesses and diameters indicated in the Table, the nearest values specified in national and international standards may be accepted on agreement with the Register.

2. For the tabulated values no allowance need be made for negative manufacturing tolerance and reduction in thickness due to bending.

3. For the pipes with diameters greater than 450 mm, the minimum thickness shall be taken in accordance with the standards agreed upon with the Register; the minimum thickness value shall not be taken less than that specified for pipes with diameter of 450 mm.

4. The minimum internal diameters of drain, sounding, air and overflow pipes shall be accepted in compliance with 7.2.3, 10.1.12, 10.2.8 and 10.4.7 accordingly.

5. For pipes protected against corrosion by special coatings, linings, etc., the minimum wall thicknesses of pipes, listed in columns 3, 4 and 5, may be reduced by an amount of not more than 1 mm.

6. For sounding pipes, the thicknesses stated in colns 3 and 5 apply to the parts, which are outside the tanks, for which these pipes are intended.

7. For threaded pipes, the wall thickness shown is the minimum thickness at the bottom of the thread.

8. The thicknesses stated in columns 6 and 7 apply to the pipes, which are galvanized on the inside.

9. The minimum wall thicknesses of bilge and ballast lines passing through cargo tanks, as well as cargo lines will be subject to special consideration by the Register in each case.

10. The Table is not applicable to the exhaust gas piping.

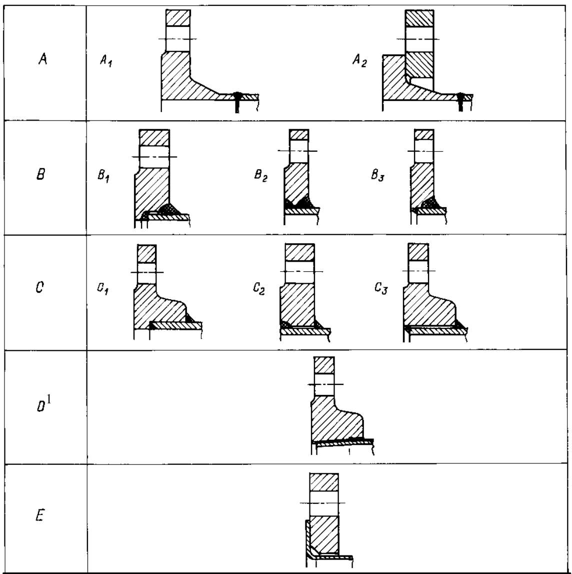
11. For low pressure carbon dioxide system the wall thickness of pipes on a length from tank to discharge nozzles shall be the same as in column 7.

12. Wall thickness of scuppers and discharge pipes shall not be less than stated in 4.3.2.

13. Wall thickness of ballast and air pipes passing through cargo tanks shall comply with the requirements of Table 9.10.1.

The applied seals shall be compatible with the conveyed medium at the design pressure and temperature. For non-standard joints the strength dimensions of flanges and connecting bolts shall be subjected to special consideration by the Register in each case.

Flange connections shall be chosen in accordance with the national or international standards approved by the Register, depending on the medium being conveyed, design pressure and temperature, external and cycling loads, as well as the pipeline location.



[1] In tapered threaded connection of type *D* the outside diameter of pipe thread shall not be less than the pipe outside diameter. The pipe shall be flared after the flange is fitted.

Fig. 2.4.3.2

2.4.3.2 Connection of flanges and pipes shall be made in accordance with Fig. 2.4.3.2.

Other types of joints may be accepted by the Register upon the special consideration.

2.4.3.3 Choice of flange and pipe joints type depending on pipeline class shall be conducted in accordance with Table 2.4.3.3.

Table 2.4.3.3

Class of piping	Toxic, corrosive and combustible media, liquefied gas[3]	Fuel oil, lubricating oil, combustible hydraulic oil	Steam	Other media[1]
I	*A, B* [5]	*A, B*	*A, B* [2,5]	*A, B*
II	*A, B, C*	*A, B, C*	*A, B, C, D*[4]	*A, B, C, D*[4], *E*[4,6]
III	—	*A, B, C*	*A, B, C, D*	*A, B, C, D, E*[6]

[1] Including water, air, gases, non-combustible hydraulic oil.
[2] When design temperature exceeds 400 °C — only type *A*.
[3] When design pressure is over 1 MPa — only type *A*.
[4] Types C_3, *D* and *E* (refer to Fig. 2.4.3.2) shall not be used when design temperature exceeds 250 °C.
[5] Type *B* — only for pipes with outside diameter of 154,4 mm and lower.
[6] For Type *E* the flanging technology shall be approved by the Register.

2.4.4 Tapered threaded connections.

2.4.4.1 Threaded connections shall be accomplished in compliance with the requirements of the approved national or international standards. Such connections shall not be applied in systems conveying toxic and flammable media or media causing severe corrosive or erosive wear, as well as in conditions with heavy fatigue loads.

The threaded slip-on joints with taper thread may be applied in Class I pipelines with the diameter up to 33,7 mm and Class II and III pipelines with the diameter up to 60,3 mm.

Joints with parallel thread may be applied in Class III pipelines with the diameter up to 60,3 mm.

In particular cases, sizes in excess of those mentioned above may be accepted by the Register after special consideration if in compliance with the national or international standards.

2.4.4.2 Application of threaded connections in CO_2 fire-extinguishing systems is allowed only inside the spaces to be protected and in CO_2 cylinders room.

2.4.5 Mechanical joints.

2.4.5.1 The present requirements are applicable to compression couplings, pipe unions and slip-on joints shown in Table 2.4.5.1. Application of such joints may be also accepted by the Register.

Due to the great variations in design and configuration of mechanical joints, no specific recommendations regarding the check calculation of their strength are given.

Type approval of the mechanical joints shall be based on the results of testing of their specimens.

2.4.5.2 Mechanical joints, their application and pressure ratings shall be approved by the Register. The approval shall be based on the type tests in accordance with a program approved by the Register.

2.4.5.3 Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this shall be taken into account in determining the minimum wall thickness of the pipe.

2.4.5.4 Construction of mechanical joints shall prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

2.4.5.5 Material of mechanical joints shall be compatible with the piping material and media being conveyed.

2.4.5.6 Mechanical joints shall withstand a test pressure not less than 4 times the design pressure.

For design pressures of 20 MPa and above, the required test pressure may be reduced on agreement with the Register.

2.4.5.7 Mechanical joints listed in Table 2.4.5.13 intended for use in systems conveying flammable media and in essential purpose systems shall be of fire resistant type.

Table 2.4.5.1

Examples of mechanical joints

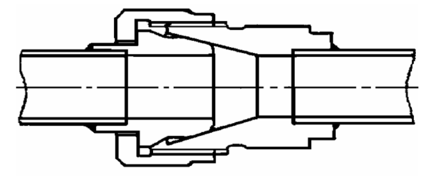
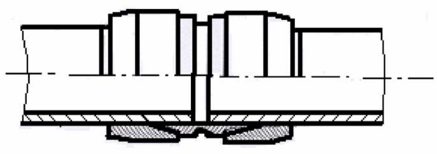
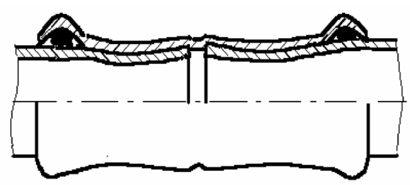
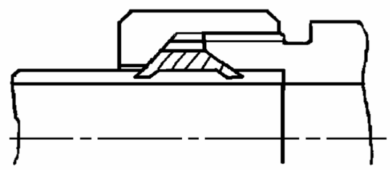
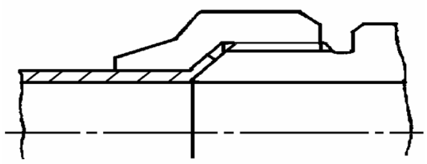
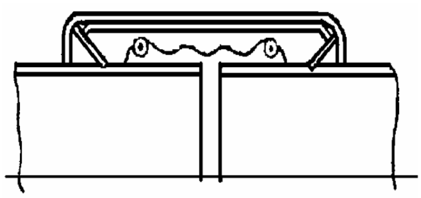
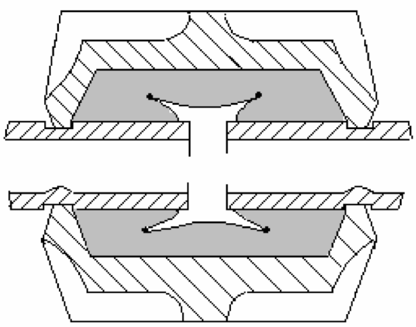
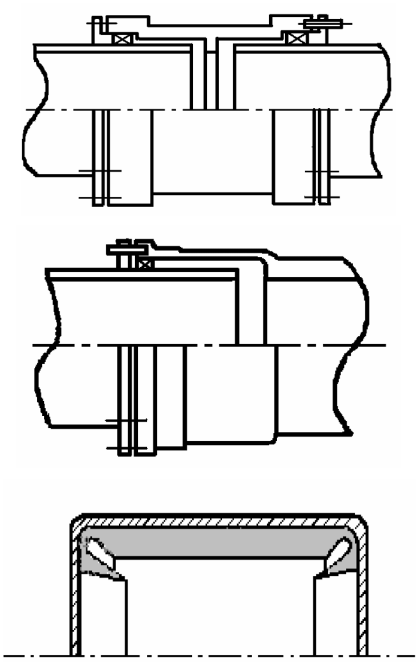
Pipe unions	
Welded and brazed types	
Compression couplings	
Swage type	
Press type	
Bite type	
Flared type	
Slip-on joints	
Grip type	
Machine grooved type	

Table 2.4.5.1 — continued

Slip type	

2.4.5.8 Mechanical joints, which in the event of damage could cause fire or flooding, shall not be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

2.4.5.9 The mechanical joints shall be designed to withstand internal and external pressure as applicable and where used in suction lines shall be capable of operating under vacuum.

2.4.5.10 The number of mechanical joints in oil systems shall be kept to a minimum. Application of standard flanged joints shall be preferred.

2.4.5.11 Piping, in which a mechanical joint is fitted, shall be adequately adjusted, aligned and supported. Supports or hangers shall not be used for alignment of piping at the point of connection.

2.4.5.12 Slip-on joints shall not be used in pipelines in cargo holds, tanks, and other spaces, which are not easily accessible, unless approved by the Register.

Application of these joints inside tanks may be permitted only for the same media that is in the tanks.

Usage of slip-on joints as the main means of pipe connection is not permitted. They shall be used only in cases where compensation of lateral pipe deformation is necessary.

2.4.5.13 Application of mechanical joints and their acceptable use for each service is indicated in Table 2.4.5.13-1; dependence upon the class of piping, piping dimensions, working pressure and temperature is indicated in Table 2.4.5.13-2.

2.4.5.14 Mechanical joints shall be tested in accordance with a program approved by the Register, which shall include at least the following:

.1 leakage test;
.2 vibration test;
.3 fire endurance test (where necessary);
.4 pressure pulsation test (where necessary);
.5 vacuum test (where necessary);
.6 burst pressure test;
.7 pull-out test (where necessary);
.8 assembly test (where necessary).

The scope and nature of the tests shall be specified depending on the type of joint and the purpose of piping.

2.4.5.15 The installation of mechanical joints shall be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these shall be supplied by the manufacturer.

2.5 FLEXIBLE HOSES

2.5.1 F l e x i b l e h o s e a s s e m b l y is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

2.5.2 Application.

2.5.2.1 The requirements 2.5.3 to 2.5.6 apply to flexible hoses of metallic or non-metallic material intended for permanent connection between a fixed piping system and items of machinery. The requirements may also be applied to temporary connected flexible hoses or hoses of portable equipment.

2.5.2.2 Flexible hose assemblies may be accepted for use in fuel oil, lubricating, hydraulic and thermal oil systems (cold portions), fresh water and sea water cooling systems, bilge and ballast systems, and Class III steam systems where they comply with 2.5.3 to 2.5.6. Flexible hoses in high-pressure fuel oil injection systems shall not be accepted.

2.5.2.3 The present requirements are not applicable to hoses of water fire main system.

2.5.3 Design and construction.

2.5.3.1 Flexible hoses shall be designed and constructed in accordance with the approved standards. Flexible hoses constructed of rubber or plastics materials and intended for use in bilge, ballast, compressed air, fuel oil, lubricating, hydraulic and thermal oil systems shall incorporate a single or double closely woven integral wire braid or other suitable material reinforcement.

Where rubber or plastics materials hoses shall be used in oil supply lines to burners, the hoses shall have external wire braid protection in addition to the

Table 2.4.5.13-1

Application of mechanical joints depending on the pipeline service

Nos.	Systems	Kind of connections		
		Pipe unions	Compression couplings[1]	Slip-on joints
	Flammable fluids (flash point ⩽60 °C)			
1	Cargo oil lines	+	+	+[2]
2	Crude oil washing lines	+	+	+[2]
3	Vent lines	+	+	+[3]
	Inert gas			
4	Water seal effluent lines	+	+	+
5	Scrubber effluent lines	+	+	+
6	Main lines	+	+	+[2,5]
7	Distribution lines	+	+	+[2]
	Flammable fluids (flash point ⩾60 °C)			
8	Cargo oil lines	+	+	+[2]
9	Fuel oil lines	+	+	+[3,5]
10	Lubricating oil lines	+	+	+[3,5]
11	Hydraulic oil	+	+	+[3,5]
12	Thermal oil	+	+	+[3,5]
	Sea water			
13	Bilge lines	+	+	+[6]
14	Water fire main and water spray	+	+	+[3]
15	Foam system	+	+	+[3]
16	Sprinkler system	+	+	+[3]
17	Ballast system	+	+	+[6]
18	Cooling water system	+	+	+[6]
19	Tank cleaning services	+	+	+
20	Non-essential systems	+	+	+
	Fresh water			
21	Cooling water system	+	+	+[6]
22	Condensate return	+	+	+[6]
23	Non-essential system	+	+	+
	Sanitary/drains/scuppers			
24	Deck drains (internal)	+	+	+[4]
25	Sanitary drains	+	+	+
26	Scuppers and discharge (overboard)	+	+	—
	Sounding/vent			
27	Water tanks/cofferdams	+	+	+
28	Fuel oil tanks (flash point ⩾60 °C)	+	+	+[3,5]
	Miscellaneous			
29	Starting/control air[6]	+	+	—
30	Service air (non-essential)	+	+	+
31	Brine	+	+	+
32	CO_2 system[6]	+	+	—
33	Steam	+	+	—

S y m b o l s:
\+ application is allowed;
— application is not allowed.

[1] If compression couplings include any components, which readily deteriorate in case of fire, they shall be also of approved fire resistant type as required for slip-on joints.
[2] In pump rooms and open decks – only approved fire resistant types.
[3] Approved fire resistant types.
[4] Above upper deck only.
[5] Not inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces, provided the joints are located in easily visible and accessible positions.
[6] Inside machinery spaces of category A – only approved fire resistant types.

Table 2.4.5.13-2

Application of mechanical joints depending upon the class of piping

Types of joints	Classes of piping systems		
	I	II	III
Pipe unions			
Welded and brazed type	+ (outside diameter ⩽60,3 mm)	+ (outside diameter ⩽60,3 mm)	+
Compression couplings			
Swage type	+	+	+
Bite type, flared type	+ (outside diameter ⩽60,3 mm)	+ (outside diameter ⩽60,3 mm)	+
Press type	—	—	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	—	+	+
Slip type	—	+	+

Symbols:
+ application is allowed;
— application is not allowed.

integral reinforcement. Flexible hoses for use in steam systems shall be of metallic construction.

2.5.3.2 Flexible hoses shall be complete with approved end fittings. Except the flange connections, the end connections shall comply with the applicable requirements of 2.4.5 and each type of hose/fitting combination shall be subject to prototype testing.

2.5.3.3 The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding (e.g. when they are connected directly to side openings). In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 0,5 MPa and provided there are double clamps at each end connection.

2.5.3.4 Flexible hose assemblies intended for installation in piping systems where pressure pulses or high levels of vibration are expected to occur in service, shall be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 2.5.5 shall take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

2.5.3.5 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media and sea water systems where failure may result in flooding (e.g. when they are connected directly to side openings), shall be of fire-resistant type. Fire resistance shall be demonstrated by testing in accordance with the requirements of 2.5.5.6.

2.5.3.6 Flexible hose assemblies shall be selected for the intended location and application taking into consideration ambient conditions, compatibility with the conveyed fluids under working pressure and temperature conditions consistent with the manufacturer's instructions.

2.5.4 Installation.

2.5.4.1 In general, flexible hoses shall be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery equipment or piping.

2.5.4.2 Flexible hose assemblies shall not be installed where they may be subjected to torsion deformation (twisting) under normal operation conditions.

2.5.4.3 The number of flexible hoses in piping systems shall be kept to minimum and shall be limited for the purpose stated in 2.5.2.

2.5.4.4 Where flexible hoses are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces the risk of ignition due to failure of the hose assembly shall be mitigated by the use of screens or other similar protection to the satisfaction of the Register.

2.5.4.5 Flexible hoses shall be installed in clearly visible and readily accessible locations.

2.5.4.6 The installation of flexible hose assemblies shall be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

orientation (with consideration for allowable movement in service);

end connection support (where necessary);

avoidance of hose contact that could cause rubbing and abrasion;

minimum bend radii.

2.5.5 Tests.

2.5.5.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assemblies shall be submitted by the manufacturer and shall be sufficiently detailed to demonstrate performance in accordance with the specified standards.

2.5.5.2 The tests shall be carried out on different nominal diameters of hose type complete with end fittings and shall incorporate tests in accordance with 2.5.5.3 to 2.5.5.6. Other standards may be accepted when agreed by the Register.

2.5.5.3 Each flexible hose assembly shall be tested by test pressure equal to 1,5 times the design pressure during 5 min. No residual deformations and damages are accepted.

2.5.5.4 All flexible hose assemblies shall be tested by burst pressure equal to four times the design pressure. Residual deformations without visible damages or leaks are accepted.

2.5.5.5 Pressure impulse tests shall be carried out during prototype tests for flexible hose assemblies intended for installation in systems where pressure impulses are expected. Pressure impulse tests shall be carried out to ISO 6802, ISO 6803, ISO 10380 or equivalent.

2.5.5.6 Fire resistance tests shall be carried out during prototype tests of flexible hose assemblies referred to in 2.5.3.5. The tests are carried out to ISO 15540 and ISO 15541 or equivalent.

2.5.6 Marking.

2.5.6.1 Flexible hoses shall be permanently marked by the manufacturer with the following details:

hose manufacturer's name or trademark;
date of manufacture (month/year);
designation type reference;
nominal diameter;
pressure rating;
temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components shall be clearly identified.

3 PLASTIC PIPING

3.1 DEFINITIONS

3.1.1 For the purpose of the present Section, the following definitions have been adopted.

N o m i n a l p r e s s u r e is the maximum permissible working pressure as defined in 6.8.2.3, Part XIII "Materials".

F i r e r e s i s t a n c e is the ability of plastic pipeline to maintain strength and integrity (i.e. ability to operate to its designated purpose) within the set period of time under flame exposure.

P l a s t i c m a t e r i a l s are thermoplastic (thermoplasts) and thermosetting (thermosets) materials with or without reinforcement, such as polyvinylchloride (PVC) and fibre reinforced plastic (FRP).

D e s i g n p r e s s u r e is the maximum working pressure expected under operating conditions or the maximum pressure setting of the pressure-relief valve or pressure relieving device, if fitted.

J o i n t is the connection of pipes by glueing, application of binding bands, welding, etc.

P i p i n g / p i p i n g s y s t e m is a combination of plastic pipes, formed components, pipe joints and any internal or external coatings or linings necessitated by operating conditions.

F o r m e d c o m p o n e n t s are bends, elbows, connecting branches, etc. made of plastic.

3.2 SCOPE OF APPLICATION. GENERAL REQUIREMENTS

3.2.1 The present requirements apply to all pipelines made from plastics.

3.2.2 The requirements are not applied to flexible non-metal joints, rubber hose, as well as to mechanical unions used in systems with metal pipes.

3.2.3 General requirements to plastic pipes and fittings are stated in 6.8, Part XIII "Materials".

3.3 REQUIREMENTS FOR PIPING DEPENDING ON THEIR PURPOSE AND LOCATION

3.3.1 Fire-resistance.

3.3.1.1 Pipes and formed components, integrity of which has significant influence on ship's safety, shall meet the requirements of fire-resistance.

3.3.1.2 Depending on pipeline ability to maintain integrity during fire-resistance tests according to the procedure stated in Annexes 1 and 2 to IMO resolution A.753(18), three degrees of fire-resistance are specified:

L1 for pipelines withstanding fire-resistance test in dry condition during 1 hour;

L2 for pipelines withstanding fire-resistance test in dry condition during 30 min;

L3 for pipelines withstanding the fire-resistance test in filled condition during 30 min.

Plastic pipelines scope of application depending on fire-resistance degree, location and media conveyed is given in Table 3.3.1.2.

Table 3.3.1.2

Application of plastic pipelines

Nos	Medium to be conveyed	Piping systems	A	B	C	D	E	F	G	H	I	J	K
			Location										
1	Liquid cargoes with flash point ⩽60 °C	Cargo	—	—	L1	—	—	O	—	O[10]	O	—	L1[2]
		Crude oil tank washing	—	—	L1	—	—	O	—	O[10]	O	—	L1[2]
		Exhaust gas	—	—	—	—	—	O	—	O[10]	O	—	+
2	Inert gas	Pipeline from hydraulic lock	—	—	O[1]	—	—	O[1]	O[1]	O[1]	O[1]	—	O
		Pipeline from purifier	O[1]	O[1]	—	—	—	—	—	O[1]	O[1]	—	O
		Main pipe	O	O	L1	—	—	—	—	—	O	—	L1[6]
		Distribution pipelines	—	—	L1	—	—	O	—	—	O	—	L1[2]
3	Flammable liquids with flash point > 60 °C	Cargo	+	+	L1	+	+	—[3]	O	O[10]	O	—	L1
		Fuel oil	+	+	L1	+	+	—[3]	O	O	O	L1	L1
		Oil	+	+	L1	+	+	—	—	—	O	L1	L1
		Hydraulic	+	+	L1	+	+	O	O	O	O	L1	L1
4	Sea water	Drainage	L1[7]	L1[7]	L1	+	+	—	O	O	O	—	L1
		Drain pipelines of internal spaces	L1[4]	L1[4]	—	L1[4]	O	—	O	O	O	O	O
		Sanitary drains (internal)	O	O	—	O	O	—	O	O	O	O	O
		Drainage from weather decks	O[1,8]	O[1,8]	O[1,8]	O[1,8]	O[1,8]	O	O	O	O	O[1,8]	O
		Firemain system and water spraying	L1	L1	L1	+	—	—	—	O	O	+	L1
		Foam fire-extinguishing	L1	L1	L1	+	—	—	—	O	O	L1	L1
		Sprinkling	L1	L1	L3	+	—	—	—	O	O	L3	L3
		Ballast	L3	L3	L3	L3	+	O[10]	O	O	O	L2	L2
		Essential purpose cooling systems	L3	L3	—	—	—	—	—	O	O	—	L2
		Non-essential purpose cooling systems	O	O	O	O	O	—	O	O	O	O	O
		Crude oil tank washing	—	—	L3	—	—	O	—	O	O	—	L3[2]
5	Fresh water	Essential purpose cooling systems	L3	L3	—	—	—	—	O	O	O	L3	L3
		Condensate return system	L3	L3	L3	O	O	—	—	—	O	O	O
		Non-essential purpose systems	O	O	O	O	O	—	O	O	O	O	O
6	Other media	Air, sounding and overflow pipes: water tanks and dry compartments	O	O	O	O	O	O[10]	O	O	O	O	O
		Flammable liquids, $T_{flash} > 60$ °C	+	+	+	+	+	+[3]	O	O[10]	O	+	+
		Pneumatic control systems	L1[5]	L1[5]	L1[5]	L1[5]	L1[5]	—	O	O	O	L1[5]	L1[5]
		Air pipes for domestic needs	O	O	O	O	O	—	O	O	O	O	O
		Brine	O	O	—	O	O	—	_	—	O	O	O
		Low pressure steam	L2	L2	O[9]	O[9]	O[9]	O	Ō	O	O	O[9]	O[9]

Symbols and abbreviations:
A - machinery spaces of category A;
B - other machinery spaces;
C - cargo pumps rooms, including accesses and trunks;
D - cargo spaces of roll-on/roll-off ships;
E - dry cargo rooms and trunks;
F - cargo tanks and trunks;
G - fuel oil tanks and trunks;
H - ballast tanks and trunks;
I - cofferdams, dry compartments, etc;
J - accommodation, service spaces and control stations;
K - weather decks;
L1 - fire-resistance test in dry condition during 60 min;
L2 - fire-resistance test in dry condition during 30 min;
L3 - fire-resistance test in filled condition during 30 min;
O - fire-resistance test is not required;
— - not applicable;
+ - only metal materials with fusion point above 925 °C.

[1] From the side the valves with remote control located outside of the room shall be provided.
[2] For cargo tanks the remotely closing valves shall be provided.
[3] When cargo tanks contain flammable liquids with flash temperature > 60 °C, "O" may be used instead of "-" or "+".
[4] For drainage pipelines servicing only the particular space "O" may be used instead of "L1".
[5] When control functions are not foreseen, "O" may be used instead of "L1".
[6] For pipeline between engine room and deck hydraulic lock "O" may be used instead of "L1".
[7] For passenger ships "+" shall be used instead of "L1".
[8] Scupper holes of weather decks in the positions 1 and 2 according to Regulation 13 of the International Convention on Load Line, 1966, shall be "+", if they are not provided with the appropriate blanking means.
[9] For essential purposes, such as heating of cargo tanks and ship's typhon, "+" shall be used instead of "O".
[10] For tankers, where the requirements of item 3(f), Regulation 13F, Annex I, MARPOL-73/78 shall be met, "-" shall be used instead of "O".

3.3.2 Flame spreading, flame-retardant coatings.

3.3.2.1 All pipes, with the exception of pipes located on weather decks, in tanks, in cofferdams, void spaces, pipelines tunnels, etc. shall obtain characteristic of slow spreading of flame on the surface, not exceeding the average values fixed in IMO resolution A.653(16) and determined according to the procedure given in Annex 3 to IMO resolution A.753(18) considering the changes arising from curved surface of pipes or specified by other standards approved by the Register.

3.3.2.2 When fire-retardant coatings are applied to provide the required degree of fire-resistance they shall comply with the requirements of 6.8, Part XIII "Materials".

3.3.2.3 Fire-retardant coatings in junctions shall be applied after conducting of hydraulic tests of the system in compliance with pipe manufacturer recommendations according to the procedure approved by the Register in each case.

3.3.2.4 Fire-retardant coatings shall be used according to the approved recommendations of the manufacturer.

3.4 INSTALLATION REQUIREMENTS

3.4.1 Supports.

3.4.1.1 Choice of supports and distances between them shall be determined depending on permissible stresses and maximum allowable pipe swag.

Distances between supports shall not exceed the values recommended by the manufacturer.

In selection of supports and distances between them pipes sizes, mechanical and physical properties of pipe material, mass of pipes and liquid containing in them, external pressure, working temperature, influence of heat expansion, load of outer forces, axial forces, hydraulic impact, vibration, which may occur in the system, shall be taken into consideration. Allowance shall be made for the possible simultaneous effect of the above mentioned loads.

3.4.1.2 The load from pipe weight shall be equally distributed over the entire load-bearing face of the support. Measures shall be taken to minimize pipe wearing in the points of their junction with the supports.

3.4.1.3 Components of system having significant mass, such as valves, compensators, etc. shall be fitted with separate supports.

3.4.2 Heat expansion compensation.

3.4.2.1 When assembling of plastic pipelines the compensation tolerance for relative displacement between piping and steel structures with regard to difference in heat expansion ratio and ship's hull deformation shall be provided.

3.4.2.2 When calculating heat expansions the working temperature of system and the temperature, at which assembling is carried out, shall be taken into account.

3.4.3 Environmental stresses.

3.4.3.1 In pipe laying, where necessary, allowance shall be made for periodically involved concentrated loads. At least, the force generating by the load of one person of 100 kg in the middle of span of any pipe with the outer diameter over 100 mm shall be taken into consideration.

3.4.3.2 To ensure the appropriate rigidity of piping, including pipelines with open ends, the Register may require to increase the wall thickness in comparison with thickness specified on the basis of strength control.

3.4.3.3 When necessary, pipes shall be protected from mechanical damage.

3.4.4 Installation of electrically conducting pipes.

3.4.4.1 In systems of liquids transmission with electrical conductivity less than 1000 pico-siemens per meter (PS/m), such as raffinates, distillates, the electrically conductive pipes shall be used.

3.4.4.2 Regardless of the liquids transmitted the plastic pipes passing through explosive areas shall be electrically conductive.

Resistance in any point of pipeline system as relative to earth shall not exceed 10^6 Ohm. Pipes and formed components having electrically conducted layers shall preferably be of equal conductivity.

Such pipes shall be sufficiently protected from damage by electric discharge caused by difference in the electrical conductivity of layers.

3.4.4.3 After installation earth connection shall be checked. Earthing wires shall be accessible for examination.

3.5 PLASTIC PIPES JOINTS

3.5.1 Strength of joints.

3.5.1.1 Strength of joints shall not be less than strength of a pipeline where they are mounted.

3.5.1.2 Pipes may be connected with the use of glued, welded, flanged and other connections.

3.5.1.3 Glues used for pipes joints shall keep tightness of joints in the whole pressure and temperature range.

3.5.1.4 Tightening of joints shall be carried out in compliance with the instructions of the manufacturer.

3.5.2 Testing of joints quality.

3.5.2.1 For the inspection of pipe joint quality it is necessary in accordance with the accepted procedure to prepare test assemblies, which shall include at least one joint of pipe with pipe and pipe with formed component.

3.5.2.2 Following joint setting, a test connection shall be subjected to a hydraulic pressure test during at least 1 hour at the pressure 2,5 times exceeding the design one. Leakage and breaks of joint are not allowed. Tests shall be arranged in such a way that joints are loaded both in longitudinal and transverse directions.

3.5.2.3 When selecting pipes for test specimen the following shall be taken into consideration:

when the maximum outer diameter of joint assembly is less than 200 mm, the test assembly shall incorporate a pipe with the maximum diameter;

when the maximum outer diameter of joint assembly is over 200 mm, the outer diameter of test joint assembly shall be 200 mm or shall be equal to 25 per cent of the maximum diameter of the coupling, whatever is greater.

3.6 PLASTIC PIPING LAYING

3.6.1 Where plastic pipes pass through watertight bulkheads and decks, "A" and "B" class divisions the requirements of 5.1 shall be met.

3.7 INSPECTION DURING THE INSTALLATION

3.7.1 Installation shall be carried out in accordance with the instructions of the manufacturer.

3.7.2 The method of pipe connection (junction) shall be developed and approved prior to the installation.

3.7.3 Surveys and tests stated in the present Section of the Rules shall precede the approval of the method.

3.7.4 Personnel involved in the works shall be properly qualified and attested.

3.7.5 In the method of joints connection the following shall be reflected: the applied materials, tools and accessories, the requirements on preparation of joints, temperature conditions, the requirements on dimensions and tolerances, as well as the acceptance criteria upon the work and testing completion.

3.7.6 Any alterations in the method resulting in change of physical and mechanical properties of the joint call for its repeated consideration and re-approval.

3.8 TESTING OF PIPING AFTER INSTALLATION ABOARD THE SHIP

3.8.1 After installation the pipeline system of essential purpose shall be hydraulically tested with pressure at least 1,5 times higher than the design pressure.

3.8.2 The pipeline system of non-essential purpose may be tested for tightness with the working pressure.

3.8.3 For electrically conductive pipes the availability of grounding shall be checked and the spot check of resistance shall be carried out.

4 FITTINGS

4.1 CONSTRUCTION, MARKING, ARRANGEMENT AND INSTALLATION OF FITTINGS

4.1.1 Construction.

4.1.1.1 The covers of valves with internal diameter more than 32 mm shall be secured to valve bodies by bolts or studs.

Threaded covers may be used for the valves having internal diameter up to 32 mm inclusive, if reliable stops are fitted on these covers.

The nut of plug in a cock shall be well locked to prevent loosening while handling the cock.

4.1.1.2 Valves with remote control except those mentioned under 4.1.1.4 shall be arranged for local manual operation independent of the remote operating mechanism.

In the case of valves, which are provided with remote control according to requirements of the present Rules, operating of the valves by local manual means shall not render the remote control system inoperable.

If the valves are provided with remote control, they shall be so constructed that in case of failure of the remote control system, the valves remain, or automatically return, in a position that will not bring the ship in dangerous situation.

4.1.1.3 Compressed air shall not be used in remote control systems to operate actuators inside cargo tanks.

4.1.1.4 Where the valves inside cargo tanks are remote-controlled by means of a hydraulic system, they shall be also operable with the aid of a hand pump, which can be connected to the hydraulic system in positions where the pipes are laid down to each valve, or to a separate pipe laid directly to the valve actuator.

4.1.1.5 The supply tank of the hydraulic remote control system of the valves inside cargo tanks shall be located as high as practicable above the level of the top of cargo tanks, and all supply pipes shall enter the cargo tanks through the highest part of the cargo tanks.

The supply tank shall also have an air pipe laid to a safe position on the open deck and fitted with a flame-arresting gauze at the open end.

This tank shall be fitted with a low level audible and visual alarm.

4.1.2 Marking of fittings.

4.1.2.1 The shut-off fittings shall be provided with conspicuous nameplates fixed in place and bearing clear inscriptions to show the purpose of fittings.

4.1.2.2 At the control stations, the remote-controled valves shall have identification plates, as well as position indicators "open" and "closed".

Where the remote control is used only to close the valves, the indicators need not be fitted.

4.1.3 Installation of fittings.

4.1.3.1 The fittings arranged on watertight bulkheads shall be secured to welded pads by studs, or alternatively the fittings may be welded to bulkhead pieces.

The stud holes shall not be through holes.

4.1.3.2 The valve chests and the hand-controlled valves shall be fitted in places where they are at all times readily accessible in normal operating conditions.

Where the valves of the fuel oil system are installed in the machinery space, the valve control gear shall be fitted above the plating.

4.1.3.3 The measuring instruments of fuel oil and lubricating oil systems shall be provided with valves or cocks to shut the instruments off from piping. Thermometer sensors shall be fitted in compact sleeves.

4.2 FILTERS

4.2.1 The design and construction of filters shall facilitate cleaning.

4.2.2 Filters shall be provided with a device to indicate the absence of pressure therein before they are opened.

The tubes of such devices shall be directed to trays so that spillages are not sprayed around.

4.2.3 For filters forming part of systems with a combustible working medium, an interlock is recommended so that they cannot be opened when under pressure and that the working medium cannot be supplied therein when opened.

4.2.4 Filters shall be so arranged that they are readily accessible for maintenance.

Filters and strainers forming part of systems with a combustible working medium shall be located as far away as practicable from sources of ignition.

4.2.5 The pipelines used to supply and carry away fuel oil in/from the filters shall be equipped with shut-off valves or cocks.

4.2.6 Filters on seawater suction mains shall comply with 15.3.1.

4.3 SEA CHESTS AND ICE BOXES. BOTTOM AND SIDE FITTINGS. OPENINGS IN SHELL PLATING

4.3.1 Sea chests and ice boxes.

4.3.1.1 Number and arrangement of sea chests for the cooling water system shall comply with 15.2.1.

In ships with the ice strengthening of categories **Arc4** and **Arc5** one of the sea chests shall function as an ice box. In icebreakers and ships with **Arc6** to **Arc9** ice categories, at least two sea chests shall be ice boxes.

In icebreakers and ships with the ice strengthening or categories **Arc4** to **Arc9** the ice box design shall allow for an effective separation of ice and removal of air from the ice box to ensure reliable operation of the sea-water system.

Sea inlet valves shall be secured directly to sea chests or ice boxes.

4.3.1.2 In icebreakers and ships strengthened for ice navigation, provision shall be made for the heating of the sea chests and ice boxes as well as of the ship side valves and fittings above the load waterline. For this purpose:

cooling water recirculation shall be used for ice boxes and sea chests;

ship side valves and fittings shall be supplied with heating medium through a non-return shut-off valve. The heating arrangements shall be so designed as to prevent the side valves and fittings and shell plating from being damaged under the influence of lowest temperatures.

On agreement with the Register other methods of side fittings heating may be used.

For ice boxes the recirculated water pipes shall be laid to the upper and lower part of the box, and the total sectional area of these pipes shall not be less than the area of the cooling water discharge pipe.

For sea chests, the diameter of the water recirculating pipe shall not be less than 0,85 of the discharge pipe diameter.

4.3.1.3 Provision shall be made for the access into these boxes via detachable gratings or manholes. If a manhole is provided in the ice box it shall be located above the deepest load line.

4.3.2 Openings in shell plating. Bottom and side fittings.

4.3.2.1 The number of openings in shell plating shall be kept to a minimum. Therefore, whereover possible, discharge pipes shall be connected to common discharges.

4.3.2.2 The location of sea inlet and discharge openings in ship sides shall be such as to prevent:

.1 sewage, ash and other wastes being sucked by sea water pumps;

.2 sewage and discharge water penetrating into the ship spaces through side scuttles as well as any discharge of water into lifeboats and liferafts when lowered.

Where it is impracticable to comply with the requirements of 4.3.2.2.2, discharge openings shall be fitted with appropriate arrangements to prevent the ingress of water into ship spaces, lifeboats and liferafts.

4.3.2.3 All the openings in ship side for sea chests and ice boxes shall be fitted with gratings. Instead of gratings, holes or slots in shell plating are permissible. The net area through the gratings or slots shall not be less than 2,5 times the area of the valve connected to the sea inlet. The diameter of holes and the width of slots in ratings or shell plating shall be about 20 mm. The gratings of the sea chests shall be provided with a steam or compressed air connection for clearing purposes. For ice boxes, clearing arrangements are not compulsory.

Clearing pipes shall be provided with screw-down non-return valves. The pressure of steam or compressed air in the clearing system shall not exceed 0,5 MPa.

4.3.2.4 The overboard discharges from enclosed spaces below the freeboard deck or from enclosed superstructures and deckhouses on the freeboard deck shall be fitted with accessible means for preventing water from passing inboard. Discharges from piping, which have, or may have, open ends within the mentioned spaces shall comply with the requirements of 3.2.11, Load Line Rules for Sea-Going Ships.

4.3.2.5 In ships of less than 24 m in length, openings in shell plating of spaces on and below the freeboard deck may have one hand-controlled non-return shut-off valve.

In floating docks, each discharge of pipes from spaces below the margin line, which have inboard ends in those spaces, shall have a non-return valve with a positive means of closing from a readily accessible position above the safety deck.

4.3.2.6 The scuppers and overboard discharge pipes from open decks and spaces not specified in 4.3.2.4 either 450 mm below the freeboard deck or less than 600 mm above the summer load waterline shall be fitted with non-return valves (dampers) at the outer shell. In this case, the wall thickness of scuppers and discharge pipes shall not be less than stated in column 3 of Table 2.3.8.

No valves may be provided if the wall thickness of pipes below the freeboard deck and in spaces within enclosed superstructures is less than:

7 mm for $d \leqslant 80$ mm,

10 mm for $d = 180$ mm,

12,5 mm for $d \geqslant 220$ m,

where d = external diameter of pipes.

Intermediate sizes shall be determined by linear interpolation.

In open superstructures and deckhouses, overboard scuppers shall be provided.

In spaces intended for the carriage of motor vehicles with fuel in their tanks, overboard scupper pipes shall be provided to prevent accumulation of water during the operation of the water spraying system.

In floating docks, the overboard scuppers and discharge pipes below the margin line from spaces above the margin line and open decks shall have non-return valves at the outer shell. The valves may be omitted where the pipe thickness below the margin line is not less than that of the outer shell plating, however, it need not exceed 12 mm.

4.3.2.7 In machinery spaces, the inlets and discharges in the outer shell of the cooling water piping of the main and auxiliary engines and systems shall have readily accessible valves or sluice valves locally controlled. The valve controls shall be fitted with an indicator to show whether the valve is open or closed.

The discharge valves at the shell shall be of the non-return shut-off type.

4.3.2.8 The driving means for operating bottom and side inlet fittings shall be located in readily accessible places and shall be fitted with an arrangement indicating whether the valve is open or shut.

In passenger ships, these means shall be located above the floor level of the engine room.

4.3.2.9 In periodically unattended machinery spaces, the control gear of inlet and outlet valves of the sea-water system that lie below the waterline and the control gear of the ejector drainage system shall be so arranged that they are accessible and there is enough time to activate them while the space is being flooded.

If the level, to which a space can be flooded with the ship in the fully loaded condition, is above the controls, provision shall be made to operate them from a position above this level.

Machinery spaces fully automated in respect of control of sea water inlet and outlet valves of systems and main and auxiliary machinery pipelines shall be regarded equal to attended machinery spaces on condition that the provision is made of arrangements, activating when the space is being flooded.

4.3.2.10 Bottom and side fittings shall be attached to welded pads.

The fittings may be also installed on distance pieces welded to the shell plating, provided they are straight, rigid enough and have the minimum length and cathodic protection against contact corrosion. Distance pieces shall be located in readily accessible places for maintenance and for measuring of shell plating thickness under service conditions. The use of flanged joins of D and E types (refer to 2.4.3.2) is not permitted. The design of connections shall be submitted to the Register for approval.

The wall thickness of a distance piece is determined according to 2.2.5.4, Part II "Hull".

The stud holes shall not penetrate the shell plating and shall be only within the welded pads.

4.3.2.11 Side fittings below the bulkhead deck, bottom fittings or gaskets shall have no components, the material of which would readily deteriorate in the event of fire.

4.3.2.12 The spindles and closing parts of bottom and side fittings shall be manufactured of corrosion-resistant materials.

4.3.2.13 The shell openings from garbage chutes of spaces located below the freeboard deck shall be provided with closing devices for preventing water from passing inboard. The closing devices shall meet the requirements of 3.2.11.1 of the Load Line Rules for Sea-Going Ships.

4.4 AIR PIPE AUTOMATIC CLOSING DEVICES

4.4.1 Air pipe automatic closing devices shall be self-draining have reliable attachments, and shall also:

.1 prevent the free entry of water into the tanks;

.2 allow the passage of air or liquid to prevent excessive pressure or vacuum coming on the tank.

4.4.2 Air pipe automatic closing device shall be constructed to allow inspection of the inside of the casing, as well as changing the seals.

4.4.3 Efficient float seating arrangements shall be provided for the closures. Besides seating arrangements other means shall be provided to prevent the float from contacting the inner chamber in its normal state and to prevent the float damage from the water impact in case the tank is overfilled.

4.4.4 The clear area through an air pipe automatic closing device in the open position shall be at least equal to the area of the inlet.

4.4.5 Air pipe automatic closing devices shall be so suitable for use at inclinations up to 40°.

4.4.6 In the case of air pipe automatic closing devices of the float type, suitable guides shall be provided to ensure unobstructed operation under all working conditions of heel and trim.

4.4.7 The maximum allowable tolerances for wall thickness of floats shall not exceed 10 per cent of thickness.

4.4.8 Casings of air pipe automatic closing devices shall be of approved metallic materials with minimum wall thickness of 6 mm adequately protected against corrosion. The thickness of the zinc coating to be applied by the hot method shall be 70 to 100 microns.

4.4.9 For areas susceptible to erosion due to the ballast water impact when the tank is being overfilled, (e.g. the inner chamber area above the air pipe, overlap of $\pm 10°$ either side) an additional harder coating shall be applied. This shall be an aluminum bearing epoxy, or other equivalent, coating, applied over zinc.

4.4.10 Elements of closures made of non-metallic materials shall be compatible with the media carried in the tank and suitable for operating at ambient temperatures between -25 °C and $+85$ °C.

4.4.11 Air pipe automatic closing devices shall be type approved and the minimum test requirements shall be in compliance with 21.4.

5 PIPING LAYING

5.1 PIPING LAYING THROUGH WATERTIGHT AND FIRE-RESISTING STRUCTURES

5.1.1 The number of pipelines passing through the watertight bulkheads shall be kept to a minimum.

Pipelines passing through main watertight bulkheads, shall, as a rule, be situated at a distance from the ship's side of at least one-fifth of the ship's breadth (refer to 7.3.5).

Where this requirement is impracticable, measures shall be taken to prevent the spread of sea water beyond the damaged compartment into other watertight compartments and tanks in case of damage to the ship's hull and deterioration of pipes.

5.1.2 In passenger ships and special-purpose ships the collision bulkhead shall not be pierced below the bulkhead deck by more than one pipe for dealing with the contents of the forepeak.

Where the fore peak is divided by a longitudinal bulkhead into watertight compartments, two suction pipes are allowed to be laid through the collision bulkhead, i.e. one for each compartment.

Each pipe passing through the collision bulkhead shall be fitted with a screw-down valve directly at the collision bulkhead inside the forepeak operable from a readily accessible place from the bulkhead deck.

The requirements for cargo ships as regards pipelines passing through the collision bulkhead may be, upon agreement with the Register, extended to special-purpose ships not more than 50 m in length.

5.1.3 Each pipe passing through the collision bulkhead of cargo ships shall be fitted with a screw-down valve directly at the collision bulkhead inside the forepeak.

This valve may be fitted on the after side of the collision bulkhead, provided that it is not located in a cargo space.

Valve controls shall be operated from the position above the bulkhead deck for the ships having a mark of subdivision in the class notation and above the freeboard deck for all other ships.

The screw-down valve may not be fitted on the pipes passing through the collision bulkhead above the bulkhead deck or freeboard deck.

5.1.4 Where pipelines pass through watertight bulkheads, decks and other watertight structures, there shall be used appropriate bulkhead (sleeves), welded pads and other details to ensure the integrity of the structure concerned.

The holes for studs shall not penetrate through the plating of watertight structure and shall be kept within the welded pads.

Gaskets made of lead or a material, which will be readily deteriorated in the event of fire, shall not be used.

Sockets attached by welding to watertight decks and bulkheads shall have the wall thickness, as a minimum, 1,5 mm greater than that of pipes connected to the sockets.

5.1.5 Where plastic pipes pass through watertight bulkheads and decks forming boundaries of watertight compartments, valves capable of being operated from above the bulkhead deck shall be fitted.

The valves shall be of steel or another material equivalent to steel in fire resistance.

This requirement does not apply to ballast pipes laid within the double bottom.

5.1.6 Where it is necessary to carry pipes through fire-resisting divisions, the requirements of 2.1.2.2, Part VI "Fire Protection" shall be complied with.

5.1.7 Where plastic pipe passes through a division of the main vertical fire zone, provision shall be made for bulkhead steel sleeve and valve that may be closed from either side of the bulkhead. The valves shall be of steel or another material equivalent to steel in fire resistance.

5.2 PIPING LAYING IN TANKS

5.2.1 Bilge pipes, drinking water and feed water pipes shall not be laid through fuel oil and lubricating oil storage tanks, nor shall fuel oil and lubricating oil pipes pass through drinking water and boiler feed water tanks, unless the pipes are laid in oiltight ducts forming part of the tank structure.

Sea water and lubricating oil piping, with no ducts as well as air, overflow and sounding pipes may pass through the fuel storage tanks, if these pipes are of seamless type and have no detachable joints inside the storage tanks; where detachable joints cannot be avoided, they shall be flanged with oilproof gaskets placed between them.

5.2.2 Where the pipes passing through the tanks are not carried in ducts and thermal expansion shall be considered, pipe bends shall be arranged inside the tank.

Where pipes are laid in ducts, it is recommended that thermal compensators be arranged outside the duct.

5.2.3 The pipes laid in oil tankers shall comply with the requirements of 9.2.

5.3 PIPING LAYING IN CARGO HOLDS AND OTHER SPACES

5.3.1 Pipes shall be secured in a way as not to interfere with the stresses from thermal expansion, undue deformation of ship structure and vibration.

5.3.2 Pipes passing through cargo holds, chain lockers and other spaces, in which they are subject to mechanical damage, shall be adequately protected.

5.3.3 Fuel, steam and water pipes as well as pressure pipes of the hydraulic drives shall not, as a rule, be carried in dry cargo holds. Bilge pipes are excluded from this requirement.

In exceptional cases, which are subject to special consideration by the Register, these pipes may be allowed, provided they are laid in special ducts or not in ducts where the pipes employed are of increased thickness and protected by strong steel casings.

5.3.4 Steam pipes shall not be laid in paint room, lantern room or other spaces intended for the carriage of readily flammable materials.

5.3.5 Pipes conveying fuel oil shall not be laid through the accommodation and service spaces as well as under the coating, with the exception of fuel pipe of the emergency diesel-generator and the filling pipes, which are allowed to be laid through sanitary spaces, provided the pipes used have a thickness of not less than 5 mm and no detachable joints are employed.

5.3.6 Pipes having considerable longitudinal extension and conveying hot media shall have thermal compensators or as many bends as will provide adequate self-compensation of the pipeline.

Thermal compensators are fitted in order to take up the axial and transverse displacements and shall not be used to correct misalignment of the pipes. Pipelines shall have appropriate supports. Brackets and hangers shall not be used to produce forces that provide alignment of the pipes or elements.

The radii of bends shall be in compliance with 2.2.1.

5.3.7 The pipes of all the systems and the vent ducts shall, where necessary, be fitted with arrangements for blow-down of the working medium or draining of liquid, if any.

Appropriate structural measures shall be taken to protect ship's hull and equipment from adverse effect of the agents discharged.

5.3.8 The pipes of fire fighting system shall be laid in conformity with the requirements of 3.1.4.1, Part VI "Fire Protection".

5.3.9 Group I and II refrigerant piping laying through accommodation and service spaces shall be carried out in compliance with 6.2.8, Part XII "Refrigerating Plants".

5.4 PIPING LAYING IN REFRIGERATED CARGO SPACES

5.4.1 It is recommended that no pipes be laid through refrigerated cargo spaces, unless they are intended to serve these spaces. Where laying of such pipes cannot be avoided, they shall be carefully insulated. This requirement equally applies to air and sounding pipes. In these spaces the pipes shall not have sections, in which water may collect and freeze.

5.5 PIPING LAYING IN THE VICINITY OF ELECTRICAL AND RADIO EQUIPMENT

5.5.1 Pressure pipes are not permitted to be laid above and behind the main and emergency switchboards as well as the control panels of essential machinery and equipment.

Such pipes may be carried at a distance not less than 500 mm from the fronts and sides of these switchboards and control panels, provided that at a distance less than 1500 mm from switchboards and control panels no detachable joints are used or the flanged joints have protective casings.

5.5.2 Laying of pipes through special electrical spaces (refer to 1.2, Part XI "Electrical Equipment") and also through accumulator battery rooms is not allowed, with the exception of fire smothering pipes, compressed air pipes and the pipes serving the electrical equipment installed in these spaces.

5.5.3 Laying of pipes through the space containing the gyrocompass is not allowed, with the exception of cooling pipes for gyrocompass.

5.5.4 Laying of pipes through the radioroom is not allowed.

5.6 PIPING LAYING IN UNATTENDED MACHINERY SPACES

5.6.1 Class I pipes conveying fuel oil and lubricating oil shall have welded joints. Detachable joints are permitted to be used, but their number shall be kept to a minimum; if considered necessary, protective casings shall be provided in places where detachable joints are fitted.

5.7 PIPING LAYING IN SHIPS WITH TWIN HULLS

5.7.1 When routed along the common upper deck, the pipes connecting identical systems of both hulls shall be provided with compensators where necessary and protected against damage.

Damage to these pipes shall not involve failure of the systems connected by them.

6 SHIP'S HOSES

6.1 CONSTRUCTION OF HOSES

6.1.1 The requirements of the present Section cover ship's hoses for taking over and transfer of liquid cargo, fuel oil, lubricating oil, bilge and dirty ballast waters and transfer of cargo vapors.

6.1.2 Only the hoses as finished items consisting of sleeves and end components (branch pipes with flanges, nipples or other joints) may be used in ships. The hoses shall have type approval of the Register, the manufacturer of sleeves shall be recognized by the Register.

6.1.3 As a rule, a hose sleeve shall be made of rubber, reinforced with fabric, textile cord or cord from steel wire. In addition, the hose sleeve can be reinforced with one or several layers of wire coil, rings or by other means. Application of other materials and structures shall be specially considered by the Register in each case.

Sleeve material shall be resistant to the conveying medium within the whole range of temperatures, for this purpose special coating of the inner surface is allowed.

The outer surface shall be resistant to wear, attrition, exposure to sun rays, atmosphere and impermeable for sea water and cargo. The outer surface may be coated with polyurethane or other material, which affords buoyancy. Such coating shall display the similar properties in reference to external actions.

Construction and material of sleeves and hoses intended for transfer of liquefied gases is subject to special consideration by the Register in each case.

6.1.4 End components shall be connected to the hose sleeve mechanically or chemically. Connection of sleeves with end components by means of clamps is permitted only by agreement with the Register.

6.1.5 When welding is used in the structure of end components, such welding shall be performed by certified welders and is subject to 100 per cent check by methods of non-destructive inspection.

6.1.6 The material of end components and flanges shall exclude the possibility of spark formation during interaction with ship's hull. Surfaces of end components shall be protected from corrosion influence of sea water and medium conveyed.

6.1.7 The hose is assumed to be floating when its buoyancy reserve is at least 20 per cent, provided the hose is completely immersed in sea water and completely filled with it. The hose buoyancy reserve is calculated as follows:

$$K = \frac{B - (W_h + W_w)}{W_h + W_w} \times 100\% \qquad (6.1.7)$$

where K = buoyancy reserve, %;
B = weight of sea water displaced by the hose at its complete immersion, including weight of sea water displaced by materials ensuring buoyancy and weight of sea water inside the hose, kg;
W_w = weight of sea water inside the hose, kg;
W_h = weight of empty hose in air, including weight of materials ensuring buoyancy, kg.

Materials applied for provision of buoyancy shall be properly secured.

6.1.8 Floating hoses shall be orange-colored or marked with orange strip in the shape of spiral. The width of strip is 100 mm, the pitch of spiral is 450 mm. The strip is fixed to the facing in the process of curing.

6.1.9 For the transfer of cargo at sea from one ship to another and during the cargo operations with the use of offset point berths, as a rule, the floating hoses shall be used; in the hose lines the quick-action device for emergency disconnection shall be provided.

The structure of such device shall be specially considered by the Register in each case. In the hose lines equipped with quick-action device of emergency disconnection the allowance shall be made for hydraulic impact which may occur when the device is actuated and, if necessary, the flow velocity of liquid shall be decreased.

The hoses of the devices for cargo and bunkering operations shall be a matter of special consideration by the Register in each case.

6.1.10 On both ends of a hose the following shall be clearly marked. In hose documentation the following shall be indicated:

name of the manufacturer or trade mark;

serial number of the hose according to the manufacturer's data;

month and year of production;

allowable working pressure;

indication of electrical conductivity.

6.1.11 Hoses shall be stored on ship in the place shielded from direct sun rays, with allowance for the minimum bending radius and in accordance with the recommendations of the hose manufacturer. Provision shall be made for design means for discharge and removal of cargo remains from the hoses shall be provided. Measures for prevention of wearing through of the hoses while handling and operation shall be taken.

6.1.12 For cargo vapor discharge, hoses with the allowable nominal pressure of at least 0,2 MPa and vacuum of at least 0,014 MPa shall be used. Disruptive pressure of the hose shall not be less than 5 times working pressure of the hose. The last meter from each end of the hose shall be painted in compliance with Fig. 6.1.12 and marked with the

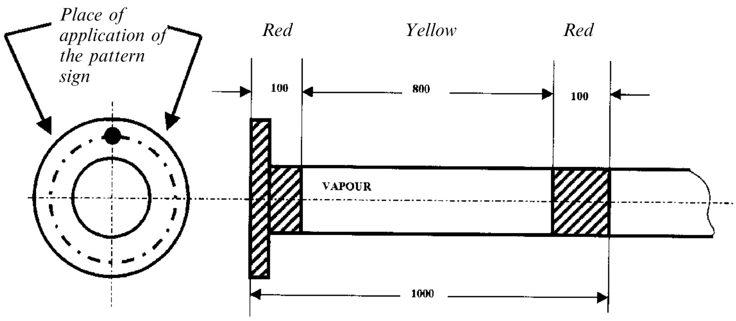


Fig. 6.1.12 Marking of cargo vapor discharge hose

sign "vapors" made in black letters with the height not less than 50 mm. Each flange shall have an additional bore on the line of coupling bolts enabling to connect the flange to vapor discharge connector branch pipe (refer to Fig. 9.9.11-1). In the system for vapor to shore discharge only electrically conductive hoses shall be used.

6.2 TESTING OF HOSES

6.2.1 Each sleeve type used for manufacture of hoses shall be subjected to type tests according to 6.2.2 to 6.2.5, 6.2.7, 6.2.8. Each hose type shall be type tested according to 6.2.2, 6.2.6, 6.2.7, 6.2.8. The type tests of hoses may be combined with the type tests of sleeves. After manufacture, each hose shall be tested in accordance with 6.2.6.

6.2.2 Allowable working pressure P_w is determined as follows:

$$P_w = P_{burst}/K \qquad (6.2.2)$$

where P_w = pressure, at which the break of hose or end connection tightness occurs;
K = coefficient assumed equal to:
4 for transfer of crude oil and oily products, bilge and polluted ballast water;
5 for transfer of chemical cargoes, liquefied gases and cargo vapours.

Allowable working pressure of the hose shall not be less than 1,0 MPa, with exception of the hoses specified in 6.1.12.

When conducting the burst pressure tests, the testing of samples with the length not less than 10 nominal diameters but at least 1 m may be allowed.

6.2.3 Sleeves for cargo and fuel oil hoses of ice-class ships shall be subjected to cold endurance type tests. For this purpose samples of the hoses shall be kept at the temperature of -40 °C during 4 hours. In 4 hours the sample shall be tested for elasticity by means of bending for 180° two times in the opposite directions around the adapter with a diameter of R, where R is a minimum bending radius; whereupon a visual examination is carried out. After freezing and bending no cracks shall appear on the internal and external surfaces of the sample. Where necessary, the sample may be cut along the axis for the internal surface inspection.

On agreement with the Register, another method for freeze resistance test with allowance made for special structural features may be accepted.

6.2.4 The sleeves of hoses intended for operation under ambient pressure conditions shall be vacuum tested with negative pressure of 85 kPa during 10 min. After the tests the hose shall be examined and rejected where deformation or flattening is found.

6.2.5 The samples manufactured as strip test pieces in accordance with the procedure approved by the Register (Fig. 6.2.5) are subject to adhesion test of all the rubber sleeve layers. The adhesion strength of rubber contact faces is determined as a ratio of the mean force F originated at detachment, divided by the strip width and shall be at least 3 N/mm.

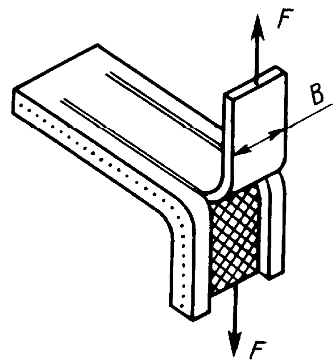


Fig. 6.2.5

6.2.6 Each hose after manufacturing shall be subjected to the following tests:

.1 determination of weight. After weighing, the hose weight shall be recorded in the certificate. For floating hoses, the buoyancy reserve shall be defined according to 6.1.7.

.2 hydrostatic tests by pressure of 1,5 times the working pressure.

.3 electrotechnical tests including:

measuring of resistance between flanges of hoses lacking electrical conductivity (the resistance shall not be less than 25000 Ohm and not more than 10^6 Ohm);

conductivity test for electrically conductive hoses with the voltage of 4,5 V and a bulb for testing.

6.2.7 The cargo hoses of oil tankers and hoses for taking on fuel and oil shall undergo type tests at normal temperature for 15 cycles of pressure rise from zero up to 1,5 times the maximum allowable working pressure. After 15 cycles the sample shall be subjected to strength test by burst pressure according to 6.2.2.

6.2.8 Cargo hoses for transfer of chemical cargoes and liquefied gases shall undergo type tests at normal temperature for 200 cycles of pressure rise from zero up to twice the maximum allowable working pressure. After 200 cycles the sample shall be subjected to strength test by burst pressure according to 6.2.2.

7 BILGE SYSTEM

7.1 PUMPS

7.1.1 Each self-propelled ship shall be provided with at least two power bilge pumps.

Independent ballast (except for segregated ballast), sanitary or general service pumps of sufficient capacity may be accepted as power bilge pumps, and in ships of 91,5 m in length and less, in special purpose ships having not more than 50 special personnel on board, one of the bilge pumps may be a main engine driven pump, as well as a water or steam ejector, provided the steam boiler is always in operation.

If fire pumps are used as bilge pumps, the requirement of 3.2.3.2, Part VI "Fire Protection" shall be met.

In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN**, one of the pumps may be driven from the main engine and the other may be an ejector or a hand pump.

In special purpose ships, and all other ships receiving a subdivision mark 2 and over in their class notation (refer to Part V "Subdivision"), the number and arrangement of bilge pumps shall be specially considered by the Register in each case.

7.1.2 Passenger ships, special purpose ships carrying more than 50 special personnel shall have at least three power pumps connected to the bilge main; one of these pumps may be driven from the main engine.

Where the subdivision index R determined from the formula in 2.2.2 and 6.2.2.2.3, Part V "Subdivision", is equal to or greater than 0,5, at least four such pumps shall be provided.

Independent ballast, sanitary or general service pumps of sufficient capacity may be used as power bilge pumps.

Where in ships intended for the carriage of motor transport a pressure water-spraying system is installed, the Register may require the bilge pumps to be increased in capacity or number.

7.1.3 Centrifugal bilge pumps shall be of the self-priming type, or alternatively the system shall be provided with vacuum arrangement.

It is recommended that one of the bilge pumps installed be of the reciprocating type.

7.1.4 In passenger ships 91,5 m and over in length or having the subdivision index R in excess of 0,5 and in special purpose ships (carrying more than 50 special personnel) 91,5 m and over in length and having the subdivision index R in excess of 0,5 (refer to 2.2.2 and 6.2.2.2.3, Part V "Subdivision"), the arrangement of bilge pumps shall be such that at least one pump will be available for use in all ordinary circumstances in which the ship may be flooded. This requirement is considered satisfied if one of the pumps is a pump of a reliable submersible type having a source of power situated above the bulkhead deck, or the pumps and their sources of power are so disposed in different watertight compartments that under any condition of flooding, anticipated for the given ship, at least one pump in an undamaged compartment will be available in operative state.

7.1.5 It is recommended that in passenger ships and special purpose ships not specified in 7.1.4 and in ships having a subdivision mark in the class notation the bilge pumps, wherever practicable, be placed in different watertight compartments with the system so arranged that requirements of 7.3.6 are met.

7.1.6 Each bilge pump required in 7.1.1 and 7.1.2 shall have a capacity Q, in m^3/h, not less than that determined from the formula

$$Q = 5{,}65 \times 10^{-3} \times d_1^2 \qquad (7.1.6)$$

where d_1 is inner diameter of the main determined in accordance with 7.2.1, mm.

The bilge pump may be replaced by two pumps with a total capacity not less than that specified above. For passenger ships, each bilge pump shall have a capacity determined on the assumption that the rated speed of water through the internal diameter required in 7.2.1 shall not be less than 2 m/s.

7.1.7 For drainage of non-propelled ships having no power-driven machinery, at least two hand pumps of reciprocating type shall be installed, and these shall have a total capacity not less than specified in Table 7.1.7.

Table 7.1.7

0,8 LBD[1], m^3	Total pump capacity, m^3/h
Up to 100	$1{,}11 \cdot 10^{-3}$
101 — 600	$2{,}22 \cdot 10^{-3}$
601 — 1100	$2{,}72 \cdot 10^{-3}$
1101 — 1800	$3{,}34 \cdot 10^{-3}$

[1]For definitions of L, B, D (length, breadth and depth, m), refer to Part IV "Stability".

In each case D is measured up to the bulkhead deck only.

In a ship having an enclosed cargo space on the bulkhead deck, which is drained in accordance with 7.6.12.2 and which extends for the full length of the ship, D shall be measured to the next deck above the bulkhead deck.

Where the enclosed cargo spaces cover a lesser length, D shall be taken as the depth to the bulkhead deck plus lh/L where l and h shalltal length and height of enclosed cargo spaces, respectively.

The pumps shall be arranged above the bulkhead deck and shall have a sufficient suction head.

In non-propelled ships provided with power sources, it is recommended that power pumps shall be fitted, the number and capacity of which shall comply with the requirements for the hand pumps.

7.1.8 In ships with twin hulls, provision shall be made for an independent bilge system for each hull, which shall comply with the requirements of the Chapter.

7.1.9 In berth-connected ships, at least two bilge pumps shall be installed, power-driven and having each a capacity not less than 11,0 m^3/h whereas the design water speed in the branch bilge suctions shall not be less than 2 m/s under normal service conditions.

The pumps shall ensure drainage of any space below the bulkhead deck, and their drives shall be so arranged along the ship length that at least one of the pumps installed in an intact compartment could drain a flooded space.

7.1.10 Ships with distinguishing marks **FF1**, **FF1WS**, **FF2**, **FF2WS** in the class notation shall have bilge pumping arrangements for pumping water out of flooded compartments of ships in distress.

Used as such arrangements may be pumps (fixed and/or portable) and ejectors.

The type, number and capacity of the pumps shall be specified by the designer and agreed upon with the Register.

7.2 PIPING DIAMETERS

7.2.1 The internal diameter d_1, in mm, of the main bilge line and that of bilge suctions directly connected to the pump, except in 7.2.3, shall be determined by the formula

$$d_1 = 1{,}68\sqrt{L(B+D)} + 25. \quad (7.2.1\text{-}1)$$

In vessels of dredging fleet having hopper spaces, the diameter of the bilge main and the direct bilge suctions directly connected to the pump may be obtained from the formula

$$d_1 = 1{,}68\sqrt{L(B+D) - l_1(b+D)} + 25 \quad (7.2.1\text{-}2)$$

where l_1 = length of hopper space, m;
b = mean width of hopper space, m;
for L, B, D, refer to 7.1.7.

In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN**, the internal diameter of the bilge main and of direct bilge suctions directly connected to the pump may be obtained from the formula

$$d_1 = 1{,}5\sqrt{L(B+D)} + 25 \quad (7.2.1\text{-}3)$$

7.2.2 The internal diameter d_1, in mm, of the branch bilge suctions connected to the bilge main, and that of the hand pump suction, shall be determined by the formula

$$d_1 = 2{,}15\sqrt{l(B+D)} + 25 \quad (7.2.2\text{-}1)$$

where l = length of hopper space, as measured at its bottom, m;
for B, D, refer to 7.1.7. In the case of ships with twin hulls, B is assumed to be the breadth of one hull.

In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN**, the internal diameter of branch bilge suctions connected to the bilge main and the diameter of the hand pump suction may be obtained from the formula

$$d_1 = 2{,}0\sqrt{l(B+D)} + 25. \quad (7.2.2\text{-}2)$$

7.2.3 The internal diameter of the main bilge line and bilge suctions determined from Formulae (7.2.1-1, 7.2.2-1) shall not be less than 50 mm, and the internal diameter determined from Formulae (7.2.1-3, 7.2.2-2) shall not be less than 40 mm. The internal diameter of the pipes directly connected to the pump shall not, in any case, be less than the bilge pump suction diameter.

7.2.4 The cross-sectional area of the pipe, connecting the distribution chest with the bilge main shall not be less than the total cross-sectional area of two largest branch bilge suctions connected to that chest, but it need not be greater than the sectional area of the bilge main.

7.2.5 In oil tankers and other ships, in which the bilge pumps are intended for draining only the engine room, the cross-sectional area of the bilge main shall not be less than twice the cross-sectional area of the branch suction, the diameter of which is determined by Formula (7.2.2-1).

7.2.6 The diameter of the emergency bilge suction in the engine room shall be determined in compliance with 7.3.8.

7.3 PIPING LAYING

7.3.1 The bilge lines and their branch suctions shall be so arranged as to enable any watertight compartment to be drained by one of the pumps required in 7.1.1 and 7.1.2. This requirement does not apply to the spaces of ammonia refrigerating machinery, the peaks, the pump rooms and cofferdams of oil tankers, drained by individual pumps, as well as to the tanks intended only for storage of liquids.

Drainage of spaces not connected to the bilge system shall be carried out by the drain pipes laid to the drained spaces or by hand pumps, compliance with the requirements of 7.12.2 shall also be provided.

7.3.2 The system shall be arranged so as to prevent the possibility of sea water passing inside the ship, or from one watertight compartment into another, in case of pipe break or any other pipe damage in any other compartment because of collision or grounding. For this purpose the suction valves of the drainage pipes open ends, connected directly to the chests, shall be of screw-down non-return type. In case the only general pipeline system for all pumps is available, the provision shall be made for the possibility to control the required valves servicing suction branch pipes from the places above the bulkhead deck. Other equivalent arrangements are allowed.

7.3.3 The arrangement of the bilge pipes shall be such as to ensure the possibility of draining the engine rooms through the suctions directly connected to the pump, the other compartments being simultaneously drained by other pumps.

7.3.4 The arrangement of the bilge pipes shall be such as to enable one of the pumps to be operated in case the rest of pumps are inoperative or are used for other purposes.

7.3.5 The bilge suction pipes, where they are at any part situated nearer to the ship's side than one-fifth of the breadth of the ship (measured at right angles to the centre line at the level of the deepest subdivision load line), as well as when passing in duct keel or within double bottom, shall have non-return valves fitted to their branch suctions in each watertight compartment.

7.3.6 In passenger ships of more than 91,5 m in length, special purpose ships having more than 50 special personnel on board and in passenger ships having the subdivision index *R* greater than 0,5, all the distribution chests, cocks and valves associated with the bilge pumping system shall be so arranged that in the event of flooding one of the bilge pumps may be operative on any flooded compartment. Moreover, damage of a pump or its pipe connecting to the bilge main outboard of a line drawn at one-fifth of the breadth of the ship shall not put the bilge system out of action.

Where there is only one system of pipes common to all the pumps, the necessary cocks and valves for controlling the bilge suctions shall be fitted with means enabling them to be controlled from above the bulkhead deck.

In the places of their installation they shall be provided with the controls with clear indication of their purpose and also means for indicating whether they are open or closed.

Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it shall be independent of the main system and shall be so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case, only the cocks and valves required for controlling the emergency system need be suited for being operated from above the bulkhead deck, while the pump and associated suction pipes shall be situated farther from the ship's side than one-fifth of the breadth of the ship.

7.3.7 In general, the bilge pipes shall be laid outside the double bottom. Where it is necessary to lay these pipes through the tanks for storage of fuel oil, lubricating oil, boiler feed water and drinking water, the pipes shall meet the requirements of 5.2.1.

Where the pipe is laid within the double bottom, the bilge suctions in each watertight compartment shall be fitted with non-return valves.

7.3.8 Oily-water separating and filtering equipment shall be used for purification of water before discharging overboard. The installation and operation of such equipment shall not interfere with normal working of the bilge and ballast systems indicated in 13.1.2.

7.4 DRAINAGE OF MACHINERY SPACES

7.4.1 Where the engines and boilers are located in the same compartment and the double bottom extends either the full length forming bilges at the wings, or the full length and breadth of the compartment, it will be necessary to provide two bilge suctions at each side near the bulkheads in the compartment, one of which shall be connected directly to an independent bilge pump.

7.4.2 Where the engines and boilers are located in the same compartment with no double bottom, and the rise of floors is not less than 5°, two bilge suctions shall be provided, one of which shall be direct-connected to an independent bilge pump; where the rise of floor is less than 5°, additional bilge suctions connected to the bilge main shall be provided, one at each side.

7.4.3 Where the engines and boilers, as well as the auxiliaries or electric propulsion motors, are located in separate watertight compartments, the number and position of bilge suctions therein shall be adopted as set forth in 7.6. In ships having in the class notation a mark of subdivision, each of these compartments shall be fitted with an additional bilge suction direct-connected to an independent bilge pump.

In passenger ships each of the independent power bilge pumps, located in machinery spaces, shall have direct suctions in these spaces. More than two such suctions are not required for these spaces. Where two or more such suctions are fitted, at least one of them shall be located on the port and the other on the starboard side. Bilge pumps not associated with each other, located in other spaces may have direct suctions in these spaces.

7.4.4 Where the machinery space is situated at the after end of the ship, bilge suctions shall be fitted in the forward wings of the space. On agreement with the Register, one or two suctions shall be provided depending on the shape of the aft end.

7.4.5 Suctions for bilge drainage of machinery spaces and tunnels shall be fitted with readily accessible mud boxes. The pipes between the mud boxes and bilges shall be as straight as practicable. The lower ends of these pipes need not be fitted with strum boxes. Mud boxes shall have covers that may be easily opened.

In small ships, instead of the mud boxes, strum boxes may be used, provided they are accessible for cleaning.

7.4.6 In all self-propelled ships provision shall be made for emergency bilge drainage of the engine rooms, in addition to the suctions required by 7.4.1 to 7.4.4. For this purpose any of the main circulating pumps in steam ships, and the cooling pump of maximum capacity in motor ships, shall be fitted with direct suction pipe at the drainage level of the engine room and fitted with non-return stop valve. The diameter of this direct suction shall be at least two-thirds of that of the pump suction in steam ships, and shall be of the same size as the suction branch of the pump in motor ships.

No strum boxes or strainers shall be fitted on the suction for emergency bilge drainage.

Where the pumps specified above are not suitable for operation as bilge pumps, a direct emergency bilge suction shall be laid from the drainage level of the engine room to the largest available power pump, which is not a bilge pump. The capacity of this pump shall exceed that required in 7.1.6 by an amount satisfactory to the Register. The diameter of the emergency bilge suction shall not be less than that of the pump suction branch.

The spindles of the screw-down non-return valves fitted to the suction branches shall extend above the engine room floor plates to a sufficient height and shall have nameplate "For emergency use only".

The use of fire pumps for emergency bilge drainage of engine rooms shall be in compliance with 3.2.3.2, Part VI "Fire Protection".

In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN** which have no independent pump of a capacity exceeding that of the bilge pump, the emergency drainage system of machinery spaces may be operated by an attached sea-water cooling pump.

7.4.7 Where there is a double bottom, the machinery spaces shall be fitted with bilge wells of a capacity not less than 0,2 m^3.

7.4.8 Additional bilge suctions shall be laid in the log and echo sounder trunks, and also to the double-bottom bilge wells under the machinery and in other places, which may accumulate water.

7.4.9 In ships having an electric propulsion plant, the arrangements shall be such that the bilge wells under the propulsion motors are properly drained and automatic alarms are fitted to give warning at excess of permissible level in the wells.

Automatic drainage of bilge wells is recommended to be used.

7.4.10 The space of ammonia refrigerating machi-nery shall have an independent bilge system. Where a water spraying system is provided in this space, the capacity of the bilge pump shall be sufficient for the water consumption during the operation of that system. The discharge pipe of the bilge system shall be laid directly overboard.

The space for freon refrigerating machinery may be drained through the bilge main of the ship.

7.5 DRAINAGE OF TUNNELS

7.5.1 Each shaft tunnel and each accessible pipe tunnel shall be drained by a bilge suction situated in the after part of the tunnel.

Where required, additional suctions shall be provided in the fore part of the tunnel. The bilge suctions of the shaft tunnel shall be made in compliance with the requirements set forth in 7.4.5.

7.6 DRAINAGE OF CARGO SPACES

7.6.1 Each cargo space, where the double bottom forms bilges at the wings, shall have at least one bilge suction in the after part of the hold at each side of the ship.

7.6.2 Where the inner bottom plating extends the full breadth of the space, bilge wells shall be arranged in the after part of the hold, one at each side.

The capacity of the wells shall comply with the requirements of 7.4.7.

7.6.3 In spaces where the inner bottom plating has an inverse camber, provision shall be made also for suctions at the centre line, in addition to the suctions situated at the wings. Where a bilge well extends over the entire breadth of the space and the inverse camber exceeds 5°, one branch suction may be laid to this well.

7.6.4 Where manholes for access to bilge wells are provided, they shall be arranged as near to the suction strums as practicable.

7.6.5 Where there is no double bottom and the rise of floor in the space exceeds 5°, one bilge suction may be fitted near the centre line. If the rise of floor is less than 5°, at least two suctions shall be fitted, one at each side of the hold.

7.6.6 Where the length of a hold exceeds 35 m, the bilge suctions shall be fitted in the fore and after parts of this hold, with the requirements of 7.6.1 to 7.6.5 being complied with.

7.6.7 At narrow ends of cargo spaces, one bilge suction may be allowed.

7.6.8 The drain pipes from spaces located below the bulkhead deck and communicating with the cargo space in the same compartment may be laid into the wells of that hold.

Drainage into the wells of cargo spaces from spaces located in other watertight compartments below the bulkhead deck is not permitted.

The requirements for drainage into the bilges of refrigerated cargo spaces are given in 7.8.

7.6.9 Where a ceiling or removable covers is fitted over the bilges or wells in cargo spaces, provision shall be made for free access of water into the bilges or wells.

7.6.10 Branch bilge suctions shall be fitted with strum boxes or strainers having perforations 8 to 10 mm in diameter. The total area of these perforations shall not be less than twice the clear area of the given suction pipe.

The strum boxes and strainers shall be removable, or provision shall be made for cleaning them without having to disassemble the suction.

7.6.11 In bulk carrier cargo spaces the bilge system shall be so designed that its operability may not be affected when bulk cargo is carried.

7.6.12 For the drainage of enclosed cargo spaces located on the bulkhead deck of a passenger or cargo ship that is assigned a subdivision distinguishing mark in its class notation, and on the freeboard deck of other cargo ships, the arrangements specified under 7.6.12.1 and 7.6.12.2 shall be provided.

7.6.12.1 Where the freeboard up to the bulkhead deck or the freeboard deck height is such that the deck edge is immersed when the ship heels more than 5°, the drainage shall be by means of scuppers discharging directly overboard.

The scuppers and drain pipes shall be arranged and fitted according to 4.3.2.6.

7.6.12.2 Where the freeboard is such that the edge of the deck is immersed when the ship heels 5° or less, the drainage of the enclosed cargo spaces on this deck shall be laid to suitable spaces of adequate capacity having a high water level alarm and suitable arrangements for discharge overboard. In such cases it shall be ensured that:

.1 the number, size and disposition of the scuppers are such as to prevent unreasonable accumulation of free water;

.2 the above-mentioned pumping arrangements for the drainage of cargo spaces provide water drainage with any fixed water fire-extinguishing systems, including spraying systems, that are required, respectively, for passenger and cargo ships.

The bilge system (refer to 7.1) shall have a capacity not less than 125 per cent of the total capacity of the water fire main and water-spraying system pumps with due regard for the required number of fire nozzles;

.3 valves of the drainage arrangements shall be controlled from a position outside the space protected, located nearby the water-spraying system controls. Bilge wells shall have sufficient capacity and be arranged in the vicinity of the side plating not more than 40 m apart in each watertight compartment. Water contaminated with petrol or other dangerous substances shall not be drained to machinery spaces or other spaces containing sources of ignition;

.4 where the enclosed cargo space is protected by a fire smothering system the deck scuppers are fitted with means to prevent the escape of the gas.

7.6.13 The bilge system of cargo holds with weathertight hatch covers above the superstructure deck outside the positions 1 and 2 (refer to 7.1.4, Part III "Equipment, Arrangements and Outfit" of the present Rules and 3.2.1 of the Load Line Rules for Sea-Going Ships) shall have the pumps of an increased capacity with regard to additional water ingress due to:

.1 the stable amount of precipitation equal to 100 mm/h, which penetrate through the total area of gaps between closures sections;

.2 the consumption of water by a sprinkler system (if fitted), whichever is greater.

The internal diameter of a bilge main shall be increased in compliance with an increased pump capacity.

Each cargo hold shall be fitted with an alarm on a limiting water level in bilge wells.

7.6.14 On container ships, holds fitted with weathertight closures and intended for carrigate of dangerous cargoes shall be considered as open-type container holds in accordance with paragraphs 10 and 11 of MSC/Circ.608/Rev.1.

7.7 DRAINAGE OF CARGO PUMP SPACES OF OIL TANKERS

7.7.1 The cargo pump rooms of oil tankers shall be drained by separate pumps or ejectors arranged in these rooms. Stripping pumps may be used as bilge pumps, provided non-return shut-off valves are fitted at the open ends of the bilge suctions and a shut-off valve is arranged on a pipe connecting the valve box and the stripping pump.

The pump rooms in oil tankers of up to 500 gross tonnage may be drained by hand pumps.

Construction of the pumps shall preclude the possibility of spark formation to a maximum.

Arrangement of the driving machinery of the pumps shall meet the requirements of 4.2.5, Part VII "Machinery Installations".

The cargo pump rooms shall be provided with a visual and audible high bilge water level alarm to give warning to the cargo control station and navigating bridge.

7.8 DRAINAGE OF REFRIGERATED CARGO SPACES

7.8.1 Provision shall be made for drainage of water from all the spaces, trays, chutes and other places, which may accumulate water.

7.8.2 Drain pipes from non-refrigerated spaces shall not be laid into the bilges of refrigerated spaces.

7.8.3 Each drain pipe of refrigerated cargo spaces shall be fitted with a liquid sealed trap or with another equivalent arrangement. The head of liquid shall be such that the arrangement will work effectively under any conditions of service.

The liquid sealed traps shall be placed in accessible positions outside the insulation. Where drain pipes from the 'tween-deck spaces and the hold are laid into a common bilge well, non-return valves shall be fitted to the open ends of the drains from the hold.

7.8.4 No shut-off valves shall be fitted on the drains from refrigerated spaces.

7.9 DRAINAGE OF FORWARD SPACES OF BULK CARRIERS

7.9.1 The present requirements apply to the means for draining and pumping ballast tanks forward of the collision bulkhead, and bilges of dry spaces, any part of which extends forward of the foremost cargo hold, except the enclosed spaces the volume of which does not exceed 0,1 per cent of the ship maximum displacement volume and the chain lockers.

7.9.2 The means for draining and pumping ballast tanks forward of the collision bulkhead, and bilges of dry spaces, any part of which extends forward of the cargo hold, shall be capable of being brought in operation from the navigating bridge or propulsion machinery control position or from a readily accessible enclosed space, the location of which is accessible from the navigating bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. A pipe trunk or other similar means of access shall not be taken as being a "readily accessible enclosed space".

7.9.3 The drainage arrangements shall be such that when they are in operation, other systems essential for the safety of the ship including fire-fighting and bilge systems remain available and ready for immediate use.

The systems for normal operation of electric power supplies, propulsion and steering shall not been affected by the operation of bilge systems.

It shall be also possible to immediately start fire pumps and have a readily available supply of water and to be able to configure and use bilge system for any compartment.

7.9.4 The drainage arrangements shall be such that any accumulated water can be drained directly by a pump or eductor. The drainage arrangements shall be designed to remove water at a rate of not less than $320 \cdot A$, m^3/h, where A is the cross-sectional area in m^2 of the largest air or venting pipe leading from the exposed deck to the space that is required to be drainaged.

7.9.5 Bilge wells shall be provided with gratings or strainers that will prevent blockage of the bilge system with debris.

7.9.6 Where pipes serving tanks or bilges mentioned in 7.9.2 pierce the collision bulkhead, as an alternative to the valve control specified in 5.1.3, valve operation by means of remotely operated actuators may be accepted, provided that the location of such valve controls complies with 7.9.2.

7.9.7 Where the piping of closed spaces bilge system is connected to the piping arrangements for the drainage of water ballast tanks, two non-return valves shall be provided to prevent the ingress of water into dry spaces from the water ballast tanks. One of these non-return valves shall be fitted with shut-off isolation arrangement. The non-return valves shall be located in readily accessible positions. The valve control position shall meet the requirements of 7.9.2.

Moreover, the valve shall comply with the requirements of 4.1.1.2 and 4.1.2.2.

7.9.8 Any dry spaces or cofferdams other than chain lockers, the volume of which does not exceed 0,1 per cent of the ship maximum displacement volume, fully or partly located forward of the foremost cargo hold, shall be fitted with water level detectors giving audible and visual alarms at a water level of 0,1 m above the deck.

7.9.9 The cargo spaces of bulk carriers shall be provided with alarms complying with the requirements of 2.4, Part XV "Automation", located on the navigating bridge, as well as 7.10, Part XI "Electrical Equipment".

The visual signals of each cargo space shall be clearly distinguishable.

The alarm system detectors shall be positioned at two levels:

at a height of 0,5 m above the inner bottom;

at a height of 15 per cent of the depth of cargo space but not more than 2 m above the inner bottom.

For cargo holds, which are used for water ballast, an alarm-overriding device may be installed to be activated when ballast is loaded thereinto.

The water ballast tanks forward of the collision bulkhead shall be provided with detectors giving an audible and visual alarms when the liquid in the tank reaches a level not exceeding 10 per cent of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use.

7.10 DRAINAGE OF COFFERDAMS

7.10.1 Cofferdams filled with water shall be provided with drainage means. The location of branch suctions shall comply with the requirements of 7.6. In oil tankers and combination carriers, the filled cofferdams adjoining cargo tanks or slop tanks shall have automatic drain arrangements.

7.11 FORE AND AFT PEAK DRAINAGE

7.11.1 Where the peaks are not used as water ballast or other tanks, they may be drained by their own hand pumps or water ejectors.

For draining of fore compartments in oil tankers, other than cargo compartments, provision shall be made for a separate pump or ejector, which may also be used for filling and draining of the tanks intended only for water ballast.

7.12 DRAINAGE OF OTHER SPACES

7.12.1 Drainage of the chain lockers and boatswain's stores may be carried out by means of hand pumps, water ejectors or other means.

7.12.2 Drainage of the steering engine rooms and other compartments situated above the after peak may be carried out by hand pumps or water ejectors, as well as through drain pipes laid into the bilges of shaft tunnel or engine room. The drain pipes shall be fitted with readily accessible self-closing valves and shall be of not less than 39 mm in inner diameter.

In passenger ships, drain pipes shall not be used for drainage of the above-mentioned spaces.

7.12.3 Drain pipes shall not be laid into the bilges of the engine rooms and shaft tunnels from the spaces situated in other watertight compartments below the bulkhead decks (with the exception of cases specified by 7.12.2).

Drain pipes from these spaces may be laid into the engine rooms and shaft tunnels only if terminating in closed drain tanks.

Where several watertight compartments have a common drain tank, the drain pipes from these compartments shall be fitted with non-return valves to prevent the passage of water from one compartment into another in the event of flooding.

The drain tank may be discharged through the bilge main, provided a non-return valve is fitted on the branch suction or the distribution chest.

7.12.4 Drain pipes from enclosed superstructures and deckhouses may be laid into the bilges (wells) of the engine room or the holds.

In ships having in the class notation a mark of subdivision, these pipes shall be fitted with valves controllable from a place above the bulkhead deck to prevent penetration of water in the above-mentioned spaces shall the engine room or hold become flooded.

7.12.5 Drain pipes for drainage of storerooms for explosives shall be fitted with valves controllable from locations outside these rooms.

7.12.6 Drainage facilities in way of helidecks shall be constructed of steel and shall lead directly overboard independent of any other system. Drainage shall not fall onto any part of the ship.

7.13 DRAINAGE OF FLOATING DOCK COMPARTMENTS

7.13.1 Machinery spaces and dry compartments shall be provided with draining means. The requirements of this Section, except 7.3.2 and 7.3.9, are not applicable to the drainage system of floating docks.

7.14 DRAINAGE OF CARGO SPACES INTENDED FOR THE CARRIAGE OF DANGEROUS CARGO

7.14.1 Closed cargo spaces intended for the carriage of flammable liquids with flash point below 23 °C or toxic liquids of subclass 6.1 mentioned in 7.2.4 and Table 7.2.4-3, Part VI "Fire Protection" shall be equipped with self-contained fixed drainage system located outside the engine room.

7.14.2 The internal diameter of the main bilge line and that of the bilge suctions directly connected to the pump shall be determined from Formula (7.2.1-1).

7.14.3 In spaces intended for the carriage of dangerous goods, the drainage and pumping arrangements shall be such as to prevent the build-up of free surfaces of water when fire-extinguishing systems are used.

The capacity of drainage system shall not be less than 1,25 times the combined capacity of both the water spraying system pumps and fire hose nozzles, the required number of which is stated in 7.2.5.2, Part VI "Fire Protection".

The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls.

Bilge wells shall be of sufficient holding capacity and shall be arranged at a distance of not more than 40 m from each other in each watertight compartment.

7.14.4 The Register may permit the use of the ship's main drainage system for the drainage of such spaces, if the design prevents accidental pumping of flammable or toxic liquids through the pipelines and pumps of the engine room through installation of a blank flange or a locked up shut-off valve.

7.14.5 The capacity of the independent main drainage system connected with the general ship system shall be at least 10 m^3/h when one space is drained and at least 25 m^3/h when two or more spaces are drained.

7.14.6 Cargo spaces may be drained by gravity overboard or into a closed drainage tank situated outside the engine room. The tank shall have an air pipe carried to the safe position on the open deck.

7.14.7 Cargo spaces are permitted to be drained into bilge wells of the underlaying spaces if these spaces satisfy the requirements imposed upon similar cargo spaces.

7.14.8 Container ships of open type shall be fitted with self-contained fixed hold drain system located outside the engine room.

8 BALLAST, HEEL AND TRIM SYSTEMS

8.1 PUMPS

8.1.1 The ballast system shall be served by at least one pump. The capacity of the ballast pump shall be such as to ensure the speed of water of not less than 2 m/s, with the suction pipe diameter taken from Formula (8.2.1) as for the largest ballast tank.

For each hull of a ship with twin hulls, an independent ballast system shall be provided.

8.1.2 General service pumps of sufficient capacity, as well as a bilge, fire or standby cooling pump, may be used for ballasting (refer to 8.1.3).

Fire pumps may be permitted subject to compliance with 3.2.3.2 and 3.2.3.4, Part VI "Fire Protection".

8.1.3 Where the fuel oil tanks are generally used as ballast tanks, the standby cooling pump or a fire pump shall not be used for ballasting, nor shall the ballast pump be used as fire pump or standby cooling pump.

8.1.4 The pumps used for pumping out ballast water from the double-bottom tanks shall be of self-priming type and comply with 5.2.4, Part IX "Machinery".

8.1.5 In passenger ships, ballast tanks shall not, generally, be intended for the carriage of fuel oil. Possible relaxations from this requirement, shall be specially considered by the Register in each case (refer also to 13.1.2).

8.1.6 In oil tankers emergency ballast discharge by stripper and cargo pumps is allowed, provided the requirements of 9.10.2 are complied with.

8.2 PIPING DIAMETERS

8.2.1 The internal diameter d_i, in mm, of the ballast pipes for separate tanks shall be determined by the formula

$$d_i = 18\sqrt[3]{v} \qquad (8.2.1)$$

where v = ballast tank capacity, m^3.

The diameter may be adopted by the nearest standard size.

8.2.2 The diameter of the ballast main shall not be less than the maximum diameter of the suction determined by Formula (8.2.1).

8.3 PIPING LAYING

8.3.1 The arrangement of the suctions shall be such as to ensure pumping of the water from any of the ballast tanks, whether the ship is on even keel or listed 5°.

8.3.2 In icebreakers and ships with ice strengthening of **Arc4** to **Arc9** categories, the fore and after peaks, as well as structural wing tanks for water ballast, located above the waterline and in way of cargo holds, shall be provided with heating arrangements. The double-bottom tanks in way of cargo holds, intended for water ballast, are recommended to be fitted with heating coils.

8.3.3 The suction and discharge pipes of segregated ballast tanks shall not communicate with sea chests and pipelines servicing cargo tanks.

8.4 BALLAST SYSTEM OF FLOATING DOCKS

8.4.1 The ballast system shall be so designed that at least two pumps are available at any ballast compartment.

8.4.2 In floating docks intended for service under negative temperatures, the pumps and fittings shall be located in warmed spaces of the dock or shall be provided with local heating.

8.4.3 If the fittings of the ballast system are controlled from a power source, then the sea inlet and discharge valves at side shall have manual emergency driving means laid to above the safety deck. In this case, the distributing valves are recommended to be fitted with a device automatically closing them, shall supply from the power source by interrupted.

8.5 HEEL AND TRIM SYSTEMS

8.5.1 The heel and trim systems shall be in compliance with 8.3.2 and 8.3.3.

8.6 BALLAST SYSTEM OF BULK CARRIERS

8.6.1 Each water ballast tank forward of the collision bulkhead shall be provided with a water level detector giving audible and visual alarms when the liquid in the tank reaches a level not exceeding 10 per cent of the tank capacity.

8.6.2 On bulk carriers, the means for draining and pumping ballast tanks forward of the collision bulkhead shall comply with 7.9.

8.7 BALLAST SYSTEMS FOR BALLAST WATER EXCHANGE AT SEA

The requirements of this Chapter are mandatory for ships having the Ballast Water Management Plan.

8.7.1 Permissible methods of ballast water exchange at sea:

refill method is a process, by which a ballast tank or hold is first emptied of at least 95 per cent of its volume and then refilled with replacement ballast water;

flow-through method is a process, by which replacement ballast water is pumped through the ballast tank or hold allowing the water to overflow or flow through other arrangements. At least 3 times the tank or hold volume shall be pumped through the tank or hold;

dilution method is a process, by which replacement ballast water is filled in the ballast tank or hold through the tank top with simultaneous discharge of the same water quantity and maintaining a constant level in the tank or hold. At least 3 times the tank or hold volume shall be pumped through the tank or hold.

8.7.2 Ballast water system shall provide pumping in and out any ballast tank and hold under any environmental conditions permitted by the Ballast Water Management Plan.

8.7.3 Where the flow-through method of water ballast exchange is used, overpressure in the tank or hold more than designed pressure shall be avoided.

8.7.4 Every ballast tank or hold shall be provided with shut-off valves for pumping in and/or out.

8.7.5 To ensure that the movement of ballast water only takes place as required, shut-off valves for the ballast tanks or holds shall be permanently closed, except the water ballast handling. In general, the shut-off valves shall be of self-closing spring type or equivalent.

8.7.6 The relative positions of ballast water intake and discharge openings shall be such as to preclude as far as practicable the possibility of contamination of replacement ballast water by water being pumped out.

8.7.7 The ballast system intended for ballast water exchange shall be served by at least two pumps. Where the ship's Ballast Water Management Plan permits the use of the refill method, each pump shall be capable of providing ballast water exchange of the largest ballast water tank or group of tanks as per the ship's Ballast Water Management Plan within three hours.

8.7.8 Ballast water exchange of cargo holds used for the carriage of water ballast may require an extended period of time but not more than 24 hours by one pump.

8.7.9 The ballast system design shall permit the ballast water exchange operations with the minimum number of operational modes.

8.7.10 The internal arrangements of ballast tanks as well as ballast water piping inlet and outlet arrangements shall permit the complete ballast water exchange and the cleaning of any sediments.

8.7.11 Design of sea suction line strainers shall be such as to permit cleaning of strainers without interrupting of water ballast handling.

8.7.12 Ballast pumps and all valves to be operated during ballast water exchange shall be provided with a means of remote control from a central ballast control station. Furthermore, the ballast pumps shall be provided with a means of local control.

8.7.13 A manually operated independent means of control of all valves required for ballast water exchange shall also be provided for emergency operation in the event of main centralized remote control failure. Where the valves are located inside tanks or other hardly accessible spaces, the manually operated independent means of control may be achieved by connections to the control lines of individual valves.

8.7.14 The central ballast control station shall include the following:

a valve position indicating system;

a current tank level indicating system;

a draught indicating system;

a means of communication between the central ballast control station and those spaces containing the means of local control for the ballast pumps and the manually operated independent means of control.

8.7.15 The centralized remote control system shall be arranged so that the failure of any one of the control system components will not cause the loss of operation to the pumps or valves or other systems.

8.7.16 Design of ballast tanks shall permit, when necessary, taking samples of the ballast water and sediments. Fitting of tank hatch in addition to conventional manhole is recommended for this purpose. Spaces straight below any tank opening shall be kept free of obstructions that could impede taking samples or free access.

8.7.17 The capability of the ballast water system to provide ballast water exchange by the flow-through method without the risk of overpressure in the ballast tanks shall be demonstrated by calculations and testing on board.

8.7.18 The flow-through method with water flowing over the upper deck is not permitted. The use of collecting pipes, internal overflow pipes or interconnecting pipe/trunk arrangements between tanks may be allowed to avoid water flowing over the upper deck.

8.7.19 Where dilution method is used, the following arrangements shall be provided:

special arrangements automatically maintaining the constant ballast water level. These arrangements shall provide for a manual emergency stop of the ballast pump in case of valve failure or incorrect control actions.

high and low water level alarms in tanks where the ballast water level will significantly change affecting the safety of the ship during water ballast handling.

9 SYSTEMS SPECIAL TO TANKERS AND COMBINATION CARRIERS

9.1 APPLICATION

9.1.1 The requirements of the present Section apply to ships with the descriptive notation **"Oil tanker"**. For the ships with the descriptive notation **"Oil tanker (>60 °C)"** and **"Bilge water removing ship"**, compliance with 9.2.1 to 9.2.8, 9.3.1 to 9.3.3, 9.3.5, 9.3.6, 9.4.1, 9.4.4, 9.4.5, 9.5.1, 9.5.2, 9.5.6, 9.6, 9.7.1 to 9.7.3, 9.7.5, 9.7.7, 9.7.9, 9.7.13, 9.7.15, 9.7.17, 9.10.1, 9.10.2 is mandatory. Compliance with the other paragraphs of the Section is recommended for the above ships.

9.2 GENERAL REQUIREMENTS FOR PIPING IN CARGO AREA

9.2.1 Remote-controlled valves shall comply with the requirements of 4.1.1.2 to 4.1.1.4.

9.2.2 The spindles used to operate the valves placed inside the cargo tanks shall be carried to the open deck in gastight sealing glands. Replacement of the sealing shall be made from the open deck. The drives shall have arrangements showing whether the valve is open or closed. The drive shall be constructed as to prevent accumulation of oil residues in them. Where the rubbing parts of the valve drives pass inside cargo tanks and cofferdams, as well as on the cargo deck, precautions shall be such as to preclude spark formation.

9.2.3 In enclosed spaces inside the cargo area, the temperature of steam or heating medium shall not exceed 220 °C.

9.2.4 The pipe flanges and fastening pieces intended for hose connections from shore installations shall be made of materials precluding spark formation.

9.2.5 The piping on deck and in cargo tanks shall be efficiently secured and fitted with thermal compensators. Where thermal expansion is compensated by pipe bends, the radii of pipe bends shall comply with the requirements of 2.2.

9.2.6 All the pipe lengths interconnected by flanges shall have reliable electric connections. At one place minimum, electric connection to the hull shall be made (similar to the requirements of 2.5, Part XI "Electrical Equipment").

9.2.7 To prevent the passage of flame into cargo holds, in the structures of fittings, cargo pipes and venting arrangements and in the covers of cargo tanks, use of materials, which easily lose their properties under the effect of heat, is not permitted.

9.2.8 In combination carriers, provision shall be made for devices in the form of blank flange to isolate slop tanks from cargo tanks.

9.2.9 All piping on board, through which communication between liquid-free spaces of cargo tanks is possible, shall be equipped with a flame arrester.

9.2.10 To keep cargo spills within the cargo area, provision shall be made for a permanent continuous coaming on the upper deck, of at least 300 mm in height and extending from side to side.

9.3 CARGO OIL SYSTEM

9.3.1 Cargo piping shall not pass through the tanks not intended for cargo storage and shall not be connected to other tanks or piping including the fuel oil pipes of the propulsion plant.

Cofferdams shall have no connections to cargo tanks. No by-pass valves are permitted in cofferdams.

The piping, by means of which hazardous mixing of different types of cargo or watering of cargo can take place, shall have a double number of shut-off valves.

9.3.2 The terminations of the filling pipes of cargo tanks shall be laid, as far as practicable, as near to the tank bottom as possible, but not nearer than 1/4 of the pipe inner diameter.

9.3.3 The slop tanks of oil tankers shall be generally served by independent piping systems. Where such systems are not provided, all the suction and discharge pipes of slop tanks shall be equipped with spectacle flanges or other blocking arrangements.

9.3.4 In combination carriers, reliable means shall be provided for isolating the piping connecting the pump with the slop tanks.

The means of isolation shall consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement shall be located adjacent to the slop tanks, but where this is unreasonable or impracticable, it may be located within the pump-room directly after the piping penetrates the bulkhead.

9.3.5 In combination carriers where the ship is in the dry cargo mode, a permanently installed system shall be provided for discharging the contents of the slop tanks directly to the open deck. This system shall generally have no connection to other systems. Its connection to other systems by means of spool pieces shall be subject to special consideration by the Register in each case.

The manifold for slop tank contents installed on the open deck shall be equipped with a shut-off valve and a blank flange.

9.3.6 Where cargo hoses are connected to cargo manifolds, provision shall be made for a tray, in which cargo oil residues would accumulate.

9.3.7 Irrespective of purpose, piping laid through dangerous zones and intended for hose connection from shore or from another ship, shall be provided with the following facilities to ensure intrinsical safety:

.1 insulating flange connections or nonconducting pipe lengths;

.2 insulating mats, pads and railing to prevent the contact between the metal components of hoses and the hull.

The measured resistance between the metal components of hoses and the hull shall not be less than 25 kOhm.

9.4 CARGO PUMPS

9.4.1 Cargo pumps and cargo stripping pumps shall serve only their direct purpose except as provided for in 7.7.1 and 9.10.2. These pumps shall not have any connections to tanks other than cargo tanks.

Cargo pumps and cargo stripping pumps shall be either installed in a separate space or they shall be submersible pumps.

9.4.2 The arrangement of driving machinery of cargo pumps and cargo stripping pumps shall comply with the requirements of 4.2.5, Part VII "Machinery Installations".

9.4.3 The design of pumps, fittings and pump drives shall be such as to preclude spark formation to maximum extent possible. Structural measures shall be taken to limit the zero delivery time of submersible cargo pumps.

9.4.4 Devices shall be provided to stop cargo pumps and cargo stripping pumps from the top flat of the pump room at main deck level or from a readily accessible location on deck.

Where a central cargo control station is provided, the pump stopping arrangements shall be installed at the cargo control station as well.

The stopping arrangements of electrically driven pumps shall comply with the requirements of 19.2.4.5, Part XI "Electrical Equipment".

9.4.5 The pressure gauges of the cargo oil discharge and cargo stripping mains shall be fitted at pumps and on the top flat of the pump room, or at the central cargo control station.

9.4.6 Where any machinery (both electric and hydraulic) used to drive cargo and ballast pumps, as well as the arrangements used to supply and control the pumps and fittings of the cargo and ballast systems are integrated, the requirements of 19.2.7, Part XI "Electrical Equipment" shall be met.

9.5 BOW AND AFT LOADING SYSTEM

9.5.1 Bow and aft cargo piping of an oil tanker shall be permanently installed. Where necessary, the connections of such piping may be detachable.

9.5.2 Bow and aft cargo piping shall be laid outside accommodation and service spaces, and outside machinery spaces adjacent to accommodation spaces and control stations.

9.5.3 Bow and aft cargo piping shall be connected by welded joints. If necessary, expansion joints may be used. Within the hazardous zone, piping may have detachable joints.

For pipe-to-valve connections, flange connections, as mentioned in 2.4, may be used. Cargo piping of this type shall be marked accordingly. They shall be disconnectable from the principal cargo mains either with two valves in the cargo area, provided with devices for their sealing when shut, or with a single valve used alongside a spool piece or spectacle flange.

9.5.4 The pipe section used as shore connection shall be fitted with a shut-off valve and a blank flange, and provided with a tray. In case a special coupling is used, the blank flange may be omitted. The area of 3 m around the manifolds shall be considered a hazardous zone 1 (refer to 19.2.3, Part XI "Electrical Equipment").

9.5.5 In cargo piping, arrangements for the discharge of cargo residues shall be provided. Outside the hazardous zone, cargo piping shall be fitted with arrangements to make it clean of cargo and purge it with inert gas. Between cargo piping and inert gas system, isolating device shall be fitted.

9.5.6 In oil tankers equipped with bow loading system and intended for cargo-handling operations at point berths carried out to sea, an emergency high-speed device shall be installed for the cargo hose disconnection. The design and arrangement of such a device is subject to special consideration by the Register in each case.

9.6 CARGO HEATING SYSTEM

9.6.1 As a heating medium for heating of cargo in tanks, the use of steam, hot water and thermal oil is permitted.

Application of other fluids is subject to special consideration by the Register in each case.

9.6.2 Upstream from each steam heating coil, a non-return stop valve shall be fitted, and upstream to stop fittings at the outlet the gauge valve for checking of the condensate quality shall be installed.

9.6.3 The return of condensate from the heating system shall be performed via the check tank.

The air pipes of the check tank for heating steam condensate from the cargo tanks containing the cargoes with the flash point below 60 °C shall be provided with flame arresters and be lead to a safe place.

9.6.4 Thermal oil systems for cargo heating shall be used with due regard to the requirements of 20.11.

9.6.5 In ships with the descriptive notations **"Oil tanker (>60 °C)"** and **"Oil/ore carrier (>60 °C)"** in the class notation, the maximum heating temperature shall be lower than the flash point of the carrying cargo at least for 15 °C.

9.6.6 The cargo heating system shall be equipped with the facilites for cargo temperature control in the tanks. Control of the current temperature in tanks, as well as light and audible alarms on exceeding of the maximum permissible cargo temperature or on cargo flow velocity loss when pumped through the heaters, shall be provided.

9.6.7 The steam temperature in the cargo pump room heating system shall not exceed 220 °C.

9.7 VENTING SYSTEM

9.7.1 The venting system shall ensure gas exchange and safe pressure in cargo tanks during the loading, discharging and carriage of liquid cargo. For this purpose, the system shall include one or more devices to limit the following:

.1 pressurization above cargo tank test pressure during loading or ballasting with the maximum specified output;

.2 pressure fall below 7 kPa during unloading with the maximum cargo pump delivery.

9.7.2 The venting systems of cargo tanks shall be entirely distinct from the air pipes of other compartments.

The design and arrangement of the outlets of venting arrangements shall be such as to minimize the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition or collecting in the vicinity of deck machinery and equipment.

9.7.3 The venting system shall include arrangements to provide for:

.1 free flow of small volumes of vapour, air or inert gas mixtures caused by thermal variations in the cargo tank;

.2 free flow of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.

9.7.4 Vent outlets for free flow of vapour mixtures, intended for compensation of thermal pressure variations, shall be arranged:

.1 not less than 2 m above the cargo tank deck;

.2 not less than 5 m from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment, which may constitute an ignition hazard, such as anchor windlass and chain locker openings.

9.7.5 The venting arrangements in each cargo tank may be independent or combined with other cargo tanks and may be incorporated into the inert gas piping. Where the arrangements are combined with other cargo tanks, pressure/vacuum, valves may be mounted on the inert gas mains.

9.7.6 Where the arrangements are combined with other cargo tanks, a stop valve and a flame arrester shall be provided to isolate each cargo tank. Where stop valves are fitted, they shall be provided with locking arrangements which shall be under the control of the responsible ship's officer. There shall be a clear visual indication of the operational status of the valves. Where tanks have been isolated, it shall be ensured that relevant isolating valves are opened before cargo loading or ballasting or discharging of those tanks is commenced.

Flame arresters shall be located so as to render the penetration of cargo oil therein impossible under any navigational conditions, rolling included.

9.7.7 Any isolation of venting arrangements shall continue to permit the flow caused by thermal variations in a cargo tank in accordance with 9.7.3.1.

9.7.8 The system for the venting of vapours displaced from the cargo tanks during loading, discharging and ballasting shall consist of either one or more mast risers, or a number of high-velocity vents permitting to discharge of the vapour mixtures with a velocity of not less than 30 m/s. The vapour mixture shall be discharged vertically upwards.

9.7.9 The vent outlets of pipes required by 9.7.3.2 shall be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1,25.

When determining the capacity of venting systems equipped with flame arresters, the pressure drop as the gases pass through the flame arrester shall be considered. In any case, the adopted pressure drop value shall be by 50 per cent greater than that for a flame arrester in the clean condition.

The internal diameter of vent pipes shall not be less than 80 mm, and that of mains, not less than 100 mm.

9.7.10 Where the method is by free flow of vapour mixtures, the vent outlets shall not be less than 6 m above the cargo tank deck or fore and aft gangway, if situated within 4 m of the gangway, and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard.

9.7.11 Where the method is by high-velocity discharge, the vent outlets shall be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to closed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute and ignition hazard.

9.7.12 In each cargo tank, a secondary means of allowing full flow relief of vapour, air or inert gas mixtures to prevent overpressure or under pressure on the event of failure of the arrangements mentioned in 9.7.3.2 shall be fitted.

Alternatively, pressure sensors may be fitted in each tank, with a monitoring system in the ship cargo control, which is activated by detection of overpressure or underpressure conditions within a tank.

Pressure/vacuum-breaking devices of the inert gas system may be used as a secondary means of allowing full flow relief of vapour, air or inert gas mixtures.

9.7.13 Permanent arrangements shall be provided to drain the venting arrangements and vent lines to a cargo tank.

9.7.14 The venting system shall be provided with devices to prevent the passage of flame into the cargo tanks.

The design, testing and locating of flame arresters shall comply with the requirements based on ISO 15364 and MSC/Circ. 450 and MSC/Circ. 677.

9.7.15 The hatches and other openings of cargo tanks used for measuring temperature, ullage, sampling, gas analysis, except openings for permanently installed gauges, shall be provided with self-closing covers or valves. Flame arresters and screens are not required in these openings. Ullage openings shall not be used for pressure equalization.

9.7.16 Arrangements, required in 9.7.1.1, may be provided with a bypass arrangement when they are located in a vent main or masthead riser. Where such an arrangement is provided, there shall be suitable indicators to show whether the bypass is open or closed.

9.7.17 In combination carriers, the arrangements for isolating venting systems of slop tanks containing oil or oil residues shall consist of blank flanges, which will remain in position at all times when cargoes other than liquid cargoes are carried.

9.7.18 The venting systems of oil tankers designed to carry boiling oily products, the Reid vapour pressure of which exceeds atmospheric pressure, shall be subject to special consideration by the Register in each case.

9.8 PURGING AND GAS FREEING OF CARGO TANKS

9.8.1 On the ships fitted with an inert gas system, arrangements (except those mentioned in 9.7.10 and 9.7.11) may be provided for purging and gas freeing empty tanks, which would ensure and exit vertical velocity of at least 20 m/s when any three tanks are being simultaneously supplied with inert gas. Their outlets shall extend not less than 2 m above deck level.

9.8.2 On the ships not fitted with an inert gas system, special fans, which may be portable, shall be provided for purging and gas freeing empty tanks. During gas freeing operations, hydrocarbon vapours may be vented (except devices mentioned in 9.7.10 and 9.7.11) through special pipes, which shall comply with the following requirements:

the pipe outlets shall extend not less than 2 m above deck level;

gas exit velocity of at least 30 m/s in the vertical direction shall be maintained;

the pipe outlets shall be arranged horizontally not less than 10 m away from openings to enclosed spaces containing sources of ignition, from air intakes, deck machinery and other equipment which may present ignition hazard.

Gas exit velocity may be reduced to 20 m/s, provided the device is fitted to prevent the passage of flame, as required by 9.7.14.

9.8.3 On individual cargo tanks, the gas outlet pipe shall be positioned as far as practicable from the inert gas/air inlet. The inlet of such outlet pipes may be located either at deck level or at not more than 1 m above the bottom of the tank.

9.8.4 Each gas outlet shall be fitted with suitable blanking arrangements.

9.9 CARGO VAPOUR DISCHARGE SYSTEM

9.9.1 Cargo vapour discharge system shall be arranged so that not to prevent the normal operation of venting system.

9.9.2 Cargo vapour discharge system shall be designed basing on the maximum loading capacity. The pressure drop in the cargo vapour discharge piping, obtained by means of hydraulic calculation, shall not exceed 80 per cent of the opening pressure of any discharge valve of venting system.

9.9.3 The instructions approved by the Register shall be constantly kept on the ship, proceeding from which the allowable loading speed of different cargoes may be defined, taking into consideration the requirements of 9.9.1 and 9.9.2.

9.9.4 Vapours of incompatible cargoes shall not be mixed when passing the vapour discharge system.

9.9.5 When the inert gas distribution piping is used to collect cargo vapours, measures shall be taken for insulating inert gas pipes from the cargo vapour discharge system.

9.9.6 Provision shall be made for elimination of condensate, which may be accumulated in the system.

9.9.7 Piping of the system shall be electrically continuous and have safety earthing.

9.9.8 Cargo vapour discharge manifolds shall be fitted with a pressure sensor and alarm system to produce alarm signals at high-pressure level (but not higher than that at which the high-speed venting device is actuated) and for vacuum (but not lower than the pressure, at which the vacuum valve is actuated).

9.9.9 In the area of the adapter sleeve of the cargo vapour discharge manifold, the easily accessible check valve with manual control shall be installed.

9.9.10 Hoses applied in the vapour discharge system shall comply with the requirements of 6.1.12.

9.9.11 To exlude false connection of vapour discharge piping to onshore terminal liquid cargo piping, studs with a diameter of 12,7 mm and the length not less than 25,4 mm shall be mounted on vapour discharge connecting flanges at the upper point of the coupling bolts line, as shown in Fig. 9.9.11-1. The vapour discharge manifold marking shall comply with Fig. 9.9.11-2.

9.10 SHIP SERVICE SYSTEMS IN CARGO AREA

9.10.1 Ballast, sounding and air pipes of segregated ballast tanks shall not pass through cargo tanks. Cargo and similar pipes intended to serve cargo and slop tanks shall not be laid through segregated ballast tanks. This requirement may be dispensed with, in the case of shorter pipes, provided they are completely welded or equivalent, with thickened flanged connections, the number of which shall be kept to a minimum. Thermal expansion of the pipes shall be compensated by the pipe bends. The bend radii shall be in accordance with the requirements of 2.2.1. In Fig. 9.10.1, the recommended design of an air pipe is shown by way of an example. Piping shall be seamless and its material shall be steel. The pipe wall thickness shall not be less than indicated in Table 9.10.1. The application of another pipe material

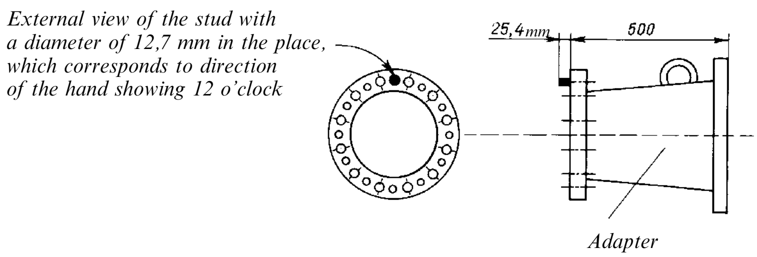


Fig. 9.9.11-1

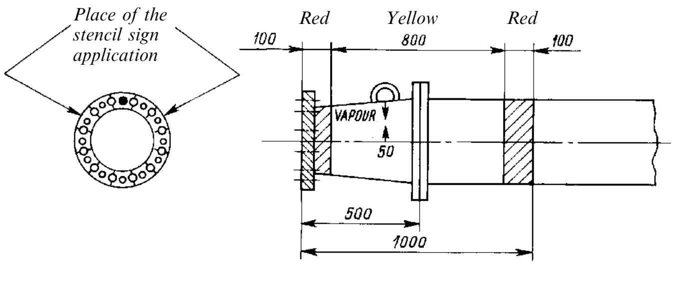


Fig. 9.9.11-2

Table 9.10.1

Internal diameter, in mm	Up to 50	Up to 100	Up to 125	Up to 150	150 and above
Minimal wall thickness, in mm	6,3	8,6	9,5	11,0	12,5

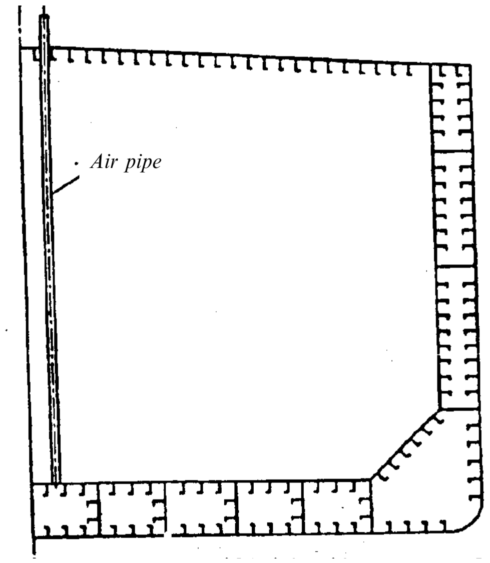


Fig. 9.10.1

shall be subject to special consideration by the Register in each case.

9.10.2 Emergency ballast discharge may be affected by means of a connection to a cargo pump through a spool piece, which shall be mounted in a conspicuous, readily accessible position in the pump room. To prevent the passage of petroleum products into the ballast tanks, a non-return valve shall be fitted on the segregated ballast connections. The ballast pump shall be located in the cargo pump room or another space with the safety level equivalent to that of a cargo pump room not containing sources of ignition.

9.10.3 In oil tankers, the ballast system of the ballast tanks installed in the cargo area may be used for pumping ballast from the forepeak, provided that:

.1 the particular tank is considered a hazardous zone;

.2 the open ends of its air pipes on the open deck are located within 3 m of sources of ignition;

.3 provision is made for measuring hazardous gas concentrations in the tank from the upper deck by means of portable apparatus;

.4 the tank is accessible and the level therein can be measured from the upper deck.

Where there is a cofferdam between cargo tanks and the forepeak; the tank may be accessible through a gastight manhole on the open deck. In this case, the manhole cover shall bear a warning inscription to the effect the tank may be opened only after it has been examined for the presence of gas or after electrical equipment has been disconnected, which may be hazardous in and enclosed space.

9.10.4 In oil tankers, the open ends of air pipes of cofferdams, fuel oil and lubricating oil tanks adjoining cargo and slop tanks shall be laid to the open deck where the vapours displaced from the above tanks do not present a fire hazard and where flame arresting fittings of a Register-approved type are available. The flow area of the fittings shall not be less than the air pipe area.

9.10.5 Steaming pipes of cargo tanks shall be equipped with non-return/shut-off valves.

9.11 LEVEL AND OVERFLOW CONTROL OF CARGO TANKS

9.11.1 Provision shall be made to guard against liquid rising in the venting system to a height, which would exceed the design head of cargo tanks. This shall be accomplished by high-level alarms or overflow control systems. The overflow control system shall be two-level and independent of tank level gauging devices, it shall give visible and audible high- and limit-level alarms in cargo tanks to the ship operator and to the cargo control room (if any), give and alarm for deenergization of the system or level sensors, have the possibility of checking the alarm circuit prior to cargo operations. For the purpose of this regulation, spill valves are not considered equivalent to an overflow system.

9.11.2 Each oil tanker equipped with a fixed inert gas system shall be provided with closed measurement devices for taking ullages of cargo and slop tanks. In oil tankers, semiclosed or closed measurement devices for taking ullages of cargo and slop tanks shall be applied. Open sounding devices are admitted in oil tankers with the descriptive notation **"Oil tanker (>60 °C)"** and as a reserve means in oil tankers not equipped with the inert gas system.

9.11.3 The cargo tanks sounding pipes shall be so designed as to include hermetic self-closing valves fitted on pipes laid to the open deck; the pipe laid to the deck shall be as high as to prevent cargo spillage onto the deck during sounding.

9.11.4 In oil tankers intended for the carriage of cargoes with flash point below 60 °C , the sounding rods shall be made of a non-sparking material.

9.12 CARGO TANK WASHING SYSTEM

9.12.1 Fixed tank washing machines shall comply with the following requirements:

.1 during the operation of the machines or with the machines immersed in fluid, any induced stresses both in the machine piping and deck connections shall not exceed the permissible values;

.2 support attachments and footing of the machines shall be approved by the Register;

.3 the machines shall be made of steel or any other material, which tendency to sparking during friction is not greater than that of steel;

.4 the complete installation shall be permanently earthed to the ship hull.

9.12.2 The casing of portable washing machines shall be made of a material, which would not spark when in contact with cargo tank structures. Secure electrically conductive coupling shall be ensured among the tank washing machine, hose and permanent washing water main. Hoses for washing with portable washing machines shall be armed with wire.

9.12.3 After washing, the water shall be discharged to the sludge tank through an opening located not less than 1 m below the water level. The free fall of liquid to the sludge tank containing washing water and oil residues shall be impossible. The requirements of this paragraph may be waived where the sludge and cargo tanks are inerted.

9.12.4 Crude oil washing systems shall comply with the requirements of 2.4, Part II "Requirements for Ship's Construction and Equipment for the Prevention of Pollution by Oil" of the Rules for the Prevention of Pollution from Ships.

9.13 STATIC ELECTRICITY PROTECTION

9.13.1 Cargo hoses, compressed air hoses, tank washing hoses and other hoses used in the cargo area shall comply with the requirements of Section 6, conduct electricity through their whole length, including connections and flanges (with the exception of shore connections), and shall be earthed to remove electrostatic charges.

9.13.2 Portable pumps and ventilators to be used in the cargo area shall be equipped with devices for electrostatic earthing prior to operation.

9.13.3 The cargo system shall make it possible to regulate the intensity of loading each particular tank so that the flow velocity would not exceed 1 m/s at suction pump outlet in the tank at the initial stage of loading. The above flow velocity can be increased, if cargo tanks are fitted with special suction wells to reduce the level of tank atmosphere electrization, which design shall be approved by the Register. For maximum loading intensity, the flow velocity shall not exceed 7 m/s. The requirements of this paragraph may be waived, if cargo tanks are inerted during cargo-handling operations.

9.14 MONITORING THE COMPOSITION OF ATMOSPHERE IN CARGO AREA

9.14.1 Oil tankers and combination carriers shall carry at least two portable instruments for measuring oxygen and flammable vapour concentrations (refer to item 15 of Table 5.1.2, Part VI "Fire Protection").

9.14.2 Structural measures shall be taken to facilitate flammable vapour concentration measurements in all spaces of the cargo area. The above measurements shall be possible from open deck or readily accessible locations. Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces shall be fitted with permanent gas sampling lines. Where plastic pipe material are used, they shall be electrically conductive.

9.14.3 In cargo pump rooms and in ballast pump rooms fitted with the equipment containing cargo a system for continuous monitoring of the concentration of hydrocarbon gases shall be fitted. Sampling of atmosphere for analysis shall be carried out in succession (including the exhaust vent). The interval between measurements shall be as short as possible. Detector heads of gas analyzers shall be located in the areas with limited air circulation (at recesses and remote angles). When the hydrocarbon gas concentration reaches a pre-set level, which shall not be higher than 10 per cent of the lower flammable limit, a continuous audible and visual alarm signal shall be automatically effected in the pump-room, engine control room, cargo control room and navigation bridge to alert personnel to the potential hazard.

In combination carriers, such system, in addition to the cargo pump-rooms, shall be installed in cofferdams and pipe tunnels adjacent to the drainage tanks.

9.14.4 Where fixed gas analysers are fitted outside the cargo area, the following conditions shall be met:

.1 sampling pipes shall be provided with flame arresters and gas samples shall be vented to the atmosphere through a special pipe mounted at a safe location;

.2 sampling pipe assemblies at gastight bulkhead penetrations shall be type-approved and their fire resistance shall be equal to that of the bulkhead;

.3 each sampling pipe shall be provided with a manual insulation valve fitted on the gas-safe side of the gasight bulkhead;

.4 instruments and equipment for gas analysis shall be arranged inside a special hermetic steel cabinet and one of the sampling points shall be located in the cabinet. When the dangerous gas concentration inside the cabinet reaches 30 per cent of the lower flammability limit, the gas supply to the gas analyzer shall be automatically stopped;

.5 sampling lines shall not generally be laid through spaces outside the hazardous area. Where it is not possible to install the gas analysis cabinet on a gastight bulkhead, the sampling pipes shall be as short as practicable, they shall be made of steel or an equivalent material and shall not have detachable joints except joints with the gas analysis cabinet and insulating valves on the gastight bulkhead.

9.14.5 In oil recovery ships and bilge water removing ships the sampling arrangements or the atmosphere monitoring system detectors shall be located as follows:

.1 near the forced ventilation openings;

.2 at least at two locations at the open deck at a height not more than 1m above the deck;

.3 in machinery spaces of category A;

.4 in air locks;

.5 in cofferdams adjacent to cargo tanks.

9.15 OIL RECOVERY SYSTEM OF OIL RECOVERY SHIPS

9.15.1 The system and devices for the recovery and transfer of oil shall be installed outside machinery spaces and accommodation spaces.

9.15.2 The system shall ensure both the recovery and transfer of oil being recovered.

9.15.3 Where, in multi-purpose ships, a permanently installed oil recovery system is incompatible with the cargo of the cargo system installed, relevant isolating arrangements shall be provided.

9.15.4 Where the ship is fitted with portable oil recovery equipment, not more than two suctions connected by piping to all oil collecting tanks shall be provided on the upper deck for connecting to the discharge hoses of the oil recovery equipment.

The arrangement of suctions on the upper deck shall make it possible to simultaneously connect two oil recovery systems installed on the opposite sides of the oil recovery ship.

Pipe connecting suctions to tanks shall not pass through accommodation spaces or spaces located as high as the open deck.

Laying of pipes through enclosed intrinsically safe spaces (refer to 19.2.3.4, Part XI "Electrical Equipment") shall be subject to special consideration by the Register in each case.

9.16 INERT GAS SYSTEM

9.16.1 General.

9.16.1.1 The inert gas system may be used:

.1 as a principal means of fire extinguishing in dry cargo holds, provided an independent inert gas generator is installed;

.2 as a means of warning the outbreak of a fire by rendering and maintaining the atmosphere of the cargo tanks non-flammable at all times, except when such tanks are required to be gas free.

9.16.1.2 The system shall be capable of:

.1 maintaining the atmosphere in any part of any cargo tank with an oxygen content not exceeding 8 per cent by volume and at a positive pressure at all times in port and at sea except when it is necessary for such tank to be gas free; maintaining the atmosphere in any part of any dry cargo hold with an oxygen content not exceeding 14 per cent by volume;

.2 eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas free;

.3 purging empty cargo tanks with inert gas and air.

9.16.1.3 Inert gas with an oxygen content of not more than 5 per cent by volume shall be delivered to the cargo tanks.

9.16.1.4 The temperature of the inert gas supplied to the protected space shall be not in excess of:

.1 65 °C for cargo tanks;

.2 50 °C for dry cargo holds.

9.16.1.5 The inert gas supply may be treated flue gas from main or auxiliary boilers or separate gas generators. The Register may accept systems using flue gases from other sources or any combinations thereof provided an equivalent standard of safety is achieved. Each source of flue gas shall be provided with automatic combustion control to provide for the fulfilment of the requirement of 3.9.1.3.

Carbon dioxide smothering system due to the risk of ignition of the mixture of vapours of flammable liquids with air from discharges of static electricity generated at carbon dioxide supply shall not be used for the purpose of inertization.

9.16.2 Capacity.

9.16.2.1 The system shall be capable of delivering inert gas to the cargo tanks at a rate of at least 125 per cent of the maximum total capacity of the cargo pumps during discharging the ship.

9.16.2.2 The capacity of the system shall be sufficient for the hourly receipt of the amount of gas equal to minimum 25 per cent of the gross amount of the most spacious hold among the protected ones to ensure the cargo holds protection. The work of the system with such capacity shall be carried on for 72 hours.

9.16.3 Equipment.

9.16.3.1 A flue gas scrubber shall be fitted which will effectively cool the volume of gas and remove solids and sulphur combustion products. The cooling water shall be delivered by an independent pump. Provision shall be made for an alternative supply of cooling water from a stand-by pump without interfering with any essential services on the ship.

9.16.3.2 The gas scrubber shall be designed so that the capacity of the system will not drop for more than 3 per cent and the gas temperature at the outlet will not rise more than 3°C as against the design values under all normal conditions of heel and trim.

9.16.3.3 Provision shall be made in the gas scrubber housing for inspection holes and sight glasses made of impact-, and heat-resisting material for inspections and maintenance.

9.16.3.4 At least two blowers shall be fitted which together are capable of delivering at least the volume of gas required by 9.16.2; and where possible there shall be established equal supply for each blower, but at any rate for each of them it shall not be less than 1/3 of aggregate required supply.

9.16.3.5 Provision shall be made in the blower casing for maintenance devices.

9.16.3.6 Interior surfaces of the scrubber and blowers shall be made of corrosion-resistant materials or lined with a coating material.

9.16.3.7 Filters or equivalent devices shall be fitted to minimize the amount of water and solid particles carried over to the inert gas blowers.

9.16.4 Cargo tank protection against pressure/ vacuum.

9.16.4.1 The inert gas system shall be so designed that the maximum pressure which it can exert on any cargo tank will not exceed the test pressure of any cargo tank.

9.16.4.2 One or more pressure-vacuum breaking devices shall be provided on the inert gas supply main provided they are not fitted on the gas venting system or individually on each tank. Control, location and design of these arrangements are to comply with 9.7.

9.16.4.3 A positive pressure not exceeding 21 kPa shall be maintained in the cargo tanks when they are filled or being filled with inert gas under normal working conditions.

9.16.5 Non-return valves.

9.16.5.1 At least two non-return devices shall be fitted in the inert gas supply main in the cargo area on deck. One of them shall be a deck water seal, and the other — a non-return valve or an equivalent device fitted forward of the deck water seal. They shall be located between the automatic valve required by 9.16.6.5 and the aftermost connection to any cargo tank or cargo pipeline.

9.16.5.2 The deck water seal shall be capable of being supplied by two separate pumps, each of which shall be capable of maintaining an adequate supply at all times and automatically starting each pump feeding the water seal and automatically filling the seal with water upon inert gas supply failure (for half-dry and dry water seals).

A drain pipe of the deck water seal shall not pass through machinery spaces. Discharge pipes shall be laid directly overboard.

9.16.5.3 Provision shall be made to ensure that the water seal is protected against freezing in such a way that the integrity of seal is not impaired by overheating.

9.16.5.4 The deck water seal and all loop arrangements shall be capable of preventing return of hydrocarbon vapours at a pressure equal to the test pressure of the cargo tanks.

9.16.5.5 The non-return valve (refer to 9.16.5.1) may be of non-return shut-off type or of non-return type with a shut-off valve being additionally fitted in the inert gas supply main forward of the non-return valve.

9.16.5.6 A water loop or other approved arrangement shall be fitted to each associated water supply and drain pipe and each venting or pressure-sensing pipe leading to gas safe spaces[1]. Means shall be provided to prevent such loops from being emptied by vacuum.

9.16.5.7 Provision shall be made in the deck water seal for sight holes and glases for monitoring the water level and making inspections.

9.16.5.8 Materials used in non-return devices shall be resistant to the effect of acids generated during cooling, cleaning and by gases coming through the pipes.

9.16.6 Pipes.

9.16.6.1 The inert gas main may be divided into two or more distributing pipes forward of the non-return devices required by 9.16.5.1.

9.16.6.2 The distribution inert gas supply pipes shall be fitted with branch piping leading to each cargo tank. Branch piping for inert gas shall be fitted with either shut-off valves or equivalent means of control for isolating each tank.

Where shut-off valves are fitted, they shall be provided with locking arrangements to prevent the control of the valves by unauthorized persons.

The control system operated shall provide positive indication of the operational status of the shut-off valves.

9.16.6.3 In combination carriers the arrangement to isolate the inert gas system from the slop tanks shall consist of blank flanges.

9.16.6.4 Outlets of the pipes discharging inert gas into dry cargo holds shall be located in the lower part

[1] Gas safe space is a space in which the entry of hydrocarbon gases would produce hazards with regard to flammability or toxicity.

of the protected space. Such spaces of 500 m^3 in volume and more shall be provided with two pipe outlets located in the opposite parts of the space. Pipe outlets discharging inert gas into the cargo tanks shall be located in the upper part.

9.16.6.5 A gas regulating valve shall be fitted in the inert gas supply main. It shall be capable of automatically regulating the flow of inert gas to the cargo tanks as referred to in 9.16.8.8 unless means are provided to automatically control the speed of the inert gas blowers.

9.16.6.6 If a connection is fitted between the inert gas supply main and the cargo piping system, arrangements shall be made to ensure an effective isolation having regard to the large pressure difference which may exist between the systems. It shall consist of two shut-off valves, the valve on the cargo main being of a non-return type, and an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks.

9.16.6.7 The valve separating the inert gas supply main from the cargo main and which is on the cargo main side shall be a non-return shut-off valve.

9.16.6.8 Piping systems shall be so laid as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.

9.16.6.9 Suitable arrangements shall be provided for the safe venting of the section of the line between the valves referred to in 9.16.5.5 and 9.16.6.5 in case when the first of these valves is closed.

9.16.6.10 The diameter of the pipes shall be such as to ensure the gas flow rate in any section of the piping to be not more than 40 m/s.

9.16.6.11 The piping from the gas scrubber to the blowers and recirculation lines as well as drain pipe of gas scrubbing and cooling system shall be lined with corrosion-resistant coating.

9.16.6.12 An arrangement shall be provided to connect the inert gas main to the external supply of inert gas. The arrangement shall consist of a flange joint for 250 mm piping fitted forward of the non-return valve specified in 9.16.6.5.

Flange design shall comply with the requirements of 2.4.3.

9.16.6.13 The inert gas supply main may be used for the venting of the cargo tanks.

9.16.7 Instruments and alarms.

9.16.7.1 On the discharge side of gas blowers, instruments shall be provided for continuous indication of the inert gas temperature and pressure.

9.16.7.2 Instrumentation shall be fitted for continuously indicating and permanently recording, when the inert gas is being supplied:

.1 the pressure of the inert gas supply main forward of the non-return devices required by 9.16.5.1;

.2 the oxygen content of the inert gas in the inert gas supply main on the discharge side of the gas blowers.

These devices shall be placed in the cargo control room; but where no cargo control room is provided, they shall be placed in a position easily accessible to the officer in charge of cargo operations.

9.16.7.3 In addition to the requirements of 9.16.7.2, the following meters shall be fitted:

.1 in the navigating bridge to indicate at all times the pressure (refer to 9.16.7.2.1) and the pressure in the slop tanks of combination carriers, wherever those tanks are isolated from the inert gas supply main;

.2 in the main machinery control room or in the machinery space to indicate the oxygen content (refer to 9.16.7.2.2).

9.16.7.4 Suitable arrangements shall be provided on each cargo tank for measuring oxygen and hydrocarbon vapour concentration using portable instruments.

9.16.7.5 Suitable means shall be provided for the zero and span calibration of both fixed and portable gas concentration measurement instruments referred to in 9.16.7.2 and item 15 of Table 5.1.2, Part VI "Fire Protection".

9.16.7.6 Audible and visual alarms shall be provided to indicate:

.1 low water pressure or low water flow rate to the flue gas scrubber;

.2 high water level in the scrubber;

.3 increase of gas temperature, this alarm being operated when the temperatures referred to in 9.16.1.4 are reached;

.4 failure of inert gas blowers;

.5 oxygen content more than 14 per cent by volume in cargo holds;

.6 oxygen content in the inert gas main more than 8 per cent by volume;

.7 failure of the power supply to the automatic control system for the gas regulating valve and to the indicating devices referred to in 9.16.7.2;

.8 low water level in the deck water seal referred to in 9.16.5.1;

.9 gas pressure less than 1 kPa in the inert gas main. The alarm arrangement shall be such as to ensure that the pressure in slop tanks in combination carriers can be monitored at all times;

.10 high gas pressure (when the pressure reaches 10 kPa).

.11 insufficient fuel feeding (if inert gas generators are available);

.12 failure of power supply to the generator (if inert gas generators are available);

.13 failure of power supply to automatic generator control system (if inert gas generators are available).

9.16.7.7 Indicating units of the alarms required in 9.16.7.6.3, 9.16.7.6.4, 9.16.7.6.6 and 9.16.7.9 shall be placed in the machinery space and in the cargo control room, where provided, but in any case they shall be placed in a position where the alarm may be immediately received by responsible members of the crew.

9.16.7.8 Audible and visual alarms indicating the low water level in the water seal of half-dry and dry type shall operate on failure of the inert gas supply.

9.16.7.9 Additional audible alarms independent of the alarms required in 9.16.7.6.9 or automatic shutdown of the cargo pumps shall be provided to operate when the pressure in the main drops to 0,5 kPa.

9.16.8 Systems using flue gas of boilers (these requirements are additional to those of 9.16.1 to 9.16.7).

9.16.8.1 The flue gas scrubber and blowers shall be located aft of all cargo tanks, cargo pump rooms and cofferdams separating these spaces from machinery spaces of category A.

The design and location of scrubber and blowers with relevant piping and fittings shall prevent the gas leakages into enclosed spaces.

9.16.8.2 Suitable shut-off arrangements shall be provided on the suction and discharge connections of each blower. Arrangements shall be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge.

9.16.8.3 Shut-off valves shall be fitted in the inert gas supply mains between the boiler uptake and the flue gas scrubber. The valves shall be provided with an indicator to show whether they are open or shut. Precautions shall be taken to maintain them gastight and keep the seatings clear of soot.

Arrangements shall be provided to ensure that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

9.16.8.4 If the blowers shall be used for gas freeing, their air inlets shall be provided with blanking arrangements.

9.16.8.5 A shut-off valve (refer to 9.16.8.3) shall be made of materials capable of withstanding the flue gas temperature and resistant to the corrosive action of the gas.

9.16.8.6 The piping between the shut-off valve and the scrubber shall be made of corrosion-resistant steel.

9.16.8.7 An additional water seal or other effective means of preventing flue gas leakage shall be fitted between the shut-off valves (refer to 9.16.8.3) and the scrubber.

9.16.8.8 The valve referred to in 9.16.6.5 shall be located at the forward bulkhead of the forwardmost gas safe space through which the inert gas supply main passes.

9.16.8.9 Automatic shutdown of the inert gas blowers and gas regulating valve shall be arranged on predetermined limits being reached in respect of 9.16.7.6.1, 9.16.7.6.2 and 9.16.7.6.8. Automatic shutdown of the gas regulating valve shall also be arranged in case of blower failure.

9.16.9 Inert gas generator system (the requirements for this system stated below are additional to those given in 9.16.1 to 9.16.7).

9.16.9.1 For inert gas generator (the machinery including blower, combustion chamber, scrubber, fuel oil pump, burner, automatic combustion control and supervisory equipment) use shall be made of fuel oil meeting the requirements of 1.1.2, Part VII "Machinery Installations".

9.16.9.2 The generators shall be located in the space referring to machinery spaces of category A.

9.16.9.3 In ships in whose tanks toxic substances may be carried the gas generators shall not be located in the machinery spaces and shall be located in a compartment reserved solely for their use according to the requirements of 9.16.8.1. Such a compartment shall be separated from the machinery spaces at least by a gastight steel bulkhead, having no doors or other openings, and from the accommodation spaces and cargo area by open decks, cofferdams or similar spaces. Adequate positive pressure type mechanical ventilation shall be provided for such a compartment. Access to such compartments shall be only from an open deck outside the cargo area. Access shall be provided on the end bulkhead of the superstructure or deckhouse, not facing the cargo area and/or on the outboard side of the superstructure or deckhouse at a distance of at least $L/25$, but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area.

The inert gas supply main shall not be located in, or have any connection with systems located in machinery spaces, accommodation spaces and service spaces.

9.16.9.4 Despite the provisions of 9.16.3.4, the Register may permit only one blower if it is capable of delivering to the protected cargo spaces the total volume of gas required by 9.16.2, provided sufficient spares for the air blower and its prime mover are carried on board to enable any failure of the air blower and its prime mover to be rectified by the ship's crew.

9.16.9.5 Two fuel oil pumps shall be fitted to the inert gas generator. The Register may permit only one fuel oil pump, provided sufficient spares for the fuel oil pump and its prime mover are carried on board to enable any failure of the pump and its prime mover to be rectified by the ship's crew.

9.16.9.6 Where more than one inert gas generator is provided, suitable shut-off arrangements shall be fitted on the discharge outlet of each generator plant.

9.16.9.7 Arrangements shall be made to vent the inert gas to the atmosphere during starting-up or in case of equipment failure.

9.16.9.8 Where the inert gas generator is served by positive displacement blowers, a pressure relief device shall be provided to prevent excess pressure being developed on the discharge side of the blower.

9.16.9.9 Audible and visual alarms shall be provided to indicate:

.1 insufficient fuel oil supply;

.2 failure of power supply to the generator;

.3 failure of power supply to the automatic control system for the generator.

9.16.9.10 The gas regulating valve shall be automatically controlled to close and to interrupt the fuel oil supply to the generator on predetermined limits being reached in respect of 9.16.7.6.1 and 9.16.7.6.2.

Automatic shut-down of the gas regulating shall also be arranged in respect of 9.16.9.9.2.

9.16.10 Inert gas systems for oil tankers.

9.16.10.1 On tankers where the inert gas system is required, inertization of space in double hull may be accomplished through detachable branch pipes connected with the inert gas system of cargo tanks or via stationary pipelines.

9.16.10.2 If detachable branch pipes are used, connection arrangements on the system main shall be provided.

9.16.10.3 If stationary pipelines are used, a separate deck gate and shut-off valve shall be provided.

9.16.11 Systems with inert gas supplied from cylinders.

9.16.11.1 The systems are designed for purposes stated under 9.16.1.1.2 in respect of fuel oil storage tanks mentioned in 13.13.4.

9.16.11.2 The cylinders of the systems, generally filled with nitrogen, and their spaces shall comply with the requirements of 12.9 of the present Part and 6.4.5, Part X "Boilers, Heat Exchangers and Pressure Vessels".

9.16.11.3 The system piping of Class I and Class II, respectively, shall be tested on board in conformity with Section 21.

9.16.12 Nitrogen generator system.

9.16.12.1 The present requirements cover the system in which the inert gas (nitrogen) originates at separation of compressed air to the basic gases while passing through the nitrogen generator (group of empty fibres of semipermeable membranes or through adsorbent placed in hermetic casing). The system shall also comply with requirements 9.16.2.1, 9.16.4, 9.16.6.1 to 9.16.6.3, 9.16.6.12 (applicable to 9.16.12.8), 9.16.7.4, 9.16.7.5, 9.16.7.9 (applicable to 9.16.12.14.7) and 9.16.8.8 (applicable to 9.16.12.8).

9.16.12.2 Air compressor and nitrogen generator shall be placed in the engine room or in a separate room which is then referred to other engine rooms (refer to 2.4.2, Part VI "Fire Protection"). It shall be located outside the cargo area and it shall have no direct access to the accommodation, service spaces and control stations.

9.16.12.3 The system shall produce inert gas with at least 95 per cent content of nitrogen and no more than 5 per cent of oxygen. The system shall be fitted with an automatic device which would enable emission of gas into the air while preparation of the system for the specification level and even during its faults.

9.16.12.4 The system shall have to air compressors of equal capacity. The system may have one compressor provided there are enough spare parts for it aboard to repair by the crew.

9.16.12.5 Equipment for processing of air ingoing into generator (aircooler, airheater, separator, filters) shall clean it from moisture, particles and oil and maintain specification temperature.

9.16.12.6 The nitrogen receiver may be installed in the cargo area. The room where it is installed shall have exit to the open deck, the door is to open outwards.

9.16.12.7 Tapping of air enriched with oxygen from the nitrogen generator and tapping of nitrogen from safety devices of the nitrogen receiver is to extend outside rooms to the places away from entrances, air intakes and openings of closed in spaces.

9.16.12.8 On the outlet from the nitrogen generator there shall be installed devices which maintain permanent pressure of the inert gas.

9.16.12.9 A shut-off valve shall be installed between the nitrogen generator and receiver.

9.16.12.10 At least two non-return shut-off devices shall be fitted in the inert gas system. One of them shall have double blocking and blowoff arrangement, another — the local locking device. They shall be installed on the main in the cargo area before branch pipes specified in 9.16.6.2.

9.16.12.11 There shall be mounted instruments for the permanent temperature and pressure indication: on the compressor delivery side; on the intake side of the nitrogen generator.

9.16.12.12 There shall be mounted instruments for the permanent temperature and pressure indication and registration during system operation:

.1 oxygen content in the inert gas at the output of nitrogen generator;

.2 pressure in the main before the retaning sealing valves required by 9.16.12.10.

9.16.12.13 Instruments specified in 9.16.12.12 shall be fitted in the cargo control room, if any. If there is no cargo control room onboard the instruments shall be fitted in such a place where alarm may be received by the responsible crewmembers.

9.16.12.14 Audible and visual alarm shall be provided to indicate:

.1 low air pressure in the compressor specified in 9.16.12.11;

.2 high air temperature specified in 9.16.12.11;

.3 high level of water in the separator specified in 9.16.12.5;

.4 breakdown of electrical heater (if fitted) specified in 9.16.12.5;

.5 high oxygen content specified in 9.16.12.3 and 9.16.12.12;

.6 stop of energy supply of instruments specified in 9.16.12.12;

.7 drop of gas pressure referred to in 9.16.12.12;

.8 increase of gas pressure referred to in 9.16.12.12.

9.16.12.15 Automatic stop of compressor shall take place if alarm turns on as specified in 9.16.12.14.1 to 9.16.12.14.5 and 9.16.12.14.8. Automatic compressor protection shall comply with the requirements of 4.5, Part XV "Automation".

9.16.12.16 Automatic locking of arrangements specified in 9.16.12.8 shall take place if power is disconnected from the compressor.

9.16.12.17 Alarm required by 9.16.12.14 shall be installed in the engine room and cargo control room if such post is provided but in any case in such a room where alarm may be immediately received by the responsible crew member.

10 AIR, OVERFLOW AND SOUNDING PIPING

10.1 AIR PIPES

10.1.1 Each tank intended for the storage of liquid and each filled cofferdam, as well as the ice boxes and sea chests, shall have air pipes.

The air pipes of ice boxes and sea chests shall have shut-off valves fitted directly on the them.

Air pipes of double-bottom tanks and of tanks adjoining the shell plating, as well as the air pipes of ice boxes and sea chests, shall be carried to above the bulkhead deck.

10.1.2 The air pipes shall be fitted at the highest part of the tank and, as a rule, at a place that is at maximum distance from the filling pipe. The number and arrangement of the pipes shall be selected depending on the shape and size of the tank, and shall also preclude the formation of air pockets.

If the air pipes of fuel tanks are used as overflow (air/overflow) pipes, the requirements of 10.2.4 shall be complied with.

10.1.3 The tanks extending from side to side of the ship shall be fitted with air pipes at either side. The air pipes shall not be used as filling pipes, except when the tank is fitted with more than one air pipe.

The air pipes of tanks carrying liquids of different kinds are not permitted to be laid into a common line.

10.1.4 The height of the air pipes laid to the open deck measured from the deck to the point where water may have access below shall not be less than:

760 mm on the freeboard deck;

450 mm on superstructure decks.

Where such a height is an obstacle to operations on board a smaller height may be approved, provided the availability of closing arrangements or other circumstances make this substitution reasonable. Besides, in ships of restricted areas of navigation **R2**, **R2-RSN**, **R3** and **R3-RSN** the above pipe heights may be reduced on agreement with the Register. However, they shall not be less than 600 and 380 mm, accordingly.

Minimum wall thicknesses of the air pipes above deck shall be:

6 mm for $d \leqslant 80$ mm,

8,5 mm for $d \geqslant 165$ mm.

Intermediate sizes shall be determined by linear interpolation.

Air pipes shall be located in protected places where there is no possibility of their damage during cargo handling operations.

Location and arrangement of air pipes for fuel oil service, settling and lubricating oil tanks shall be such that in the event of a broken air pipe this will not directly lead to the risk of ingress of sea water splashes or rainwater.

10.1.5 The upper end of each air pipe shall be made as a bend, with its opening facing downwards or shall have another construction agreed upon with the Register.

10.1.6 The open ends of air pipes of fuel oil and lubricating oil tanks shall be laid to positions on the open deck where the vapours issuing from the mentioned tanks cannot incur a fire hazard.

The air pipes of fuel oil tanks with heating arrangements shall meet the requirements of 13.3.5.

10.1.7 The air pipes of independent lubricating oil storage tanks, may terminate in spaces where the tanks are installed if precautions are taken that will preclude spillage of oil onto electrical equipment or heated surfaces in case the tank is overflowing.

10.1.8 The outlets of air pipes situated on the open freeboard deck and superstructure deck of the first tier (refer to 1.2.5, Part III "Equipment, Arrangements and Outfit"), as well as the outlets of the air pipes on the decks of higher tiers within the area limited by the angle of flooding (refer to 1.2, Part IV "Stability") shall have permanently attached self-closing covers preventing the sea water from getting into the tanks, but allowing a free access of air and liquids. Closing devices shall meet the requirements of 4.4.

10.1.9 The total cross-sectional area of the air pipes in tank filled by gravity shall not be less than the total sectional area of the filling pipes of these tanks.

10.1.10 The total cross-sectional area of the air pipes of a tank filled by the ship's pumps or shore pumps, shall not be less than 1,25 times the cross-sectional area of the filling pipe of that tank.

The cross-sectional area of a common air pipe from several tanks shall be at least 1,25 times the area of the common filling pipeline of these tanks, the requirements of 10.2.3 being complied with.

10.1.11 Where a tank filled by shipboard pumps or from shore pumps is fitted with an overflow pipe, the total cross-sectional area of the air pipes of the tank shall not be less than one-third of the filling pipe area.

Where the air pipes from several tanks fitted with overflow pipes are combined, the cross-sectional area of the common air pipe shall be at least one-third of the area of the common filling pipe of these tanks, the requirements of 10.2.3 being complied with.

10.1.12 An inner air pipe diameter shall be at least 50 mm under all conditions. This requirement does not apply to the air pipes indicated in 10.1.9.

10.1.13 The arrangement of the air pipes shall preclude the formation of hydraulic seals in the pipes.

10.1.14 The air pipes of fuel oil and lubricating oil tanks in way of accommodation and refrigerated cargo spaces shall not have detachable connections.

10.1.15 Nameplates shall be affixed to the upper ends of all air pipes.

10.1.16 The air pipes from crankcases of internal combustion engines shall comply with the requirements of 2.3.4, Part IX "Machinery" and 11.1.9 of the present Part.

10.1.17 The air pipes from ballast compartments of floating docks shall be laid to a height not less than 300 mm above the margin line.

It is permitted to lay air pipes through the plating of wing walls.

Other requirements of the present Chapter are not applicable to the air pipes of the ballast compartments in floating docks.

10.1.18 In passenger ships the open ends of air pipes terminating in the superstructure, shall be located at a height of 1 m above the waterline of the ship inclined up to 15° or the maximum angle of heel determined by calculations during intermediate flooding, whichever is the greater.

As an alternative to this air pipes of tanks, other than oil tanks, may be laid through the superstructure side.

10.1.19 The open ends of the cargo tanks air pipes of oil recovery ships shall be laid to positions on the open deck where the issuing vapours cannot incur a fire hazard and shall be protected with flame-arresting fittings.

The clear area through the fitting shall not be less than open flow area of the air pipe.

10.1.20 Test tank air pipes of cargo heating system condensate shall meet the requirements of 9.6.3.

10.2 OVERFLOW PIPES

10.2.1 Fuel oil tanks shall be provided with overflow pipes directing fuel to an overflow tank or storage tank, the capacity of which shall be increased by a value not less than the overflow tank capacity as stipulated by 10.3.1, and which shall be equipped in accordance with 10.3.2.

No overflow pipes may be fitted where the fuel oil system is so designed that no spilling overboard can occur during the loading and transfer of fuel. Besides fuel oil tanks, the overflow pipes shall be fitted on lubricating oil tanks specified in 14.4.4 and 20.4.3.

10.2.2 The cross-sectional area of overflow pipes shall not be less than 1,25 of the filling pipe area. The cross-sectional area of the common overflow pipe of several tanks shall not be less than 1,25 of common filling pipe area.

10.2.3 Where the overflow pipes from several integrated tanks located in different watertight compartments are laid to a common header or pipe, this header or pipe shall be located above the deepest damage waterline in ships having a subdivision mark in the class notation and above the deepest load waterline in other ships.

10.2.4 Where air pipes are simultaneously used as overflow pipes, they shall not be connected to the air pipes of overflow tanks. In this case, the overflow pipes or a common overflow pipe shall be connected directly to the tank.

10.2.5 Where a tank is used alternatively for the carriage of fuel oil, water ballast or liquid and dry cargoes, then in the case of a common overflow system the overflow pipes shall be so arranged as to preclude the possibility of liquid flowing from one tank into another and liquid cargo vapours entering tanks containing dry cargo. In such cases, subject to the Register approval the overflow pipes may be fitted with shut-off valves, provided such pipes are not used as air pipes.

10.2.6 The overflow pipes of daily tanks and of fuel oil and lubricating oil settling tanks shall be laid to overflow tanks located below the tanks mentioned above.

10.2.7 A sight glass shall be fitted on vertical overflow pipes at a readily visible and accessible location, or an alarm device shall be provided to give warning when the predetermined level is reached in the overflow tank (refer also to 10.3.2).

10.2.8 Minimum overflow pipe bore shall be 50 mm.

10.2.9 Overflow pipes shall be extended up to the bottom of the overflow tanks with a minimal clearance. The flow area in the clearance shall not be less than the sectional area of the overflow pipe.

10.3 OVERFLOW TANKS

10.3.1 The capacity of an overflow fuel tank shall not be less than the maximum capacity of the fuelling and fuel transfer system within 10 min.

10.3.2 An overflow tank shall be provided with audible and visual alarms operating whenever the tank filling reaches 75 per cent.

10.4 SOUNDING ARRANGEMENTS

10.4.1 Each tank intended for the storage of liquid, cofferdams and void spaces with bilge connections, as well as bilges and bilge wells in spaces, which are not accessible at all times, shall be provided with sounding pipes for level management generally extended to the open decks. In tanks, other sounding arrangements may be used, which design is approved by the Register.

Sounding pipes of independent tanks are not required to be laid to the open deck.

Upper ends of the sounding pipes of the fuel oil and lubricating oil tanks shall not be laid to the spaces which may present the risk of ignition of leakage from the sounding pipes. Laying of the sounding pipes of the fuel tanks to accommodation and service spaces is prohibited.

10.4.2 Other oil-level gauges may be used instead of the sounding pipes, provided that they meet the following requirements:

.1 in passenger ships the installation of such means shall not require penetration below the top of the tank and their failure or overfilling of the tanks shall not permit release of fuel;

.2 in cargo ships the failure or overfilling of the above measuring instruments shall not permit release of fuel. The level indicators may be used with flat glass and self-closing cocks fitted between the level indicators and the fuel tanks. When the upper part of the indicator is connected to the top of the tank, the upper self-closing valve may be not installed. The use of glass pipes in the level indicators is not permitted.

10.4.3 Where the double bottom forms bilges at the wings, or the ship has a flat bottom, the sounding pipes shall be installed at each side. These pipes shall be laid to positions above the bulkhead deck, which are at all times accessible for taking soundings. The sounding pipes shall be as straight as practicable and shall not interfere with taking soundings with a sounding rod.

10.4.4 As a rule, the sounding pipes of fuel and oil tanks shall not terminate in machinery spaces. Where this requirement is impracticable, termination of sounding pipes in machinery spaces may be permitted on condition the following requirements are met:

.1 in passenger ships, such pipes shall not require penetration below the top of the tank and their failure or overfilling of the tanks shall not permit release of fuel;

.2 in cargo ships, the failure of such pipes or overfilling of the tank shall not permit release of fuel;

.3 the sounding pipes shall terminate in locations remote from ignition hazards or they shall be screened;

.4 terminations of sounding pipes shall be fitted with self-closing blanking devices and with a small-diameter self-closing control cock located below them;

.5 structural measures shall be taken to prevent the spillage of fuel or oil on heated surfaces from the blanking device;

.6 the pipes shall terminate at least 0,5 m above the plating.

10.4.5 The sounding pipes of the double-bottom water storage tanks are permitted to be laid into spaces below the bulkhead deck that are located above them and are accessible at all times. Such pipes shall not be used as air pipes and shall be fitted with self-closing cocks.

10.4.6 Provision shall be made under the open ends of the sounding pipes for welded striking plates or other strengthening to protect the bottom plating from damaging by a sounding rod.

In case of slotted sounding pipes with closed ends, adequately strong closing plugs shall be provided.

10.4.7 The internal diameter of the sounding pipes shall be at least 32 mm and for ships of the restricted area of navigation **R3-RSN** it shall not be less than 25 mm. Sounding pipes, which pass through refrigerated cargo spaces, in which the temperature may be reduced to 0 °C and below, as well as sounding pipes of oil storage tanks in oil recovery ships shall have a internal diameter of not less than 50 mm.

10.4.8 Nameplates shall be affixed to the upper ends of the sounding pipes.

10.4.9 In oil tankers each cargo tank shall be provided with overflow prevention system to meet the following requirements:

.1 be separated of sounding system of cargo tanks;

.2 give visible and audible high- and limit-level alarms in cargo tanks to ship's operator and to cargo handling room;

.3 give an alarm on de-energization of system or level sensors;

.4 have the possibility of checking the alarm circuit prior to cargo operations;

.5 give a code signal for sequential switch-off of shore pumps and valves, or both, and valves shall be switched off by ship's operators. Application of ship's automatically closed valves is allowed only upon the permission and under the agreement with Port Administration.

10.4.10 The ends of the sounding pipes laid to the exposed decks shall be fitted with tight plugs complying with the requirements of 2.1.8.

The use of closings of a different type shall be specially considered by the Register in each case.

If the sounding pipes project above the open deck, they shall be located at such positions where they cannot be damaged, otherwise they shall have appropriate guards.

10.4.11 In floating docks the sounding pipes of ballast compartments shall be laid to the top deck of the side walls.

11 EXHAUST GAS SYSTEM

11.1 EXHAUST GAS PIPING

11.1.1 The exhaust gas pipes shall, as a rule, be laid to the open decks.

11.1.2 Where the exhaust gas pipes are laid through the shell plating in the vicinity of load waterline or below it, provision shall be made for arrangements precluding the possibility of sea water entering the engine.

11.1.3 In oil tankers, oil recovery tankers, supply vessels, ships adapted for the carriage of explosive and fire hazardous cargoes and on ships servicing or towing the above-mentioned ships, the uptakes of boilers, exhaust pipes of main and auxiliary engines, incinerators shall be fitted with spark arresters of the construction approved by the Register.

11.1.4 The exhaust gas pipes shall be laid at a distance not less than 450 mm from the fuel oil tanks.

11.1.5 Each main engine shall have an individual exhaust gas pipe. Where required, departures may be allowed, subject to special consideration by the Register.

Where three or more auxiliary engines are fitted, their exhaust gas pipes may be connected to a common exhaust line provided that the engine with the greatest output has an autonomous exhaust pipe. Besides, the common exhaust line shall be fitted with reliable devices which will preclude:

gases of the common line entering the pipes of the engines not actually at work;

damage of any of the engines when started.

In ships of restricted areas of navigation **R2**, **R2-RSN**, **R3** and **R3-RSN**, the exhaust gas pipes of the main and auxiliary engines may be permitted to connect to a common exhaust line, provided the foregoing precautions are taken. The exhaust gas pipes from DF-engines shall comply with the requirements of 9.5.2, Part IX "Machinery".

11.1.6 The waste boilers and the composite waste heat/oil fired boilers, which by reason of structural features cannot be left without water while heated by exhaust gases, as well as the boilers mentioned in 3.2.16, Part X "Boilers, Heat Exchangers and Pressure Vessels" shall be provided with a by-pass line and dampers disconnecting the boilers from exhaust gas supply, when necessary.

11.1.7 The uptakes of boilers incinerators and the exhaust gas pipes of internal combustion engines shall be thermally insulated by means of suitable insulating material, double walls or screens.

Where an insulating material is used for thermal insulation, the requirements of 2.1.1.5, Part VI "Fire Protection" shall be taken into consideration.

Double walls or screens are not required only in such positions where the possibility of their coming into contact with fuel or lubricating oil leaks is precluded.

11.1.8 When the uptakes of main and auxiliary boilers are arranged to discharge into a common uptake, dampers are permitted, provided they have arrangements to be locked open. When required, manholes and vertical ladders shall be provided for inspection and cleaning of the uptakes and air ducts of boilers.

11.1.9 In oil recovery ships, the outlets of exhaust gas piping of main and auxiliary engines, uptakes of boilers, incinerators and other equipment containing sources of ignition as well as air pipe vent openings of crankcases in internal combustion engines shall be located at least 6 m above the deepest waterline, but in any case outside the dangerous zones as defined in 19.2.3, Part XI "Electrical Equipment".

11.1.10 The exhaust gas piping of remotely and automatically started diesel generators shall be fitted with non-disconnectable draining devices to prevent the entry of water into the engine. The devices shall be readily accesible for maintenance and clearing and shall have a drain pipe bore not less than 25 mm, boilers and incinerators.

11.1.11 The exhaust gas pipes of engines shall be fitted with thermal compensators. The exhaust gas piping shall have, handholes and, when necessary, drain cocks.

11.1.12 Where waste heat boilers are used, structural arrangements shall be provided to prevent the ingress of water into the exhaust gas duct of the internal combustion engines during washing. The draining pipes for the cleaning water shall be laid to the machinery space bilges and be provided with hydraulic seals.

11.2 SILENCERS AND SPARK ARRESTERS

11.2.1 The silencers and spark arresters shall be so arranged as to permit cleaning and shall be fitted with appropriate handholes or drain cocks.

11.2.2 Where spark arresters of the wet type are used, the requirements of 11.1.12 shall be met.

12 VENTILATION SYSTEM

12.1 VENTILATION DUCTS AND VENTILATOR HEADS, AIR INLETS

12.1.1 Generally, ventilation ducts shall not be laid through watertight bulkheads below the bulkhead deck. Where it is not practicable to avoid laying ventilation ducts through watertight bulkheads below the bulkhead deck, means of closure shall be provided at the penetrations ensuring watertightness and strength equal to that of local ship's structures and operated from a position above the bulkhead deck. Where ventilation ducts are laid through more than one watertight bulkhead, the means of closure of such openings shall be operated by power and be capable of being closed from the main control station situated above the bulkhead deck.

12.1.2 Where trunkways and vertical ducts of the ventilation system pass through watertight decks, they shall be watertight and equivalent in strength to adjacent hull structures within a single watertight compartment below the bulkhead deck.

12.1.3 Ventilation ducts shall be adequately protected against corrosion or constructed of corrosion-resistant materials.

12.1.4 Ventilation ducts for removal of explosion and fire-dangerous vapours and gases shall be gas-tight and shall not communicate with the ducts of other spaces.

12.1.5 Ventilation ducts laid to cargo spaces, machinery spaces and other spaces fitted with smothering facilities shall have closing arrangements complying with 3.1.2.3, Part VI "Fire Protection".

12.1.6 In places of possible sweating the ventilation ducts shall be properly insulated. Drain plugs shall be provided for the portions of ducts where water is likely to accumulate.

The inlets and outlets of the ventilation systems shall be provided with drives for closing them from positions outside these spaces.

12.1.7 The ventilator heads of supply ducts and the air inlets of ventilation systems shall be so located that the risk of drawing in air contaminated by gas, oil vapours, etc., is minimized, and admission of sea water into the ventilation ducts is precluded.

In icebreakers and ships with ice strengthening precautions shall be taken to prevent admission of snow into the ventilation ducts. It is recommended to arrange the air intakes on both sides of the ship and to provide for heating arrangements.

12.1.8 The ventilator coamings shall have a height in accordance with 7.8, Part III "Equipment, Arrangements and Outfit".

12.1.9 The arrangement of ventilator heads in cargo spaces, special category spaces, open and closed spaces of ro-ro ships shall comply with the requirements of 2.1.4.7, Part VI "Fire Protection".

12.2 VENTILATION SYSTEMS OF CARGO SHIPS OF 500 GROSS TONNAGE AND UPWARDS, OIL TANKERS AND COMBINATION CARRIERS CARRYING PETROLEUM PRODUCTS WITH FLASH POINT 60 °C AND MORE, PASSENGER SHIPS CARRYING NO MORE THAN 36 PASSENGERS, SPECIAL PURPOSE SHIPS CARRYING NO MORE THAN 200 SPECIAL PERSONNEL AND BERTH-CONNECTED SHIPS

12.2.1 The ventilation systems of accommodation spaces, service spaces and control stations shall comply with requirements of this Chapter.

12.2.2 The ventilation ducts shall be constructed of non-combustible materials. However, ducts with a cross-sectional area not exceeding 0,02 m^2 and a length not over 2 m may be constructed of material having low flame spread characteristics (refer to 1.6.3.5, Part VI "Fire Protection"), if the following conditions are met:

the ducts is used only at the end section of the ventilation system;

the duct is at a distance of at least 0,6 m, measured along the duct, from the penetration of an "A" or "B" class division (refer to 2.1.2, Part VI "Fire Protection"), including continuous "B" class ceilings.

Flexible bellows of combustible material may also be used for connection fans to the ducting in air conditioning room.

12.2.3 Where the ventilation ducts with a free sectional area exceeding 0,02 m^2 pass through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve unless the ducts passing through the bulkheads or decks are of steel in the vicinity of passage through the deck or bulkhead. The ducts and sleeves shall comply in this part with the following:

.1 the sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the bulkhead or deck through which the duct passes. Equivalent penetration protection may be provided to the satisfaction of the Register;

.2 ducts with a free cross-sectional area exceeding 0,075 m^2 shall be fitted with fire dampers in addition to the requirements of 12.2.3.1.

The fire damper shall operate automatically and shall also be capable of being closed manually from both sides of the bulkhead or deck. Manual closing from both sides of the bulkhead or deck may be effected by mechanical arrangements or by remote operation of the fire damper by means of failure-free electrical switches or by means of pneumatic damper drive through releasing of the compressed springs, etc.

The fire dampers shall be readily accessible. Where they are fitted behind the lining, the latter shall be provided with a sight hole, at which a plate bearing the fire damper number shall be secured. A similar plate with number shall be secured to the required remote control device. Fire dampers are not required, where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce.

12.2.4 Galley ventilation systems shall be separate from the ventilation systems serving other spaces. In cargo ships of less than 4000 gross tonnage and in passenger ships carrying no more than 36 passengers, supply galley ventilation may be provided by separate ducts from ventilation installation common with other spaces through an automatic fire damper fitted in the galley ventilation duct close to the ventilation installation and isolating, where necessary, all portions of ventilation duct. The galley ventilation ducts passing through accommodation and service spaces and control stations shall be:

.1 constructed of steel having a thickness of at least 3 and 5 mm for ducts the width and diameter of which are up to and including 300 and 760 mm and over, respectively. For ducts, the width or diameter of which are between 300 and 760 mm, the thickness shall be determined by interpolation;

.2 suitably supported and stiffened;

.3 constructed of "A" class divisions with wall thickness in accordance with 12.2.4.1;

.4 insulated to A-60 standard throughout the accommodation and service spaces or control stations.

The above-stated requirements apply also to ducts intended for ventilation of accommodation spaces, service spaces or control stations, which pass through machinery spaces of category A, galleys, cargo spaces of roll-on/roll-off ships, car deck spaces and special-category spaces. If a ventilation duct is laid through the main vertical fire zone divisions, the requirements of 12.2.8 shall be also complied with.

Ventilation systems of machinery spaces of category A, car deck spaces, cargo spaces of roll-on/roll-off ships, special-category spaces and other cargo spaces shall be separated from one another and from ventilation systems of other spaces. When the above-stated ventilation ducts pass through accommodation and service spaces or control stations they are subject to the requirements of 12.2.4.1 to 12.2.4.4.

12.2.5 Where ventilation ducts with a cross-sectional area exceeding 0,02 m^2 pass through "B" class bulkheads, the openings shall be lined with steel sheet sleeves of 900 mm in length, unless the ducts are of steel for this length in way of the bulkhead. When passing through a "B" class division, this length shall be divided into 450 mm on each side of the bulkhead.

12.2.6 All necessary measures shall be taken for permanent ventilation of the control stations outside the machinery spaces, to ensure visibility and absence of smoke to the extent required for normal operation of the equipment in control stations and working of the attending personnel.

For the ventilation of these control stations two alternative and separate means of air supply shall be provided. The air supply ducts shall be fitted with fire or smoke dampers capable of being easily closed from within the control station so that, in the event of fire, smoke is kept from penetrating into the spaces.

These requirements need not be applied to the control stations situated on the open deck, to which they have a direct exit or where there are equally effective local closures of the control stations.

12.2.7 Galley ventilation systems shall be separate from the ventilation systems serving other spaces.

The exhaust ducts from galley ranges shall be constructed of "A" class divisions where they pass through accommodation spaces or spaces containing combustible materials.

Each galley ventilation duct passing through accommodation spaces or other spaces containing combustible materials shall be fitted with:

a grease trap readily removable for cleaning;

a fire damper located in the lower end of the duct;

fixed means for extinguishing fire within the duct;

arrangements, operable from within the galley, for shutting off the exhaust fans (refer also to 5.8.2, Part XI "Electrical Equipment").

12.2.8 Where in passenger ships it is necessary that a ventilation duct passes through a division of the main vertical fire zone, a failsafe automatic closing fire damper shall be fitted adjacent to the division. The damper shall be also capable of being manually closed from each side of the division. As for the types of manual closing, refer to 12.2.3.2. The position for operating the damper shall be readily accessible and be marked in red light-reflecting colour. The duct between the division and damper shall be made of steel or other equivalent material and, bulkhead, shall be provided with insulation corresponding to the degree of fire integrity of the division. At least at one side of the bulkhead the damper shall be fitted with a readily visible indicator showing whether the damper is open.

12.2.9 Provision shall be made for closing the inlets and outlets of all ventilation systems from outside the ventilated spaces. Manual closing arrangements shall be readily accessible and have indelible, readily visible marking, which shows whether the duct is open or closed.

12.2.10 The ventilation ducts and their passages through "A" or "B" class divisions in ships of less than 500 gross tonnage shall, generally, be constructed in compliance with the requirements of the Chapter. The relaxations from these requirements are subject to special consideration by the Register in each case.

12.2.11 Mechanical ventilation shall have controls grouped so that all ventilators can be switched off at two positions located as far apart as possible. The controls of machinery spaces mechanical ventilation shall be grouped so that the control can be effected at two positions one of which is outside machinery spaces. The ventilators servicing cargo spaces mechanical ventilation shall be switched off at the safe position outside such spaces (refer also to 5.8.1 to 5.8.3, Part XI "Electrical Equipment").

12.2.12 The following arrangements shall be tested in accordance with the Fire Test Procedures Code (refer to 1.2, Part VI "Fire Protection"):

.1 fire dampers, including relevant means of operation; and

.2 duct penetrations through "A" class divisions. Where steel sleeves are directly joined to ventilation ducts by means of riveted, screwed or welded flanges, the test is not required.

12.2.13 Flange connection gaskets made of combustible material shall not be used in ventilation ducts constructed of "A" class divisions and in any ventilation ducts passing through "A" or "B" class divisions, within 600 mm from the opening, measured along the duct.

12.2.14 Fire dampers fitted on the ventilation ducts from galley ranges in compliance with 12.2.7 and 12.3.6 do not need to pass the test according to IMO resolution A.754(18), but shall be of steel and capable of stopping the draught, if necessary. The requirements to "A" class divisions apply only to the part of the duct outside the galley.

12.3 VENTILATION SYSTEMS OF PASSENGER SHIPS CARRYING MORE THAN 36 PASSENGERS AND SPECIAL PURPOSE SHIPS CARRYING MORE THAN 200 SPECIAL PERSONNEL

12.3.1 The ventilation systems of accommodation spaces, service spaces and control stations shall comply with the requirements of 12.2, besides meeting the requirements of the Chapter.

12.3.2 In general, the ventilation fans and ducts shall be disposed within the main vertical fire zone, which they serve.

12.3.3 Where the ventilation ducts are laid through the decks, measures shall be taken to minimize the possibility of smoke and flammable gases passing from one 'tween-deck space to another. If necessary, the vertical ducts shall be insulated providing fire integrity as required by 2.2.1.3, Part VI "Fire Protection".

12.3.4 Except in cargo spaces, ventilation ducts shall be constructed of the following materials:

.1 ducts with a cross-sectional area more than 0,075 m^2 and all vertical ducts serving more than a single 'tween-deck space shall be constructed of steel or other equivalent material;

.2 ducts with a cross-sectional area less than 0,075 m^2 other than the vertical ducts mentioned in 12.3.4.1 shall be constructed of non-combustible materials; where such ducts penetrate "A" or

"B" class divisions, due regard shall be given to ensuring the fire integrity of the divisions;

.3 short lengths of ducts not, in general, exceeding 0,02 m^2 in sectional area nor 2 m in length — of materials mentioned in 12.2.2.

12.3.5 Ventilation systems of stairway enclosures shall be independent of other systems.

12.3.6 Exhaust ducts from galley ranges, in which grease or fat is likely to accumulate, shall meet the requirements of 12.2.4 and shall be fitted with:

.1 a grease trap readily removable for cleaning unless an alternative approved by the Register grease removal system is fitted;

.2 a fire damper located in the lower end of the duct, which is automatically and remotely operated, and in addition a remotely operated fire damper located in the upper end of the duct (the lower end of the duct means position where the duct is connected to exhaust hood at the galley range; the upper end of the duct means position where the duct is closed as it leaves the galley);

.3 fixed means for fire extinguishing within the duct;

.4 remote control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in 12.3.6.2 and for operating the fire-extinguishing system, which shall be placed in a position close to the entrance to the galley. Where a multi-branch system is installed, means shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system;

.5 hatches for inspection and cleaning arranged close to the fire dampers. One hatch shall be located nearby the exhaust fan, other hatches — in the lower part of ducts.

12.3.7 Where public spaces span three or more decks and contain combustibles such as furniture and enclosed spaces such as shops, bars and restaurants, such spaces shall be equipped with a ventilation activated by a smoke extraction system and capable to ventilate the entire volume during not more than 10 min. Provision shall be made for manual control of the fans.

12.3.8 The requirement of 12.2.11 does not apply to switching-off of air-conditioner ventilators if they do not dispense an outside air to spaces serviced.

12.4 VENTILATION SYSTEMS OF OIL TANKERS AND COMBINATION CARRIERS CARRYING CRUDE OIL AND PETROLEUM PRODUCTS WITH FLASH POINT 60 °C AND BELOW

12.4.1 In addition to requirements of 12.1, 12.2, 12.6 and 12.9, the ventilation systems shall comply with the requirements of the Chapter.

12.4.2 The ventilation inlets of accommodation spaces, service spaces and control stations shall be located on the aft transverse bulkhead not facing cargo tanks, or on the side of the superstructure or deckhouse at a distance equal, at least, to 4 per cent of the ship's length, but not less than 3 m from the end of the superstructure or deckhouse facing cargo tanks. This distance, however, need not exceed 5 m.

The inlets and outlets of ventilation ducts for machinery spaces shall be situated as far aft as practicable. Special consideration shall be given to location of these vents in oil tankers equipped to load and discharge at the stern.

12.4.3 Cargo pump rooms shall be mechanically ventilated and discharges from the exhaust fans shall be laid to a safe place on the open deck. The ventilation of these rooms shall have sufficient capacity to minimize the possibility of accumulation of flammable vapours. The number of air changes shall be at least 20 per hour, based upon the gross volume of the space. The air ducts shall be arranged so that all of the space is effectively ventilated. The suction ventilation shall be of mechanical type using fans of the non-sparking type. Input ventilation may be self-ventilation. Lighting shall be interlocked with ventilation in accordance with 19.2.4.5, Part XI "Electrical Equipment".

12.4.4 The inlets of exhaust ducts shall be situated so as to provide extraction of air from below the floor plates. The bottom framing, as well as the floor plates and gratings of the pump room shall be so constructed as not to impede the free flow of air to the inlets of the exhaust ducts.

Outside the pump room these ducts shall be gastight and, generally, shall not communicate with the ducts of other spaces.

The pump rooms shall have also an emergency ventilation operating in the event of lower inlets being flooded. For this purpose an emergency intake about 2 m above the lower grating shall be provided on the exhaust duct. This intake shall have a damper capable of being operated from the main deck and lower grating level. The damper may be omitted if the areas of the inlets are chosen such that at least 20 air changes per hour will be ensured through the lower inlets, and at least 15 air changes per hour through the upper inlets in case of the lower inlets being flooded.

Where the ventilation system of the pump room is used for ventilating the cargo line and the communica-ting cargo tanks, duplicate shut-off fit-tings shall be provided at the connections of the ventilation duct to the cargo line.

12.4.5 The construction of the ventilation fans in cargo pump rooms shall comply with the require-ments of 5.3, Part IX "Machinery" and the location of their driving motors shall meet the requirements of 4.2.5, Part VII "Machinery Installations".

12.4.6 The outlets of exhaust ducts for cargo pump rooms shall not be less than 2 m remote from any opening leading into ship spaces, which may contain a source capable of ignition oil vapours, and shall be so located that no contamination of air entering the inlets of ventilation systems will occur.

The outlets of ventilation ducts shall be fitted with flame-arresting fittings.

The air intakes shall be situated at least 2,4 m above the cargo deck and at least 5,0 m from any openings of the cargo tanks and outlets of the pressure/relief valves, and at least 10 m from the outlets of vent pipes that expel freely the vapour/air mixture or are fitted with high-speed devices.

12.4.7 In combination carriers, all cargo spaces and all enclosed spaces adjacent to the cargo spaces shall be capable of being mechanically ventilated. This ventilation may be provided by portable fans.

12.4.8 On oil tankers:

.1 double hull and double bottom spaces shall be fitted with suitable connections for the supply of air;

.2 if an inert gas system is required, spaces mentioned in 12.4.8.1 shall be connected to the fixed inert gas distribution systems; provision shall be also made for arrangements to prevent leakage of the hydrocarbon gas from the cargo tanks into such spaces through the inert gas distribution system.

Where these spaces are not connected constantly to the inert gas distribution sources arrangements shall be provided to ensure such connection;

.3 provision shall be made for measuring oxygen and flammable vapour concentrations in double hull spaces. For this purpose, fixed gas sampling line systems or flexible gas sampling hoses may be used, as well as portable instruments;

.4 the internal diameter of fixed pipes for gas sampling, their laying as well as the materials for construction of the pipes shall be such as to prevent plugging. Where plastic materials are used, they shall be electrically conductive and pipes shall be safely earthed.

12.5 VENTILATION OF MACHINERY SPACES AND TUNNELS

12.5.1 The ventilation of machinery spaces of category A shall be such as to ensure that when the machinery and boilers therein are operating at full load in all service conditions including heavy weather, a supply of air is maintained to the spaces sufficient for the safety and comfort of the personnel and the operation of machinery.

The ventilation shall ensure removal of gases heavier than air from the lower zones of those spaces, from below floor plates, from where fuel system equipment, settling and supply tanks are installed.

Any other machinery spaces shall be adequately ventilated appropriate to the purpose of the machinery space.

The requirements for the ventilation of spaces containing refrigerating machinery are given in 3.1.6 and 3.1.7, Part XII "Refrigerating Plants".

12.5.2 Shaft tunnels shall be properly ventilated. The pipe tunnels laid in the double bottom shall have mechanical exhaust ventilation.

12.5.3 In the space containing emergency diesel-generator (automatically started), provision shall be made for an automatic arrangement to ensure an air supply sufficient for the emergency diesel-generator to run under full load in any service conditions when the space is closed.

12.5.4 In spaces mentioned under 4.2.7, Part VII "Machinery Installations", independent mechanical exhaust ventilation or a ventilation device separable from the machinery space ventilation shall be installed. The construction of fans shall comply with the requirements of 5.3, Part IX "Machinery".

12.6 VENTILATION OF SPECIAL CATEGORY SPACES, CARGO SPACES INTENDED FOR THE CARRIAGE OF MOTOR VEHICLES WITH FUEL IN THEIR TANKS AND CLOSED RO-RO CARGO SPACES

12.6.1 These spaces shall have mechanical exhaust ventilation system independent from other ventilation systems, which shall function during the whole period the motor vehicles are carried in such spaces.

If individual spaces have effective closures, ventilation ducts shall be separate for each of them. The fans shall be operated from outside the ventilated spaces and to be capable of ensuring at least:

.1 10 air changes per hour:

in cargo spaces for the carriage of motor vehicles with fuel in their tanks in passenger ships carrying more than 36 passengers;

in special category spaces in all passenger ships;

in closed ro/ro cargo spaces with electrical equipment in accordance with 19.3.4, Part XI "Electrical Equipment" in all ships;

.2 6 air changes per hour in all other ships.

12.6.2 The ventilation shall be such as to provide even distribution of air supply and shall prevent formation of trapped zones.

12.6.3 The ventilation system shall be equipped with devices indicating any loss or reduction of theventilating capacity and operation of the fans. These devices shall be installed in the wheelhouse.

Instead of them, the following means may be provided:

.1 visual signal indicating the operation of each fan;

.2 interlock to permit the electric motor of the fan to start only if the ventilation duct is open;

.3 audible signal for spontaneous stop of the electric motor.

12.6.4 The construction of the fans shall comply with the requirements of 5.3, Part IX "Machinery".

12.6.5 Arrangements shall be provided for effective closure of the ventilation system in case of fire.

12.6.6 The ventilation ducts and their closures shall be made of steel.

12.6.7 Ducts intended for ventilation of special-category spaces, which pass through other special-category spaces, shall be constructed of steel. Where such ventilation ducts pass through special-category spaces, which do not form part of the of the same main horizontal zone, the ducts shall be insulated to A-60 standard. Ventilation ducts shall not pass through machinery spaces unless they are constructed of "A-60" class divisions.

12.7 VENTILATION OF CARGO SPACES ADAPTED FOR THE CARRIAGE OF DANGEROUS CARGOES[1]

12.7.1 Closed cargo spaces in cases mentioned in 7.2.4, Part VI "Fire Protection" shall have mechanical exhaust ventilation, separate for each such space, sufficient to give at least 6 air changes per hour, based upon the volume of an empty hold.

Supply ventilation of these spaces may be natural.

On agreement with the Register, mechanical supply and natural exhaust ventilation systems are permissible.

The number of air changes may be reduced with regard to the method of transportation (refer to Note 1 to Table 7.2.4-1, Part VI "Fire Protection").

12.7.2 For closed cargo spaces intended for the carriage of dangerous cargoes in bulk at least natural ventilation in accordance with 7.2.8.3, Part VI "Fire Protection" is required.

However, when conditions of carriage require a mechanical ventilation system, a stationary system may be dispensed with, provided that portable fans ensuring adequate effectiveness of the ventilation are used.

12.7.3 The ventilation shall be such as to provide uniform change of air within the cargo space and to prevent formation of trapped zones.

The ventilation system shall be such that vapours of dangerous cargoes are removed from upper or lower part of the space, with regard to density of the vapours in relation to air.

12.7.4 The construction of ventilation fans shall comply with the requirements of 5.3, Part IX "Machinery".

The electric motors of the fans shall be of flameproof design. It is not recommended to arrange them in way of gas exhaust.

The inlets and outlets of ventilation systems shall be protected by screens with mesh size of 13×13 mm.

12.7.5 The ventilator heads of exhaust ducts from cargo spaces adopted for the carriage of dangerous cargoes emitting readily flammable and toxic vapours or gases shall be so located that the issuing vapours or gases will not enter other ship spaces.

12.7.6 Rooms containing bilge pumps servicing cargo spaces for carriage of dangerous cargoes shall be provided with separate artificial exhaust ventilation sufficient to give at least 6 air changes per hour.

12.7.7 During carriage of cargoes capable of producing explosive mixtures with air, and cargoes susceptible to spontaneous ignition (such is only the case for grain cake (b) and (c)) provision shall be made for two fixed or portable fans of flameproof design with a total capacity sufficient to provide 6 air changes per hour.

12.7.8 Ventilation system of ships carrying packaged irradiated nuclear fuel, plutonium and high-level radioactive wastes (INF cargo, refer to 7.1.2, Part VI "Fire Protection") shall comply with the following requirements:

.1 provision shall be made for adequate ventilation or cooling of closed cargo spaces so that at any time the mean ambient temperature within these spaces does not exceed 55 °C;

.2 ventilation or cooling systems serving cargo spaces intended for carriages of INF cargo shall be independent from similar systems serving other spaces; and

.3 equipment indispensable for operation, such as fans, compressors, heat exchangers, cooling liquid supply systems shall be duplicated for each cargo space.

12.7.9 The open top container holds shall be mechanically ventilated by means of special ducts from the lower parts of cargo holds. The ventilation capacity shall be at least 2 air changes per hour based on the empty hold volume below weather deck.

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[1] For "dangerous cargoes", refer to 7.1.2, Part VI "Fire Protection".

12.8 VENTILATION OF REFRIGERATED CARGO SPACES

12.8.1 The requirements to the ventilation of refrigerated cargo spaces are set out in 3.3.5 to 3.3.8, Part XII "Refrigerating Plants".

12.9 VENTILATION OF FIRE-EXTINGUISHING STATIONS

12.9.1 The foam fire-extinguishing and smothering stations, located below the upper deck or not accessible from the weather deck shall be equipped with efficient independent ventilation system with capacity sufficient to provide not less than 6 air changes per hour.

The carbon dioxide fire-extinguishing stations shall be provided with an exhaust and supply ventilation independent from other ventilation systems. The inlets of exhaust ducts shall be located in lower part of the station.

12.9.2 The high-expansion foam fire-extinguishing stations shall be equipped with devices ensuring air supply in an amount sufficient for the operation of foam generators.

12.10 VENTILATION OF ACCUMULATOR BATTERY ROOMS AND BOXES

12.10.1 The accumulator battery rooms and boxes shall be provided with independent ventilation system capable of removing air from upper part of the ventilated spaces.

The exhaust ducts shall be gastight.

12.10.2 The inlet air shall be supplied into the lower part of the ventilated space.

12.10.3 The outlets of ventilation ducts shall be so constructed as to preclude the admission of sea water, atmospheric precipitation and solids.

No flame-arresting fittings shall be installed.

The discharges of exhaust ducts shall be laid to places where the issuing gases do not present a fire hazard.

12.10.4 The boxes of accumulator batteries having a charging capacity not over $2{,}0 \cdot 10^2$ W may be ventilated through the openings in the lower and upper parts of the box to ensure removal of the gases.

12.10.5 The rate of air flow Q, in m^3/s, for the ventilation of an accumulator battery room or box shall not be less than that determined by the formula

$$Q = 3{,}06 \cdot 10^{-5} In \qquad (12.10.5)$$

where I = maximum charging current during gas emission, but not less than 0,25 of maximum current of the charging device, A;
n = number of battery cells.

12.10.6 The cross-sectional area, F, in m^2, of a duct, in case of natural ventilation of accumulator battery rooms and boxes, shall not be less than determined by the formula

$$F = 1{,}04Q, \qquad (12.10.6)$$

but not less than 0,004 m^2.

Q is the rate of air flow determined by Formula (12.10.5).

12.10.7 Natural ventilation of the spaces may be used in the following cases:

.1 the required amount of air, calculated by Formula (12.10.5), is less than $2{,}36 \times 10^{-2}$ m^3/s;

.2 the angle of the duct deflection from the vertical is less than 45°;

.3 the number of bends of the duct does not exceed 2;

.4 the length of the duct does not exceed 5 m;

.5 the operation of ventilation system does not depend on the direction of the wind;

.6 the cross-sectional area of the duct shall be taken not less than that determined by Formula (12.10.6).

12.10.8 Where the rate of air flow determined by Formula (12.10.5) is $2{,}36 \times 10^{-2}$ m^3/s and over, the accumulator battery room shall be provided with mechanical exhaust ventilation.

12.10.9 The internal surfaces of the exhaust ducts, as well as the ventilating fans shall be protected against the action of the electrolyte vapours.

12.10.10 The motors of the ventilating fans shall not be arranged in way of gas exhaust.

The construction of the ventilating fans shall comply with the requirements of 5.3, Part IX "Machinery".

12.11 VENTILATION OF HANGARS FOR HELICOPTERS

12.11.1 The hangars for helicopters shall be provided with mechanical exhaust ventilation sufficient to give at least 10 air changes per hour. Fans shall be of flameproof design and shall comply with requirements of 5.3.3, Part IX "Machinery" and 19.3.4, Part XI "Electrical Equipment".

12.12 VENTILATION OF SPACES IN OIL RECOVERY SHIPS

12.12.1 Ventilation systems serving dangerous and safe spaces shall be independent of each other. Spaces in zones belonging to different classes as listed under 19.2.3, Part XI "Electrical Equipment" shall be served by different systems.

12.12.2 Safe spaces and air locks shall be equipped with mechanical supply ventilation to ensure excessive pressure therein as compared to adjacent dangerous spaces.

12.12.3 Provision shall be made for automatic switch on of ventilators and signalling for loss of excessive pressure in safe spaces and air locks. Alternatively, the following may be provided:

.1 light signalling of each ventilator operation;

.2 blocking to ensure the electric motor of the ventilator is switched on only when the vent duct cover is open;

.3 sound signalling of spontaneous stop of electric motor of the ventilator.

12.12.4 The suctions of supply ventilation ducts shall be located outside dangerous spaces on open decks.

12.12.5 Exhaust duct openings shall be located outside dangerous spaces on open decks.

12.12.6 Dangerous spaces in Zone 1 shall be provided with mechanical exhaust ventilation to ensure at least 20 air changes per hour. Application of ventilation systems for 10 air exchanges per hour is allowed, provided the system is fitted with automatic switching for 20 air changes per hour, when the gas concentration of (20 ± 10) per cent of the lower limit of the explosive range is reached in the atmosphere of the space.

Dangerous spaces in Zone 2 shall be provided with ventilation to ensure at least 10 air changes per hour.

12.12.7 In dangerous spaces, the exhaust ventilation ducts shall be gas-tight, rigid enough and shall not pass through safe spaces (except where the ducts of the pressure part of ventilation are laid through safe spaces in gas-tight tunnels).

12.12.8 In spaces and air locks, the ventilation systems shall be equipped with instruments to monitor the operation of ventilators and other devices mentioned under 12.12.3 and 12.12.6.

12.13 VENTILATION OF SPACES INTENDED FOR INERT GAS EQUIPMENT

12.13.1 In spaces intended for the inert gas equipment of cargo tanks including generators, scrubbers, ventilators and their fittings, provision shall be made for artificial exhaust ventilation which shall ensure at least six air changes per hour as determined proceeding from the empty space volume.

Forced ventilation may be natural ventilation.

When the above equipment is installed in machinery spaces, the requirements of 12.5 shall be complied with.

12.13.2 For ventilating spaces mentioned under 9.16.9.3, Part VI "Fire Protection", provision shall be made for artificial forced ventilation, which shall ensure the number of air changes not less than stipulated under 12.13.1.

13 FUEL OIL SYSTEM

13.1 PUMPS

13.1.1 At least two pumps shall be provided for fuel transfer, one of which being a standby pump.

Any suitable pump, including the fuel oil separator pump, may be used for standby purpose.

For cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN**, no standby pump is required.

In ships with a daily consumption of fuel less than 1 t, a hand pump is admissible.

13.1.2 Where the fuel oil tanks, including the deep tanks, are used also for water ballast, provision shall be made for reliable arrangements disconnecting the ballast system from these tanks when carrying fuel oil and the fuel oil system, when containing water.

In addition, the requirements of the Rules for the Prevention of Pollution from Ships shall be complied with.

13.1.3 The fuel oil and lubricating oil transfer pumps and the separator pumps, besides local hand control, shall be provided with stopping means operable from always accessible positions outside the space where the pumps are installed.

13.1.4 Shut-off valves shall be fitted on the pressure side and suction side of fuel oil and lubricating oil pumps.

Devices for measuring fuel oil temperature are recommended to be provided on the suction pipes of the fuel oil pumps.

This requirement is mandatory for installations with fuel oil flash point of less than 60 °C.

13.2 PIPING LAYING

13.2.1 In general, the fuel oil pipeline shall have no communication with other piping systems. Where the fuel oil tanks are used also for water ballast, the requirements of 13.1.2 shall be complied with.

13.2.2 Welded joints shall be generally applied for the assembly of piping for fuel oil with a flash point below 60 °C and for oil heated above 60 °C, whereas the number of detachable joints shall be reduced to a minimum. Such pipes containing oil under a pressure of 0,18 N/mm^2 and above shall not be placed in a concealed position, they shall be readily accessible and their locations shall be adequately illuminated.

13.2.3 The fuel pipes shall not be laid above the internal combustion engines, turbines, exhaust gas pipes, steam pipes (except heating steam coils), steam boilers and boiler uptakes. In exceptional cases, it is allowed to lay the fuel pipes above the said equipment provided that in these positions the pipes have no detachable joints or are shielded and that in necessary places provision is made for trays preventing the spillage of fuel on the equipment or other sources of ignition.

13.2.4 The fuel suction pipes from tanks of more than 500l capacity, as well as the pipes intended to equalize the level of fuel in tanks, where such tanks are located outside the double bottom, shall be provided with shut-off valves fitted directly on the tanks. These valves shall be capable of being closed from accessible places located outside the space containing the tanks. Control for remote operation of the shut-off valve fitted on the daily service tank of the emergency diesel-generator shall be arranged in a position separated from the control for remote operation of other tanks.

If the fuel tanks are arranged above the inner bottom plating and so that they are adjacent to the tunnels of the shafting and pipelines or other similar spaces, the valves on those tanks may be fitted with local controls on condition that an additional valve is fitted in accessible position outside the said spaces. If the additional valve is fitted in the machinery space, this valve shall be capable of being remotely closed from outside the machinery space.

Daily service tanks are recommended to be provided with quick-closing valves.

13.3 HEATING ARRANGEMENTS OF FUEL OIL

13.3.1 For fuel oil heating the heat-carrying agents enumerated in 9.6.1 may be applied. In case of using electric heating appliances for fuel oil heating, the requirements of 15.3, Part XI "Electrical Equipment" shall be complied with.

13.3.2 Heating coils and electric heating appliances shall be fitted as low as possible in the tanks.

13.3.3 In daily service tanks and settling tanks, the suction ends of fuel pipes shall be so positioned above the heating coils and electric heating appliances that the latter remain submerged as far as practicable.

13.3.4 When fuel oil and lubricating oil steam heaters or other heating medium heaters are used, except cases when the heated medium temperature does not reach a flash point, the system shall be fitted with an alarm on a high temperature or a flow drop in addition to the system for temperature monitoring.

13.3.5 The maximum temperature of fuel oil heating in storage tanks shall be 15 °C below the fuel oil flash point.

Fuel oil in service tanks, settling tanks and any other tanks in the engine and boiler supply system may be heated above this limit, provided:

.1 the length of air pipes of these tanks or the use of cooling devices permits to lower the temperature of escaping vapours below 60 °C or the outlets of air pipes are situated at least 3 m away from ignition sources;

.2 non-intrinsically safe electrical equipment is not located within a vapour space of fuel oil tanks;

.3 there are no openings from the vapour space of the fuel tanks into machinery spaces;

.4 enclosed spaces shall not be located directly over such fuel tanks, except for well-ventilated cofferdams;

.5 ends of air pipes shall be equipped with flame arresters.

13.4 DRAINAGE ARRANGEMENTS OF FUEL OIL TANKS

13.4.1 For draining water from the bottom of the daily service and settling tanks, these tanks shall be fitted with self-closing valves and pipes connected to drain tanks.

The drain pipes shall be fitted with sight glasses. Where trays are available, open funnels may be used instead of sight glasses.

13.5 ARRANGEMENTS FOR COLLECTION OF LEAKAGE FUEL

13.5.1 Tanks, pumps, filters and other equipment shall be fitted with drip trays where there is a possibility of fuel oil leakage.

13.5.2 Drain pipes from the drip trays shall be laid into fuel oil drain tanks.

Drainage of fuel oil into the bilges and overflow tanks is not permitted.

13.5.3 The internal diameter of the drain pipes shall be at least 25 mm.

13.5.4 The ends of the drain pipes shall be laid to the tank bottom with a gap not less than 1/4 of the internal diameter of the pipe.

Where the drain tank is situated in the double-bottom space, structural measures shall be taken to prevent penetration of water into the machinery spaces through the open ends of the drain pipes in the event of damage to the shell plating.

Provision shall be made for an alarm device to give warning if the fuel oil reaches the upper predetermined level in the drain tank.

13.5.5 If drain pipes from drip trays fitted in different watertight compartments are laid into a common drain tank, structural precautions shall be made to prevent water from one flooded compartment to enter the other compartment via the open ends of drains.

13.6 FILLING OF STORAGE TANKS

13.6.1 The bunkering of the ship shall be carried out through a permanent pipeline, provided with the valves and fittings necessary for the filling of all the basic fuel storage tanks.

In ships with twin hulls, the filling pipes shall ensure the filling of the fuel tanks of any of the hulls as well as pumping of fuel from the tanks of one hull into the tanks of the other.

The end of the filling pipe shall be laid to the tank bottom with a gap not less than 1/4 of the internal diameter of the pipe.

13.6.2 In passenger ships provision shall be made for bunkering stations, which are separated from the other spaces, and fitted with drain pipes laid into fuel oil drain tanks.

13.6.3 The filling pipes of the tanks situated above the double bottom shall be connected to the tanks near the top.

Where this is impracticable, the filling pipes shall be fitted with non-return valves installed directly on the tanks.

Where the filling pipe is used as a suction pipe, the non-return valve shall be replaced by a remote-controlled shut-off valve operable from accessible position outside the space, in which the tank is located.

13.7 FUEL OIL TANKS

13.7.1 The structural members of fuel oil tanks shall comply with the requirements of Part II "Hull".

13.7.2 The arrangement of the fuel tanks in the machinery spaces shall comply with the requirements of 4.3, Part VII "Machinery Installations".

13.7.3 The fuel tanks situated on weather decks and superstructure decks, as well as in other exposed positions shall be protected against the action of sunrays.

13.7.4 In glass-reinforced plastic ships (refer to 2.8, Part XVI "Hull Structure and Strength of Glass-Reinforced Plastic Ships and Boats") the fuel tanks shall not directly adjoin the accommodation spaces. The air gap between the fuel tank and accommodation space shall be efficiently ventilated.

In general, the fuel tanks shall not be located in machinery spaces. If they are located in such spaces, they shall be constructed of steel or equivalent material (refer to 1.2, Part VI "Fire Protection").

13.7.5 Fuel oil tanks shall be separated from the feed water and vegetable oil tanks by cofferdams, the structural members of which shall comply with the requirements of Part II "Hull".

13.7.6 In ships of 400 gross tonnage and upwards, compartments situated forward of the collision bulkhead shall not be used for carriage of fuel oil or other flammable liquids.

13.7.7 In ships having distinguishing mark of provision with means for fire fighting on other ships in the class notation the fuel oil tanks shall contain fuel oil reserve sufficient to provide the operation of pumps of special fire-extinguishing systems during 24 hours for ships with distinguishing mark **FF3WS** and 72 hours for ships with distinguishing marks **FF1**, **FF1WS**, **FF2** or **FF2WS**.

13.8 FUEL OIL SUPPLY TO INTERNAL COMBUSTION ENGINES

13.8.1 The equipment of fuel system shall be capable of supplying fuel oil duly prepared and cleaned to the extent required for the given engine.

The main and auxiliary engines shall be supplied with fuel oil from two fuel oil service tanks for each type of fuel used on board.

The fuel oil service tank is considered to mean a tank containing only the fuel oil prepared for use, i.e. the fuel oil the grade and properties of which meet the requirements specified by a manufacturer of the equipment. The fuel oil service tank intended for a particular fuel oil grade shall be marked accordingly and need not be used for other purposes.

The capacity of each tank shall be sufficient for 8 h operation of the main and auxiliary engines and boilers at maximum continuous rating.

Use of settling tanks as the fuel oil service tanks is not permitted.

The equipment of the fuel oil system with two service tanks for each type of fuel used on board and equivalent arrangements complying with the requirements for the most commonly used fuel oil systems are shown in Figs. 13.8.1-1 and 13.8.1-2.

The scheme shown on Fig. 13.8.1-1*b*, is applied in cases when the main and auxiliary engines can

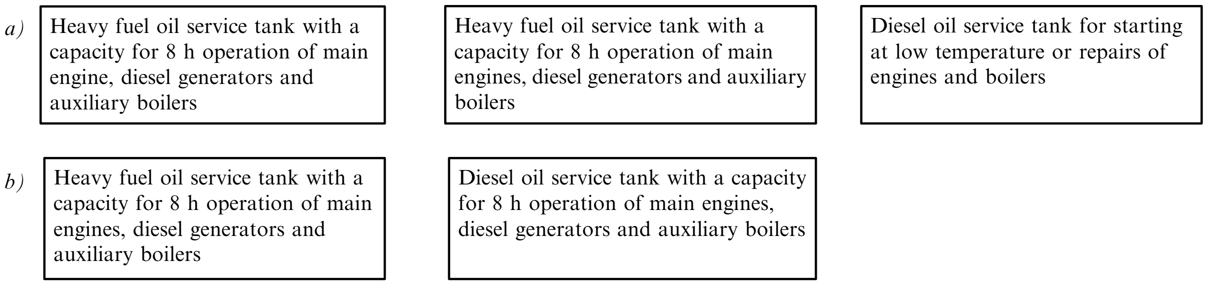


Fig. 13.8.1-1 Heavy fuel oil service tanks for main and auxiliary engines and auxiliary boilers fuel supply:
a) tanks required by SOLAS-74 Convention;
b) tanks equivalent to those required by the Convention.

N o t e. Where pilot burners are used in auxiliary boilers, an additional diesel oil tank with a capacity for 8 h operation may be required

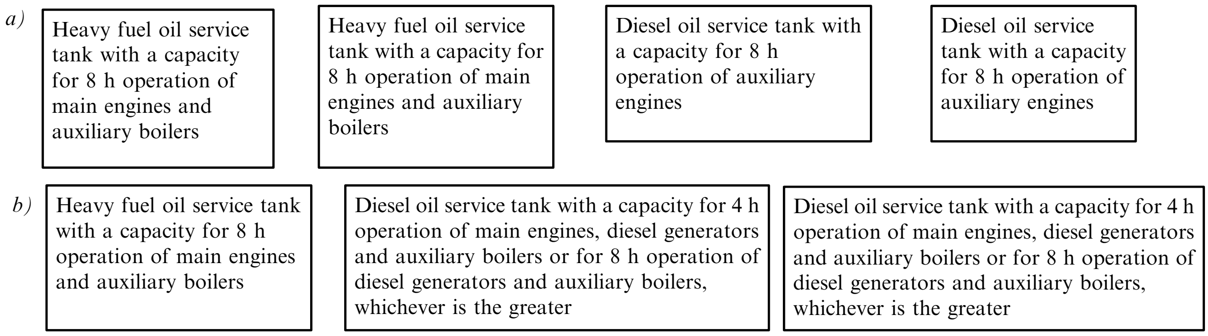


Fig. 13.8.1-2 Fuel oil service tanks for main engines and auxiliary boilers and diesel oil service tanks for auxiliary engines:
a) tanks required by SOLAS-74 Convention;
b) tanks equivalent to those required by the Convention

operate at all loads on heavy fuel oil; as applied to the main engines, heavy fuel oil can be used when starting and reversing them.

The schemes shown on Fig. 13.8.1-1*b* and Fig. 13.8.1-2*b* are applied only in cases when arrangements and systems are used providing a quick switch from one fuel oil grade to another and capable of operating on two fuel oil grades at sea under all normal operating conditions.

Exemption from these requirements may be granted by the Register for fishing ships, ships of less than 500 gross tonnage, as well as for dredging ships, ships less than 24 m in length and berth-connected ships.

13.8.2 The filters fitted in the fuel oil supply lines to the engines shall be such that any filter can be cleaned without interrupting the operation of the engine. The design and construction of filters shall meet the requirements of 4.2.

13.8.3 When fuel oil is supplied to the engines, the following requirements shall be satisfied:

.1 where one booster pump is fitted to serve the main engines, except where the machinery installation comprises two or more engines, each having its own booster pump, the arrangements shall be such that the engines are supplied with fuel oil in the event of damage to the booster pump;

.2 where fuel oil is supplied to engines forming part of machinery installations comprising two or more main engines supplied with fuel oil from a single source, arrangements shall be provided to cut off fuel oil supply to each individual engine. The cut off fittings shall be remotely operated from the control station (refer also to 3.2.1.11, Part VII "Machinery Installations").

The Register may grant an exemption for cargo ships of less than 500 gross tonnage that navigate in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN**.

13.8.4 Where the engines operate on different grades of fuel, precautions shall be taken to prevent auxiliary engines and other consumers from being supplied with fuel that is unfit for their operation.

13.8.5 The diesel-generating sets intended for use as emergency units shall be supplied with fuel from an independent daily service tank situated in the emergency diesel generator room. Consumption of fuel from this tank by other consumers is not allowed, except cases specified in 9.4.2, Part XI "Electrical Equipment" provided the requirements of 2.2.6, Part IX "Machinery" are complied with. The tank capacity shall be such as to ensure operation of the diesel generator for the period stated in 9.3.1, and 19.1.2.1, Part XI "Electrical Equipment". When emergency diesel generator is used for feeding consumers not in an emergency condition during the ship's moorage as well as in case of its use as a means to ensure that the machinery can be brought into operation from the dead ship condition (refer to 2.1.6, Part VII "Machinery Installations"), provision shall be made of automatic refilling of emergency diesel generator daily service tank and of low-level alarm corresponding to the volume of the emergency diesel-generator daily service tank.

13.8.6 The fuel oil system shall be provided with inspection and measuring instruments in accordance with 2.1.2, Part IX "Machinery". Sight glasses on pipelines shall be heat-resistant.

13.8.7 Fuel system components and connections within fuel supply lines shall be designed considering the maximum peak pressure to be experienced in service including any high pressure pulses and hydraulic impacts, which are generated and transmitted back into the fuel supply and spill lines by the action of fuel injection pumps.

13.9 FUEL OIL SUPPLY TO BOILERS

13.9.1 The fuel oil supply system with mechanical atomization, serving the main boilers and the auxiliary boilers for essential services (refer to 1.2, Part X "Boilers, Heat Exchangers and Pressure Vessels") shall include at least two sets of fuel pumps, suction and discharge filters.

Each set of machinery shall be calculated for the full steam generating capacity of the boilers served.

Apart from the local controls, the fuel pumps shall have means enabling them to be stopped from easily accessible positions outside the spaces, in which they are situated.

The main boilers shall generally be supplied from two fuel tanks.

13.9.2 The pumps supplying fuel oil to the boilers shall not be used for other purposes.

13.9.3 The pipes conveying fuel oil to the burners of each boiler shall be fitted with a quick-closing valve operated by hand.

This requirement is applicable to the boilers put into action by hand igniters and also to boilers with gravity feed of fuel oil to the burners.

13.9.4 Where fuel oil is fed to the burners by gravity, filters shall be fitted in the supply pipeline to the burners.

13.9.5 It shall be possible to bring the main boilers into operation without having to recourse to a source of power outside the ship.

13.9.6 If the fuel tanks of main and essential auxiliary boilers are used also as water ballast tanks, provision shall be made for settling tanks.

Where two daily service tanks are available, settling tanks need not be provided.

13.9.7 The oil burning installation of the boilers shall comply with the requirements of Section 5, Part X "Boilers, Heat Exhangers and Pressure Vessels".

13.9.8 Thermometers and pressure gauges shall be installed in suitable positions on the pipes supplying fuel oil to the burners.

13.10 FUEL OIL SUPPLY TO GAS TURBINES

13.10.1 The main gas turbine shall have at least two fuel feed pumps: main and standby, of which one may be driven from the main turbine. The capacity of the standby pump shall not be less than that of the main pump.

Where there are two gas turbines or more, one independent standby pump will suffice.

13.10.2 The fuel oil system of a gas turbine shall comply with the requirements of 13.8 of the present Part and 8.5, Part IX "Machinery".

13.11 USE OF CRUDE OIL OR SLOPS AS FUEL FOR TANKER BOILERS

13.11.1 In oil tankers crude oil or slops may be used as fuel for main and auxiliary boilers according to the following requirements.

For this purpose, all arrangement drawings of a crude oil installation with pipeline layout and safety equipment shall be submitted to the Register for approval.

13.11.2 Crude oil or slops may be taken directly from cargo tanks or flow slop tanks fitted in the cargo tank area. They shall be separated from non-gas-dangerous areas by means of cofferdams with gastight bulkheads.

13.11.3 The construction and workmanship of the boilers and burners shall be proved to be satisfactory in operation with crude oil.

The outer hood of the boilers shall be gastight separated from the engine room.

The boilers themselves shall be tested for gastightness before being used.

The whole system of pumps, strainers, separators and heaters, if any, shall be fitted in the cargo pump room or in another room, to be considered as dangerous and separated from engine and boiler room by gastight bulkheads.

Where crude oil is heated by steam or hot water, the outlet of the heating coils shall be laid to a separate observation tank installed together with the above-mentioned components.

This closed tank shall be fitted with a venting pipe laid to the atmosphere in a safe position according to the requirements of 10.1.6 for oil tankers. The venting pipe outlet shall be fitted with easily removable flame proof wire gauze.

13.11.4 The arrangement of prime movers of pumps, separators, etc. shall comply with the requirements of 4.2.5, Part VII "Machinery Installations".

13.11.5 The pumps shall be fitted with a pressure relief bypass from delivery to suction side.

It shall be possible to stop them by a remote control placed in a position near the boiler fronts or machinery control room and from outside the engine room.

13.11.6 When it is necessary to preheat crude oil or slops, their temperature shall be automatically controlled and a high temperature alarm shall be fitted.

13.11.7 The piping for crude oil or slops and the draining pipes for the tray defined in 13.11.9 shall have wall thickness in compliance with column 5 of Table 2.3.8.

The number of connections for these pipes shall be minimum.

The pipe detachable connections shall be of the flange type and shall comply with the requirements of Table 2.4.3.3 for piping of Class 1.

Within the engine room and boiler room these pipes shall be fitted within metal duct, which shall be gastight and tightly connected to the fore bulkhead separating the pump room and to the tray.

This duct (and the enclosed piping) shall be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure.

Besides, the duct shall be fitted at a distance from the ship's side of at least 20 per cent of the ship's beam amidships.

It shall be fitted with inspection openings with gastight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.

In order to detect leakages, level position indicators with relevant alarms shall be fitted on the drainage tank specified in 13.11.9.

Also a vent pipe shall be fitted at the highest part of the duct and shall be laid to the open in a safe position according to the requirements of 10.1.6 for oil tankers. The outlet shall be fitted with easily removable flame proof wire gauze.

The duct shall be permanently connected to the inert gas system or steam supply in order to make possible:

injection of inert gas or steam in case of fire or leakage;

purging of the duct before carrying out work on the piping in case of leakage.

13.11.8 In way of the bulkhead, to which the duct defined in 13.11.7 is connected, delivery and return oil pipes shall be fitted on the pump room side with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room.

The remote control valves shall be interlocked with the hood exhaust fans mentioned in 13.11.10 to ensure that whenever crude oil is circulating the fans are running.

13.11.9 Boilers shall be fitted with a tray or gutterway of a height not less than 200 mm and be placed in such a way as to collect any possible oil leakage from burners, valves and connections.

Such a tray or gutterway shall be fitted with easily dismountable flame proof wire gauze at their upper part.

Delivery and return oil pipes shall pass through the tray or gutterway by means of a tight penetration and shall then be connected to the oil supply manifolds.

A quick closing master valve shall be fitted on the oil supply to each boiler manifold.

The tray or gutterway shall be fitted with a draining pipe discharging into a collecting tank in pump room. This tank shall be fitted with a venting pipe laid to the open in a safe position and with the outlet fitted with wire gauze easily dismountable for cleaning.

This draining pipe shall be fitted with arrangements to prevent the return of fuel oil to the boiler or engine room.

13.11.10 The boilers shall be fitted with a suitable hood placed in such a way as to enclose as much as possible of the burners, valves and oil pipes, without preventing, on the other side, air inlet to burner register.

The hood, if necessary, shall have means of inspection and access to oil pipes and valves placed behind it.

It shall be fitted with a duct laid to the open in a safe position, the outlet of which shall be fitted with an easily dismountable flame wire gauze.

At least two mechnaically driven exhaust fans having spark proof impellers shall be fitted so that the pressure inside the hood is less than that in the boiler room.

The exhaust fans shall be connected with automatic change-over in case of stoppage or failure of the one in operation.

The exhaust fan prime movers shall be placed outside the duct and a gastight bulkhead penetration shall be arranged for the shaft.

Electrical equipment installed in gas dangerous areas or in areas, which may become dangerous (i.e.

in the hood or duct in which crude oil piping is placed), shall be of certified safe type.

13.11.11 When using fuel oil for delivery to and return from boilers fuel oil burning units in accordance with 13.9 of this Part and Section 5, Part X "Boilers, Heat Exchangers and Pressure Vessels" shall be fitted in the boiler room.

Fuel oil delivery to, and returns from, burners shall be effected by means of a suitable mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.

13.11.12 The boiler compartments shall be fitted with a mechanical ventilation plant and shall be designed in such a way as to avoid the formation of gas pockets. Ventilation shall be particularly efficient in way of electrical plants and machinery and other plants which may generate sparks. These plants shall be separated from those for service of other compartments and shall comply with the requirements of 12.4.

13.11.13 A gas detector plant shall be fitted with intakes in the duct mentioned in 13.11.7, in the hood duct (downstream of the exhaust fans in way of the boilers) and in all zones where ventilation may be reduced.

Optical and acoustic warning devices shall be installed near the boiler fronts and in the machinery space. An acoustical alarm, audible in the machinery space and control room, shall be provided.

13.11.14 Means shall be provided for the boiler to be automatically purged before firing.

13.11.15 Independent of the fixed fire extinguishing system required for engine and boiler rooms, an additional fire extinguishing plant (refer to 3.1.2.8, Part VI "Fire Protection") shall be fitted in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in 13.11.9.

The emission of extinguishing medium shall automatically stop the exhaust fan of the boiler hood (refer also to 13.11.8).

13.11.16 A warning notice shall be fitted in an easily visible position near the boiler front. This notice shall specify that when an explosive mixture is signalled by the gas detector plant defined in 13.11.13, the watchkeepers shall immediately shut off the remote controlled valves on the crude oil delivery and return pipes in the pump room, stop the relative pumps, inject inert gas into the duct mentioned in 13.11.7 and turn the boilers to normal running on fuel oil.

13.11.17 The Register reserves the right to require installation of one pilot burner in addition to the normal burning control.

13.12 APPLICATION OF NATURAL GAS (METHANE) AS A FUEL

13.12.1 Gas fuel piping shall not be laid through control stations, accommodation and service spaces.

Laying of gas fuel pipelines through other spaces is allowed in compliance with the requirements of 13.12.2 or 13.12.3.

13.12.2 The pipeline represents a piping system with double walls containing gas fuel inside the internal pipe. The following conditions shall be met:

.1 the space between the walls shall be filled with inert gas under pressure exceeding gas fuel pressure;

.2 inert gas pressure shall be constantly monitored by the alarm system;

.3 at the alarm system actuation the automatic valves mentioned in 13.12.5 and the main gas valve indicated in 13.12.6 shall be automatically closed prior the inert gas pressure drops lower than the pressure of gas fuel, and vent valve stated in 13.12.5 shall be automatically opened;

.4 the system shall be arranged so that the internal part of gas fuel supply pipeline between the main gas valve and engine be automaticaly purged with inert gas, when the main gas valve is closed.

13.12.3 Gas fuel pipelines shall be installed in the pipe or duct with artificial exhaust ventilation of the space between them. The capacity of exhaust ventilation shall be calculated basing on the velocity of gas fuel flow, structure and location of protective pipes or ducts and provide at least 30 air changes per hour.

Therewith the following conditions shall be met:

.1 the pressure in the space between the external and internal walls of pipelines or ducts shall be kept lower than the atmospheric pressure;

.2 provision shall be made for the gas leakage detector and the cut-off of the gas supply to the engine room;

.3 electrical motors shall be of explosion-proof design and be located outside the pipes and ducts;

.4 when the required air flow is not maintained by the ventilation system, the main gas valve, mentioned in 13.12.6, shall be closed automatically. Ventilation shall function every time when gas is supplied through the pipeline;

.5 air intakes of the ventilation system shall be provided with non-return devices. These requirements are not compulsory when gas detectors are fitted in the air intakes;

.6 provision shall be made for inertization and degasification of gas fuel pipeline system section located in the engine room.

13.12.4 For the engine rooms of category A where gas fuel is used besides the requirements of 13.12.2 and 13.12.3 the additional requirements to ventilation shall be met.

13.12.4.1 Engine rooms shall be fitted with ventilation system precluding gas pockets. Ventilation shall be particularly effective in the area of electrical equipment installation, machinery or other possible sources of spark formation.

The ventilation system shall be separated from ventilation of other spaces and meet the requirements of 12.5.

13.12.4.2 Engine rooms shall be equipped with the effective gas detection system in the places of possible gas lock and leakage. When the concentration of gas is equal to 30 per cent of low flammability limit, the audible and visible alarms shall be actuated, and when the concentration of gas is equal to 60 per cent of low flammability limit, the supply of gas fuel to the engine room shall be cut off.

13.12.5 Gas fuel supply system shall be fitted with three automatic valves. Two of them shall be installed in succession in the system of gas fuel supply to the engine. The third valve (ventilation) shall be mounted for gas discharge from the pipe section located between two automatic valves installed in succession to the safe place on the weather deck. The system shall be constructed so that when:

the pressure in the gas fuel supply pipeline fluctuates from the set values;

loss of energy for valve driving;

violation of the conditions stated in 13.12.2 and 13.12.3;

stop of the engine because of any reason;

two valves installed in succesion shall be closed automatically and the third valve (ventilation) shall be opened automatically.

As an alternative, one of two valves installed in succession and the ventilation valve may be combined in one body, provided their performance of the above-mentioned functions.

All three valves shall be manually operated.

13.12.6 The main gas valve shall be installed outside the engine room and be equipped with remote control to enable its closing from the engine room.

This valve shall to be automatically closed in the following cases:

leakage of gas fuel;

violation of the conditions stated in 13.12.2 and 13.12.3;

actuation of oil mist concentration sensor in the engine crankcase or in the temperature control system of the engine bearings.

It is advisable, that the main gas valve is automatically closed at the actuation of interlocked gas valves (refer to Table 9.7.1, Part IX "Machinery").

13.12.7 Gas line shall have sufficient structural strength with regard to stresses caused by the mass of the pipeline, internal pressure, loads caused by bends of the ship's hull and accelerations.

13.12.8 The structure of protective pipes or ducts of the ventilation system mentioned in 13.12.2 and 13.12.3 shall have strength sufficient to withstand fast increase of pressure in case of pipeline break. A number of split connections in protective pipes or ducts shall be minimum.

13.12.9 As a rule, gas pipelines shall be connected with complete-penetration butt welds and special means for provision of weld root quality and completely radiographically tested.

All butt welds after welding are subjected to heat treatment depending on the material.

The use of other joints shall be specially considered by the Register in each case.

13.12.10 The installation for gas fuel supply and reservoirs for its storage shall comply with the following requirements:

.1 the construction, control and safety system of gas compressors, pressure vessels and heat-exchangers incorporated in the gas fuel supply system, shall meet the requirements of the appropriate Parts of the Rules;

.2 during the design work and calculation the possibility of fatigue failure of gas pipelines because of vibration as well as fluctuation of pressure when gas fuel is supplied by the compressors, shall be taken into consideration.

13.12.11 Gas supply to dual-fuel engines and gas turbine engine shall meet the requirements of 8.10 and 9.8, Part IX "Machinery".

13.13 FUEL OIL SYSTEMS FOR HELICOPTERS

13.13.1 The fuel oil system for supplying other ships and helicopters with fuel having a flash point below 43 °C shall comply with the requirements of the present Part and 6.1, Part VI "Fire Protection".

13.13.2 An fuel oil pump shall take in fuel oil simulteneously from one tank only. Pipelines shall be made of steel or equivalent material, shall be short (where possible) and shall be protected against damages.

13.13.3 Fuel oil pumps shall be provided with shutdown means positioned in a remote safe place. Service tanks shall be provided with quick-closing valves driven from outside the tank area.

13.13.4 Tanks for helicopter fuel shall be arranged in compliance with 6.1.14 to 6.1.17, Part VI "Fire Protection".

13.13.5 A fuelling pipeline shall be provided with a safety device, which prevents the excess of pressure in a fuelling hose above the permissible one.

13.13.6 All pipelines and equipment of the system for bunkering, storage and fuelling shall be electrically continuous and shall be earthed to the ship hull.

13.13.7 Each fuel oil tank shall be fitted with filling, outlet, sounding and air pipes. The end of a filling pipe shall not be more than 300 mm above a tank bottom. It is recommended to use closed-type flow-meters. The sounding pipe shall end 30 to 50 mm above a tank bottom and shall be laid to the open deck.

13.13.8 Air pipes of fuel oil tanks shall be laid to a height of at least 2,4 m above the open deck. Open ends of air pipes shall be spaced at a distance of at least 10 m from air in-takes and openings of enclosed spaces with ignition sources, and from a deck machinery and equipment, which may present an ignition hazard, and shall be fitted with flame-arresting meshes or other fittings approved by the Register.

13.14 LIQUEFIED GAS SYSTEM FOR DOMESTIC NEEDS

13.14.1 The use of gas meeting the requirements of current national standards is permitted.

13.14.2 Liquefied gas may be used for galley ranges, as also for straight-through liquid heaters (including provision refrigerators) consuming not more than 1 kg of liquefied gas per hour.

The use of liquefied gas system in passenger ships and oil tankers is subject to special consideration by the Register in each case.

13.14.3 Only standard gas containers and gas-consuming appliances of type approved by competent technical supervision bodies may be installed on board the ship.

13.14.4 An automatic safety gas shut-off device shall be fitted on gas-consuming appliances, which operates in the event of flame failure.

For straight-through heaters this device shall have check flame.

13.14.5 Gas containers shall be stowed in a special compartment on the open deck, complying with the requirements of 2.1.5.3, Part VI "Fire Protection" with direct access to the open deck.

Where provision is made for stowage of not more than two gas containers, they may be arranged in an enclosed recess in the superstructure or deckhouse, or in a steel locker.

Furthermore, the stowage compartment for gas containers shall meet the following requirements:

.1 efficient natural ventilation shall be provided, account being taken of the provisions of 12.1.4 and 12.4.6.

In addition to natural ventilation, mechanical ventilation may be used, the requirements of 12.1.4 being taken into consideration;

.2 where necessary, structural arrangements shall be made to maintain the temperature in the compartment not exceeding +50 °C;

.3 electric illumination and electrical equipment at a distance of 2 m from openings to the compartment shall comply with the requirements of 2.9, Part XI "Electrical Equipment";

.4 a warning notice recalling of the risk of explosion and prohibiting the use of naked flame and smoking shall be displayed on the door.

13.14.6 The installation of gas containers in the compartment shall comply with the following requirements:

.1 cylinders shall be installed with stop valves upwards and be secured with quick-detachable arrangements. Other measures shall be taken to quickly release containers;

.2 a reducing valve shall generally be fitted on the container head; in this case, flexible hose of approved type may be used for connection of the reducing valve to the liquefied gas pipeline;

.3 if a group of containers is connected to the manifold, only one reducing valve shall be fitted between each container and the manifold; in this case, containers shall be connected to manifold by copper pipes;

.4 where more than one container is connected to the manifold, shut-off valve or cock shall be fitted between each container and the manifold. A notice prohibiting the simultaneous use of more than one container shall be displayed in the compartment.

13.14.7 Compartments containing gas-consuming appliances shall be equipped in compliance with 2.1.5.2, Part VI "Fire Protection" and meet the following requirements:

.1 they shall not be arranged below the upper deck and be provided with efficient natural ventilation for extraction of combustion products and air taking from the lower part of the compartment;

.2 where the compartment is partially below the open deck, it shall be provided with mechanical ventilation;

.3 straight-through gas-consuming appliances shall be provided with separate lines for removal of combustion products.

13.14.8 Pipes shall be of seamless steel or copper. Steel pipes shall be protected against corrosion.

13.14.9 The thickness of pipe walls shall meet the requirements of column 2 or 8, Table 2.3.8.

13.14.10 Pipes from gas containers to gas-consuming appliances shall be laid over the open deck and be protected against mechanical damages.

13.14.11 Pipe joints shall be welded. Threaded or flange joints are permitted only in places of connection of instrumentation lines, gas-consuming appliances and fittings.

13.14.12 A shut-off valve or cock shall be fitted on the pipe where it pierces the bulkhead of the container compartment, this valve or cock being operated from outside the compartment. The valve or cock shall be provided with a turning limiter and a plug position indicator.

13.14.13 Where more than one gas-consuming appliance is installed, a shut-off valve or cock provided with a turning limiter and a plug position indicator shall be fitted on branches from a common pipe line to each gas-consuming appliance.

Where these valves or cocks are fitted in the container compartment, provision shall be made for their operation from outside the compartment; in this case, the installation of a cock or valve on the common pipe line may be omitted (refer to 13.14.12).

13.14.14 The reducing valve shall provide the pressure of not more than 5 kPa in the system.

13.14.15 The reducing valve or the pipe line after it shall be provided with a safety valve with a setting pressure less than 7 kPa with gas outlets piped to a safe place of the upper deck.

Where the reducing valve is so designed that gas outlet to a low pressure pipe line is closed in case of failure or break of the diaphragm, the safety valve need not be provided.

13.14.16 Fittings may be of bronze, brass or other corrosion-resistant material.

13.14.17 Liquefied gas pipe lines from containers to reducing valves shall be tested:

in ship, by hydraulic pressure of 2,5 MPa;

in ship, by air pressure of 1,7 MPa.

Pipelines from reducing valves to gas-consuming appliances shall be tested by air pressure of 0,02 MPa after installation on board.

13.15 FUEL OIL SUPPLY SYSTEM FOR GALLEY EQUIPMENT

13.15.1 It is permitted to use fuel oil with a flash point not less than 60 °C for galley equipment.

13.15.2 The capacity of fuel oil service tanks located in galleys shall not exceed the daily consumption requirement.

13.15.3 A shut-off valve on the supply pipe shall be remotely controlled from readily accessible place outside the galley. It is recommended to use quick-closing type valves.

13.15.4 Tanks, fuel oil pumps and heaters shall be placed at least 2 m from the nearest point on the heating equipment, and at a 0,5 m distance from the same in the plan view of the place.

13.15.5 If the galley space is sufficiently large, fuel oil tanks, pumps and other appliances of the fuel oil system shall be placed in special enclosures.

13.15.6 All oil-fired equipment, burners included, shall be fitted with trays underneath (or an equivalent protection provided directly on the steel deck), with beads not less than 75 mm in height, extending not less than 100 mm outside the equipment perimeter.

14 LUBRICATING OIL SYSTEM

14.1 LUBRICATING OIL PUMPS OF INTERNAL COMBUSTION ENGINES, GEARS AND COUPLINGS

14.1.1 For an installation with one main engine provision shall be made for not less than two lubricating oil pumps, main and standby, of the same capacity. One of these pumps may be driven from the main engine.

14.1.2 Where two or more main engines are installed, each of them shall have its own lube oil pump, with provision for one stand-by pump driven independently and having a capacity sufficient to ensure the operation of each engine.

It is permitted to have on the ship a spare pump as stand-by provided that it is accessible for mounting in operational conditions.

A common lubrication system of main engines is subject to special consideration by the Register in each case.

14.1.3 With three and more main engines, the number and capacity of the oil pumps are, in each case, subject to special consideration by the Register.

14.1.4 In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN**, standby pumps may not be installed irrespective of the number of main engines.

This exception shall not apply to the following ships of restricted navigation area **R2**:

tugs with one main engine;

passenger ships with one main engine.

14.1.5 Where the turbo-blowers of the main engine have an independent electrically driven lubricating oil pump, provision shall be made for a standby pump of adequate capacity and a gravity tank containing sufficient oil to maintain lubrication of the turbo-blowers during idle rotation if the oil pump stops working.

Warning alarms shall operate for low level in the tank and automatic start-up of standby pump shall be ensured at stoppage of the pump at work.

Means shall be provided to enable the oil flow in turbo-blower bearings to be controlled.

14.1.6 Lubricating oil pumps of main gearing, as well as the pumps supplying the main fluid couplings, shall comply with the requirements of 14.1.1 to 14.1.4 for the main engines.

14.1.7 Each auxiliary engine and each emergency diesel generator engine (refer to 2.2.5, Part IX "Machinery") shall have a separate lubricating system.

A common lubricating system of the auxiliary engines is, in each case, subject to special consideration by the Register.

14.1.8 The lubrication of oil-lubricated sterntube bearings shall comply with the requirements of 5.6.3 and 5.6.4, Part VII "Machinery Installations".

14.2 LUBRICATING OIL SUPPLY TO INTERNAL COMBUSTION ENGINES AND GEARS

14.2.1 The design of a lubricating oil drain tank and the operating oil level in it, as well as the arrangement of pump suction pipes shall prevent a lubricating oil flow separation at the maximum static and dynamic heel and trim angles, which are probable for the given ship. The lubricating oil drain pipes from the engine crankcase shall terminate in the oil drain tank so as to be submerged in oil all the time of the engine operation. No communication is permitted between lubricating oil drain pipes of two or more engines.

14.2.2 The pipes of the lubricating oil system shall not communicate with other piping systems, except where they are connected to separators, which may be used for fuel oil separation. In the latter case, arrangements shall be fitted, which will preclude mixing of fuel oil and lubricating oil.

While separating a lube oil, precautions shall be taken to prevent mixing of lubricating oils of different specifications.

14.2.3 The lubrication system shall provide effective cleaning of oil, for which purpose filters shall be fitted as follows:

.1 magnetic filter generally on the suction side of the pump of the gears;

.2 one coarse filter (strainer) on the suction side of the main engine pump; two parallel filters or one duplex filter or a self-cleaning filter on the discharge side of the main engine pump. The design and construction of filters shall meet the requirements of 4.2 and 13.8.2.

14.2.4 The capacity of each oil filter shall exceed by 10 per cent the maximum capacity of the pump.

14.2.5 The lubricating system shall be fitted with instrumentation in accordance with 2.12, Part IX "Machinery".

The pressure gauge indicating the pressure after the oil cooler shall be placed at the control station.

14.3 LUBRICATING OIL PUMPS OF STEAM TURBINES AND GEARS

14.3.1 The lubricating oil system of the main turbine set shall be serviced by two oil pumps, the capacity of each pump being sufficient to ensure lubrication of the turbine set for maximum output condition. At least one of the pumps shall be independently driven.

Where two main turbine sets are arranged in the same space, one independent standby pump may be fitted for both turbine sets.

14.3.2 Lubricating oil pumps shall be of self-priming type and shall be so disposed that reliable start-up is always possible.

14.3.3 In general, the lubricating oil for main turbine sets shall be supplied from the gravity tank, with arrangements to be such that lubrication is supplied to the turbines also in the event of damage to the main oil pump, and until the turbines come to rest at failure in power supply from the main sources of power to the motors of oil pumps.

The use of pressure lubrication system shall be considered by the Register in each case.

14.4 LUBRICATING OIL SUPPLY TO STEAM TURBINES AND GEARS

14.4.1 The circulating oil pipe line, including all branch pipes of consumers, shall be made of copper, bimetal, cupro-nickel or equivalent materials.

14.4.2 Oil may be taken from the main turbine lubricating system only for control, adjustment and protection needs, as well as for lubricating the main thrust bearing.

14.4.3 Each lubricating system shall be fitted with audible and visual alarms warning of oil pressure drop and placed at the main turbine control station. In gravity lubrication system, the alarms shall operate at such level in the gravity tank as to enable the protection devices to cut in the standby pump during the time left before the tank is emptied.

14.4.4 The capacity of the gravity tank shall not be less than a 5-minute consumption of oil, with the turbine running at rated output.

The tank shall be fitted with an overflow pipe with a sight glass well lighted and visible from the control station. The cross-sectional area of the overflow pipe shall be at least 1,25 times that of the discharge pipe of the pump.

It shall be possible to supply lubricating oil to consumers from the pump, excepting the tank.

14.4.5 The lubrication system of the main turbine set shall be fitted with two oil coolers, one of which is a standby cooler.

Where two turbine sets are situated in the same space, one standby oil cooler may be installed for both turbine sets.

Servicing of oil coolers shall be provided according to 15.1.7.

14.4.6 The lubrication system of the main turbine sets and associated gearing shall comply with the requirements of 14.1.6, 14.2.3 and 14.2.5.

14.4.7 The branch pipes of the circulating oil pipeline shall be fitted with throttle valves for regulating the amount of oil supplied to each consumer.

14.5 LUBRICATING OIL TANKS

14.5.1 The lubricating oil tanks shall be separated from the feed water and vegetable oil tanks by cofferdams, the structural members of which shall comply with the requirements of Part II "Hull".

14.5.2 The lubricating oil drain tanks in ships with main turbines shall in any case be separated from the bottom shell plating by a cofferdam, the structural members of which shall comply with the requirements of Part II "Hull".

For other ships, the arrangement of cofferdams is recommended.

Where the cofferdams are not available, the drain pipes from crankcases shall have non-return or shut-off valves capable of being operated from above the engine room floor plating.

In these cases lubricating oil drain tanks shall be provided with the relevant pipelines with fittings for emergency lubricating oil suction by pumps from engines crankcases if tanks are holed.

Valves shall have drives located above the engine room plating.

14.5.3 Provision shall be made for a lubricating oil storage tank with a capacity sufficient for filling the system with oil to the working condition.

This tank is recommended to be situated outside the double bottom.

In ships of restricted areas of navigation **R2** and **R3**, the lubricating oil storage tank need not be provided.

14.5.4 The suction pipes from the tank situated outside the double bottom shall be fitted with shut-off valves installed directly on the tanks.

In tanks of a capacity of more than 500 l which, with the exception of gravity lubrication systems, may be open in normal conditions, such valves shall be remote-controlled from always accessible positions outside the space containing the tank.

14.5.5 Arrangements for heating of the lubricating oil shall comply with the requirements of 13.3.

14.5.6 For lubricating oil tanks arranged in machinery spaces of category A (refer to 1.2, Part VII "Machinery Installations") and, whenever practicable, in other machinery spaces, the requirements of 10.4, 13.5.1 and 13.6 of this Part and 4.3.3, 4.3.4, Part VII "Machinery Installations", shall be complied with, as far as lubricating oil tanks installed above heated surfaces of engines and machinery are concerned.

14.6 ARRANGEMENTS FOR COLLECTION OF LEAKAGE LUBRICATING OIL

14.6.1 The requirements of 13.5 apply to arrangements for collection of leakage lubricating oil.

14.7 LUBRICATING OIL SUPPLY TO GAS TURBINES

14.7.1 The lubricating oil system of a gas turbine plant shall comply with the requirements of 14.1 to 14.5 as far as these requirements are applicable to the given plant.

15 WATER COOLING SYSTEM

15.1 PUMPS

15.1.1 Water cooling systems of main engines shall comply with the following requirements:

.1 a sea water cooling system of one main engine shall include two cooling water pumps, one of which is standby. The capacity of the standby pump shall not be less than that of the main pump. At least, one pump shall be driven independently.

A fresh water cooling system of the main engine shall also comply with these requirements.

One common independent standby pump may be used for both fresh and salt water cooling; the capacity of this pump shall not be less than that of the main pumps; precautions shall be taken to prevent mixing of fresh and salt water;

.2 one independent standby pump ensuring the operation of each engine running at maximum load shall be installed in a salt water cooling system of two and more main engines, each served by a separate cooling water pump.

No standby pump may be provided where a reserve pump is available, which may be assembled on board.

A fresh water cooling system shall also comply with these requirements.

It is permitted to install one common independent standby pump, the capacity of which shall ensure fresh or sea water cooling of any engine; precautions shall be taken to prevent mixing of fresh and salt water;

.3 it is allowed to cool several engines by one independently driven pump. In this case, the capacity of the pump shall be sufficient for simultaneous cooling of all engines when running at maximum load. One standby pump, the capacity of which shall not be less than that of the main pump cooling simultaneously all engines, shall be provided.

The cooling pipe shall have a water control valve at inlet to each engine;

.4 in the installations with an automation mark in the class notation provision shall be made for separate fresh water and salt water standby pumps, the capacity of which shall not be less than that of the main pumps;

.5 in ships of restricted areas of navigation, special standby facilities are not compulsory; however, it shall be possible to cool the engine by sea water directly.

In ships of restricted areas of navigation **R2**, **R2-RSN**, **R3** and **R3-RSN**, having two and more main engines direct standby sea water cooling is not compulsory.

15.1.2 The oil and air coolers of the electric propulsion motors shall have standby means of cooling, equivalent to the main means.

15.1.3 Where each of the auxiliary engines is provided with an independent cooling water pump, the standby pumps for these engines are not required.

Where, however, a group of auxiliaries is supplied with cooling water from a common system, one standby pump for salt water and fresh water is sufficient.

If a common cooling line is fitted for the main and auxiliary engines, standby pumps for cooling the auxiliary engines are not required.

For the diesel-generators kept ready for immediate use (hot condition) continuous priming with hot water shall be possible, where necessary.

15.1.4 The ballast, bilge or other general service pumps operated only for clean water may be used as standby cooling pumps.

The use of fire pumps for this purpose is permitted if the requirements contained in 3.2.3.2, Part VI "Fire Protection", are complied with.

15.1.5 An independent cooling system for pistons shall include a standby pump with a capacity not less than that of the main pump.

15.1.6 An independent cooling system of the fuel valves shall include a standby pump with a capacity not less than that of the main pump.

15.1.7 The oil coolers of the main turbine sets shall generally be served by the circulating pumps of the main condensers.

Where for servicing the oil coolers an independent circulating pump is fitted, provision shall be made also for a standby pump having a capacity of at least 0,66 of the consumption of water for the oil cooler, with the turbine running at rated output.

Any one general service pump may be used as a standby pump.

15.1.8 A reserve pump with a capacity not less than that of the main pump shall be provided in an independent sea water cooling and lubricating system for stern bearings. Any sea water general purpose pump referred to in 15.1.4 may be used as a reserve pump.

15.2 PIPING LAYING

15.2.1 Sea water cooling system shall be supplied from at least two sea inlets (bottom and side) arranged in the engine room and interconnected. In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN**, the number of sea inlets is subject to a special consideration by the Register in each case.

15.2.2 It is recommended that the cooling systems servicing the auxiliary engines and condensers of auxiliary turbines shall be supplied with water from separate sea inlets. Where these sea inlets are located in the engine room, the suctions of the above-mentioned systems shall be connected through isolating valves to the cooling main supplied from sea inlets according to 15.2.1.

15.2.3 The requirements for design of sea chests and ice boxes in ships with ice strengthening and icebreakers are given in 4.3.1.

15.3 COOLING WATER FILTERS

15.3.1 Filters shall be fitted on the suction lines of water cooling system servicing the main and auxiliary engines. Filters shall be provided with a facility that makes it possible to be sure, before the filters are opened up, that there is no pressure. Means shall be provided to enable the filters to be cleaned without having to stop the cooling pumps.

In a water cooling system of a turbine installation, filters are recommended to be fitted.

15.4 COOLING OF INTERNAL COMBUSTION ENGINES

15.4.1 In a fresh water cooling system of the engine provision shall be made for an expansion tank where the level of water is higher than the maximum level of water in the engine. The expansion tank shall be connected to the suction piping of the pumps and may be common for the cooling system of several engines.

The tank shall be provided with a device for monitoring the water level.

In the cooling system of engines, the arrangement of the sea water discharge pipes shall be such that the highest cooled spaces of the engines, air coolers and oil coolers are always filled with water and formation of trapped zones is excluded.

15.4.2 The cooling system shall be fitted with thermometers and temperature control devices.

It is recommended that suitable alarms shall be provided to warn on the limit value of the cooling water temperature (refer to 2.12, Part IX "Machinery").

15.4.3 The cooling system of an engine to be used as emergency engine shall comply with the requirements of 2.2.5, Part IX "Machinery".

15.4.4 Where fuel oil or lubricating oil is used in the cooling systems of nozzles or pistons, such systems shall comply with Section 13 or Section 14, accordingly.

15.5 COOLING OF GAS TURBINE INSTALLATIONS

15.5.1 The cooling system of turbine casings shall comply with the requirements indicated in 15.4.

15.5.2 Only fresh water cooling shall be used for turbine casings.

Sea water cooling may be admitted in exceptional cases.

15.5.3 The cooling system of the air cooler shall comply with the requirements of 19.2.1, 19.2.3 and 19.3.1.

The standby pump may not be provided, if in the event of failure in water supply to the air coolers, 30 per cent of turbine rating is maintained.

15.6 KEEL COOLING SYSTEMS

15.6.1 Keel cooling systems of the internal combustion engines are allowed for use on the ships, except ice breakers and ships with **Arc4** to **Arc9** ice strengthening categories. Application of keel systems in ships of restricted area of navigation with such ice strengthening categories is subjected to the special consideration by the Register in each case.

15.6.2 For ships equipped with one main engine not less than two sea-water coolers, one of which is stand-by, shall be provided.

15.6.3 For ships equipped with two or more main engines one standby cooler shall be provided to keep each engine running. For ships of restricted area of navigation equipped with two or more main engines the standby cooler may not be fitted.

15.6.4 Each cooler shall be provided with air discharge arrangement.

15.6.5 On the pipelines for supply and rejection of cooled medium to coolers the check valves shall be provided.

15.6.6 Provision shall be made for drainage and purging of cooler.

16 COMPRESSED AIR SYSTEM

16.1 NUMBER AND CAPACITY OF STARTING AIR RECEIVERS

16.1.1 The compressed air system of the main engines shall ensure simultaneous starting and reversing of all the main engines and starting arrangements shall comply with the requirements of 2.9, Part IX "Machinery".

The requirements for the starting system of gas turbines are given in 8.1, Part IX "Machinery".

16.1.2 The total amount of starting air for the main engines starting and the associated pneumatic control systems shall be stored in not less than two air receivers or two groups of them so arranged that they may be used independently; the capacity of each air receiver, or each group of air receivers shall be at least 50 per cent of that required in 16.1.3 and 16.1.4 (refer also to 16.1.6).

Where an electric tyfon is used in ships of restricted areas of navigation **R2** and **R3**, it is permitted to fit one air receiver of a capacity sufficient to meet the requirements of 16.1.3 and 16.1.4.

16.1.3 The total capacity of air receivers for starting and reversing of the main engines shall be sufficient to provide not less than 12 starts alternating between "ahead" and "astern" of each engine in cold and ready to start conditions, as well as the function of engine control systems.

For ships with ice strengthening of categories **Arc6** to **Arc9** and icebreakers the total capacity of air receivers is subject to special consideration by the Register in each case.

16.1.4 The total capacity of air receivers for starting of the main engines connected to a controllable pitch propeller or some other device, enabling to start without opposite torque, shall be sufficient to provide not less than 6 starts of each engine being in cold and ready to start conditions, and where there are more than two engines, at least 3 starts of each engine. At the same time, the function of engine control systems shall be provided.

16.1.5 For starting of the auxiliary engines provision shall be made for one air receiver with a capacity sufficient to provide 6 starts of the largest engine in cold and ready to start conditions.

On special agreement with the Register, such air receiver may be dispensed with.

In this case it shall be possible to start the auxiliary engines from one main air receiver or a group of same.

16.1.6 It is permitted that the starting air stored in one air receiver, or in a group of air receivers of the main engines according to 16.1.2, be used to feed the tyfon whistle, as well as for domestic needs, provided the capacity of the air receiver is increased by an amount of air specified below for a special air receiver of the tyfon, or where the air receiver is fitted with automatic replenishing means or with alarms warning on a drop of pressure of not more than 0,49 MPa below the working pressure.

Where an air receiver is fitted especially for the tyfon, its capacity shall be determined so that the tyfon will be able to work continuously for 2 min, with hourly performance of compressor being not less than required to provide continuous operation of tyfon during 8 min.

If air from the air receiver of the tyfon is consumed also for other purposes, the capacity of the air receiver shall be increased as compared with that designed for tyfon only, with provision for automatic replenishing or signalling means which shall operate as soon as the amount of air in the air receiver is such as required for tyfon only.

In ships having a mark of automation the replenishing of air receivers shall proceed according to 4.5, Part XV "Automation".

16.1.7 The air receivers of auxiliary engines indicated in 16.1.5 may be replenished from the main air receivers stated in 16.1.6, with any possibility of back flow being excluded.

16.1.8 The starting devices of the emergency diesel generator shall comply with the requirements of 9.5, Part XI "Electrical Equipment".

Where a compressed air system is used as one of the means of starting the emergency diesel generator, the air receiver may be maintained from main or auxiliary starting air compressors through a non-return valve fitted in the emergency generator room, or from an electric compressor supplied from the emergency switchboard.

16.2 COMPRESSORS

16.2.1 The number of the main air compressors shall be at least two. The total capacity of the main compressors shall be sufficient for the filling of the main air receivers during one hour for starting the main engines, beginning from the atmospheric pressure to the pressure required to carry out the number of starts and reverses referred to in 16.1.3 and 16.1.4. For ships, the main engines of which are started without a load, one of the main compressors may be attached on the engine. The capacity of individual main compressors shall be approximately the same. The capacity of the independently driven compressors shall not be less than 50 per cent of that required of all the main compressors, but not less than the air consumption for the whistle according to 16.1.6.

For ships with ice categories **Arc6** to **Arc9** with reversible engines, as well as in icebreakers, the number and capacity of compressors are, in each case, subject to special consideration by the Register.

16.2.2 In cargo ships of less than 500 gross tonnage navigating in restricted areas **R3** and **R3-RSN** with reversible main engines, one independently driven compressor is permitted, whereas with main engines of a non-reversible type, one attached compressor is permitted. For the above ships having combined starting systems, one attached compressor may be installed. The capacity of the compressors shall be in accordance with the requirements of 16.2.1.

16.2.3 In ships with the main and auxiliary engines arranged for compressed air starting, provision shall be made, in case of the ship blackout, for starting the main compressors during not more than one hour. For this purpose it is allowed to use a hand compressor or a hand operated diesel compressor to fill a separate air receiver, which capacity is sufficient for three starts of one of the diesel generators or one of the main compressors, where it is driven by an internal combustion engine.

A separate air receiver need not be installed where the diesel compressor or hand compressor is capable of filling the smallest of the air receivers specified in 16.1.5 during the aforesaid time period.

Where the motor of the compressor supplying one of the air receivers considered in this paragraph can be energized by the emergency diesel generator, the above-mentioned provisions are not necessary.

This requirement is not applicable to cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-RSN**, **R3** and **R3-RSN**.

16.3 PIPING LAYING

16.3.1 All pressure pipes from starting air compressors shall be laid directly to the starting air receivers, and all starting pipes from the air receivers to main or auxiliary engines shall be entirely separated from the compressor pressure pipe system.

16.3.2 Each of the starting air receivers specified in 16.1 shall be capable of being filled from each main compressor specified in 16.2. Possibility of back flow shall be precluded (refer to 16.1.7).

16.3.3 Non-return shut-off valves shall be installed on the discharge pipe of each compressor.

The manifold supplying starting air to each engine shall have a non-return valve placed before the cylinder starting valve.

The non-return valve may be omitted, if provision is made in the engine design for suitable devices protecting the manifold from the effects of an internal explosion (refer to 2.9.1, Part IX "Machinery").

16.3.4 The temperature of air entering the receiver shall not exceed 90 °C. Where required, provision shall be made for coolers.

16.3.5 The pipes shall be laid as straight as practicable with a slight slope in the direction of the master starting valve of the engine for water drainage.

16.3.6 Suitable arrangements for draining the accumulations of oil and water shall be fitted on the pipes between compressors and air receivers, unless drain arrangements are fitted on the compressors.

16.3.7 If the pressure relief valves or fuse plugs fitted on air receivers are arranged to discharge a compressed air outside engine rooms, the cross-sectional area of discharge pipes shall not be less than a two-fold cross-sectional area of the pressure relief valves or fuse plugs; appropriate arrangements for draining water from the pipes shall be provided.

17 FEED WATER SYSTEM

17.1 PUMPS

17.1.1 Each main boiler and an essential auxiliary boiler or a group of boilers shall be provided with at least two independent feed pumps.

For auxiliary boilers, which are not intended for essential services, as well as for exhaust gas boilers so constructed that they can be left without water when heated by exhaust gas, one feed pump is sufficient.

For boilers with manual feed regulation the capacity of each pump shall not be less than 1,50 times the rated capacity of the boilers, and for boilers with automatic control systems, not less than 1,15 times their rated capacity.

Where several pumps are installed, their adopted capacity shall be such that in the event of damage to any of the pumps the total capacity of the rest of the pumps is not less than the capacity required in the foregoing for each pump.

The capacity of each feed pump of a straight-through boiler shall not be less than the rated capacity of the boiler.

17.1.2 In the case of steam driven feed pumps, live steam shall be supplied to the line having connections from all the boilers fed by these pumps.

17.1.3 The main and essential auxiliary boilers with forced circulation as well as waste heat boilers connected to exhaust gas systems of two-stroke diesels with inlet gas temperature of 270 °C and lower, shall be serviced by not less than two circulating pumps, one of which is a standby pump.

17.2 PIPING LAYING

17.2.1 In case of open circuit feed system, the feed pumps and injectors shall be provided with suctions from the hot well and from the feed water storage tanks.

17.2.2 The feed system of each main boiler and each auxiliary boiler for essential services shall be so constructed as to enable a boiler or a group of boilers to be fed by each pump through two separate feeding systems, i.e. the main and the auxiliary lines.

For non-essential auxiliary boilers, one feeding pipeline is sufficient.

17.2.3 All structural measures shall be taken to prevent feed water being contaminated by oil and oily products.

17.2.4 The main boilers and essential auxiliary boilers shall be provided with automatic devices for monitoring of feed water salinity.

17.2.5 For the waste heat boilers with forced circulation, mentioned in 17.1.3, provision shall be made for the circulating water consumption, corresponding to at least 5-times design steam capacity to eliminate excessive heat emission in case of ignition of sediments. For this purpose a standby circulating pump of a waste heat boiler or another suitable pump may be used.

17.2.6 Each exhaust gas heated economizer shall be provided with arrangements for water treatment, pre-heating and deaeration to ensure the quality of feed water compliance with the manufacturer's requirements.

17.3 TANKS

17.3.1 Feed water tanks shall be separated from tanks containing oil fuel, lubricating oil and vegetable oil by cofferdams, the structural members of which shall comply with the requirements of Part II "Hull".

18 STEAM AND BLOW-OFF SYSTEMS

18.1 PIPING LAYING

18.1.1 Where two or more boilers are connected to a common steam line, a non-return valve shall be fitted on the steam pipe of each boiler before connection to the common line.

These valves need not be fitted if the stop valves of the boilers are of non-return shut-off type.

18.1.2 The blow-down and the scum valves of two or more boilers may be connected to a common discharge, provided a not-return stop-check valve is fitted on the blow-off pipe of each boiler before the connection to the discharge line.

18.1.3 The machinery connected with the steam lines shall be relieved of the stresses caused by thermal expansion of pipes. It may be achieved by means of self-compensation (pipe bends) or by installation of thermal compensators in appropriate positions.

18.1.4 In the steam lines supplying the machinery and arrangements designed for a lesser pressure than the boiler pressure, there shall be fitted reducing valves, and requirements of 1.4.4 shall be complied with.

18.1.5 If provision is made for a steaming system for fuel and cargo oil tanks, each tank shall be fitted with non-return shut-off valves.

18.1.6 The steam pipelines in the engine and boiler rooms shall be laid in the upper parts of these spaces, where practicable, in a position accessible for observation and servicing.

Laying of steam lines under the floor plates of engine and boiler rooms, with the exception of heating coils and boiler blow-off pipes, is not permitted.

Steam lines shall not be laid near the fuel oil tanks.

Steam lines shall not be laid in spaces used for carriage of flammable substances and in paint rooms.

Steam lines with working temperatures above 220 °C are not permitted to be laid in cargo pump rooms of tankers.

18.1.7 While laying steam lines, the minimum distance from pipeline insulation shall be observed:

to hull structures — 50 mm;

to cable routing — 150 mm.

18.1.8 Steam radiators shall be located at a distance of at least 50 mm from hull structures. If the hull structures are lined with a combustible material, the portions located against the heating elements shall be protected with heat insulation of non-combustible material. In the absence of heat insulation the heating elements shall be located at a distance of not less than 150 mm from the combustible lining.

18.2 BLOW-OFF ARRANGEMENTS OF STEAM LINES

18.2.1 Pipelines coveying live steam shall have condensate drain arrangements to protect the machinery against water hammer.

18.2.2 The open ends of the pipes for steam line blow-off shall be laid below the floor plates of the engine and boiler rooms (refer also to 5.3.7).

18.3 CALCULATION OF STEAM PIPES FOR THERMAL EXPANSION

18.3.1 The calculation of steam pipes for thermal expansion shall be based on the methods generally adopted in structural mechanical for computing beam elements. On agreement with the Register, the calculation may be prepared on a computer or by means of a model method.

18.3.2 The calculation of steam pipes for thermal expansion shall include a summary table of stresses and safety factors for all the pipe ranges dealt with in the calculation.

The steam pipes working under temperatures, which do not cause stress relaxation, shall, as a rule, be calculated for thermal expansion taking into account the initial prestressing, as well as prestressing in cold condition.

The steam pipes working under conditions of stress relaxation shall be calculated in cold condition for a 100 per cent prestressing considered as great as the displacements due to full thermal expansion (displacements of supports included), but with an opposite sign. Where a steam pipe in hot condition undergoes displacements, it shall be calculated in view of these displacements and, after that, for a 100 per cent prestressing in cold condition (displacements of supports included).

Note. The temperatures, which cause the pipes to relax are as follows:

350 °C and over — for carbon steel pipes;

420 °C and over — for alloy steel pipes.

18.3.3 In the calculation of thermal expansion the pipe fittings and formed elements (elbows, T-joints, etc.) may be assumed rigid and need not be calculated for flexibility.

18.3.4 The design stress in pipes shall be calculated depending on the pipe cross-sectional area, including the positive manufacturing tolerance for pipe wall thickness. The same sizes shall be used for determining the stresses from displacements. As for the stresses caused by internal pressure, they shall be determined depending on pipe cross-sectional area, including the negative manufacturing tolerance for pipe wall thickness.

18.3.5 For all types of butt joints of steam pipes welded with a back sealing run at the root, butt joints welded from both sides and made by automatic submerged arc welding, including joints welded on a removable backing ring, with surface dressing, the efficiency factor in the formula for stress calculation of piping may be assumed equal to a unity ($\varphi = 1$).

18.3.6 In a calculation, the three components of reaction for a plane frame in general and the six components for a space frame shall be determined by force method, well known in structural mechanics beam system. In determining the components of reactions, the space frame of the pipe is reduced to three plane frames. To minimize the error due to reduction of the space frame to three plan frames, the axes of coordinates plotted for the pipe length under consideration shall be arranged parallel (or perpendicular) to the longest straight portion of the pipe and in a way that the curved portions be projected on the coordinate plane without distortion as far as is possible, or in form of straight lines.

18.3.7 The flexibility coefficient k of the curved portion shall be determined by the formulae:

$$k = \frac{10 + 12\lambda^2}{1 + 12\lambda^2} \text{ for } \lambda \geqslant 0{,}4; \quad (18.3.7\text{-}1)$$

and

$$k = 1{,}65/\lambda \text{ for } 0{,}2 \leqslant \lambda < 0{,}4 \quad (18.3.7\text{-}2)$$

where $\lambda = sR/r^2$ — geometrical coefficient of bent pipe;
s = wall thickness of straight pipe, mm;
R = bending radius of the curved portion, mm;
r = average radius of cross-sectional area of a straight pipe, mm.

18.3.8 In calculating the steam pipes for thermal expansion, the maximum stresses to be determined are as follows:

resultant stress for a straight pipe conveying hot steam under working pressure, as well as for cold pipe not subjected to internal pressure;

total local stress acting on the inside of a bent pipe conveying hot steam under working pressure, as well as in bent pipe when cold and not subjected to internal pressure.

Bent pipes with $\lambda \geqslant 1{,}44$ may be regarder as straight, when determining the resultant stress, and need not be calculated for total local stress.

When the assembled steam pipeline is subjected to a hydraulic test on board ship, the resultant stresses shall be shown also for a cold pipeline at they hydraulic test pressure.

18.3.9 The resultant stress σ_c in a straight pipe when exposed to internal pressure and to the bending and twisting moments shall be determined by the formula

$$\sigma_{res} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_1\sigma_3 - \sigma_2\sigma_3 + 3\tau^2} \quad (18.3.9)$$

where σ_1 = total normal stress from bending and internal pressure, MPa;
σ_2 = circumferential stress due to internal pressure, MPa;
σ_3 = radial stress due to internal pressure, MPa;
τ = shearing stress, MPa.

18.3.10 The total stress acting on the inside of a bent pipe shall be determined in all cases of bending (plane, perpendicular to curvature plane of a bent pipe, and tangential) as a sum of bending stresses and circumfe-rential stress from internal pressure.

18.3.11 Safety factors, relating to the yield point and average stress producing rupture, which shall be used in the calculation of the resultant stress and the total local stress, are as follows:

1,2 — for plane frame;
1,5 — for space frame.

19 CONDENSER INSTALLATIONS

19.1 GENERAL

19.1.1 Each main turbine set shall be fitted with an independent condenser installation ensuring a stable vacuum under all rated operating conditions.

The auxiliary turbines may have a common condenser installation. In running conditions, waste steam from the auxiliary turbo-generators may be discharged into the main condenser or into the stages of the main turbine set.

19.2 PUMPS

19.2.1 The main condenser shall be serviced by two circulating cooling pumps, one of which is a standby pump.

The capacity of the standby pump shall not be less than 30 per cent of rated quantity of circulating water for all consumers.

Any pump of sufficient capacity may be used as a standby pump (refer to 15.1.4).

In twin-screw ships it is allowed to use one standby circulating pump for both turbine sets.

Where, for servicing the main condenser, provision is made for simultaneous operation of both pumps, the capacity of each pump shall make not less than 50 per cent of the rated quantity of circulating water for all the consumers. No standby circulating pump is required in this case.

19.2.2 Where the auxiliary condenser is common for all the turbo-generators, it shall be serviced by two circulating cooling pumps, one of which is a standby pump.

Any pump of sufficient capacity may be used as a standby pump.

19.2.3 A sea inlet scoop arrangement of water cooling may be permitted if a circulating pump is fitted, which has a capacity sufficient to ensure the full astern speed condition. The standby circulating pump shall meet the requirements of 19.2.1.

19.2.4 The condensate system of a steam turbine installation shall be serviced by two condensate pumps. The capacity of each pump shall exceed by not less than 25 per cent the maximum design amount of steam and condensate entering the condenser. In the installations with two main condensers arranged in the same engine room, the standby condensate pump may be common for both condensers.

19.3 PIPING LAYING

19.3.1 The laying of pipes and their connections shall comply with the requirements of 15.2.

19.3.2 The condensate collector, discharge pipe and condensate pump shall be so arranged as to preclude flooding of the lower rows of pipes and to ensure the required positive pressure and smooth delivery of condensate to the pump.

Provision shall be made for a handhole for cleaning the condensate collector.

19.3.3 The nozzles of the ejectors of the condenser installations shall be protected against damage and clogging, for which purpose a metal screen shall be fitted in the steam pipe.

19.4 INSTRUMENTATION

19.4.1 The condenser installation shall be fitted with gauges and alarms, including:

.1 a condensate level indicator for the condenser;

.2 vacuum and pressure gauges for the condenser and ejector coolers;

.3 a pressure gauge in the steam line to ejector;

.4 thermometers for the cooling water discharge pipes of the condenser and ejector coolers;

.5 salinometers with visual and audible alarms indicating condensate salinity.

20 THERMAL LIQUID SYSTEMS

20.1 DEFINITIONS

20.1.1 *Thermal liquid boiler* is the heat-exchange apparatus for heating a thermal liquid up to the required temperature using the energy of fuel oil burnt in it, of an engine exhaust gases or electric power.

Thermal liquid heater is the heat-exchange apparatus for heating a thermal liquid with steam, water electric power or thermal liquid of another circuit.

Working pressure in the thermal liquid system is the highest pressure that may arise in any part of the system in operation.

Thermal liquid system is the system, in which a thermal liquid circulates in a liquid phase.

Thermal liquid temperature is the temperature measured in the centre of a pipeline cross section.

20.2 REQUIREMENTS FOR THERMAL LIQUID

20.2.1 A thermal liquid may be used within the range of working temperatures specified by a manufacturer. In this case, the maximum working temperature of the thermal liquid shall not be less than 50 °C below the temperature of boiling beginning at an atmospheric pressure.

20.2.2 In thermal liquid heaters, the heating medium temperature shall be below the temperature of boiling beginning of the thermal liquid being heated.

20.3 PUMPS

20.3.1 In order to ensure the thermal liquid circulation, a system shall be provided with a pump. Provision shall be made for redundancy of circulating pumps in boiler circulation circuits, and also in essential consumers circuits.

20.3.2 Manometers shall be fitted on the side of the thermal liquid outlet from pumps.

20.3.3 Engines of thermal liquid circulating pumps shall be fitted with disconnectors meeting the requirements of 5.7.1, Part XI "Electrical Equipment".

20.4 EXPANSION TANK

20.4.1 A thermal liquid system shall be provided with an expansion tank placed, as a rule, at the highest point of the system.

20.4.2 An expansion tank shall be fitted with a liquid level indicator meeting the requirements of 10.4.

The lowest permissible liquid level shall be marked on the level indicator.

20.4.3 The expansion tank of an open system shall be equipped with an air pipe, and also with an overflow pipe laid to a drain tank or storage tank if the former is lacking.

20.4.4 Provision shall be made for the alarm, which indicates when the lowest and highest thermal liquid levels are reached in the tank. When the thermal liquid level is lower than the lowest permissible level, heating in boilers shall be automatically discontinued and circulating pumps shall be stopped.

20.4.5 The expansion tank of a closed system shall be equipped with a manometer and safety valve. The safety valve outlet pipe shall be connected to a drain or storage tank. The opportunity of the closed system operation in the mode of the open system shall be provided.

20.4.6 The expansion tanks having thermal insulation shall be fitted with thermometers to monitor the thermal liquid temperature.

20.4.7 The expansion tank capacity within the level indicator range measured form the lowest permissible level mark up to the overflow pipe top shall be sufficient for an increased volume of the thermal liquid in the whole system due to a liquid temperature charge during operation.

20.4.8 The expansion tank shall be fitted with a valve locally and remotely controlled outside the space, in which the tank is located for an emergency discharge of the thermal liquid.

20.5 STORAGE AND DRAIN TANKS

20.5.1 The system shall be provided with a storage and a drain tanks. The storage tank capacity shall be at least 40 per cent of the system capacity. Depending on the system purpose and the ship navigation area, the storage tank capacity may be reduced.

20.5.2 The drain tank capacity shall be sufficient for draining the thermal liquid from the largest disconnectible section. For emergency draining of the thermal liquid from boilers (refer to 3.5, Part X "Boilers, Heat Exchangers and Pressure Vessels") the tank shall be provided with capacity sufficient for draining into it of the thermal liquid from the whole system.

20.5.3 The common tank for storage of the thermal liquid supply and of its drain from a system may be used. In this case, the capacity of that tank shall be adequate for the simultaneous storage of the thermal liquid supply and drain. The tank location shall provide an opportunity to drain into it the complete thermal liquid.

20.6 PIPING AND FITTINGS

20.6.1 Thermal liquid piping laying shall meet the requirements of 13.2 and Section 5.

20.6.2 Bellows-type fittings shall be used in the system. The application of gasket-type fittings is in each case subject to special consideration by the Register.

20.6.3 The use of copper and its alloys is not permitted for the system components contacting the thermal liquid.

20.6.4 Seals and gaskets shall be of materials resistant to thermal liquids.

20.6.5 Threaded connections shall not be used for thermal liquid pipelines.

20.6.6 Steel pipe wall thickness shall meet the requirements of 2.3.1. In this case, the design pressure shall be assumed not less than 1,4 MPa.

20.6.7 The thermal liquid arrangement design shall provide for filling the system, filling up the expansion tank, and also the thermal liquid pumping.

20.6.8 An opportunity of thermal liquid sampling shall be provided in each independent circulation circuit.

20.6.9 The system shall be designed so as to prevent deterioration of the thermal liquid quality due to local overheating or air contact.

20.6.10 The system shall be provided with an effective arrangement for trapping and removal of emitting vapours and gases. The operation of this arrangement shall not result in circulation and heating of the thermal liquid in an expansion tank above 50 °C.

20.6.11 An opportunity of controlling of at least thermal liquid flow rate and temperature by means of a manual control from a local position shall be provided in the system.

20.6.12 The company nameplate in the conspicuous place in the immediate vicinity of circulating pumps shall be provided. It shall contain the following main information on the system:

manufacturer;

year of mounting;

maximum design working temperature of the thermal liquid;

system capacity;

maximum permissible working pressure.

20.7 AIR PIPES

20.7.1 Air pipes of thermal liquid tanks shall meet the requirements of 10.1.

20.8 ARRANGEMENS FOR COLLECTING OF THERMAL LIQUID LEAKAGES

20.8.1 Arrangements for collecting of thermal liquid leakages shall meet the requirements of 13.5.

20.8.2 Provision shall be made for the arrangements on the gas side in waste-heat boilers and on exhaust gas piping, which prevent an ingress of the leaking thermal liquid into an engine, and also of the water used for fire extinguishing or boiler washing.

20.9 THERMAL LIQUID BOILERS

20.9.1 The requirements of 3.5, Part X "Boilers, Heat Exchangers and Pressure Vessels" apply to thermal liquid boilers and heaters.

20.10 INSULATION

20.10.1 The insulation of the system piping and equipment shall meet the requirements in 4.6, Part VII "Machinery Installations".

20.11 HEATING OF LIQUID CARGOES

20.11.1 Where a thermal liquid is used for liquid cargoes or other liquid products heating, it shall be compatible with heated products when in contact due to leakages of heater coils or pipes. The use of a thermal liquid, which may enter into a hazardous reaction with a heated product, is not permitted.

20.11.2 The use of thermal liquid systems for heating liquid cargoes with a flash point below 60 °C is permitted only if an independent intermediate system located within a cargo area is fitted. However, such a system may be unnecessary if the following conditions are observed:

.1 the system is designed so that with a circulating pump switched off the excessive pressure in coils is at least 0,03 MPa above the static cargo head;

.2 means for detection of flammable cargo vapours in the thermal liquid system expansion tank are provided;

.3 valves of separate heating coils are provided with locking arrangements, which ensure that the coils are permanently under the above static pressure.

20.12 THERMAL LIQUID SYSTEM PIPING TESTING

20.12.1 Thermal liquid systems piping and their components shall be tested according to the requirements of 21.2 like fuel oil pipelines with a design pressure over 0,35 MPa.

21 TESTS

21.1 HYDRAULIC TESTS OF FITTINGS

21.1.1 The fittings intended for Class I and Class II piping shall be subjected to a hydraulic test by the pressure indicated in 1.3.1, Part IX "Machinery".

21.1.2 The fittings intended to work under a design pressure of 0,098 MPa and less, as well as in vacuum conditions shall be tested by a pressure not less than 0,196 MPa.

21.1.3 Valves, cocks and other fittings intended to be fitted on the ship side below the loadline shall be tested by hydraulic pressure not less than 0,5 MPa.

21.1.4 After assembly, the fittings shall be checked for leakage by a hydraulic pressure equal to the design pressure.

21.2 HYDRAULIC TESTS OF PIPING

21.2.1 All Class I and Class II pipes, as well as steam, feed, compressed air and fuel oil pipes with design pressure over 0,35 MPa irrespective of their class, shall be tested by hydraulic pressure in the presence of a Surveyor to the Register after completion of manufacture and before insulating and coating, by a test pressure, in MPa:

$$p_{test} = 1,5p \qquad (21.2.1\text{-}1)$$

where p = design pressure (refer to 2.3.1), MPa.

The test pressure for steel pipes, MPa, intended for design temperatures over 300 °C, shall be determined from the following formula, but it need not exceed $2p$:

$$p_{test} = 1{,}5\frac{\sigma_{100}}{\sigma_t} p \qquad (21.2.1\text{-}2)$$

where σ_{100} = permissible stress at 100 °C;
σ_t = permissible stress at design temperature.

In case where during the test excessive stress arises the value of test pressure, as obtained from Formula (21.2.1-2), may be reduced to 1,5*p* on agreement with the Register.

In no case shall be stresses arising during the test exceed 0,9 of the yield point at the temperature of testing.

21.2.2 Pressure testing of small bore pipes (less than 15 mm) of any class may be omitted at discretion of the Register, depending on the application of these pipes.

21.2.3 All the piping systems shall be checked for tightness in operating conditions in the presence of a Surveyor to the Register, except that particular testing is required for the following piping:

.1 heating coils in tanks and liquid or gas fuel lines shall be tested by 1,5*p*, but not less than 0,4 MPa;

.2 liquefied gas pipelines shall be leak tested in comfliance with 13.14.17.

21.2.4 Where, for technical reasons, the hydraulic test of the entire pipeline cannot be carried out, proposals shall be submitted to the Register for testing of separate pipe lengths, in particular, the end joints.

21.2.5 In the case where hydraulic tests of an assembled piping system are carried out on board, testing of piping for tightness and strength may be combined.

21.3 TESTING OF DEVICES TO PREVENT THE PASSAGE OF FLAME INTO CARGO TANKS IN OIL TANKERS

21.3.1 Prior to assembly on board, flame arresters, flame screens, high velocity vents and pressure/vacuum valves along with protective devices against atmospheric precipitation shall be tested in accordance with the IMO procedure to be found in MSC/Circ. 677.

21.4 TESTING OF AIR PIPE AUTOMATIC CLOSING DEVICES

21.4.1 Each type and size of air pipe automatic closing device shall be surveyed and shall undergo the following tests:

.1 determination of the flow characteristics.

Measuring of the pressure drop versus rate of volume flow shall be carried out using water and with any intended flame or insect screens in place;

.2 tightness test during immersion/emerging in water.

An automatic closing device shall be subjected to a series of tightness test involving not less than two immersion cycles under the following conditions:

the automatic closing device shall be submerged slightly below the water surface at a velocity of approximately 4 m/min and then returned to the original position immediately. The quantity of leakage shall be recorded;

the automatic closing device shall be submerged to a point slightly below the surface of the water. The submerging velocity shall be approximately 8 m/min and the device shall remain submerged for not less than 5 min.

Each of the above tightness tests shall be carried out in the normal position as well as at an inclination of 40°.

The maximum allowable leakage per cycle shall not exceed 2 ml/mm of nominal diameter of inlet pipe.

21.4.2 Impact and compression loading tests shall be carried out on non-metallic ball type floats by the manufacturer bearing in mind the requirements of Table 21.4.2, as follows:

Table 21.4.2

Test condition	Test temperature, °C		
	−25	+20	+85
Dry	+	+	+
After immersing in water[1]	+	+	+
After immersing in fuel oil[1]	—	+	—

Symbols: "+" where the test shall be conducted;
"—" where the test shall not be conducted.

[1] Immersing in water and fuel oil shall be for at least 48 hours.

.1 impact test shall be conducted on a pendulum type testing machine. The floats shall be subjected to 5 impacts of 2,5 N/m each and shall not suffer permanent deformation, cracking or surface deterioration at this impact loading. Subsequently the floats shall be subjected to 5 impacts of 25 N/m each. At this impact energy level some localized surface damage at the impact point may occur, but no permanent deformation or cracking of the float shall appear;

.2 compression test shall be conducted with the floats mounted on a supporting ring of a diameter and bearing area corresponding to those of the float seating with which it is intended that the float shall be used. Loads shall be applied through a concave cap of the same internal radius as the test float. A load of 350 kg shall be applied over one minute and maintained for 60 min. The deflection shall be measured at intervals of 10 min after attachment of the full load. The record of deflection against time shall show no continuing increase in deflection and, after release of the load, there shall be no permanent deflection;

.3 testing of metallic ball type floats shall be conducted in accordance with 21.4.2.1.

21.5 TESTING OF PLASTIC PIPES

21.5.1 Plastic pipes shall be tested taking into consideration the requirements of 6.8, Part XIII "Materials", and where necessary, their fire resistance shall be confirmed and flame spread tested in accordance with 3.3.1 and 3.3.2.1 of the present Part.

21.5.2 The quality of joints shall be tested taking into consideration the requirements of 3.5.2, and piping as assembled on board shall be tested in accordance with the requirements of 3.8.

PART IX. MACHINERY

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to the following engines and machinery:

.1 main internal combustion engines;

.2 main steam turbines;

.3 main gas turbines;

.4 gears and couplings;

.5 engines driving electric generators or auxiliary and deck machinery, units in assembly;

.6 pumps included into the systems covered by Part VI "Fire Protection", Part VIII "Systems and Piping" and Part XII "Refrigerating Plants";

.7 air compressors;

.8 fans of main boilers, turboblowers (turbochargers) and fans of internal combustion engines;

.9 fans included into the system covered by Part VIII "Systems and Piping";

.10 steering gear;

.11 anchor machinery;

.12 towing winches;

.13 mooring machinery;

.14 hydraulic drives;

.15 centrifugal separators for fuel oil and lubricating oil.

1.2 SCOPE OF SURVEYS

1.2.1 The provisions specifying the procedure of survey conducted by the Register during the manufacture of the machinery and equipment, as well as the procedure of consideration and approval of technical documentation are contained in General Regulations for the Classification and Other Activity.

1.2.2 The Register carries out the survey during the manufacture of engines and machinery listed in 1.1, except for manually driven machinery.

1.2.3 Prior to manufacturing of the machinery, the following documents shall be submitted to the Register for approval:

.1 on internal combustion engines:

.1.1 engine particulars as per data sheet or specification;

.1.2 general view plans with engine longitudinal and transverse sections;

.1.3 drawings of bedplate, columns, engine bed, crankcase, cylinder block and other parts, cast or welded, with welding details and instructions including requirements for of pre- and postweld heat treatment of details, requirements for welding consumables, parameters and welding conditions;

.1.4 assembly drawing of thrust bearing as well as thrust bearing casing, cast or welded, with welding details and instructions (if thrust bearing is integral with engine but not integrated in bedplate);

.1.5 assembly drawing of cylinder cover;

.1.6 drawing of the rods;

.1.7 drawings of cylinder jacket or engine block as well as cylinder liner;

.1.8 drawings of connecting rod, crosshead and rod;

.1.9 drawings of crankshaft as an assembly and details;

.1.10 drawings of counterweights including their fastening (if not integral with crankshaft);

.1.11 drawing of thrust shaft or intermediate shaft (if integral with engine);

.1.12 drawing of piston as an assembly;

.1.13 drawings of shaft coupling bolts;

.1.14 assembly drawing of camshaft and its drive;

.1.15 specification of main details material with indication of test pressure values (where required);

.1.16 drawings of securing engine structure to the foundation;

.1.17 drawings of main piping and systems associated with engine:

starting air,

fuel oil,

lubricating oil,

cooling water,

control, governing and protection,

shielding and insulation of the gas exhaust pipes;

.1.18 drawings of fuel injection pumps, nozzles, high pressure delivery fuel oil piping and their protection in case of damage, the documentation containing specification of the maximum allowable pressure, dimensions and materials of the fuel injection system parts, subject to high-pressure action;

.1.19 drawings of the crankcase safety valves and scavenging air manifold and their arrangement as well as schematic layout of engine crankcase oil mist detection/monitoring and alarm system (having regard to 2.3.9.7 and 2.3.11);

.1.20 strength calculations pertaining to machinery parts regulated by the Rules;

.1.21 test program for prototype and production models of engines;

.1.22 engine operation and service manual containing the maintenance and repair requirements, and information on any tool and gauges, which shall be used during assembly and adjustments while the above requirements are fulfilled;

.1.23 drawing of the torsional vibration damper or anti-vibrator (if provided), description and operation manual;

.1.24 drawings of camshaft gear and chain drive;

.1.25 drawings of hydraulic system for engine valve control;

.1.26 where engines incorporate the electronic control system, the failure mode and effects analysis shall be submitted to demonstrate that the failure of electronic control system will not result in the loss of essential services for the operation of the engine and that operation of the engine will not be lost or degraded beyond the stated performance criteria of the engine;

.2 on all other machinery regulated by the present part of the Rules except for internal combustion engines:

.2.1 machinery particulars as per data sheet or specification;

.2.2 general view plans with machinery longitudinal and transverse sections;

.2.3 drawings of bedplates, crankcases, engine beds, casings, covers and other parts, cast or welded, with welding details and instructions;

.2.4 drawings of crankshafts, thrust shafts, output and other shafts as well as their drives (gears);

.2.5 drawings of connecting rods, piston rods and pistons;

.2.6 drawings of cylinder covers and cylinder liners;

.2.7 drawings of pinions, gear wheels and their shafts;

.2.8 drawings of driving and driven parts of hydraulic gears, disengaging and flexible couplings;

.2.9 drawing of thrust block built in the machinery;

.2.10 drawings of rotors of steam and gas turbines and compressors as well as discs and impellers;

.2.11 drawings of high pressure fuel oil piping and their protection in case of damage;

.2.12 drawings of insulation and lining of gas exhaust piping associated with machinery;

.2.13 drawings of main pipings and fuel oil, lubricating oil, cooling, gas exhaust, scavenging, air control, governing, alarm, protection and other systems, associated with machinery;

.2.14 drawings of machinery hydraulic piping systems with hydraulic drives;

.2.15 drawings of securing machinery structure to bedplate and arrangement of foundation bolts (only for main machinery, electric generator drives, steering gears; anchor, mooring and towing machinery);

.2.16 strength calculations of machinery parts, regulated by the Rules;

.2.17 list of main parts of machinery with material specification and all details for test pressure values (if required);

.2.18 operation and service manuals;

.2.19 test programs for prototype and production models of machinery.

1.2.4 Drawings of machinery parts listed in Table 1.2.4 but not mentioned in 1.2.3 are subject to agreement with the Register.

Table 1.2.4

Nos	Item	Material	Chapter of Part XIII "Materials"
1	**Internal combustion engines**		
1.1	Bedplate, crankcase, frames, thrust bearing casing, main bearing caps of suspended crankshafts	Cast iron	3.9, 3.10
		Cast steel	3.8
		Forged steel	3.7
		Rolled steel	3.2
		Aluminium alloy	5.2
1.2	Cylinder block, cylinder covers, valve housings	Cast iron	3.9, 3.10
		Cast steel	3.8
		Forged steel	3.7
1.3	Cylinder liners and their parts	Cast iron	3.9, 3.10
		Cast steel	3.8
		Forged steel	3.7
1.4	Piston	Cast iron	3.9, 3.10
		Cast steel	3.8
		Forged steel	3.7
		Aluminium alloy	5.2
1.5	Piston rod, crossheads, gudgeon pins	Forged steel	3.7
1.6	Connecting rod with crank bearing covers	Forged steel	3.7
		Cast steel	3.8
1.7	Crankshaft, thrust shaft of the built-in thrust bearing	Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9
1.8	Crankshaft detachable couplings	Forged steel	3.7
		Cast steel	3.8
1.9	Bolts and studs of the crossheads, main and connecting rod bearings, cylinder covers	Forged steel	3.7
1.10	Tie rods	Forged steel	3.7
1.11	Inlet and outlet valves	Forged steel	3.7
1.12	Connecting bolts of crankshaft sections	Forged steel	3.7
1.13	Supercharger, i.e. shaft and rotor including blades (turbochargers and starting compressors (inclusive of Roots blowers) except auxiliary blowers)	Forged steel	3.7
1.14	Camshaft, camshaft drive gears	Forged steel	3.7
1.15	Speed governors and overspeed devices	—	—
1.16	Safety valves of the crankcase (for engines having a bore exceeding 200 mm)	—	—
1.17	Counterweights if they are not integral with the crankshaft	Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9

Nos	Item	Material	Chapter of Part XIII "Materials"
1.18	Main, connecting-rod, crank bearings	—	—
1.19	High pressure fuel oil pumps	—	—
1.20	Nozzles	—	—
1.21	High-pressure oil fuel injection pipes	Rolled steel	3.4
2	**Steam turbines**		
2.1	Casings of turbines	Cast iron	3.9, 3.10
		Cast steel	3.8
		Rolled steel	3.3
2.2	Manoeuvring gear casings, nozzle boxes	Cast steel	3.8
2.3	Solid-forged rotors, shafts and disks	Forged steel	3.7
2.4	Blades	Forged steel	3.7
		Cast steel	3.8
2.5	Shrouds and lashing wire	—	—
2.6	Nozzles and diaphragms	Cast iron	3.9, 3.10
		Forged steel	3.7
		Cast steel	3.8
2.7	Gland seals	—	—
2.8	Couplings	Forged steel	3.7
		Cast steel	3.8
2.9	Bolts for joints of rotor parts, split casings and couplings	Forged steel	3.7
3	**Gears, elastic and disengaging couplings**		
3.1	Casing	Rolled steel	3.2
		Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9, 3.10
		Aluminium alloy	5.2
3.2	Shafts	Forged steel	3.7
3.3	Pinions, wheels, wheel rims	Forged steel	3.7
3.4	Coupling components transmitting the torque:	Cast steel	3.8
	.1 rigid components	Rolled steel	3.2
		Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9
		Aluminium alloy	5.1, 5.2
		Rubber, synthetic material	—
	.2 elastic components	Spring steel	—
3.5	Coupling bolts	Forged steel	3.7
4	**Compressors and piston-type pumps**		
4.1	Crankshaft	Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9
4.2	Piston rod	Forged steel	3.7
4.3	Connecting rod	Forged steel	3.7
		Cast iron	3.9
		Aluminium alloy	5.2
4.4	Piston	Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9, 3.10
		Cooper alloy	4.1
		Aluminium alloy	5.2
4.5	Cylinder block, cylinder covers	Cast steel	3.8
		Cast iron	3.9, 3.10
4.6	Cylinder liner	Cast iron	3.9. 3.10
5	**Centrifugal pumps, fans and air blowers**		
5.1	Shaft	Rolled steel	3.2
		Forged steel	3.7
5.2	Impeller	Cast steel	3.8
		Copper alloy	4.1
		Aluminium alloy	5.2
5.3	Casing	Rolled steel	3.2
		Cast steel	3.8
		Cast iron	3.9, 3.10
		Copper alloy	4.1
		Aluminium alloy	5.2

Table 1.2.4 - continued

Nos	Item	Material	Chapter of Part XIII "Materials"
6	**Steering gear**		
6.1	Tiller of main and emergency gear	Forged steel	3.7
		Cast steel	3.8
6.2	Rudder quadrant	Cast steel	3.8
6.3	Rudder stock yoke	Forged steel	3.7
6.4	Pistons with rods	Forged steel	3.7
		Cast steel	3.8
6.5	Cylinders	Steel tube	3.4
		Cast steel	3.8
		Cast iron	3.9, 3.10
6.6	Drive shaft	Forged steel	3.7
6.7	Pinions, gear wheels, tooth rims	Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9
7	**Windlasses, capstans, mooring and towing winches**		
7.1	Drive, intermediate and output shafts	Forged steel	3.7
7.2	Pinions, gear wheels and tooth rims	Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9
7.3	Sprockets	Cast steel	3.8
		Cast iron	3.9, 3.10
7.4	Claw clutches	Forged steel	3.7
		Cast steel	3.8
7.5	Band brakes	Rolled steel	3.2
8	**Hydraulic drives, screw, gear and rotary pumps**		
8.1	Shaft, screw, rotor	Forged steel	3.7
		Cast steel	3.8
		Copper alloy	4.1
8.2	Piston rod	Forged steel	3.7
		Copper alloy	4.1
8.3	Piston	Forged steel	3.7
		Cast steel	3.8
8.4	Casing, cylinder and housing of screw pump	Cast steel	3.8
		Cast iron	3.9, 3.10
		Copper alloy	4.1
8.5	Pinions	Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9, 3.10
		Copper alloy	4.1
9	**Centrifugal fuel and lubricating oil separators**		
9.1	Bowl shaft	Forged steel	3.7
9.2	Bowl body, bowl discs	Forged steel	3.7
9.3	Drive pinions	Forged steel	3.7
		Copper alloy	4.1
10	**Gas turbines**		
10.1	Casings of turbines and compressors, diaphragms and combustion chamber casings	Rolled steel	3.3
		Cast steel	3.8
10.2	Rotors and discs of turbines	Forged steel	3.7
10.3	Rotors and discs of compressors	Forged steel	3.7
10.4	Turbine blades	Rolled steel	3.3
		Forged steel	3.7
		Cast steel	3.8
10.5	Compressor blades	Forged steel	3.7
		Cast steel	3.8
10.6	Shrouds and lashing wire	—	—
10.7	Flame tubes of combustion chambers	Rolled steel	3.3
10.8	Heat-exchanging surfaces of regenerators	Rolled steel	3.3
10.9	Sealings	—	—
10.10	Flanges of couplings	Forged steel	3.7
		Cast steel	3.8
10.11	Bolts for joints of rotor parts, turbine and compressor split casings	Forged steel	3.7

N o t e . The materials shall be selected in accordance with the requirements of 1.6.

In the process of manufacture all these parts are subject to survey by the Register regarding their compliance with the approved technical documentation and the requirements of Part XIII "Materials" and Part XIV "Welding".

1.2.5 Rotors, shafts and disks of steam turbines and gas turbines engines, as well as the bolts for joints of casings of high pressure turbines are subject to ultrasonic testing during manufacture. Shafts of main gears more than 100 kg in mass, pinions, tooth rims more than 250 kg in mass are subject to ultrasonic testing during manufacture.

Parts of internal combustion engines of steel are also subject to ultrasonic testing during manufacture in accordance with the requirements of Table 1.2.5.

Table 1.2.5

Nos	Cylinder bore, mm	Part No. according to Table 1.2.4
1	Up to 400 inclusive	1.1, 1.2, 1.4, 1.6 and 1.7
2	More than 400	1.1, 1.2, 1.4, 1.5 to 1.7

Ultrasonic testing shall be carried out in accordance with the requirements of 2.2.9.2, Part XIII "Materials".

1.2.6 For the internal combustion engines the steel case and forged parts listed in Table 1.2.6, their welded connections included, shall be tested during the manufacture for the absence of the surface defects by the magnetic particle or liquid penetrant method.

Table 1.2.6

Nos	Cylinder bore, mm	Part No. according to Table 1.2.4
1	Up to 400 inclusive	1.1, 1.5, 1.6
2	More than 400	All parts

The rubber blades of main and auxiliary turbines, guide blades of main turbines and turbine blades of gas turbine engines shall also be subjected to the above testing.

1.2.7 If there are doubts about the absence of defects in the part material, the Register may require to carry out a non-destructive testing of other machinery parts and their welded connections.

1.3 HYDRAULIC TESTS

1.3.1 The machinery parts, with the exception of the internal combustion engine parts, operating under excessive pressure shall be subjected to a hydraulic test by a pressure p_{test} after final machining and before protective coating is applied. The hydraulic test pressure p_{test}, in MPa, is found by the formula

$$p_{test} = (1{,}5 + 0{,}1k)p \qquad (1.3.1)$$

where p = maximum working pressure, MPa;
k = factor taken from Table 1.3.1.

In all cases, the value of test pressure shall not be lower than the pressure setting with the safety valve fully open, but not less than 0,4 MPa for cooled spaces of parts and various seals and not less than 0,2 MPa in all other cases. If temperatures or working pressures exceed the ratings indicated in Table 1.3.1, the value of test pressure shall be approved by the Register in each case.

1.3.2 The machinery parts and assemblies may be tested separately along the spaces by test pressures prescribed in compliance with the working pressures and temperatures inside each space.

1.3.3 Parts of internal combustion engines shall be tested according to the requirements specified in Table 1.3.3.

1.3.4 The machinery parts and assemblies filled with petroleum products or their vapours (viz., reduction gear casings, sumps, etc.) under hydrostatic or atmospheric pressure shall be tested for oil-tightness by the method approved by the Register. Oil-tightness tests of welded structures may be confined to welded seams only.

Table 1.3.1

Material	Characteristic	Working temperature, °C, up to									
		120	200	250	300	350	400	430	450	475	500
Carbon steel	p, MPa	—	20	20	20	20	10	10	10	—	—
	k	0	0	1	3	5	8	11	17	—	—
Molybdenum and molybdenum-chrome steel with at least 0,4 per cent molybdenum content	p, MPa	—	—	—	—	20	20	20	20	20	20
	k	0	0	0	0	0	1	2	3,5	6	11
Cast iron	p, MPa	6	6	6	6	—	—	—	—	—	—
	k	0	2	3	4	—	—	—	—	—	—
Bronze, brass and copper	p, MPa	20	3	3	—	—	—	—	—	—	—
	k	0	3,5	7	—	—	—	—	—	—	—

Table 1.3.3

Item	Test pressure[1]
Cylinder cover, cooling space[2] Cylinder liner over the whole length of cooling space Piston crown, cooling space after assembly with the piston rod, if the latter forms a sealing	0,7 MPa
Cylinder block, cooling space Exhaust valve (body), cooling space Turbocharger, cooling space Exhaust piping, cooling space Coolers (from both sides)[3] Engine-driven pumps (lubricating oil, water, fuel booster, bilge) — working spaces Engine-driven compressors including cylinders, covers and air coolers: water side	0,4 MPa, but not less than 1,5p
air side Casings of the high pressure fuel pumps (pressure side), fuel valves and fuel pipes Scavenging pump cylinder Hydraulic system pumps and pipings, valve hydraulic drive cylinders	1,5p 1,5p or p + 30 MPa, whichever is less 0,4 MPa 1,5 p

[1] The above-stated norms may be changed for separate types of engine on agreement with the Register.
[2] In the case of steel forged cylinder cover, hydraulic testing may be substituted by a survey using non-destructive test procedures and by submitting detailed data on thicknesses and dimensions.
[3] Air coolers of turbochargers shall be subjected to hydraulic test only from the water side.

1.4 OPERATION TESTS

1.4.1 On completion of assembly, adjustment and running-in, each piece of machinery shall be bench tested under the load conditions prior to installation aboard the ship. The test program shall be approved by the Register.

In particular cases, bench tests may be substituted by tests aboard the ship on agreement with the Register.

1.4.2 The pilot models of the machinery shall be tested under a program providing for checking reliability and long-term operational capacity of certain unit components and of the machinery as a whole.

1.5 GENERAL TECHNICAL REQUIREMENTS

1.5.1 Machinery indicated in 1.1 shall remain operative under environmental conditions specified in 2.3, Part VII "Machinery Installations".

1.5.2 The design of the main engines intended for installation aboard single-shaft ships shall provide, as a rule, for a possibility of emergency operation at reduced power in case of a failure of parts, the replacement of which cannot be carried out aboard the ship or demands much time.

1.5.3 The forged, cast and welded steel parts, as well as cast iron parts of the machinery shall be heat treated during manufacture in compliance with the requirements of 3.7.4, 3.8.4, 3.9.4, 3.10.4, Part XIII "Materials" and 2.1.16, Part XIV "Welding".

1.5.4 The fasteners used in moving parts of machinery and gears, as well as fasteners difficult for access shall be properly designed or shall have special arrangements aimed at preventing their self-loosening and self-releasing.

1.5.5 The heated surfaces of machinery and equipment shall be insulated according to the requirements of 4.6, Part VII "Machinery Installations".

1.5.6 The machinery parts that are in contact with a corrosive medium shall be made of an anticorrosive material or shall have corrosion-resistant coatings.

Sea water cooling spaces of engines and coolers shall be provided with protectors.

1.5.7 The remote and automatic control and protection systems, the warning alarms included, shall comply with the requirements specified in Part XV "Automation".

1.5.8 Pumping and piping of machinery shall comply with the relevant requirements of Part VIII "Systems and Piping".

1.5.9 Electrical equipment of engines and auxiliaries shall comply with the relevant requirements of Part XI "Electrical Equipment".

1.6 MATERIALS AND WELDING

1.6.1 Materials intended for manufacture of the machinery parts stated in column 4 of Table 1.2.4 shall comply with the requirements of the appropriate chapters of Part XIII "Materials". Materials of parts stated in items 1.13, 2.5, 2.7 to 2.9, 3.4, 3.5, 5.3, 6.3 to 6.5, 7.3 to 7.5, 8.1 to 8.5, 9.1 to 9.3, 10.6, 10.8 to 10.11 of Table 1.2.4 may be also selected according to the standards. In this case, the application of materials is subject to agreement with the Register during consideration of the technical documentation.

1.6.2 Materials of parts listed in 2.1 to 2.4, 2.6, 3.2, 3.3, 3.4.1, 4.1, 6.1, 6.6, 7.1, 10.1 to 10.5 of Table 1.2.4 are subject to survey by the Register during manufacture.

Materials of the parts of internal combustion engines are subject to survey by the Register in accordance with Table 1.6.2.

Table 1.6.2

Nos	Cylinder bore, mm	Part No. according to Table 1.2.4
1	Up to 300 inclusive	1.1, 1.5, 1.6, 1.7, 1.9
2	From 301 to 400 inclusive	1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 1.9, 1.11, 1.13
3	More than 400	All parts from 1.1 to 1.13

At the discretion of the Register the survey may also be required during manufacture of pipes and fittings of the pressure systems associated with the engine.

1.6.3 When the alloy steels, including heat resistant, high temperature oxidation resistant and high strength steels, or alloy cast iron is used for the machinery parts, the information on chemical composition, mechanical and special properties confirming suitability of the material for intended application shall be submitted to the Register.

1.6.4 The parts of steam turbines and gas turbine engines operating under the conditions of high temperatures (400 °C and above) shall be subjected to tensile tests at the design temperature and, if necessary, the Register may require to submit the information on the average stress to produce rupture in 100000 hours at the design temperature.

1.6.5 Spheroidal or nodular graphite cast iron is allowed for use up to the temperature of 300 °C, and grey cast iron — up to 250 °C.

1.6.6 Manufacture of the machinery parts with application of welding shall comply with the requirements of Part XIV "Welding".

2 INTERNAL COMBUSTION ENGINES

2.1 GENERAL PROVISIONS

2.1.1 The requirements of the present Section are applicable to all internal combustion engines of power output 55 kW and above. Application of these requirements to the internal combustion engines of power output less than 55 kW is subject to special consideration by the Register in each case.

The requirements for dual-fuel internal combustion engines are specified in Section 9.

The Register may impose additional requirements upon the design, scope of surveys and tests of internal combustion engines with electronic control systems, based on the regulating documents developed by the Register.

2.2 GENERAL REQUIREMENTS

2.2.1 The engines shall be capable of working with an overload exceeding the rated power by at least 10 per cent for not less than one hour.

2.2.2 The engines intended to be used as main engines shall also comply with the requirements of 2.1, Part VII "Machinery Installations".

2.2.3 Irregularity of speed of a.c. diesel generating sets intended for parallel operation shall be such that the amplitude of angle oscillations of the generator shaft does not exceed $3{,}5^{\circ}/P$, where P is the number of pairs of generator poles.

2.2.4 The crosshead-type engines, which scavenge spaces are in open connection with the cylinders, shall be provided with the fire extinguishing system approved by the Register, which is entirely separate from the fire extinguishing system of the engine room (refer to Table 3.1.2.1, Part VI "Fire Protection").

The scavenge spaces of the main engines in ships with unattended machinery spaces of category A shall be equipped with a timely fire alarm and fire detection system (refer to 4.2.3.1, Part VI "Fire Protection").

2.2.5 The diesel generating sets intended as emergency units shall be provided with self-contained fuel supply, cooling and lubricating systems.

Cooling systems are considered to be self-contained if they are independent of the equipment specified in 4.3, Part VIII "Systems and piping".

2.2.6 Engines intended to drive emergency generators, which may be also used as sources of electrical power for non-emergency consumers (refer to 9.4.2, Part XI "Electrical Equipment") shall be equipped with oil fuel and lubricating oil filters, as well as with monitoring equipment, alarm and protective devices as required for prime movers of the main sources of electrical power when in unattended operation. Along with that, their oil fuel supply tanks shall be fitted with a low level alarm arranged at a level ensuring sufficient oil fuel capacity for the emergency services (refer to 13.8.5, Part VIII "Systems and Piping").

Besides, such engines shall be designed for continuous operation and shall be subjected to a planned maintenance scheme ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea.

2.2.7 The rated power of the engines shall be determined under the following conditions:

atmospheric pressure, kPa —100;
air temperature, °C — 45;
relative humidity, % — 60;
sea water temperature, °C — 32.

Other conditions may be specified in compliance with 2.3.1, Part VII "Machinery Installations".

2.2.8 In the crankshaft speed range $(0-1{,}2)$ n_r, where n_r is the rated speed, no restricted speed areas shall be permitted. Along with that, the requirements of 8.8.3 to 8.8.5, Part VII "Machinery Installations" shall be met.

2.2.9 Fuel oil and lubricating oil pipes, fittings, flanged connections, filters shall be screened or otherwise protected so that in case of their failure petroleum products falling onto hot surfaces (refer to 4.6, Part VII "Machinery Installations") is prevented.

2.2.10 Where special tools and gauges are required for maintenance purposes in compliance with 1.2.3.1.22, these shall be supplied by the manufacturer. Engine servicing shall be performed in compliance with the manufacturer's recommendations.

2.2.11 For engines with electronic control system where the basic operation processes (fuel supply, gas exchange, starting and reversing, cylinder lubrication) are performed by means of hydraulic (pneumatic) systems controlled by programmable electronic devices upon a signal from the crankshaft-position sensor, a single failure of any component of the electronic control system shall not result in the loss of manoeuvrability or in spontaneous stoppage of the engine (refer to 1.2.3.1.26).

2.3 ENGINE FRAME

2.3.1 The mating surfaces of the frame parts forming the engine crankcase shall be close-fitting and oil- and gastight as well as be fixed together by means of calibrating pieces.

2.3.2 Crankcase construction and detachable crankcase doors shall be of sufficient strength to withstand anticipated pressure that may arise during a crankcase explosion taking into account the installation of explosion relief valves in accordance with 2.3.5 to 2.3.7. Crankcase doors shall be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

A warning notice shall be fitted either on the control stand or on crankcase doors on each side of the engine. This warning notice is to specify that, whenever overheating is suspected within the crankcase, the crankcase doors shall not be opened before a reasonable time, sufficient to permit adequate cooling after stopping the engine.

2.3.3 The engine frame and conjugated parts shall be provided with draining arrangements (drain grooves, pipes, etc.) and other facilities preventing penetration of fuel and water into the circulating oil.

The cooling spaces of the cylinder blocks shall be fitted with drain arrangements providing complete drainage.

2.3.4 Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase is not permitted, except for dual fuel engines where crankcase ventilation shall be provided in accordance with 9.3.2. If a forced extraction of the oil mist atmosphere from the crankcase is provided (for mist detection purposes for instance), the vacuum in the crankcase shall not exceed 250 Pa.

For engines with power output up to 750 kW suction of gas from the crankcase by turbochargers or blowers may be admitted, provided reliable oil separators are fitted to prevent the oil from being carried into the engine with suction gas.

To avoid spread of flame following an explosion, crankcase ventilation pipes and oil drain pipes for each engine shall be independent of any other engine.

Crankcase ventilation pipes, where provided, shall be as small as practicable in order to minimise the inrush of air after a crankcase explosion. The ends of the ventilation pipes shall be fitted with flame-arresting devices and arranged so as to prevent water from getting into engine.

Ventilation pipes shall be laid to the weather deck to locations preventing the suction of vapours into accommodation and service spaces.

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

Drain openings of the crankcase shall be provided with gratings or screens to prevent stray objects from getting into the drain piping. The said requirement applies also to engines with dry crankcase.

2.3.5 Engine crankcases shall be provided with crankcase explosion relief valves as follows:

.1 engines having a cylinder bore of 200 mm and above, but not exceeding 250 mm or a crankcase volume of 0,6 m^3 and above, shall have at least one relief valve near each end, but, over eight crankthrows, an additional valve shall be fitted near the middle of the engine;

.2 engines having a cylinder bore exceeding 250 mm but not exceeding 300 mm or a crankcase volume of 0,6 m^3 and above shall have at least one valve in way of each alternate crankthrow, but, over eight crankthrows, an additional valve shall be fitted near the middle of the engine. In all cases, at least two valves shall be fitted on the crankcase;

.3 engines having a cylinder bore exceeding 300 mm or a crankcase volume of 0,6 m^3 and above shall be fitted with at least one valve in way of each main crankthrow;

.4 the scavenge spaces in open connection to the cylinders as well as separate spaces of crankcase, such as gear or chain cases for camshaft or similar drives, when the volume of such spaces exceeds 0,6 m^3 shall be fitted with explosion relief valves;

.5 the free area of each relief valve shall be not less than 45 cm^2. The combined free area of the valves fitted on an engine shall be not less than 115 cm^2 per cubic meter of the crankcase gross volume. In estimating the crankcase gross volume the stationary parts may be discounted, however the rotary and reciprocating components shall be included into the gross volume;

.6 no crankcase explosion relief valve is required for engines having a cylinder bore not exceeding 200 mm or a crankcase volume not exceeding 0,6 m^3.

2.3.6 Crankcase explosion relief valves shall be of a type approved by the Register. The requirements for the type tests of the valves — refer to Appendix 2 to Section 5, Part IV "Technical Supervision During Manufacture of Products" of the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships.

2.3.7 The crankcase explosion relief valves shall be designed and constructed to meet the following requirements:

.1 to open quickly at an overpressure of not greater than 0,02 MPa in the crankcase and to close quickly in order to prevent inrush of air into the crankcase;

.2 the valves shall be provided with flame arrester that permits flow for crankcase pressure relief in the crankcase and prevents passage of flame following a crankcase explosion;

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

.4 crankcase explosion relief valves shall be provided with lightweight spring-loaded valve discs or other quick-acting and self-closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent the inrush of air thereafter. The valve discs in crankcase explosion relief valves shall be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position;

.5 valves shall be provided with suitable markings that include the following information:

name and address of manufacturer;

designation and size;

date of manufacture;

approved installation orientation.

Note: A copy of the installation and maintenance manual shall be provided complete with the valve.

2.3.8 Engines with a cylinder bore in excess of 230 mm shall be fitted with alarm devices to give a signal indicating that the specified excess of the maximum combustion pressure in a cylinder has been reached.

2.3.9 Engines with power output of 2250 kW and over or with a cylinder bore of more than 300 mm installed in the periodically unattended machinery spaces shall be fitted with an oil mist concentration detector in the crankcase or an engine bearing temperature control system or other equivalent device. For high-speed engines the equivalent device means a number of structural measures to prevent explosions in the engine crankcase.

Along with that, the following requirements shall be complied with:

.1 where there are multi engine installations, each engine shall be provided with oil mist detection/monitoring and a dedicated alarm;

.2 oil mist detection/monitoring and alarm systems shall be capable of being tested on the test bed and board under engine at standstill and engine running at normal operating conditions;

.3 alarms and shutdowns for the oil mist detection/monitoring system shall meet the requirements of Part XV "Automation".

.4 oil mist monitoring and alarm information shall be capable of being read from a safe location away from the engine;

.5 the oil mist detection/monitoring arrangements shall provide an alarm indication in the event of a foreseeable functional failure;

.6 the oil mist detection/monitoring system shall provide an indication of the degree of obscurity of any lenses used in determination of the oil mist level;

.7 where oil mist detection/monitoring equipment includes the use of programmable electronic systems, the information relating to them shall be submitted to the Register for consideration.

2.3.10 Where crankcase oil mist detection/monitoring arrangements shall be fitted to engines they shall be of a type approved by the Register. Where sequential oil mist detection/monitoring arrangements are provided the sampling frequency and time shall be as short as reasonably practicable.

The requirements for type testing of crankcase oil mist detection/monitoring arrangements are specified in Appendix 3 to Section 5, Part IV "Technical Supervision during Manufacture of Products" of Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships.

2.3.11 Where alternative methods are provided for the prevention of the build-up of oil mist, they are subject to special consideration by the Register. In such case, in addition to the requirements of 1.2.3.1, the following information shall be included in the details to be submitted for consideration:

engine particulars (type, power, speed, bore, stroke and crankcase volume);

details of arrangements preventing the build-up of oil mist within the crankcase (e.g. bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements);

evidence to demonstrate that the arrangements are effective in preventing the build-up of potentially explosive conditions together with details of in-service experience;

operation, maintenance and test instructions.

Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements shall also be submitted to the Register for consideration.

2.4 CRANKSHAFTS

2.4.1 The check calculation method as described below is applicable to solid-forged and semi-built crankshafts of forged or cast steel intended for marine diesel engines having the cylinders either in line or in V-arrangement, with one crankthrow between main bearings.

Cast iron crankshafts may be approved on agreement with the Register, provided supporting calculations or experimental data are submitted.

2.4.2 The outlets of oil bores into crankpins and journals shall be formed in such a way that the safety margin against fatigue at the oil bores is not less than that acceptable in the fillets. The engine manufacturer, if requested by the Register, shall submit documentation supporting his oil bore design.

2.4.3 For the calculation of crankshafts, the documents and particulars listed in the following shall be submitted:

crankshaft drawing, which shall contain all scantlings required by the Chapter;

type designation and kind of engine (in-line engine or V-type engine with adjacent connecting rods, forked connecting rod or articulated-type connecting rod);

operating and combustion method (direct injection, precombustion chamber, etc.);

number of cylinders;

rated power, kW;

rated engine speed, $\min^{-1}$;

sense of rotation (Fig. 2.4.3-1);

firing order with the respective ignition intervals and, where necessary, V-angle α_v, deg. (refer to Fig. 2.4.3-1);

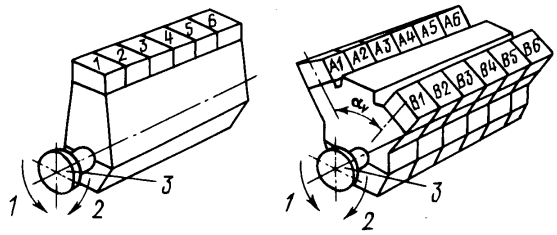


Fig. 2.4.3-1 Sense of crankshaft rotation:
1 — counter-clockwise
2 — clockwise
3 — driving shaft flange

cylinder diameter, mm;

stroke, mm;

maximum cylinder pressure P_{max}, MPa;

charge air pressure, in MPa, before inlet valves or scavenge ports, whichever applies;

nominal compression ratio;

connecting rod length L_H, mm;

oscillating weight of one crank gear, in kg (in case of V-type engines, where necessary, also for the cylinder unit with master and articulated-type connecting rod or forked and inner connecting rod);

digitalized gas-pressure-versus-crank-angle curve presented at equidistant intervals and integrally divisible by the V-angle, but not more than 5°.

For bending moments, shearing forces and torques, refer to 2.4.4.2, 2.4.5.1.

Details of crankshaft material:

material designation (according to standards, etc.);

chemical composition;

tensile strength, σ_B, MPa;

yield stress, σ_S, MPa;

reduction in area at break, Z, %;

elongation, A_5, %;

impact energy, KV, J;

method of material melting process (basic oxygen furnace, open-hearth furnace, electric furnace, etc.);

type of forging (free form forged, continuous grain flow forged, drop forged, etc.; with description of the forging process);

heat treatment;

surface treatment of fillets, journals and pins (induction hardened, open flame hardened, nitrided, rolled, shot peened, etc. with full details concerning hardening);

hardness at surface, HV;

hardness as a function of depth, mm;

extension of surface hardening.

For engines with articulated-type connecting rod (refer to Fig. 2.4.3-2), the following details shall be submitted additionally:

distance to link point L_A, mm;

link angle α_N, deg.;

connecting rod length L_H, mm;

articulated-type connecting rod length L_N, mm.

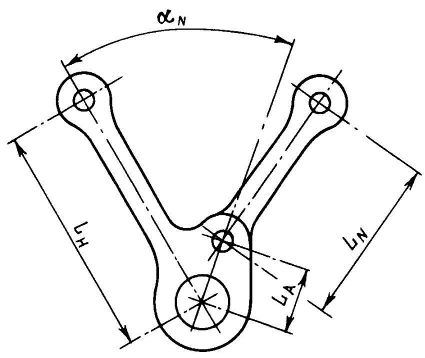


Fig. 2.4.3-2 Articulated-type connecting rod

2.4.4 Calculation of alternating stresses due to bending moments and shearing forces.

2.4.4.1 Assumptions.

The calculation is based on a statically determined system, so that only one single crankthrow is considered of which the journals are supported in the centre of adjacent bearings and which is subject to gas and inertia forces (refer to Figs. 2.4.4.1-1 and 2.4.4.1-2).

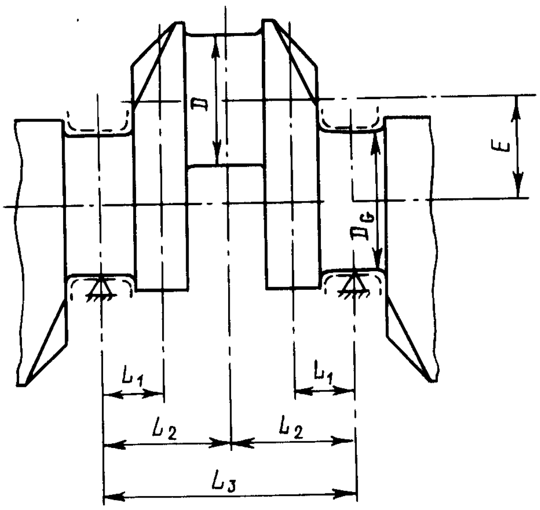


Fig. 2.4.4.1-1 Crank throw for in-line engine

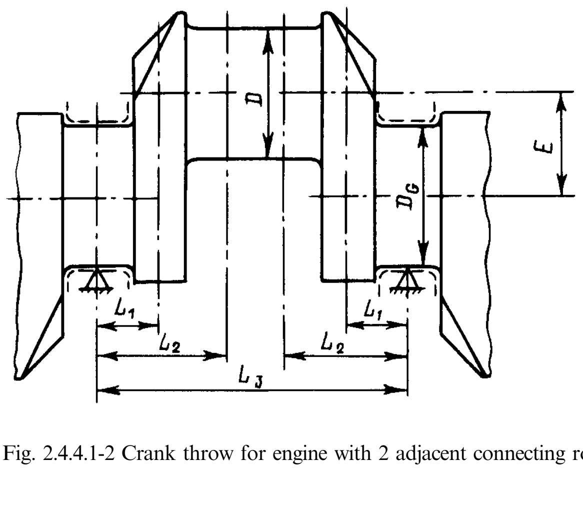


Fig. 2.4.4.1-2 Crank throw for engine with 2 adjacent connecting rods

The nominal bending moment is taken as a moment with the bending lever (distance L_1 for fillets and L_2 for oil bore, for semi-built crankshafts with recess of crankpin exceeding the value of the radius of that crankpin fillet, the distance L_1 is specified as shown on Fig. 2.4.6.1-2), due to the radial components of the connecting rod force. For crankthrows with two connecting rods acting upon one crankpin the nominal bending moment is taken as a bending moment obtained by superposition of two bending moment loads according to phase.

The nominal alternating stresses due to bending moments and shearing forces shall be related to the cross-sectional area of the crank web in the centre of the overlap of the pins (refer to Fig 2.4.6.1-1) or passing though the centre of the fillet radius of the crankpin for pins which do not overlap (refer to Fig. 2.4.6.1-2).

2.4.4.2 Calculation of nominal alternating bending and shearing stresses.

The maximum and minimum bending moment values $M_{B\max}$, $M_{BO\max}$, $M_{B\min}$ and $M_{BO\min}$ as well as the maximum and minimum shearing force values $Q_{\max}$ and $Q_{\min}$ shall be submitted to the Register, determined by calculating the radial forces acting upon the crankpin owing to gas and inertia forces.

On agreement with the Register, a simplified calculation of the radial forces may be submitted.

The nominal alternating bending moment M_{BN}, in N·m, shall be determined as

$$M_{BN} = \pm\frac{1}{2}(M_{B\max} - M_{B\min}). \qquad (2.4.4.2\text{-}1)$$

The nominal alternating bending stress in fillets σ_{BN}, in MPa, shall be determined by the formula

$$\sigma_{BN} = \pm\frac{M_{BN}}{W_{eq}}10^3 K_e \qquad (2.4.4.2\text{-}2)$$

where $W_{eq} = BW^2/6$

W_{eq} = equatorial moment of resistance related to cross-sectional area of web, mm^3;

B and M = refer to 2.4.6;

K_e = factor equal to 0,8 for 2-stroke engines and 1,0 for 4-stroke engines.

The nominal alternating shearing stress in fillets σ_{QN}, MPa, shall be determined by the formula

$$\sigma_{QN} = \pm\frac{Q_N}{F}K_e \qquad (2.4.4.2\text{-}3)$$

where $Q_N = \pm 0{,}5(Q_{\max} - Q_{\min})$;

Q_N = nominal alternating shearing force, N;

$F = BW$;

F = area related to cross-section of web, mm^2.

Nominal alternating bending stress in outlet of crankpin oil bore, σ_{BON}, MPa, shall be determined by the formula

$$\sigma_{BON} = \pm\frac{M_{BON}}{W_e}10^3 \quad (2.4.4.2\text{-}4)$$

where M_{BON} = nominal alternating bending moment at the outlet of crankpin of oil bore, N·m;
$M_{BON} = \pm 0,5(M_{BO\max} - M_{BO\min})$;
M_{BO} = vector sum of alternating bending moments M_{BTO} and M_{BRO} due to tangential and radial force, respectively, N·m, $M_{BO} = (M_{BTO}\cos\psi + M_{BRO}\sin\psi)$;
ψ = angle between oil bore and horizontal measured in the sense of rotation of the crankshaft (refer to Fig. 2.4.4.2), deg;
W_e = section modulus related to cross-section of axially bored crankpin, mm^3;
$W_e = \frac{\pi}{32}\left(\frac{D^4 - D_{BH}^4}{D}\right)$;
D and D_{BH} = refer to 2.4.6.

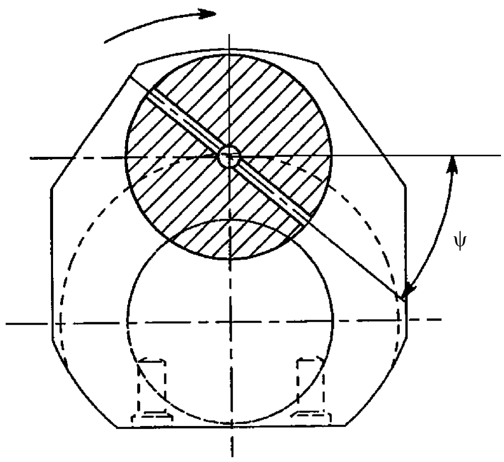


Fig. 2.4.4.2 Sectional view of the crankpin in way of oil bore

2.4.4.3 Calculation of alternating bending stresses in fillets.

The alternating bending stress in a crankpin fillet σ_{BH}, in MPa, shall be determined by the formula

$$\sigma_{BH} = \pm(\alpha_B \sigma_{BN}) \quad (2.4.4.3\text{-}1)$$

where α_B = stress concentration factor for bending in crankpin fillet (for determination, refer to 2.4.6).

The alternating bending stress in a journal fillet σ_{BG}, in MPa, shall be determined by the formula

$$\sigma_{BG} = \pm(\beta_B \sigma_{BN} + \beta_Q \sigma_{QN}) \quad (2.4.4.3\text{-}2)$$

where β_B = stress concentration factor for bending in journal fillet (for determination, refer to 2.4.6);
β_Q = stress concentration factor for shearing (for determination, refer to 2.4.6).

2.4.4.4 Calculation of alternating bending stresses in outlet of crankpin oil bore.

The alternating bending stress BO, MPa, in outlet of crankpin oil bore shall be determined by the formula

$$\sigma_{BO} = \pm(\gamma_B \sigma_{BON}) \quad (2.4.4.4)$$

where γ_T = bending stress concentration factor in outlet of crankpin oil bore (for determination of value — refer to 2.4.6).

2.4.5 Calculation of alternating torsional stresses.

2.4.5.1 Calculation of nominal alternating torsional stresses.

The calculation for nominal alternating torsional stresses shall be undertaken by the engine manufacturer according to the information below. The maximum values obtained from such calculations shall be submitted to the Register.

The maximum and minimum alternating torques shall be ascertained for each crankthrow and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 16th order for 2-stroke cycle engines and from 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance shall be made for the dampings that exist in the system and for unfavourable conditions (misfiring in one of the cylinders). The speed ranges shall be selected in such a way that the transient response can be recorded with sufficient accuracy.

The nominal alternating torsional stress τ_N, in MPa, referred to crankpin or journal shall be determined by the formula

$$\tau_N = \pm\frac{M_T}{W_P}10^3 \quad (2.4.5.1)$$

where M_T = nominal alternating torque, N·m, to be determined by the formula
$$M_T = \pm\frac{1}{2}(M_{T\max} - M_{T\min});$$

$M_{T\max}$, $M_{T\min}$ = extreme values of the torque with consideration of the mean torque, N·m;
W_p = polar moment of resistance related to cross-sectional area of bored crankpin or bored journal, in mm^3, and determined by the formulae:

$$W_P = \frac{\pi}{16}\left(\frac{D^4 - D_{BH}^4}{D}\right) \quad \text{or}$$

$$W_P = \frac{\pi}{16}\left(\frac{D_G^4 - D_{BG}^4}{D_G}\right),$$

D, D_{BH} and D_{BG}, refer to 2.4.6.

2.4.5.2 Calculation of alternating torsional stresses in fillets.

In the crankpin fillet, the alternating torsional stress, MPa, shall be determined by the formula

$$\tau_H = \pm(\alpha_T \tau_N) \quad (2.4.5.2\text{-}1)$$

where α_T = stress concentration factor for torsion in crankpin fillet (for determination, refer to 2.4.6).

In the journal fillet, the alternating torsional stress, in MPa, shall be determined by the formula

$$\tau_G = \pm(\beta_T \tau_N) \quad (2.4.5.2\text{-}2)$$

where β_T = stress concentration factor for torsion in journal fillet (for determination, refer to 2.4.6).

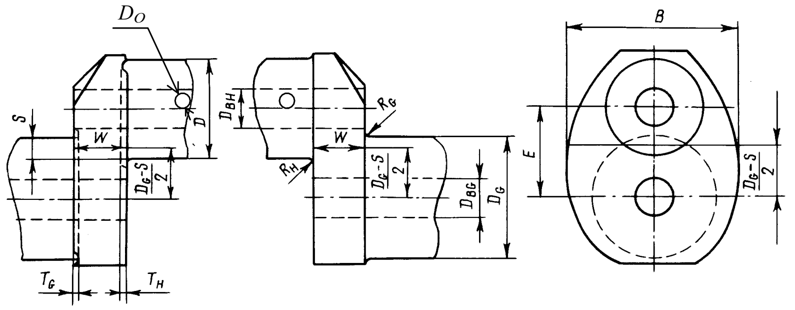


Fig. 2.4.6.1-1 Crank dimensions necessary for the calculation of stress concentration factors:
D = crankpin diameter, mm; D_{BH} = diameter of bore in crankpin, mm; R_H = fillet radius of crankpin, mm; T_H = recess of crankpin, mm;
D_G = journal diameter, mm; D_{BG} = diameter of bore in journal, mm; D_O = diameter of oil bore in crankpin, mm;
R_G = fillet radius of journal, mm; T_G = recess of journal, mm; E = pin eccentricity, mm;
S = pin overlap,mm; $S = (D - D_G)/2 - E$; W, B = web thickness and width, mm

2.4.5.3 Calculation of alternating torsional stresses in outlet of crankpin oil bore.

The alternating torsional stress σ_{TO}, MPa, in outlet of crankpin oil bore shall be determined by the formula

$$\sigma_{TO} = \pm(\gamma_T \tau_N) \qquad (2.4.5.3)$$

where γ_T = torsional stress concentration factor in outlet of crankpin oil bore (for determination of value — refer to 2.4.6).

2.4.6 Calculation of stress concentration factors.

2.4.6.1 Where the stress concentration factor cannot be furnished by reliable measurements the values may be evaluated by means of the formulae according to 2.4.6.2, 2.4.6.3 and 2.4.6.4 applicable to the fillets and outlets of crankpin oil bores of solid-forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only.

All crank dimensions necessary for the calculation of stress concentration factors are shown in Fig. 2.4.6.1-1 and Fig. 2.4.6.1-2.

For the calculation of stress concentration factors in crankpin and journal fillets and for outlet of the crankpin oil bore, the following related dimensions will be applied:

$$s = S/D \text{ with } s \leqslant 0,5;$$

$$w = W/D \text{ with } 0,2 \leqslant w \leqslant 0,8 \text{ и } T_H \leqslant R_H;$$

$$w = W_{red}/D \text{ with } 0,2 \leqslant w \leqslant 0,8 \text{ и } T_H > R_H;$$

$$b = B/D \text{ with } 1,1 \leqslant b \leqslant 2,2;$$

$$d_G = D_{BG}/D \text{ with } 0 \leqslant d_G \leqslant 0,8;$$

$$d_H = D_{BH}/D \text{ with } 0 \leqslant d_H \leqslant 0,8;$$

$$d_O = D_O/D \text{ with } 0 \leqslant d_O \leqslant 0,2;$$

$$t_H = T_H/D; \; t_G = T_G/D;$$

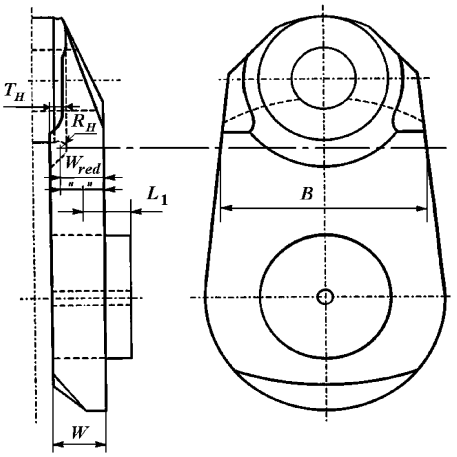


Fig. 2.4.6.1-2 Crank dimensions without web overlap necessary for calculation of stress concentration factors at $T_H > R_H$:
W_{red} = design thickness of web, mm; $W_{red} = W - T_H + R_H$

for crankpin fillets, $r = R_H/D$ with $0,03 \leqslant r \leqslant 0,13$;
for journal fillets, $r = R_G/D$ with $0,03 \leqslant r \leqslant 0,13$.

The factor f_t, which accounts for the influence of a recess in the fillets is not considered if the values of $f_t < 1$ ($f_t = 1$).

The factors $f(s, w)$ and $f(r, s)$ at the relative overlap of pins $s < -0,5$ shall be evaluated replacing actual value of s by $-0,5$.

2.4.6.2 Crankpin fillet.

The stress concentration factor for bending (α_B) is

$$\alpha_B = 2,6914 f(s, w) f(w) f(b) f(r) f(d_G) f(d_H) f_t \qquad (2.4.6.2\text{-}1)$$

where $f(s, w) = -4,1883 + 29,2004w - 77,5925w^2 + 91,9454w^3 - 40,0416w^4 + (1 - s)(9,5440 - 58,3480w + 159,3415w^2 - 192,5846w^3 + 85,2916w^4) + (1 - s)^2 \times (-3,8399 + 25,0444w - 70,5571w^2 + 87,0328w^3 - 39,1832w^4)$;

$f(w) = 2,1790w^{0,7171}$;

$f(b) = 0,6840 - 0,0077b + 0,1473b^2$;

$f(r) = 0,2081r^{(-0,5231)}$;

$f(d_G) = 0,9993 + 0,27d_G - 1,0211d_G^2 + 0,5306d_G^3$;

$f(d_H) = 0,9978 + 0,3145d_H - 1,5241d_H^2 + 2,4147d_H^3$;

$f_t = 1 + (t_H + t_G)(1,8 + 3,2s)$.

The stress concentration factor for torsion (α_T) is

$$\alpha_T = 0{,}8f(r,\ s)\ f(b)\ f(w) \qquad (2.4.6.2\text{-}2)$$

where $f(r,s) = r^{(-0{,}322+0{,}1015(1-s))}$;
$f(b) = 7{,}8955 - 10{,}654b + 5{,}3482b^2 - 0{,}857b^3$;
$f(w) = w^{(-0{,}145)}$.

2.4.6.3 Journal fillet.

The stress concentration factor for bending (β_B) is

$$\beta_B = 2{,}7146f_B(s,\ w)\ f_B(w)\ f_B(b)\ f_B(r)\ f_B(d_G)\ f_B(d_H)f_t \qquad (2.4.6.3\text{-}1)$$

where $f_B(s,\ w) = -1{,}7625 + 2{,}9821w - 1{,}5276w^2 + (1-s)(5{,}1169 - 5{,}8089w + 3{,}1391w^2) + (1-s)^2(-2{,}1567 + 2{,}3297w - 1{,}2952w^2)$;
$f_B(w) = 2{,}2422w^{0{,}7548}$;
$f_B(b) = 0{,}5616 + 0{,}1197b + 0{,}1176b^2$;
$f_B(r) = 0{,}1908r^{(-0{,}5568)}$;
$f_B(d_G) = 1{,}0012 - 0{,}6441d_G + 1{,}2265d_G^2$;
$f_B(d_H) = 1{,}0012 - 0{,}1903d_H + 0{,}0073d_H^2$;
$f_t = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$.

The stress concentration factor for shearing (β_Q) is

$$\beta_Q = 3{,}0128f_Q(s)\ f_Q(w)\ f_Q(b)\ f_Q(r)\ f_Q(d_H)f_t \qquad (2.4.6.3\text{-}2)$$

where $f_Q(s) = 0{,}4368 + 2{,}1630(1-s) - 1{,}5212(1-s)^2$;
$f_Q(w) = w/(0{,}0637 + 0{,}9369w)$;
$f_Q(b) = -0{,}5 + b$;
$f_Q(r) = 0{,}5331r^{(-0{,}2038)}$;
$f_Q(d_H) = 0{,}9937 - 1{,}1949d_H + 1{,}7373d_H^2$;
$f_t = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$.

The stress concentration factor for torsion (β_T) is

$$\beta_T = \alpha_T \qquad (2.4.6.3\text{-}3)$$

if the diameters and fillet radii or crankpin and journal are the same, and

$$\beta_T = 0{,}8f(r,\ s)\ f(b)\ f(w) \qquad (2.4.6.3\text{-}4)$$

if crankpin and journal diameters and/or radii are of different sizes

where $f(r,\ s)$; $f(b)$; $f(w)$ shall be determined by Formula (2.4.6.2-2); in this case, r is the ratio of the journal fillet radius to the journal diameter $r = R_G/D_G$.

2.4.6.4 Outlet of oil bore.

The stress concentration factor for bending γ_B shall be determined by the formula:

$$\gamma_B = 3 - 5{,}88d_O + 34{,}6d_O^2. \qquad (2.4.6.4\text{-}1)$$

The stress concentration factor for torsion γ_T shall be determined by the formula:

$$\gamma_T = 4 - 6d_O + 30d_O^2. \qquad (2.4.6.4\text{-}2)$$

2.4.7 Additional bending stresses.

In addition to the alternating bending stresses in fillets (refer to 2.4.4.3) further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations shall be considered by applying σ_{add} as given in Table 2.4.7.

For crosshead type engines the additional stress (30 MPa) includes stress due to axial vibrations (20 MPa) and stress due to misalignment and bedplate deformation (10 MPa).

Table 2.4.7

Values of coefficient k'

Type of engine	σ_{add}, MPa
Crosshead	± 30
Trunk piston	± 10

It is recommended that a value of 20 MPa be used where axial vibration calculation results of the complete dynamic system engine/shafting/gearing/propeller) are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

2.4.8 Calculation of equivalent alternating stresses.

For the crankpin fillet, the equivalent alternating stress σ_{VH}, in MPa, shall be determined by the formula

$$\sigma_{VH} = \pm\sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3\tau_H^2}\,. \qquad (2.4.8\text{-}1)$$

For the journal fillet, the equivalent alternating stress σ_{VG}, in MPa, shall be determined by the formula

$$\sigma_{VG} = \pm\sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3\tau_G^2}\,. \qquad (2.4.8\text{-}2)$$

For the outlet of crankpin oil bore, the equivalent alternating stress σ_{VO} in MPa shall be determined by the formula

$$\sigma_{VO} = +\frac{1}{3}\sigma_{BO}\left[1 + 2\sqrt{1 + 2{,}25(\sigma_{TO}/\sigma_{BO})^2}\right]. \qquad (2.4.8\text{-}3)$$

For other parameters, refer to 2.4.4.3, 2.4.5.2 and 2.4.7.

2.4.9 Calculation of fatigue strength.

Where the fatigue strength for a crankshaft cannot be furnished by reliable measurements, the fatigue strength σ_{DWH}, σ_{DWG} and σ_{DWO} in MPa, may be evaluated by means of the following formulae:

related to the crankpin diameter:

$$\sigma_{DWH} = \pm K(0{,}42\sigma_B + 39{,}3)(0{,}264 + 1{,}073D^{-0{,}2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B}\sqrt{\frac{1}{R_H}}); \qquad (2.4.9\text{-}1)$$

related to the journal diameter:

$$\sigma_{DWG} = \pm K(0{,}42\sigma_B + 39{,}3)(0{,}264 + 1{,}073D_G^{-0{,}2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B}\sqrt{\frac{1}{R_G}}); \qquad (2.4.9\text{-}2)$$

related to the crankpin in outlet of crankpin oil bore:

$$\sigma_{DWO} = K(0{,}42R_m + 39{,}3)(0{,}264 + 1{,}073D^{-0{,}2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B}\sqrt{\frac{2}{D_O}}) \qquad (2.4.9\text{-}3)$$

where K = factor for different types of forged and cast crankshafts without surface treatment equal to:

1,05 for continuous grain flow forged or drop-forged crankshafts, applied only to fatigue strength in a fillet;
1,0 for free form forged crankshafts;
0,93 for cast steel crankshafts;
for crankshafts subject for surface treatment $K = 1,3$;

σ_B = minimum tensile strength of crankshaft material, MPa.

For other parameters refer to 2.4.6.1. However, it shall be considered that for calculation purposes R_H, R_G and $D_O/2$ shall not be taken less than 2 mm.

Where the results of the fatigue tests conducted on full size crankthrows or crankshafts, which have been subjected to surface treatment are available, the K factors shall be used based on the tests.

In each case the experimental values of fatigue strength testing carried out with full size crankthrows or crankshafts are subject to special consideration by the Register in each case. The survival probability for fatigue strength values derived from testing shall not be less than 80 per cent of the average value.

2.4.10 Calculation of shrink-fits of semi-built crankshafts.

2.4.10.1 All crank dimensions necessary for the calculation of the shrink-fit are shown in Fig. 2.4.10.1.

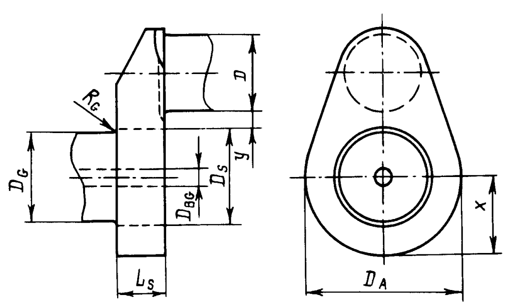


Fig. 2.4.10.1 Crank throw of semi-built crankshaft:

D_S = shrink diameter (mm);
L_S = length of shrink-fit (mm);
D_A = outside diameter of web or twice the minimum distance x between centre-lines of journals and outer contours of web, whichever is less (mm);
y = distance between the adjacent generating lines of journal and pin (mm) $y \geqslant 0,05D_S$:
Where y is less than $0,1D_S$, special consideration shall be given to the effect of stress due to the shrink on the fatigue strength at the crankpin fillet (For other parameters, refer to 2.4.6.1)

The radius of the transition from the journal to the shrink diameter shall not be less than the greater of the two values:

$$R_G \geqslant 0,015D_G \text{ and } R_G \geqslant 0,5(D_s - D_G).$$

The actual oversize Z of the shrink-fit shall be within the limits Z_{min} and Z_{max} calculated in accordance with 2.4.10.2 to 2.4.10.4.

The necessary minimum oversize is determined by the greater value calculated in accordance with 2.4.10.2 and 2.4.10.3.

2.4.10.2 The calculation of the minimum oversize Z_{min} shall be carried out for the crankthrow with the maximum torque $M_{T\max}$ (refer to 2.4.5.2) using the formula

$$Z_{min} \geqslant \frac{4 \cdot 10^3 \, S_R M_{T\max}}{\pi \mu E_m D_S L_S} \, \frac{1 - Q_A^2 Q_S^2}{(1 - Q_A^2)(1 - Q_S^2)} \quad (2.4.10.2)$$

where Z_{min} = minimum oversize, mm;
S_R = safety factor against slipping to be taken not less than 2;
μ = coefficient for static friction equal to 0,20 where $L_S/D_S \geqslant 0,40$;
E_m = Young's modulus, MPa;
$Q_A = D_S/D_A$, $Q_S = D_{BG}/D_S$.

2.4.10.3 In addition to 2.4.10.2 the minimum oversize Z_{min}, in mm, shall also be calculated according to the following formula:

$$Z_{min} \geqslant \sigma_S D_S / E_m \quad (2.4.10.3)$$

where σ_S = minimum yield stress of material for crank web, MPa.

2.4.10.4 The maximum permissible oversize Z_{max}, in mm, is calculated in accordance with the following formula:

$$Z_{max} \leqslant \frac{\sigma_S D_S}{E_m} + \frac{0,8 D_S}{1000}\,. \quad (2.4.10.4)$$

2.4.11 Acceptability factor.

Adequate dimensioning of a crankshaft is ensured if the acceptability factors (the ratio of the equivalent alternating stress to the fatigue strength) for both the crankpin and journal fillets as well as for outlet of crankcase oil bore satisfy the criteria:

$$Q_H = \sigma_{DWH}/\sigma_{VH} \geqslant 1,15,$$

$$Q_G = \sigma_{DWG}/\sigma_{VG} \geqslant 1,15,$$

$$Q_O = \sigma_{DWO}/\sigma_{VO} \geqslant 1,15.$$

2.4.12 At the junction of the web with the journal or pin, the radius of the fillet shall not be less than $0,05D$.

Where crankshafts have flanges, the radius of the fillet at the junction of the flange with the journal shall not be less than $0,08D$.

2.4.13 The edges of the oil holes shall be rounded to a radius of not less than 0,25 of the diameter of the hole with a smooth finish.

2.4.14 In built and semi-built crankshafts, no keys or pins are permitted for joining a crankpin or journal to the web. On the outer sides of junction of webs to pins or journals, reference marks shall be provided.

2.4.15 Where the thrust bearing is built in the engine frame, the diameter of the thrust shaft in way of the bearing shall not be less either than that of the crankshaft journal or the shaft diameter determined in accordance with 5.2.2, Part VII "Machinery Installations".

2.5 SCAVENGING AND SUPERCHARGING

2.5.1 The operation and manoeuvrability of main engine shall be guaranteed in the case of failure of one or all turbochargers under running conditions permitted by the engine manufacturer (refer to 2.1.7, Part VII "Machinery Installations").

2.5.2 For main engines, which turbochargers do not provide a sufficient air supply when started and within low-load range, provision shall be made for an auxiliary supercharging system generally comprising two air blowers, which would make it possible for the engine to reach running conditions, under which the necessary degree of supercharging would be ensured. If one of the blowers of the auxiliary supercharging system fails, the other one that remains intact shall ensure the operation of the system.

2.5.3 Where supercharging air is cooled, the scavenge manifolds shall be fitted with thermometers and condensate drain arrangements after each air cooler.

2.5.4 Scavenge manifolds shall be provided with relief valves set for a pressure exceeding that of scavenging air by not more than 50 per cent.

The free area of the relief valves shall not be less than 30 cm^2 per cubic metre of the manifold volume including the volume of the underpiston spaces in crosshead engines fitted with diaphragms if these spaces are not used as scavenging pumps.

2.5.5 Scavenge manifolds and underpiston spaces shall be provided with draining arrangements for removing accumulations of sludge and water.

2.5.6 The air intake pipes of engines and scavenging-and-supercharging units shall be fitted with safety gauzes.

2.6 FUEL SYSTEM

2.6.1 The fuel injection pumps or their prime movers shall ensure quick shutting off the fuel supply to any cylinder of the engine. Exemption from this requirement is allowed for engines with cylinders not over 180 mm in bore having grouped fuel pumps.

2.6.2 The high-pressure fuel oil injection pipes shall be made from thick-walled seamless steel pipes without welded or soldered intermediate joints (refer to item 1.21 of Table 1.2.4).

2.6.3 External high-pressure fuel delivery lines between the high-pressure fuel pumps and fuel injectors shall be protected with a jacketed piping system capable of containing fuel from a high-pressure line failure. A jacketed pipe incorporates an outer pipe, into which the high-pressure fuel pipe is placed, forming a permanent assembly. The jacketed piping system shall include a means for collection of leakages and arrangements and shall be provided with an alarm in case of a fuel line failure.

When in return piping the propulsion of pressure with peak to peak values exceeds 1,6 MPa, shielding of this piping is also required.

2.6.4 The fuel injection pumps and fuel delivery piping shall be so designed that they can withstand the pressure fluctuation or special means shall be provided to reduce it even to the point of disappearance.

2.6.5 For the main engine provision shall be made for an arrangement to limit the fuel supply by the rated power mode.

2.7 LUBRICATION

2.7.1 The lubricators supplying oil for lubricating the cylinders shall be fitted with an arrangement enabling to control the amount of oil delivered to each point. To supervise the oil supply to all points to be lubricated, flow indicators shall be provided in position convenient for observation.

2.7.2 Every union supplying lubricating oil to the two-stroke engine cylinders, as well as the unions arranged in the upper part of the cylinder liner shall be provided with a non-return valve.

2.7.3 The turbochargers and governors with ball or roller bearings shall have independent lubricating oil systems. Departure from this requirement may be allowed only on special agreement with the Register.

2.7.4 Provision shall be made to prevent penetration of water and fuel oil into the circulating oil and the entry of oil into the cooling water.

2.8 COOLING

2.8.1 Where telescopic devices are employed for cooling pistons or for supplying lubricating oil to moving parts, protection from hydraulic shocks shall be provided.

2.9 STARTING ARRANGEMENTS

2.9.1 The manifold supplying starting air from the master starting air valve to the cylinder starting valves shall be fitted with one or more relief valves and with a device relieving the manifold of pressure after the engine has been started.

The relief valve shall be loaded to a pressure not more than 1,2 times that in the starting air manifold.

The relieving device and the relief valve may be fitted directly on the master starting air valve.

Alternative device designed to protect the starting air manifold from the effects of inner explosions is also admitted (refer to 16.3.3, Part VIII "Systems and Piping").

2.9.2 Flame arresters or bursting discs shall be fitted on each branch pipe for air supply to the starting valves of the reversing engine cylinder covers.

In case of non-reversing engines at least one flame arrester or bursting disc shall be fitted on the manifold supplying starting air from the main starting air valve to the manifold.

Flame arresters or bursting discs may be omitted for the engines having a bore not exceeding 230 mm.

2.9.3 The starting arrangements of electrically-started engines shall meet the requirements of 13.7, Part XI "Electrical Equipment". Furthermore, it is recommended to equip electrically-started engines with engine-driven generators for automatic charging of the starting storage batteries.

2.9.4 In emergency diesel generators, the starting system and drive motor characteristics shall comply with the requirements of 16.1.8, Part VIII "Systems and Piping", and 9.3.4.2, 9.5 and 19.1.2.4, Part XI "Electrical Equipment".

Emergency diesel generators shall be capable of being readily started in their cold condition at the ambient temperature of 0 °C. Where such starting is impractical or at lower temperatures at the space, provision shall be made for heating devices to ensure safe starting and taking up the load by the diesel generators.

If necessary, provision shall be made for heating devices to ensure safe starting and taking up the load according to the requirements stated above.

Spaces for emergency diesel generators shall comply with the requirements of 9.2.6, Part XI "Electrical Equipment".

2.10 EXHAUST ARRANGEMENTS

2.10.1 In two-stroke engines fitted with the exhaust gas turboblowers, which operate on the impulse systems, provision shall be made to prevent broken piston rings and valves from entering the turbine casing.

2.11 CONTROL, PROTECTION AND REGULATION

2.11.1 The starting and reversing arrangements shall eliminate the possibility of:

.1 running the engine in the direction opposite to the required one;

.2 reversing the engine when the fuel supply is cut in;

.3 starting the engine before reversal is completed;

.4 starting the engine with the power-driven turning gear engaged.

2.11.2 Each main engine shall have a speed governor so adjusted that the engine speed cannot exceed the rated (nominal) speed by more than 15 per cent.

In addition to the governor, each main engine of power output 220 kW and upwards, which may be disengaged from the shafting or which is driving a con-trollable-pitch propeller, shall be provided with a separate overspeed device so adjusted that the engine speed cannot exceed the rated speed by more than 20 per cent.

The overspeed device shall be activated after the speed governor.

2.11.3 Each prime mover for driving a generator shall be fitted with a speed governor, which shall meet the following requirements:

.1 when the maximum electrical load step of a generator is thrown off or on (refer to Fig. 2.11.3.2), the transient speed variations in the electrical network shall not exceed 10 per cent of the rated speed. Refer also to 2.1.3.1, Part XI "Electrical Equipment;

.2 when a prime mover running at no-load is suddenly loaded to 50 per cent of the rated power of the generator followed by the remaining 50 per cent after the interval sufficient to restore the speed to steady state, the transient speed variations shall not exceed 10 per cent of the rated speed. Application of electrical load in more than two load steps can only be permitted, if the conditions within the ship's mains permit the use of such prime movers, which can only be loaded in more than two load steps (Fig. 2.11.3.2) and provided that this is already allowed for in the designing stage. This shall be verified in the form of

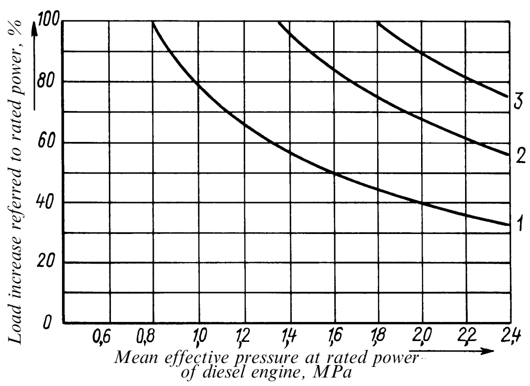


Fig. 2.11.3.2
Limiting curves for loading 4-stroke diesel engines step by step from no load to rated power as function of the brake mean effective pressure:
1 — 1st load step, *2* — 2nd load step, *3* — 3rd load step

system specifications to be approved and to be demonstrated at ship's trials. In this case the power required for the electrical equipment to be automatically switched on after black-out as well as the sequence in which it is connected shall fit the load steps. This applies analogously also to generators to be operated in parallel and where the power has to be transferred from one generator to another in the event of any one generator has to be switched off;

.3 where a.c. generators operate in parallel within 20 — 100 per cent of the total load, the load distribution between the generators shall be in proportion to their power and shall not differ by more than 15 per cent from the design load for the greater generator or by more than 25 per cent from the design load for the generator considered, whichever is less;

.4 at all loads between no-load and rated power the permanent speed variation shall not exceed the rated speed by more than 5 per cent of the rated speed;

.5 when the generator rated power is thrown off or on, as specified in 2.11.3.1 and 2.11.3.2, steady state conditions shall be achieved in not more than 5 seconds;

.6 steady state conditions are those, at which the envelope of speed variation does not exceed ± 1 per cent of the declared speed at the new power;

.7 for main engines driving shaft-generators, the values of load-relief and load-on stated in 2.11.3.1, 2.11.3.2, 2.11.3.4, 2.11.3.5 shall comply with the load of the engines. Speed governor of the driving engine shall have the parameters to meet the requirements of 2.11.3;

.8 when 100 per cent of the generator rated power is thrown off, a transient speed variation in excess of 10 per cent of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by 2.11.2.

2.11.4 The characteristics of the speed governor for the emergency generator driving engine shall meet the requirements of 2.11.3 (except for 2.11.3.2) when a 100 per cent load is taken off and put on. At stepwise loading the full (100 per cent) load shall be provided in 45 s after power loss on the main switchboard busbars.

The time delay and successive stepwise loading shall be demonstrated during sea trials of the ship.

2.11.5 Provision shall be made for local and remote control of speed variation within $-20 \div +10$ per cent of the nominal value.

2.11.6 In addition to the speed governor each driving engine stated in 2.11.3 having a power 220 kW and above shall be fitted with a separate overspeed protective device so adjusted that the speed cannot exceed the rated speed by more than 15 per cent.

2.11.7 The overspeed protective device stated in 2.11.2 and 2.11.6 including its driving mechanism and emergency stop effector shall be independent of the speed governor.

2.11.8 In addition to the requirements of the Chapter, electric (electronic) speed governors shall also comply with 2.1, Part XV "Automation".

If the electric (electronic) speed governors comprise a part of the remote automatic control system they shall meet the requirements of 3.1.8 and 3.1.10, Part VII "Machinery Installations" and also of 2.3, Part XV "Automation".

The electric (electronic) speed governors shall be of an approved type and tested in accordance with 12.3.1, Part IV "Technical Supervision During Manufacture of Products" of Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships.

2.11.9 Protection system of main and auxiliary engines (refer to 1.1.1.5), apart from the overspeed protective device, shall provide complete cut-off the fuel when the pressure of lubricating oil in the system drops below the allowable value.

2.12 INSTRUMENTS AND ALARM DEVICES

2.12.1 Main and auxiliary engines shall be equipped with instruments for measuring:

.1 lubricating oil pressure at engine inlet and in way of camshaft (where lubricating oil system is independent);

.2 freshwater pressure (or flow) in the engine cooling system;

.3 starting air pressure at main starting valve or starting device inlet;

.4 fuel pressure at fuel injection pumps inlets (where an oil-fuel priming pump is installed);

.5 exhaust gas temperature at each cylinder (for engines with a cylinder bore of 180 mm and less, exhaust piping temperature);

.6 lubricating oil temperature at engine inlet;

.7 pressure (or flow) in the fuel injector cooling system (where the system is independent);

.8 fuel temperature at fuel injection pump inlets (where the fuel requires heating);

.9 pressure (or flow) in the independent piston cooling system;

.10 oil pressure in way of main bearings where lubricating oil is supplied independently and in way of thrust bearing (for thrust bearings built in the engine);

.11 lubricating oil pressure at crosshead bearings (where lubricating oil is supplied independently);

.12 lubricating oil temperature in way of camshaft (where lubricating oil is supplied independently);

.13 lubricating oil pressure at turbocharger inlet where circulating oil of the engine is used;

.14 lubricating oil temperature and flow at the outlet of each turbocharger bearing (where gravity lubrication systems are applied);

.15 cooling liquid temperature and flow at each piston outlet (for engines with controlled piston cooling);

.16 fuel injector cooling medium temperature at outlet (where an independent system is used);

.17 freshwater temperature at each cylinder outlet or at engine outlet (where the engine has one cooling space);

.18 freshwater temperature at engine inlet;

.19 freshwater temperature at turbocharger outlet;

.20 supercharging receiver pressure;

.21 supercharging air temperature behind air coolers;

.22 exhaust gas temperature in front of turbochargers and behind them.

N o t e . Proceeding from the structural features of the engines, changes may be introduced to the list of measuring instruments on agreement with the Register.

2.12.2 Each driving above 37 kW shall be fitted with an alarm device with audible and visual signals for the failure of lubricating oil system as well as an alarm to indicate leaks from the high-pressure oil fuel injection pipes of diesel engines (refer to 2.6.3).

The following warning alarms are recommended:

.1 pressure drop in freshwater cooling system or water temperature rise at engine outlet;

.2 drop of lubricating oil level in the gravity tank of turbochargers;

.3 rise of temperature of thrust bearing built in the engine.

2.12.3 The local control stations of main engines shall be equipped with instruments in accordance with 2.12.1.1 to 2.12.1.3, 2.12.1.7, 2.12.1.9 (where media other than circulation oil are used), 4.2.5.3 and with an instrument for measuring crankshaft speed, and where disengaging couplings are fitted, with an instrument for measuring propeller shaft speed as well.

The local control stations of main reversible engines and propellers with reverse-reduction gear shall be provided with indicators of the direction of propeller shaft rotation.

2.12.4 Local control stations of auxiliary engines (refer to 1.1.1.5) shall be equipped with instruments in compliance with 2.12.1.1 to 2.12.1.3 and with an instrument for measuring the crankshaft speed.

2.13 TORSIONAL VIBRATION DAMPER. ANTIVIBRATOR

2.13.1 The damper design shall make air removal possible when filling the damper with oil or silicone liquid, and the silicone damper design shall also enable a sampling of the liquid.

2.13.2 Lubrication of a spring damper shall, as a rule, be effected from the lubricating oil circulation system of the engine.

2.13.3 The design of the damper fitted at the free end of the crankshaft shall make it possible to connect devices for measuring torsional vibration to the crankshaft.

2.13.4 The damper shall be used with regard to the requirements of 8.8.3 to 8.8.5, Part VII "Machinery Installations".

3 STEAM TURBINES

3.1 GENERAL

3.1.1 The main geared turbine installation shall be capable of reversing from full speed ahead at the rated power to astern speed, and reversing in the opposite direction by using backsteam.

3.1.2 The turbine installation intended for propulsion shall comply also with the requirements of 2.1, Part VII "Machinery Installations".

In multi-screw ships with a fixed-pitch propeller a turbine installation of each shaft shall be provided with an astern turbine.

3.1.3 Auxiliary turbines shall be started without preheating.

3.1.4 In single screw ships fitted with cross compound steam turbines, the arrangement shall be such as to enable safe navigation when the steam supply to anyone of the turbines is required to be isolated. For this emergency operation purpose the steam may be led directly to the L.P. turbine, and either the H.P. or M.P. turbine can exhaust direct to the condenser.

Adequate arrangements and controls shall be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those, which the turbine and condenser can safely withstand.

All piping and valves of these arrangements shall be readily available and properly marked. A fit up test of all combinations of pipes and valves shall be performed prior to the first sea trials.

The permissible power/speeds when deactivating one of the turbines; appropriate information shall be provided on board. The operation of the turbines under emergency conditions shall be assessed for potential influence on shaft alignment and gear teeth loading conditions.

3.2 ROTOR

3.2.1 The strength of rotor parts shall be calculated for maximum power, as well as for other possible loads at which stresses may rise to maximum values.

Moreover, a check calculation of stresses shall be made for the rotor and parts thereof at a speed exceeding the maximum values by 20 per cent.

3.2.2 The critical speed of the rotor shall be in excess of the rated speed corresponding to the rated power by not less than 20 per cent.

The critical speed of the rotor may be reduced, provided there is an ample proof of the reliability of the turbine under all operating conditions.

3.2.3 Each new design of blading requires a calculation of vibration with subsequent verification of vibration characteristics by experiments.

3.2.4 The construction of blade tenon with detachable part of the disc side and other similar constructions, which may cause considerable local loosening of the rim are not allowed.

3.2.5 Completely assembled turbine rotors shall be dynamically balanced in a machine of sensitivity appropriate to the size and the mass of the rotor.

3.3 CASING

3.3.1 In cast steel turbine casings it is permitted for some cast elements and branches for connecting receivers, pipes and fittings to be joined by welding.

3.3.2 The connection of the astern turbine steam inlet branch with the turbine casing shall not be rigid.

3.3.3 Gaskets between the flanges of horizontal and vertical joints of turbines shall not be used. Planes of the joints are allowed to be coated with graphite paste for the purpose of sealing.

3.3.4 The diaphragms fixed in the turbine casing shall have a possibility of radial thermal expansion within permissible misalignment.

3.3.5 The diaphragms shall be designed for a load corresponding to the maximum pressure drop in the stage. The actual deflection of the diaphragms shall be less than that, which may cause touching of the discs or of the rotor shaft sealing.

3.3.6 The low pressure turbine casing shall be provided with openings for the inspection of blading in the last stages. The turbines with built-in condensers shall be provided with openings for the inspection of the upper rows of condenser tubes, and, where possible, for access inside the condenser.

3.3.7 The turbine shall be so designed as to allow lifting bearing caps without dismantling the turbine casing, ends of sealing arrangements and pipelines.

3.4 BEARINGS

3.4.1 In main turbines sleeve bearings shall be used. For turbines designed for quick starting when in cold condition, it is recommended to use bearings with self-aligning shells.

3.4.2 Thrust bearings of the main turbines shall, as a rule, be of a single-collar type. The use of bearings of other types shall be approved by the Register.

The bearings loaded with specific pressure of more than 2 MPa are recommended to be fitted with pivoted races or with devices for automatic equalization of pressure exerted on the pads.

3.4.3 The thickness of antifriction lining of thrust bearing pads shall be less than the minimum axial clearance in the turbine blading, but not less than 1 mm.

3.5 SUCTION, GLAND-SEALING AND BLOWING SYSTEMS

3.5.1 The main turbine installation shall be provided with a steam suction and gland-sealing system, with automatic control of pressure of the sealing steam.

In addition to automatic control, provision shall also be made for manual control of the steam suction and gland-sealing system.

3.5.2 Each turbine shall have a blowing system to ensure complete removal of condensate from all stages and spaces of the turbine.

The blowing system shall be so arranged as to prevent the condensate from entering the turbines being at standstill.

3.6 CONTROL, PROTECTION AND REGULATION

3.6.1 Each main turbine installation shall be provided with a manoeuvring gear designed for control and manoeuvring purposes.

Manoeuvring valves for turbine installation of 7500 kW and over shall be power-driven, emergency manual control of the valves shall be provided as well.

3.6.2 The time required for resetting the controls of the turbine installation manoeuvring gear from full ahead to full astern or vice versa shall not be in excess of 15 s.

The manoeuvring gear shall be so designed as to exclude the possibility of simultaneous steam supply both to the ahead and astern turbines.

3.6.3 The main and auxiliary turbines shall be provided with overspeed devices acting on an automatic safety device (quick-closing stop valve) automatically shutting off the admission of steam into the turbine when the rotor speed is in excess of the speed corresponding to the maximum power by 15 per cent.

The quick-closing stop valve shall be actuated by the overspeed device directly connected with the turbine shaft. An oil actuator receiving impulse from an impeller directly driven by the turbine shaft may be used as an overspeed device.

In case of turbine installations with several cylinders each turbine shaft shall be fitted with an overspeed device.

The turbine installations intended for use in the plants incorporating reverse gear, controllable-pitch propeller or other arrangements disengaging the turbine from the shafting, in addition to the overspeed device, shall be fitted with a speed governor limiting the turbine speed when the load is changed before the overspeed device is put into operation.

The speed governors of auxiliary turbines intended for driving electric generators shall comply with the requirements of 2.11.3 to 2.11.7.

3.6.4 Each turbine shall be fitted with a hand-operated device to shut off the steam in emergency by closing the quick-acting stop valve.

In case of main turbine installation, this device shall be operated from two positions, one located on one of the turbines and the other in the control station.

In case of auxiliary turbine installation, this device shall be located adjacent to the overspeed device.

3.6.5 The steam pipelines between the manoeuvring gear and nozzle box shall be of the volume as small as practicable to eliminate impermissible overspeed of the turbine when the quick-closing stop valve is shut in emergency.

3.6.6 In extraction turbines, bleed pipelines shall be fitted with non-return stop valves to automatically close simultaneously with the quick-closing valve.

Where exhaust steam from auxiliary systems is led to the turbines of the main turbine installation, it shall be cut off in case of emergency operation of the quick-closing stop valve.

3.6.7 The main turbine installations and turbines for driving electric generators in addition to the overspeed device shall be fitted with devices capable of automatically actuating the quick-closing stop valve and shutting off the admission of steam into the turbine in the following cases:

.1 drop of the lubricating oil pressure in the system below the value specified by the manufacturer;

.2 rise of pressure in the condenser above the value specified by the manufacturer;

.3 maximum shifting of rotor in any turbine incorporated in the propulsion turbine set.

For main turbine installations shutting off the steam supply to the ahead turbines in case of lowering of pressure in lubricating oil system shall not prevent the admission of steam to the astern turbine.

3.6.8 To prevent inadmissible rise of the lubricating oil temperature in any of the main turbine bearings, provision shall be made for a warning alarm system.

3.6.9 Safety valve or an equivalent arrangement shall be provided at the exhaust end of all turbines.

The safety valve discharge outlets shall be visible and suitably guarded if necessary.

3.6.10 Efficient steam strainers shall be provided close to the inlets to ahead and astern high-pressure turbines or alternatively at the inlets to the manoeuvring valves.

3.6.11 For main turbine installations a slow-turning device, which operates automatically, shall be provided. Discontinuation of this automatic turning from the bridge shall be possible.

3.7 INSTRUMENTATION

3.7.1 The main turbine installation control stations shall be fitted with instruments for measuring:

.1 speed of the turbine shaft and shafting;

.2 steam pressure and temperature after the manoeuvring valve, in the nozzle boxes of ahead and astern turbines, in the governing stage chamber, bleed mains and the suction and gland-sealing system;

.3 outlet lubricating oil temperature in each bearing (the use of remote temperature indicators does not eliminate the necessity of fitting local thermometers);

.4 conditions of prestarting, reversing, stand-by keeping and bringing to prolonged inoperative state;

.5 lubricating oil pressure in the pressure pipelines after the oil cooler;

.6 vacuum in compliance with 19.4.1.2, Part VIII "Systems and Piping".

3.7.2 Apart from the instruments specified in 3.7.1, the main turbine installation shall be provided with:

.1 instruments for checking lubricating oil supply to each bearing;

.2 indicators for determining the axial position of the rotor;

.3 regular devices for measuring the wear of white metal of shells and segments of each journal and thrust bearing;

.4 bridge gauges or other instruments for checking vertical and horizontal positions of each rotor;

.5 instruments for checking the steam pressure and temperature under emergency conditions with any turbine cylinder being shut off.

3.7.3 The auxiliary turbines for driving generators shall be fitted with instruments in compliance with 3.7.1.

3.7.4 The turbine installation shall be fitted with the warning alarms for the following parameters:

.1 drop of the lubricating oil pressure in the lubricating oil system;

.2 rise of the lubricating oil temperature at each bearing outlet;

.3 rise of the lubricating oil pressure at the turbine installation inlet;

.4 rise of the pressure in the condenser;

.5 axial shift of rotors.

4 GEARS, DISENGAGING AND ELASTIC COUPLINGS

4.1 GENERAL

4.1.1 The reverse-reduction gearing intended for propulsion shall also comply with the requirements of 2.1, Part VII "Machinery Installations".

4.1.2 Parts rotating at speeds 5 to 20 m/s shall be statically balanced, while those rotating at speeds over 20 m/s shall be dynamically balanced. The accuracy of dynamic balancing shall be determined on the basis of the formulae:

$$v = 24000/n \quad \text{with } \upsilon > 300; \tag{4.1.2-1}$$

$$v = 63000/n \quad \text{with } \upsilon = 20 \tag{4.1.2-2}$$

where v = distance between the centre of gravity and the geometrical axis of rotation of the part concerned, μm;
n = rotational speed, min^{-1};
υ = peripheral velocity, m/s.

For peripheral velocities between 20 and 300 m/s, shall be determined by interpolation.

The rigid elements of couplings shall be balanced together with the parts they rigidly adjoin.

4.1.3 The design of the main gearing shall provide an access to all bearings.

The gear cases shall have a sufficient number of sight openings with easily detachable covers for carrying out internal inspection.

The sight openings shall be so arranged as to allow an inspection of the teeth over their full length and of the bearings inside the gearing.

The application of this requirement to the planetary gear is subject to special consideration by the Register in each case.

4.1.4 The gear cases shall be provided with venting arrangements.

The vent pipes shall be led to the upper weather deck or other positions where uptake is provided.

The ends of the vent pipes shall be fitted with flame-arresting devices and arranged so as to prevent water from getting into the gearing.

4.1.5 Where the main thrust bearing is housed in the gearing case, the lower part of the case shall have proper strengthening.

4.2 GEARING

4.2.1 General.

4.2.1.1 The requirements of the Chapter cover external and internal cylindrical involute spur, helical and double helical gears and bevel gears with straight, tangent and circular arc teeth, operating with lubrication and intended both as components of main propulsion plants (main gearing) and auxiliaries (auxiliary gearing) on board ships of various types.

The above requirements shall be satisfied in the case of units with parallel and intersecting shaft gears and multipliers of train and epicyclic type applied for one or more machine plants with any type of engine, and also for marine auxiliary drives.

4.2.1.2 Epicyclic gear shall be fitted with equalizers. The rim of epicyclic wheel with more than 3 planetary pinions shall be flexible in the radial direction.

4.2.2 Gears.

4.2.2.1 The pinions of main gearing shall be manufactured from alloy steel with the ultimate tensile strength of 620 MPa and above. For auxiliary gears, both constructional steels with lower physical and chemical properties and cast iron, bronze and non-metallic materials may be used.

4.2.2.2 The hardness of pinion teeth shall be at least 15 per cent greater than that of wheel teeth. This requirement does not apply to surface hardened gears (carburized, nitrided, face-hardened, etc.).

4.2.2.3 Tooth fillet radius shall not be less than $0{,}3m_n$.

4.2.2.4 The strength of teeth and other pinion and wheel elements shall be proved by calculations. These calculations of steel gear teeth for the basic criteria of durability (contact surface endurance and bending endurance) and for depth strength (for gears with chemically and thermally hardened teeth and with a large module) shall be based on the requirements of the Chapter. In some cases, for high loads and speeds a calculation of the scuffing load capacity may be required.

For high power gearing, gears rotating at speeds higher than 30 m/s, epicyclic main propulsion gears and kinematically sophisticated gears specific calculation technique may be permitted, subject to agreement with the Register.

In cases of unique geometry, arrangement or manufacture of the gearing, the Register may permit a departure from the serviceability criteria determined by the formulae to be found in the Chapter on condition relevant calculations or experimental data are submitted as substantiation.

4.2.2.5 Technical documentation on gears to be submitted to the Register shall cover the following parameters:

type of gearing, engine and coupling;

a_p = number of engagements;

load spectrum;

T_1 = torque of pinion at the maximum long-acting load, N·m;

For gears, during the operation of which a possibility exists for an action of instantaneous maximum loads $T_{1\max} > K_A T_1$ with a number of stress reversal cycles not in excess of 10^3 throughout the service period, the maximum torque of pinion at the maximum load, $T_{1\max}$, in N·m, shall be additionally indicated;

n_1 = pinion rotational speed, min^{-1};

m_n = normal module, mm;

Z_1, Z_2 = number of teeth of pinion, wheel;

b_1, b_2 = face width of pinion, wheel, mm;

b_w = active face width, mm;

h_a^* = addendum ref. to module;

c^* = bottom clearance ref. to module;

β = helix angle at reference cylinder, deg.;

α_n = normal pressure angle at reference cylinder, deg.;

x_1, x_2 = addendum modification coefficient of pinion, wheel;

Q = grade of accuracy;

f_f = profile form error in accordance with current standards, μm;

f_{pb} = base pitch error in accordance with current standards, μm;

F_β = total tooth alignment deviation in accordance with current standards, μm;

ρ_{a0} = tip radius of tool, mm;

h_k = buckling height of protuberance profile, mm;

α_0 = protuberance angle, deg.;

d_{a0} = tip diameter of teeth of gear-shaper cutter for manufacturing internal gearing, mm;

Z_0 = number of teeth of gear-shaper cutter;

x_0 = addendum modification coefficient of cutter;

materials of pinion and wheel teeth;

σ_{B1}, σ_{B2} = ultimate tensile strength of tooth core, MPa;

σ_{T1}, σ_{T2} = yield strength of tooth core, MPa;

E_1, E_2 = modulus of elasticity of the pinion and wheel teeth materials, MPa;

v_1, v_2 = Poisson's ratio of the pinion and wheel teeth materials;

method of heat treatment of pinion and wheel teeth;

R_{a1}, R_{a2} = arithmetic average roughness of the pinion and wheel contact surface and root fillet, μm;

HV_1, HV_2 = Vickers hardness of the pinion and wheel contact surface;

HB_1, HB_2 = Brinell hardness of the pinion and wheel contact surface;

HB_{c1}, HB_{c2} = Brinell hardness of the pinion and wheel teeth core;

h_{t1}, h_{t2} = depth of core hardness of pinion, wheel, mm;

v_{40}, v_{50} = kinematic oil viscosity at 40 °C and 50 °C, mm^2/s.

Besides general parameters, the initial data for bevel gearing shall include:

tooth form in longitudinal section;

$\delta_1(\delta_{w1})$, $\delta_2(\delta_{w2})$ = pitch cone angle, deg.;

m_{te} = outer transverse module, mm;

R_{we} = outer pitch cone distance, mm;

β_m = middle helix angle, deg.

4.2.2.6 The nominal tangential load F_t, in N, is calculated by the equation

$$F_t = \frac{2000 T_1}{d_1 a_p},$$

the maximum tangential load $F_{t\max}$, in N, is calculated by the equation

$$F_{t\max} = 2000 T_{1\max}/d_1 a_p$$

where for spur and helical gears:

$$d_1 = Z_1 m_t, \quad m_t = m_n/\cos\beta; \qquad (4.2.2.6\text{-}1)$$

for bevel gears:

$$d_1 = d_{m1} = m_{te} Z_1 (1 - 0{,}5 b_1/R_{we}). \qquad (4.2.2.6\text{-}2)$$

4.2.2.7 The gear shall satisfy the conditions of contact tooth surface endurance

$$\sigma_H \leqslant \sigma_{Hp}$$

and tooth bending endurance

$$\sigma_F \leqslant \sigma_{Fp}$$

where for σ_H and σ_F, refer to 4.2.2.7.1, 4.2.2.7.3;
for σ_{Hp} and σ_{Fp}, refer to 4.2.2.7.2, 4.2.2.7.4.

The rated stresses for bevel gearing are determined by formulae for equivalent cylindrical gearing. The parameters of the equivalent gearing for midsection are given in 4.2.2.7.6.

For gears subjected to peak loads the following conditions shall be satisfied:

statical strength of contact tooth surface

$$\sigma_{H\max} \leqslant \sigma_{HP\max}$$

and statical tooth bending strength

$$\sigma_{F\max} \leqslant \sigma_{FP\max}$$

where for $\sigma_{H\max}$ and $\sigma_{F\max}$ refer to 4.2.2.7.1, 4.2.2.7.3;
for $\sigma_{HP\max}$ and $\sigma_{FP\max}$ refer to 4.2.2.7.2, 4.2.2.7.4.

4.2.2.7.1 The rated contact stresses, in MPa, for the pinion and wheel teeth are calculated by the following formula:

$$\sigma_H = \sigma_{H0}\sqrt{K_A K_\gamma K_v K_{H\beta} K_{H\alpha}} \qquad (4.2.2.7\text{-}1)$$

where for σ_{HO}, refer to 4.2.2.7.1.1;
for K_A, refer to 4.2.2.7.1.7;
for K_γ, refer to 4.2.2.7.1.8;
for K_v, refer to 4.2.2.7.1.9;
for $K_{H\beta}$, refer to 4.2.2.7.1.10;
for $K_{H\alpha}$, refer to 4.2.2.7.1.11.

The rated maximum contact stresses, in MPa, for the pinion and wheel teeth are calculated by the formula

$$\sigma_{H\max} = \sigma_{HO\max}\sqrt{K_\gamma K_v K_{H\beta} K_{H\alpha}}$$

where $\sigma_{HO\max}$, refer to 4.2.2.7.1.1.

4.2.2.7.1.1 At nominal load, the contact stress for the pinion teeth is calculated by the equation

$$\sigma_{HO1} = Z_K Z_B Z_H Z_E Z_\varepsilon Z_\beta \sqrt{w_t(u \pm 1)/d_1 u} \qquad (4.2.2.7\text{-}2)$$

For wheel teeth

$$\sigma_{HO_2} = \frac{Z_D}{Z_B}\,\sigma_{HO_1}$$

where $w_t = \frac{F_t}{\tau b_w}$;

τ = 1 for spur gears;
τ = 0,85 for bevel gears;
$u = Z_2/Z_1$ = gear ratio;
for Z_1, Z_2 and b_w, refer to 4.2.2.5;
for F_t and d_1, refer to 4.2.2.6;
for Z_B (Z_D), refer to 4.2.2.7.1.2;
for Z_H, refer to 4.2.2.7.1.3;
for Z_E, refer to 4.2.2.7.1.4;
for Z_ε, refer to 4.2.2.7.1.5;
for Z_β, refer to 4.2.2.7.1.6.
Z_K = 1 for spur gears,
Z_K = 0,85 for bevel gears.

In equation (4.2.2.7-2) and later the above sign is for external meshing, the below sign — internal meshing.

The maximum contact stresses at $T_{1\max}$, in MPa, for the pinion teeth are calculated by the formula

$$\sigma_{HO\max 1} = Z_K Z_B Z_H Z_E Z_\varepsilon Z_\beta \sqrt{w_t(u \pm 1)/d_1 u}\,,$$

for wheel teeth:

$$\sigma_{HO\max 2} = \frac{Z_D}{Z_B}\,\sigma_{HO\max 1}$$

where the parameters involved shall be calculated at $F_t = F_{t\max}$, K_A = 1,0 and K_V = 1,0.

4.2.2.7.1.2 The single-pair mesh factors Z_B and Z_D are used for converting contact stresses at the pitch point to contact stresses at the inner point of single-pair contact of a pinion (wheel) and they are determined as follows:

for spur gears,

$$Z_B = M_1 = \frac{\operatorname{tg}\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \frac{2\pi}{Z_1}\right]\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} \pm (\varepsilon_\alpha - 1)\frac{2\pi}{Z_2}\right]}}$$

where for ε_α, refer to Formula (4.2.2.7-13);

if Z_B < 1, then Z_B = 1;

$$Z_D = M_2 = \frac{\operatorname{tg}\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} \mp \frac{2\pi}{Z_2}\right]\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{Z_1}\right]}}$$

if Z_D < 1, then Z_D = 1;

for helical gears with $\varepsilon_\beta \geqslant 1$,

$$Z_B = Z_D = 1;$$

if ε_β < 1,

$$Z_B = M_1 - \varepsilon_\beta(M_1 - 1) \geqslant 1;$$

$$Z_D = M_2 - \varepsilon_\beta(M_2 - 1) \geqslant 1$$

where for ε_β, refer to Formula (4.2.2.7-14).

The transverse pressure angle at working pitch cylinder α_{tw} is determined by the equation

$$\operatorname{inv}\alpha_{tw} = \operatorname{inv}\alpha_t + \frac{2(x_2 \pm x_1)\operatorname{tg}\alpha_n}{Z_2 \pm Z_1}$$

where $\operatorname{inv}\alpha = \operatorname{tg}\alpha - \alpha$;

$$\alpha_t = \operatorname{arc\,tg}(\operatorname{tg}\alpha_n/\cos\beta). \qquad (4.2.2.7\text{-}3)$$

Tip diameters of the pinion and wheel are calculated by the equations:

for external gearing,

$$d_{a1} = d_1 + 2(h_a^* + x_1 - \Delta y)m_n; \qquad (4.2.2.7\text{-}4)$$

$$d_{a2} = d_2 + 2(h_a^* + x_2 - \Delta y)m_n; \qquad (4.2.2.7\text{-}5)$$

for internal gearing,

$$d_{a1} = d_1 + 2(h_a^* + x_1 + \Delta y - \Delta y_{02})m_n; \qquad (4.2.2.7\text{-}6)$$

$$d_{a2} = d_2 - 2(h_a^* - x_2 + \Delta y - k_{x2})m_n. \qquad (4.2.2.7\text{-}7)$$

In this case, for d_1, refer to Formula (4.2.2.6-1)

$$d_2 = Z_2 m_t \qquad (4.2.2.7\text{-}8)$$

where for m_t, refer to Formula (4.2.2.6-1);

coefficients of displacement:

$$\Delta y = x_2 \pm x_1 - y;$$

$$y = (a_w - a)/m_n$$

where $a_w = a\cos\alpha_t/\cos\alpha_{tw}$; (4.2.2.7-9)

$a = 0{,}5(Z_2 \pm Z_1)m_t$;

coefficients of displacement for cutter and wheel meshing:

$$\Delta y_{02} = x_2 - x_0 - y_{02};$$

$$y_{02} = (a_{w02} - a_{02})/m_n$$

where $a_{w02} = a_{02}\cos\alpha_t/\cos\alpha_{tw02};$ (4.2.2.7-10)

$a_{02} = 0{,}5(Z_2 - Z_0)m_t;$

$\mathrm{inv}\,\alpha_{tw02} = \mathrm{inv}\,\alpha_t + \dfrac{2(x_2 - x_0)\,\mathrm{tg}\,\alpha_n}{Z_2 - Z_0}$;

with $x_2 \geqslant 2$, $k_{x2} = 0$, and with $x_2 < 2$ $k_{x2} = 0{,}25 - 0{,}125x_2$.

Base diameters of the pinion and wheel:

$$d_{b1} = d_1\cos\alpha_t; \quad (4.2.2.7\text{-}11)$$

$$d_{b2} = d_2\cos\alpha_t. \quad (4.2.2.7\text{-}12)$$

Transverse contact ratio:

$$\varepsilon_\alpha = \frac{0{,}5\sqrt{d_{a1}^2 - d_{b1}^2} \pm 0{,}5\sqrt{d_{a2}^2 - d_{b2}^2} \pm a_w\sin\alpha_{tw}}{\pi m_t\cos\alpha_t} \quad (4.2.2.7\text{-}13)$$

and overlap ratio:

$$\varepsilon_\beta = \frac{b_w\sin\beta}{\pi m_n}. \quad (4.2.2.7\text{-}14)$$

4.2.2.7.1.3 The zone factor, which accounts for the tooth flank curvature, is determined by the following formula:

$$Z_H = \sqrt{\frac{2\cos\beta_b}{\cos^2\alpha_t\,\mathrm{tg}\,\alpha_{tw}}}$$

where the helix angle at base cylinder is $\beta_b = \arcsin(\sin\beta\cos\alpha_n)$.

4.2.2.7.1.4 The elasticity factor, which accounts for the material properties of the pinion and wheel material is, for all cases, equal to

$$Z_E = \sqrt{\frac{1}{\pi\left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}\right)}}\ .$$

For steel gears ($E_1 = E_2 = 2{,}06\cdot10^5$ MPa, $\nu_1 = \nu_2 = 0{,}3$)

$$Z_E = 189{,}8\ \mathrm{MPa}^{0{,}5}.$$

4.2.2.7.1.5 The contact ratio factor, which accounts for the total contact line, is determined by the following formulae:

for spur gears,

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}}; \quad (4.2.2.7\text{-}15)$$

for helical gears with $\varepsilon_\beta < 1$,

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}(1-\varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}\ , \quad (4.2.2.7\text{-}16)$$

with $\varepsilon_\beta \geqslant 1$,

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}\ . \quad (4.2.2.7\text{-}17)$$

4.2.2.7.1.6 The helix angle factor is

$$Z_\beta = \sqrt{\cos\beta}.$$

4.2.2.7.1.7 The application factor K_A, which accounts for externally generated overloads on the gearing, is chosen from Table 4.2.2.7.1.7 in the absence of special procedures for its determination.

Table 4.2.2.7.1.7

Type of gearing	Engine	Type of coupling on input shaft	K_A	$K_{st\,\max}$
Main propulsion	Turbine	Any type	1	1,1
	ICE	Hydraulic or equivalent coupling	1	1,1
		High elastic coupling	1,25	1,4
		Other types	1,5	1,6
Auxiliary	Electric motor	Any type	1	1,1
	Turbine	Any type	1	1,1
	ICE	Hydraulic or equivalent coupling	1	1,1
		High elastic coupling	1,2	1,3
		Other types	1,4	1,5

For ships strengthened for ice navigation, the factor K_A for main gearing is determined as a product of $K_A \cdot K'_A$ where K'_A is obtained from Table 4.2.3.2.

The maximum load $T_{1\max}$ shall be determined by one of the following methods:

experimentally;

by dynamic calculation having regard to elastic and dampening characteristics of the system elements, on agreement with the Register;

basing on technical documentation or testing data of devices restricting the limiting value of the torque to be transmitted.

In the absence of the listed data, $T_{1\max}$ value may be determined using the maximum load factor $K_{st\,\max}$ by the formula

$$T_{1\max} = K_{st\,\max}T_{1\max\ eff}$$

where $T_{1\max\ eff}$ is the maximum effective torque delivered to the gearing from the engine or actuator (e.g. the maximum torque developed by a driving unit or the windlass shaft torque);

$K_{st\,\max}$ is the maximum load factor obtained from Table 4.2.2.7.1.7.

4.2.2.7.1.8 For multiple-path transmissions, the load sharing factor $K\gamma = 1{,}15$, which accounts for the maldistribution of load among paths, is equal to 1,15. For double helical, high power main propulsion gearing the factor K_γ shall be specified with due regard to the maldistribution of load among helices of the gear. In other cases, $K_\gamma = 1$.

4.2.2.7.1.9 The dynamic factor K_v, which accounts for internally generated dynamic load for the spur gearing, is estimated by the diagrams in Fig. 4.2.2.7.1.9-1, and for the helical gearing with $\varepsilon_\beta \geqslant 1$, by the diagrams in Fig. 4.2.2.7.1.9-2. In these diagrams, figures 3-9 denote accuracy grade according to the State standard 1643-81 (ISO 1328).

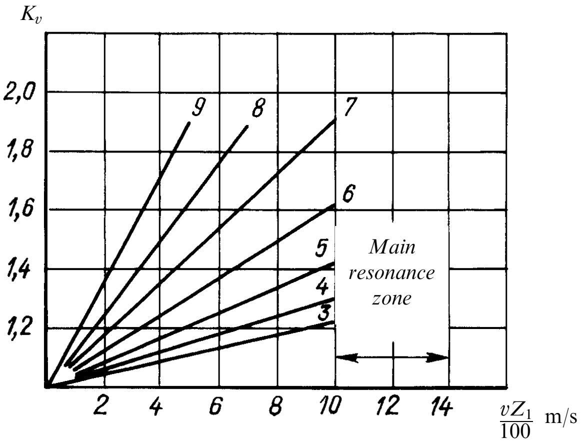


Fig. 4.2.2.7.1.9-1 K_v values for spur gears

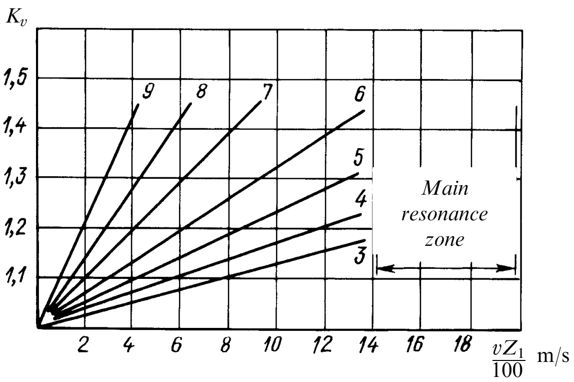


Fig. 4.2.2.7.1.9-2 K_v values for helical gears ($\varepsilon_\beta \geqslant 1$)

The factor K_v may also be determined by the following formula:

$$K_v = 1 + K_0(vZ_1)/100$$

where for K_0, refer to Table 4.2.2.7.1.9-1;

Table 4.2.2.7.1.9-1

Accuracy grade	3	4	5	6	7	8	9
Spur gears	0,022	0,030	0,043	0,062	0,092	0,125	0,175
Helical gears	0,0125	0,0165	0,0230	0,0330	0,0480	0,070	0,100

$v = \frac{d_1 n_1}{19098}$ — circumferential velocity.

For helical gearing with $\varepsilon_\beta < 1$,

$$K_v = K_\alpha - \varepsilon_\beta(K_\alpha - K_\beta) \qquad (4.2.2.7\text{-}18)$$

where K_α and K_β are the values of K_v taken from Figs. 4.2.2.7.1.9-1 and 4.2.2.7.1.9-2 respectively, calculated with the same accuracy grade.

For contact surface gears having different accuracy, K_v is determined with the less accuracy grade.

K_v values are valid for all types of gears if $vZ_1/100 < 3$ and also in the cases where:

the gears are made of steel and have toothing of the large cross section;

$F_t/b_w > 150$ N/mm and $Z_1 < 50$;

the gears operate in the subcritical zone ($vZ_1/100 < 14$ for helical gearing, $vZ_1/100 < 10$ for spur gearing).

The factor K_v accounting for the internally generated dynamic loads in case where the pinion speed exceeds 0,85 n_{E1} shall be determined from Table 4.2.2.7.1.9-2.

For bevel gears with tangent and circular arc teeth with $\varepsilon_{v\beta} \geqslant 1$ and with straight teeth if

$$v_{mt}\frac{Z_1}{100}\sqrt{u^2/(1 + u^2)} \leqslant 3 \text{ m/s},$$

as well as when the gears are made of steel and they have the width of toothing close to the width of disc, $Z_1 < 50$ and

$$v_{mt}\frac{Z_1}{100}\sqrt{u^2/(1 + u^2)} \leqslant 10 \text{ m/s}$$

where $v_{mt} = \frac{d_{m1} n_1}{19098}$, the values of the factor K_v are determined by the equation

$$K_v = 1 + \left(\frac{K_1 K_2}{F_t/b_{eH} K_A} + K_3\right) v_{mt}\frac{Z_1}{100}\sqrt{u^2/(1 + u^2)}. \qquad (4.2.2.7\text{-}19)$$

The values of K_1, K_2 and K_3 shall be obtained from Table 4.2.2.7.1.9-5. Where $F_t/b_{eH}K_A < 100$ N/mm, the value 100 N/mm shall be used.

For bevel gears with $\varepsilon_{v\beta} < 1$, the factor K_v is calculated by Formula (4.2.2.7-18) where K_α and K_β are relevant values of K_v determined by Formula (4.2.2.7-19).

4.2.2.7.1.10 The face load distribution factor, which accounts for the effect of non-uniform distribution of load along the face width, is defined as follows

$$K_{H\beta} = 1 + \frac{F_{\beta y} C_\gamma}{2 w_t K_A K_\gamma K_v} \qquad (4.2.2.7\text{-}20)$$

where $F_{\beta y}$ is in m and C_γ is in N/mm·μm.

Table 4.2.2.7.1.9-2

Parameter	Nota-tion	Method of determination
1. Resonance speed of pinion (main resonance) min^{-1}	n_{E1}	$n_{E1}=\frac{30\cdot10^3}{\pi Z_1}\sqrt{\frac{C_\gamma}{m_{red}}}$
.1 tooth mesh stiffness of a gear pair per unit face width N/(mm·μm)	C_γ	from Formula (4.2.2.7-21)
.2 single tooth mesh stiffness per unit face width N/(mm·μm)	C'	$C'=C_\gamma/(0,75\varepsilon_\alpha+0,25)$
.3 reduced mass, kg/mm	m_{red}	$m_{red}=\frac{\frac{\theta_1}{(d_{b1}/2)^2}\frac{\theta_2}{(d_{b2}/2)^2}}{\frac{\theta_1}{(d_{b1}/2)^2}+\frac{\theta_2}{(d_{b2}/2)^2}}\cdot\frac{1}{b_w}$, where θ_1 and θ_2 = mass moments of inertia about axis of rotation of the pinion and gear, kg·mm^2. For approximate calculations, the reduced mass may be determined from the formula $m_{red}=3,25\cdot10^{-6}\frac{d_5^2}{u^2+1}$ If an additional mass is added to the pinion with a moment of inertia of γ times greater than that of the pinion: $m_{red}=3,25\cdot10^{-6}\frac{d_5^2(1+\gamma)}{u^2+1+\gamma}$
2. Relative proximity between actual speed and resonance speed	n_1/n_{E1}	Depending on the ratio n_1/n_{E1} four zones are identified, namely: a) $n_1/n_{E1}<0,85$ = subcritical zone determined according to 4.2.2.7.1.9; b) $0,85\leqslant n_1/n_{E1}\leqslant 1,15$ = critical zone determined according to item 3 of this Table; c) $1,15<n_1/n_{E1}<1,5$ = intermediate zone determined according to item 5 of the Table; d) $n_1/n_{E1}\geqslant 1,5$ = supercritical zone determined according to item 4 of the Table
3. Factor accounting for the dynamic loads generated in the critical zone	K_v	From the formula $K_v=1+C_{v1}B_p+C_{v2}B_f+C_{v4}B_k$ where C_{v1}, C_{v2} and C_{v4} are determined from Table 4.2.2.7.1.9-3
.1 factor accounting for pitch error, running-in and tooth loading influence	B_p	From the formula $B_p=\frac{C'(f_{pb}-y_\alpha)}{(F_t/b_w)K_AK_\gamma}$ where f_{pb} = pitch error (if not specified, the permissible value of f_{pbr} shall be taken), μm; y_α = reduction in pitch error due to runningin, μm, determined according to 4.2.2.7.1.11
.2 factor accounting for profile error, running-in and tooth loading influence	B_f	From the formula $B_f=\frac{C'(f_f-y_\alpha)}{(F_t/b_w)K_AK_\gamma}$ where f_f = profile error (if not specified, the permissible value of f_{fr} shall be taken), μm
.3 factor accounting for tip relief influence	B_k	From the formula $B_k=\left\|1-\frac{C'C_a}{(F_t/b_w)K_AK_\gamma}\right\|$ where $C_a=1,5+\frac{(\sigma_{Hlim}/97-18,45)^2}{18}$ Note. If gears are made of different materials $C_a=(C_{a_1}+C_{a_2})/2$
4. Factor accounting for dynamic loads generated in the subcritical zone	K_v	From the formula $K_v=C_{v_5}B_p+C_{v_6}B_f+C_{v_7}$ where C_{v_5}, C_{v_6} and C_{v_7} are determined from Tables 4.2.2.7.1.9-3, 4.2.2.7.1.9-4.
5. Factor accounting for dynamic loads generated in the intermediate zone	K_v	K_v is determined by linear interpolation between the values in the critical zone for $n_1=1,15n_{E1}$ according to item 3 of the Table and in the supercritical zone for $n_1=1,5n_{E1}$ according to item 5 of the Table. $K_v=K_{v(n_1=1,5n_{E1})}+\frac{K_{v(n_1=1,15n_{E1})}}{0,35}(1,5-\frac{n_1}{n_{E1}})-\frac{K_{v(n_1=1,5n_{E1})}}{0,35}(1,5-\frac{n_1}{n_{E1}})$

Table 4.2.2.7.1.9-3

Factor	Total contact ratio	
	$1<\varepsilon_\gamma\leqslant 2$	$\varepsilon_\gamma>2$
C_{v1}	0,32	0,32
C_{v2}	0,34	$\frac{0,57}{\varepsilon_\gamma-0,30}$
C_{v4}	0,90	$\frac{0,57-0,05\varepsilon_\gamma}{\varepsilon_\gamma-1,44}$
C_{v5}	0,47	0,47
C_{v6}	0,47	$\frac{0,12}{\varepsilon_\gamma-1,74}$

Table 4.2.2.7.1.9-4

Factor	Total contact ratio		
	$1 < \varepsilon_\gamma \leqslant 1{,}5$	$1{,}5 < \varepsilon_\gamma < 2{,}5$	$\varepsilon_\gamma \geqslant 2{,}5$
C_{v7}	0,75	$0{,}125\sin[\pi(\varepsilon_\gamma - 2)] + 0{,}875$	1,0

Table 4.2.2.7.1.9-5

Type of tooth	K_1							K_2	K_3
	Accuracy grade								
	3	4	5	6	7	8	9	3 — 9	
Straight	2,19	3,18	7,49	15,34	27,02	58,43	106,64	1,0645	0,0193
Tangent and circular								1,0000	0,0100

$F_{\beta y}$ is estimated by means of the relationships:

$$F_{\beta y} = F_{\beta x} - y_\beta;$$

$$F_{\beta x} = 1{,}33 f_{sh} + f_{ma};$$

$$f_{sh} = f_{sho} w_t K_A K_\gamma K_v.$$

In all cases, f_{sho} accounts for the bending and torsion deformation of pinion and wheel and depends on many factors. If the wheel is placed symmetrically close between the seats,

$f_{sho} = 2{,}3\gamma_H \cdot 10^{-2}$ μm·mm/N for the gearing without helix correction and without end relief;

$f_{sho} = 1{,}6\gamma_H \cdot 10^{-2}$ μm·mm/N for the gearing without helix correction, but with end relief

where $\gamma_H = (bw/d_1)^2$ for the helical and spur gearing;

$\gamma_H = 3(bw/2d_1)^2$ for the double helical gearing (b_w is the total active face width).

For the gearings with helix correction, the following minimum values shall be applied:

$f_{sho} = 5 \cdot 10^{-3}$ μm·mm/N for the spur gearing;

$f_{sho} = 1{,}3 \cdot 10^{-2}$ μm·mm/N for the helical gearing;

the last values of f_{sho} are minimum design values for all cases.

For all the types of gearing without helix correction:

$$f_{ma} = 2F_\beta/3,$$

but for the gearing with helix correction:

$$f_{ma} = F_\beta/3$$

where F_β = the greatest value of $F_{\beta 1}$ and $F_{\beta 2}$ for pinion and wheel respectively.

In the case of contact of steel through-hardened teeth and the contact of surface hardened with through-hardened teeth:

$$y_\beta = \frac{320}{\sigma_{Hlim}} F_{\beta x}$$

(for σ_{Hlim}, refer to 4.2.2.7.2.1).

If $v \leqslant 5$ m/s, the maximum value of y_β is not limited.

With 5 m/s $< v \leqslant 10$ m/s,

$$y_\beta \leqslant \frac{25800}{\sigma_{Hlim}}.$$

When $v > 10$ m/s,

$$y_\beta \leqslant \frac{12800}{\sigma_{Hlim}}.$$

For surface-hardened and nitrided teeth,

$$y_\beta = 0{,}15 F_{\beta x}.$$

At any speed y_β shall not exceed 6 μm.

If the pinion and wheel teeth are surface-hardened by different procedures,

$$y_\beta = 0{,}5(y_{\beta 1} + y_{\beta 2})$$

where $y\beta_1$ and $y\beta_2$ are the values for pinion and wheel, respectively.

The tooth mesh stiffness of a gear pair is calculated by the following formula:

$$C_\gamma = \frac{(1 + 3\varepsilon_\alpha)}{q'} C_{BS} \cos\beta$$

where

$$C_{BS} = [1 + 0{,}5(0{,}2 - c^*)][1 - 0{,}02(20 - \alpha_n)];$$

$$q' = 0{,}23615 + \frac{0{,}7755}{Z_{v1}} + \frac{1{,}28955}{Z_{v2}} - 0{,}03175x_1 - \frac{0{,}5827x_1}{Z_{v1}} - 0{,}00965x_2 - \frac{1{,}2094x_2}{Z_{v2}} + 0{,}02645x_1^2 + 0{,}0091x_2^2;$$

$$Z_{v1} = \frac{Z_1}{\cos^2\beta_b \cos\beta};\ Z_{v2} = \frac{Z_2 Z_{v1}}{Z_1}. \qquad (4.2.2.7\text{-}21)$$

For the internal gearing, $Z_{v2} = \infty$.

If $(F_t/b_w)K_A < 100$ N/mm,

$$\text{then } C_\gamma = \frac{(1 + 3\varepsilon_\alpha)}{q'} C_{BS} \cos\beta \, \frac{(F_t/b_w)K_A}{100}.$$

For the cylindrical helical gears, by virtue of polar stress concentration (variability of stiffness along the contact line) $K_{H\beta} \geqslant 1{,}2$ shall apply.

For bevel gears, the factor $K_{H\beta}$ shall be determined by the following formula:

$$K_{H\beta} = 1{,}5 K_{H\beta be},$$

in view of high pressure upon the working surface of teeth where for $K_{H\beta be}$, refer to Table 4.2.2.7.1.10.

Table 4.2.2.7.1.10

Neither pinion nor wheel overhung when mounted	One of the wheels overhung when mounted, other between seats	Both pinion and wheel overhung when mounted
1,1	1,2	1,5

4.2.2.7.1.11 The transverse load distribution factor $K_{H\alpha}$, for the simultaneously contacting teeth paris may be determined by one of the formulae:

with $\varepsilon_\gamma \leqslant 2$,

$$K_{H\alpha} = \varepsilon_\alpha(0,45 + K_4); \qquad (4.2.2.7\text{-}22)$$

with $\varepsilon_\gamma > 2$,

$$K_{H\alpha} = 0,9 + 2K_4\sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}} \qquad (4.2.2.7\text{-}23)$$

where $K_4 = \frac{C_\gamma(f_{pb} - y_\alpha)}{5w_{tH}}$;

$w_{tH} = w_t K_A K_\gamma K_v K_{H\beta}$;

f_{pb} is equal to the maximum of f_{pb1} or f_{pb2} for the pinion and wheel, respectively; if $f_{pb} < f_f$, f_{pb} is substituted by the maximum value of f_{f1} or f_{f2}; for gears with tip relief, $0,5f_{pb}$ can be introduced,

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta \qquad (4.2.2.7\text{-}24)$$

where for ε_α, refer to Formula (4.2.2.7-13);
for ε_α, refer to Formula (4.2.2.7-14).

For through-hardened teeth,

$$y_\alpha = \frac{160}{\sigma_{Hlim}} f_{pb}.$$

With $v \leqslant 5$ m/s, the maximum value of y_α is not limited.

If $5 \text{ m/s} < v \leqslant 10$ m/s, the maximum value is limited by the condition

$$y_\alpha \leqslant \frac{12800}{\sigma_{Hlim}};$$

with $v > 10$ m/s,

$$y_\alpha \leqslant \frac{6400}{\sigma_{Hlim}}.$$

For surface-hardened or nitrided teeth,

$$y_\alpha = 0,075 f_{pb}.$$

At any speed y_α shall not exceed 3 µm.

If the pinion and wheel teeth are surface-hardened by different procedures:

$$y_\alpha = 0,5(y_{\alpha1} + y_{\alpha2})$$

where $y_{\alpha1}$ is for the pinion and $y_{\alpha2}$ — for the wheel.

The rated values of $K_{H\alpha}$ are limited by the condition

$$1 \leqslant K_{H\alpha} \leqslant \frac{\varepsilon_\gamma}{\varepsilon_\alpha Z_\varepsilon^2}$$

where ε_γ is determined by Formula (4.2.2.7-24);
Z_ε is determined by one of Formulae (4.2.2.7-15 to 4.2.2.7-17).

4.2.2.7.2 The permissible contact stresses for pinion and wheel are determined by the following formula:

$$\sigma_{Hp} = \frac{\sigma_{Hlim} Z_N}{S_{H\min}} Z_L Z_v Z_R Z_W Z_X \qquad (4.2.2.7\text{-}25)$$

where for σ_{Hlim}, refer to 4.2.2.7.2.1;
for Z_N, refer to 4.2.2.7.2.2;
for $S_{H\min}$, refer to 4.2.2.7.2.3;
for Z_L, refer to 4.2.2.7.2.4;
for Z_v, refer to 4.2.2.7.2.5;
for Z_R, refer to 4.2.2.7.2.6;
for Z_W, refer to 4.2.2.7.2.7;
for Z_X, refer to 4.2.2.7.2.8.

The permissible contact stresses at maximum load are determined by the following formula:

$$\sigma_{HP\max} = \frac{\sigma_{Hlim} Z_N}{S_{HST}} Z_W$$

where for S_{HST}, refer to 4.2.2.7.2.3.

4.2.2.7.2.1 In the absence of test results, the endurance limits for contact stress σ_{Hlim} shall be taken from Table 4.2.2.7.2.1.

Table 4.2.2.7.2.1

Thermal or chemical and thermal treatment of teeth		σ_{Hlim}, MPa
Pinion	Wheel	
Through-hardened	Through-hardened	$0,46\sigma_{B2} + 255$
Surface-hardened		$0,42\sigma_{B2} + 415$
Carburized, induction-hardened or nitrided	Soft-bath nitrided	1000
	Induction-hardened	$0,88HV_2 + 675$
Carburized or nitrided	Nitrided	1300
Carburized		1500
Note. With the number of cycles of at least $5 \cdot 10^7$, the values of σ_{Hlim} correspond to a failure probability of 1 per cent or less. The criterion, which accounts for σ_{Hlim}, is the pitting damage of not less than 2 per cent for the total active flank area without surface-hardening and not less than 5 per cent for that with surface-hardening.		

4.2.2.7.2.2 For ahead running, the life factor $Z_N = 1$.

For astern running and in other cases of a limited life Z_N is recommended to take as 1,1.

At the maximum load $T_{1\max}$, the life factor Z_N is equal to:

1,6 — for through-hardened or surface-hardened steel;

1,3 — for gas-nitrided steel;

1,1 — for bath-nitrided steel.

4.2.2.7.2.3 The minimum safety factors for contact stress $S_{H\min}$, for bending stress $S_{F\min}$, for static strength of contact teeth surfaces S_{HST} and for bending teeth strength S_{FST} are taken from Table 4.2.2.7.2.3.

Table 4.2.2.7.2.3

Type of gearing	Type of ship	$S_{H\min}$	$S_{F\min}$	S_{HST}[1]	S_{FST}[1]
Main propulsion	All ships except pleasure boats	1,4	1,8	1,4	1,8
	Single-screw pleasure boats	1,25	1,5	1,25	1,5
	Multiple-screw pleasure boats	1,2	1,45	1,2	1,45
Auxiliary	All ships	1,15	1,4	1,1÷1,35[2]	1,4÷1,7[2]

[1]For forged or hot rolled steel wheels. For rolled blanks these values shall be increased by 15 per cent, for castings — by 30 per cent.
[2]The maximum values for gearing, the failure of which could have grave consequences.
Note. By pleasure boats are meant ships up to 24 m in length not engaged in trade and passenger carriage or not intended for charter service.

4.2.2.7.2.4 The lubricant factor, which accounts for the effect of lubricant viscosity, is determined by one of the formulae:

$$Z_L = C_{ZL} + \frac{1 - C_{ZL}}{\left(0{,}6 + \frac{40}{v_{50}}\right)^2}$$

or

$$Z_L = C_{ZL} + \frac{1 - C_{ZL}}{\left(0{,}6 + \frac{67}{v_{40}}\right)^2}.$$

With 850 MPa $\leqslant \sigma_{Hlim} \leqslant$ 1200 MPa,

$$C_{ZL} = 0{,}83 + 0{,}08\left(\frac{\sigma_{Hlim} - 850}{350}\right).$$

4.2.2.7.2.5 The speed factor, which accounts for the linear speed effect, is determined by the following formula:

$$Z_v = C_{Zv} + \frac{1 - C_{Zv}}{\sqrt{0{,}2 + 8/v}}.$$

Within the range 850 MPa $\leqslant \sigma_{Hlim} \leqslant$ 1200 MPa,

$$C_{Zv} = C_{ZL} + 0{,}02.$$

4.2.2.7.2.6 The roughness factor accounting for the effects of surface roughness is determined by the following formula:

$$Z_R = \left(\frac{3}{R_{Z100}}\right)^{C_{ZR}}.$$

The condition $Z_R \leqslant 1{,}15$ shall be considered.

R_{Z100} is determined by means of equations:

$$R_{Z100} = R_Z \sqrt[3]{100/a_w};$$

$$R_Z \simeq 6\ R_a;$$

$$R_a = 0{,}5(R_{a1} + R_{a2}).$$

If 850 MPa $\leqslant \sigma_{Hlim} \leqslant$ 1200 MPa,

$$C_{ZR} = 0{,}12 + \frac{1000 - \sigma_{Hlim}}{5000}.$$

If $\sigma_{Hlim} <$ 850 MPa, $C_{ZL} = 0{,}83$; $C_{ZV} = 0{,}85$; $C_{ZR} = 0{,}15$ and if $\sigma_{Hlim} >$ 1200 MPa, $C_{ZL} = 0{,}91$; $C_{ZV} = 0{,}93$; $C_{ZR} = 0{,}08$.

4.2.2.7.2.7 The hardness ratio factor, which accounts for the increase of surface durability of teeth of lower hardness when meshing with surface-hardened smooth teeth (R_Z < 6 μm), is determined by the following formula:

$$Z_W = 1{,}2 - \frac{HB - 130}{1700},$$

which is valid in the range of $130 \leqslant HB \leqslant 470$,

where HB is the lowest value of HB_1 or HB_2.

With $HB < 130$, $Z_W = 1{,}2$; with $HB > 470$, $Z_W = 1$.

4.2.2.7.2.8 The size factor Z_X, which accounts for the effect of tooth size, is chosen from Table 4.2.2.7.2.8.

Table 4.2.2.7.2.8

Thermal or chemical and thermal treatment of pinion teeth	Module m_n, mm	Z_X
Carburizing or surface-hardening	$m_n \leqslant 10$ $10 < m_n < 30$ $m_n \geqslant 30$	1 1,05 — 0,005m_n 0,9
Nitriding	$m_n \leqslant 7{,}5$ $7{,}5 < m_n < 30$ $m_n \geqslant 30$	1 1,08 — 0,011m_n 0,75
Through-hardening	—	1

4.2.2.7.3 The rated values of bending stress in the critical section, in MPa, are calculated separately for the pinion teeth and wheel teeth by the following formula:

$$\sigma_F = \sigma_{F0} K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \tag{4.2.2.7-26}$$

where for σ_{F0}, refer to 4.2.2.7.3.1;
for K_A, refer to 4.2.2.7.1.7;
for $K\gamma$, refer to 4.2.2.7.1.8;
for K_v, refer to 4.2.2.7.1.9;
for $K_{F\beta}$, refer to 4.2.2.7.3.5;
for $K_{F\alpha}$, refer to 4.2.2.7.3.6.

The rated values of maximum bending stresses $\sigma_{F\max}$, in MPa, are calculated separately for the pinion teeth and wheel teeth by the following formula:

$$\sigma_{F\max} = \sigma_{F0\max} K_\gamma K_{F\beta} H_{F\alpha}$$

where for $\sigma_{F0\max}$, refer to 4.2.2.7.3.1.

4.2.2.7.3.1 Bending stress under nominal loading:

$$\sigma_{F0} = \frac{F_t}{\tau b m_n} Y_F Y_S Y_\beta \tag{4.2.2.7-27}$$

where for b and m_n, refer to 4.2.2.5;
for F_t, refer to 4.2.2.6;
for τ, refer to 4.2.2.7.1.1;

for Y_F, refer to 4.2.2.7.3.2;
for Y_S, refer to 4.2.2.7.3.3;
for Y_β, refer to 4.2.2.7.3.4.

The maximum bending stresses at $T_{1\max}$, in MPa, are calculated separately for the pinion teeth and wheel teeth by the following formula:

$$\sigma_{F0\max} = \frac{F_{t\max}}{\tau b m_n} Y_F Y_S Y_\beta .$$

The values of the parameters involved shall be determined at $F_t = F_{t\max}$, $K_A = 1{,}0$ and $K_V = 1{,}0$.

4.2.2.7.3.2 The tooth form factor applied to the external gears, for $\alpha_n \leqslant 25°$ and $\beta \leqslant 30°$ is calculated by the formula

$$Y_F = \frac{6h_F^* \cos\alpha_{en}}{(S_{Fn}^*)^2 \cos\alpha_n}$$

where for $h_F^* = h_{Fe}/m_n$, $S_{Fn}^* = S_{Fn}/m_n$;
for h_{Fe}, S_{Fn}, α_{en}, refer to Fig. 4.2.2.7.3.2-1.

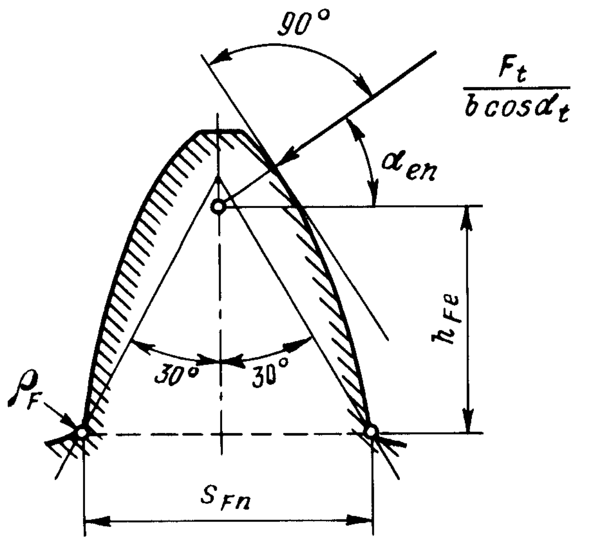


Fig. 4.2.2.7.3.2-1 Illustration to the definition of Y_F for external tooth

To determine h_F^* and S_{Fn}^* the following equation shall be used:

$$p_{bt} = \pi m_t \cos\alpha_t$$

where α_t is determined by Formula (4.2.2.7-3);

$$d_e = 2\sqrt{[p_{bt}(1-\varepsilon_\alpha) + 0{,}5\sqrt{d_a^2 - d_b^2}]^2 + (0{,}5 d_b)^2}$$

where ε_α is determined by Formula (4.2.2.7-13);
d_a and d_b for the pinion are determined by Formulae (4.2.2.7-4), (4.2.2.7-11) and for the wheel, from Formulae (4.2.2.7-5), (4.2.2.7-12);

$$\alpha_e = \arccos(d_b/d_e);$$

$$\gamma_e = \frac{1}{Z}\left(\frac{\pi}{2} + 2x\,\mathrm{tg}\,\alpha_n + 2x_{sm}\right) + \mathrm{inv}\,\alpha_t - \mathrm{inv}\,\alpha_e;$$

$$\alpha_{et} = \alpha_e - \gamma_e;$$

$$G = \rho_{a0}^* - h_{a0}^* + x$$

where $\rho_{a0}^* = \rho_{a0}/m_n$, $h_{a0}^* = h_{a0}/m_n = h_a^* + c^*$;

for ρ_{a0} and h_{a0}, refer to Figs. 4.2.2.7.3.2-2, 4.2.2.7.3.2-3;
x_{sm} is equal to zero for cylindrical gears, as to bevel gears, refer to 4.2.2.7.6;

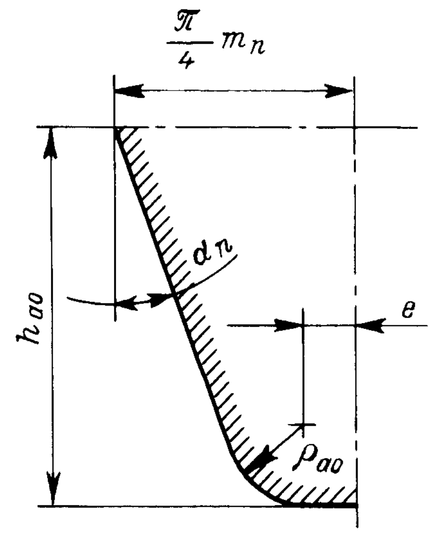


Fig. 4.2.2.7.3.2-2 Non-protuberance hob

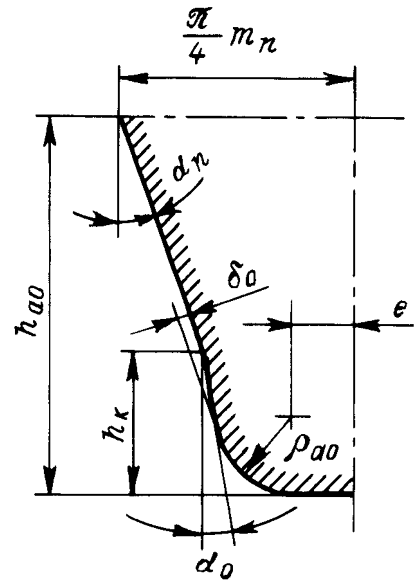


Fig. 4.2.2.7.3.2-3 Protuberance hob

$$e = \frac{\pi}{4} m_n - m_n x_{sm} - h_{a0}\,\mathrm{tg}\,\alpha_n + h_k(\mathrm{tg}\,\alpha_n - \mathrm{tg}\,\alpha_0) - \frac{(1-\sin\alpha_0)}{\cos\alpha_0}\rho_{a0}$$

where for h_k and a_0, refer to Fig. 4.2.2.7.3.2-3;

when the tool has no protuberance,

$$h_k = 0, \ \alpha_0 = \alpha_n;$$

$$H = \frac{2}{Z_v}\left(\frac{\pi}{2} - \frac{e}{m_n}\right) - \frac{\pi}{3}$$

where Z_v is determined by Formula (4.2.2.7-21);

$$\psi = \frac{2G}{Z_v} \operatorname{tg} \psi - H;$$

when solving this equation as an approximation take $\psi = \pi/6$;

$$\beta_e = \operatorname{arctg}\left(\frac{d_b}{d \cos \alpha_{et}} \operatorname{tg} \beta\right)$$

where d for the pinion is determined by Formula (4.2.2.6-1) and for the wheel, by Formula (4.2.2.7-8);

$$\alpha_{en} = \operatorname{arctg}(\operatorname{tg} \alpha_{et} \cos \beta_e);$$

$$S^*_{Fn} = Z_v \sin(\pi/3 - \psi) + \sqrt{3}\left(\frac{G}{\cos \psi} - \rho^*_{a0}\right);$$

$$h^*_F = \frac{1}{2}\left\{\frac{Z}{\cos \beta}\left(\frac{\cos \alpha_t}{\cos \alpha_{et}} - 1\right) + Z_v\left[1 - \cos\left(\frac{\pi}{3} - \psi\right)\right] - \frac{G}{\cos \psi} + \rho^*_{a0}\right\}.$$

In the case of internal gearing,

$$Y_F = \frac{6h^*_{F_2} \cos \alpha_{en}}{(S^*_{Fn_2})^2 \cos \alpha_n}.$$

To determine $h^*_{F_2} = h_{F_2}/m_n$ and $S^*_{Fn_2} = S_{Fn_2}/m_n$ (for h_{F_2} and S_{Fn_2}, refer to Fig. 4.2.2.7.3.2-4), the following equations are calculated:

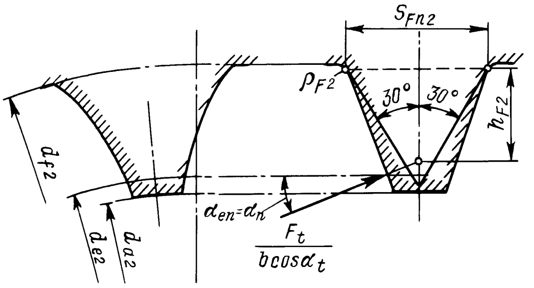


Fig. 4.2.2.7.3.2-4 Illustration to the definition of Y_F for internal tooth

$$d_{f_2} = 2a_{w02} + d_{a_0}$$

where a_{w02} is determined by Formula (4.2.2.7-10);

$$h^*_{a_{02}} = h_{a_{02}}/m_n = (d_{f_2} - d_2)/2m_n;$$

$$c = 0{,}5(d_{f_2} - d_{a_1}) - a_w$$

where d_{a1} is determined by Formula (4.2.2.7-6);
a_w is determined by Formula (4.2.2.7-9);

$$\rho^*_{a_{02}} = \frac{c}{m_n(1 - \sin \alpha_n)};$$

$$d_{e_2} = 2\sqrt{\left[-p_{bt}(1 - \varepsilon_\alpha) + 0{,}5\sqrt{d^2_{a_2} - d^2_{b_2}}\,\right]^2 + (0{,}5d_{b_2})^2}$$

where d_{a2} is determined by Formula (4.2.2.7-7);

$$h^*_{F_2} = \frac{d^*_{f_2} - d^*_{e_2}}{2\cos^2 a_n} - \left(\frac{\pi}{4} + h^*_{a_{02}} \operatorname{tg} \alpha_n\right) \operatorname{tg} \alpha_n - 0{,}5\rho^*_{a_{02}};$$

$$S^*_{Fn_2} = \frac{2(\rho^*_{a_{02}} - \delta^*_0)}{\cos \alpha_n} + 2(h^*_{a_{02}} - \rho^*_{a_{02}}) \operatorname{tg} \alpha_n - \sqrt{3}\rho^*_{a_{02}} + 0{,}5\pi$$

where $d^*_{f_2} = d_{f_2}/m_n$, $d^*_{e_2} = d_{e_2}/m_n$, $\delta^*_0 = \delta_0/m_n$;

$$\delta_0 = \left[\frac{h_k - \rho_{a0}(1 - \sin \alpha_0)}{\cos \alpha_0}\right] \sin(\alpha_n - \alpha_0),$$

refer to Fig. 4.2.2.7.3.2-3.
If $\alpha_n = 20°$,

$$h^*_{F_2} = 0{,}56624(d^*_{f_2} - d^*_{e_2}) - 0{,}13247h^*_{a_{02}} - 0{,}5\rho^*_{a_{02}} - 0{,}28586;$$

$$S^*_{Fn_2} = 0{,}72794h^*_{a_{02}} - 0{,}33163\rho^*_{a_{02}} + 0{,}93969\delta^*_0 + 1{,}5708.$$

4.2.2.7.3.3 The stress correction factor, which accounts for stress concentration, is determined by the following formula:

$$Y_S = (1{,}2 + 0{,}13L)q_s^{\left(\frac{1}{1{,}21 + 2{,}3/L}\right)}.$$

In the case of external gearing,

$$L = \frac{S^*_{Fn}}{h^*_F};$$

$$q_s = \frac{S^*_{Fn}}{2\rho^*_F} \qquad (4.2.2.7\text{-}28)$$

where $\rho^*_F = \rho^*_{a_0} + \frac{2G^2}{(Z_v \cos^2\psi - 2G)\cos \psi}$.

In the case of internal gearing,

$$L = \frac{S^*_{Fn2}}{h^*_{F_2}};$$

$$q_s = \frac{S^*_{Fn2}}{\rho^*_{a02}}. \qquad (4.2.2.7\text{-}29)$$

In case of external and internal gearing the following condition shall be met:

$$1 \leqslant q_s < 8.$$

For equivalent cylindrical gears of bevel gearing, the expression $Y_{FA} Y_{SA} Y_\varepsilon$ shall be substituted for the pro-duct $Y_F Y_S$ in Formula (4.2.2.7-27) where Y_{FA} and Y_{SA} are determined on the basis of relationships valid for Y_F and Y_S, in which the index e at the parameters is replaced by the index a corresponding to the pressure angle in case of load application to the tooth tip; $Y_\varepsilon = 0{,}25 + 0{,}75/\varepsilon_{v\alpha}$. For standard basic racks, Y_{FA} and Y_{SA} may be determined on the basis of special diagrams.

4.2.2.7.3.4 The helix angle factor is determined as follows:

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120}$$

where for ε_β, refer to (4.2.2.7-14);
β is in degrees; if $\varepsilon_\beta > 1$, then $\varepsilon_\beta = 1$ shall be introduced.

The minimum value of Y_β is limited by the condition

$$Y_\beta = 1-0{,}25\varepsilon_\beta \geqslant 0{,}75.$$

4.2.2.7.3.5 The factor $K_{F\beta}$ is determined by the relationship

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

where $K_{H\beta}$ is determined by Formula (4.2.2.7-20);

$$N=\frac{(b/h)^2}{1+b/h+(b/h)^2}. \qquad (4.2.2.7\text{-}30)$$

The lowest value of b_1/h and b_2/h is taken when solving Formula (4.2.2.7-30), and in the case of double helical gears, $b/2$ shall be substituted for b;

$h=(2h_a^*+c^*)m_n-\Delta y m_n$ is the tooth depth.

For cylindrical gears with end relief and crowning and for bevel gears, $N = 1$ shall be used.

4.2.2.7.3.6 The design values of $K_{F\alpha}=K_{H\alpha}$ shall satisfy the condition

$$1\leqslant K_{F\alpha}\leqslant\frac{\varepsilon_\gamma}{0{,}25\varepsilon_\alpha+0{,}75}.$$

$K_{H\alpha}$ shall be determined either by Formula (4.2.2.7-22) or by Formula (4.2.2.7-23).

4.2.2.7.3.7 Where gear-cutting tools other than standard tools are used, it is recommended that the parameters S_{Fn}, ρ_F and h_{Fe} be determined using the actual tooth profile.

4.2.2.7.4 The permissible bending stresses for the pinion and wheel teeth are calculated separately by the formula

$$\sigma_{Fp}=\frac{\sigma_{Flim}Y_{ST}Y_N}{S_{F\min}Y_D}\,Y_{\delta relT}Y_{RrelT}Y_X \qquad (4.2.2.7\text{-}31)$$

where for σ_{Flim}, refer to 4.2.2.7.4.1;
for Y_{ST}, refer to 4.2.2.7.4.2;
for Y_N, refer to 4.2.2.7.4.3;
for Y_D, refer to 4.2.2.7.4.4;
for $Y_{\delta relT}$, refer to 4.2.2.7.4.5;
for Y_{RrelT}, refer to 4.2.2.7.4.6;
for Y_x, refer to 4.2.2.7.4.7;
for $S_{F\min}$, refer to 4.2.2.7.2.3.

The permissible bending stresses for the pinion and wheel teeth under the maximum load are calculated by the formula

$$\sigma_{FP\max}=\frac{\sigma_{Flim}Y_{ST}Y_N}{S_{FST}Y_D}\,Y_{\delta relT}.$$

4.2.2.7.4.1 In the absence of test data, the values of endurance limit of teeth in bending are taken from Table 4.2.2.7.4.1.

4.2.2.7.4.2 The factor:

$$Y_{ST}=\sigma_{FE}/\sigma_{Flim}=2$$

where σ_{FE} is the tooth material bending endurance limit under the unidirectional pulsating stress with a minimum stress of zero.

4.2.2.7.4.3 For basic ratings, the life factor $Y_N=1$.

For limited life (when running astern, for instance), $Y_N>1$ may be permitted on agreement with the Register.

Table 4.2.2.7.4.1

Thermal or chemical and thermal treatment of teeth	σ_{Flim}, in MPa	Y_N
Through hardened carbon steel	$0{,}09\sigma_B + 150$	2,5
Through hardened alloy steel	$0{,}1\sigma_B + 185$	2,5
Soft-bath nitrided steel	330	1,2
Surface hardened steel	$0{,}35HV + 125$	2,5
Gas nitrided steel	390	1,6
Cr, Ni and Mo carburized steel	450	2,5
Other carburized steel	410	2,5

N o t e. The values of σ_{Flim} are determined during the bending endurance test of wheel teeth under unidirectional pulsating stress with a minimum stress of zero and they correspond to a failure probability of 1 per cent or less with the number of cycles 3×10^6.

For the maximum load $T_{1\max}$ condition, the values of Y_N are given in Table 4.2.2.7.4.1.

4.2.2.7.4.4 The values of the factor Y_D are adopted as follows:

for idler gears, $Y_D=1{,}5$;

for gears with occasional part load in the reverse direction, $Y_D=1{,}1$;

for gears (except idler gears) with shrink-fitted gear rings, $Y_D=1{,}25$,

or if the shrink diameter d_s and radial pressure p_r on the shrinkage surface are known,

$$Y_D=1 + \frac{0{,}2d_s^2\; dp_rb}{F_t\sigma_{Flim}(d_f^2-d_s^2)}$$

where d and d_f = reference diameter and root diameter of the wheel;

in other cases, $Y_D = 1$.

4.2.2.7.4.5 The relative notch sensitivity factor $Y_{\delta relT}$ taking into consideration the material sensiti-vity to stress concentrations is taken from Table 4.2.2.7.4.5.

Table 4.2.2.7.4.5

Thermal or chemical and thermal treatment of transition tooth surfaces	$Y_{\delta relT}$	$Y_{\delta relT}$ at $T_{1\max}$
Through-hardened carbon steel:		
forgings or rolled steel	$1 + 0{,}036(q_s-2{,}5)\times$ $\times(1-\sigma_T/1200)$	$1 + (Y_S-2)\times$ $\times(5-0{,}00015\sigma_T)$
casting	$1 + 0{,}036(q_s-2{,}5)\times$ $\times(1-\sigma_T/1200)$	$0{,}86 + 0{,}07Y_S$
Surface hardening	$0{,}956 + 0{,}0234\sqrt{1+q_s}$	$0{,}4 + 0{,}3Y_S$
Nitriding	$0{,}79 + 0{,}112\sqrt{1+q_s}$	$0{,}6 + 0{,}2Y_S$

N o t e. The value of q_s is determined either by Formula (4.2.2.7-28) or by Formula (4.2.2.7-29) depending on the type of gearing. For the range $1{,}5<q_s<4$, may be taken to be $Y_{\delta relT}=1$.

4.2.2.7.4.6 The relative surface condition factor Y_{RrelT}, which considers the influence of the transition surface roughness of the tooth, is taken from Table 4.2.2.7.4.6.

Table 4.2.2.7.4.6

Thermal or chemical and thermal treatment of teeth	Y_{RrelT}	
	$R_Z < 1$	$1 \leqslant R_Z \leqslant 40$
Through- or surface-hardening, carburizing	1,12	$1{,}675 - 0{,}53(R_Z + 1)^{0{,}1}$
Nitriding	1,025	$4{,}3 - 3{,}26(R_Z + 1)^{0{,}005}$

4.2.2.7.4.7 The size factor Y_X, which considers the influence of teeth size, is taken from Table 4.2.2.7.4.7.

Table 4.2.2.7.4.7

Thermal or chemical and thermal treatment of teeth	Module m_n, mm	Y_X
Through-hardening	$5 < m_n < 30$ $m_n \geqslant 30$	$1{,}03 - 0{,}006 m_n$ 0,85
Surface-hardening	$5 < m_n < 25$ $m_n \geqslant 25$	$1{,}05 - 0{,}01 m_n$ 0,80
Note. With $m_n \leqslant 5$ and any kind of surface hardening, $Y_X = 1$.		

The minimum value of bending endurance margin factor is chosen from Table 4.2.2.7.2.3.

4.2.2.7.5 The rated values of safety factors for contact stress and tooth root bending stress of the pinion and wheel teeth shall satisfy the conditions:

$$S_H = \frac{\sigma_{Hlim} Z_N}{\sigma_H} Z_L Z_v Z_R Z_W Z_X \geqslant S_{H\min};$$

$$S_F = \frac{\sigma_{Flim} Y_{ST} Y_N}{\sigma_F Y_D} Y_{\delta relT} Y_{RrelT} Y_X \geqslant S_{F\min}.$$

4.2.2.7.6 Durability of bevel gears is determined on the basis of equivalent cylindrical gears using the geometry of the midsection.

4.2.2.7.6.1 The relevant formulae to determine the parameters of equivalent cylindrical gears in the edge section (index v) are given below:

number of teeth,

$$Z_{v_{1,2}} = Z_{1,2}/\cos\delta_{1,2};$$

reference (working) diameters,

$$d_{v_{1,2}} = d_{m_{1,2}}/\cos\delta_{1,2};$$

centre distance and equivalent gear ratio,

$$a_v = 0{,}5(d_{v_1} + d_{v_2}),$$

$$u_v = \frac{Z_{v_2}}{Z_{v_1}} = u\frac{\cos\delta_1}{\cos\delta_2};$$

tip diameter,

$$d_{va} = d_v + 2h_{am}$$

where h_{am} = addendum for bevel gears with constant addenda;

$$h_{am} = m_{mn}(1 + x_{hm});$$

$$m_{mn} = m_{te}\cos\beta_m \frac{R_{wm}}{R_{we}};$$

for bevel gears with variable addenda,

$$h_{am_{1,2}} = h_{ae_{1,2}} - 0{,}5b\,\mathrm{tg}(\delta_{a_{1,2}} - \delta_{1,2})$$

where h_{ae} = addendum at outer end;
δ_a = outer cone angle;

addendum modification coefficients (shall be known),

$$x_{hm_{1,2}} = \frac{h_{am_{1,2}} - h_{am_{2,1}}}{2m_{mn}};$$

tooth thickness modification coefficients (shall be known),

$$x_{sm_1} = -x_{sm_2};$$

base diameters of equivalent cylindrical gears,

$$d_{vb_{1,2}} = d_{v_{1,2}}\cos\alpha_{vt}$$

where $\alpha_{vt} = \mathrm{arctg}\left(\frac{\mathrm{tg}\alpha_n}{\cos\beta_m}\right)$;

contact ratios of equivalent cylindrical gearing:

transverse contact ratio,

$$\varepsilon_{v\alpha} = \frac{g_{v\alpha}\cos\beta_m}{m_{mn}\pi\cos\alpha_{vt}}$$

where $g_{v\alpha} = 0{,}5\left(\sqrt{d_{va_1}^2 - d_{vb_1}^2} + \sqrt{d_{va_2}^2 - d_{vb_2}^2}\right) - a_v\sin\alpha_{vt}$;

overlap contact ratio,

$$\varepsilon_{v\beta} = \frac{b\sin\beta_m}{m_{mn}\pi}\tau;$$

$$\tau = \frac{b_{eH}}{b} = 0{,}85;$$

total contact ratio,

$$\varepsilon_{v\gamma} = \varepsilon_{v\alpha} + \varepsilon_{v\beta};$$

equivalent revolutions per minute,

$$n_{v_1} = \frac{d_{m_1}}{d_{v_1}} n_1.$$

4.2.2.7.6.2 The rated formulae determining the parameters of equivalent cylindrical gears in the normal section (index vn) are:

number of teeth,

$$Z_{vn_1} = \frac{Z_{v_1}}{\cos^2\beta_{vb}\cos\beta_m};$$

$$Z_{vn_2} = u_v Z_{vn_1}$$

where $\beta_{vb} = \arcsin(\sin\beta_m\cos\alpha_n)$.

Reference (working) diameters of equivalent cylindrical gears:

$$d_{vn_1} = \frac{d_{v_1}}{\cos^2\beta_{vb}} = Z_{vn_1}m_{mn};$$

$$d_{vn_2} = u_v d_{vn_1} = Z_{vn_2}m_{mn}.$$

Tip diameter

$$d_{van} = d_{vn} + d_{va} - d_v = d_{vn} + 2h_{am} = m_{mn}Z_{vn} + (d_{va} - d_v).$$

Base diameter

$$d_{vbn} = d_{vn}\cos\alpha_n = Z_{vn}m_{mn}\cos\alpha_n.$$

Transverse ratio

$$\varepsilon_{v\alpha n} = \varepsilon_{v\alpha}/\cos^2\beta_{vb}.$$

4.2.2.8 Gears with chemically and thermally hardened teeth of a large module ($m_n \geqslant 7{,}5$ mm) shall be additionally examined for depth strength. The rated safety factor for contact depth strength S_{Hd} shall be determined separately for pinion and wheel and shall satisfy the following condition:

$$S_{Hd} = \frac{\sigma_{Hdlim}}{\sigma_H} \geqslant S_{Hd\min}$$

where σ_H = determined by Formula (4.2.2.7-1);
σ_{Hdlim} = depth strength limit determined by the formulae:

$$\sigma_{Hdlim} = 5{,}5\ HBc \ \text{ if } \varphi > 0{,}6$$

and

$$\sigma_{Hdlim} = (4{,}58 + 1{,}57\varphi - 0{,}06\varphi^2)HBc\mu_T, \text{ if } \varphi > 0{,}6$$

where μ_T = a coefficient, which accounts for the probability of arising fatigue cracks not in the core, but in the hardened layer and which is determined from the diagrams in Fig. 4.2.2.8;

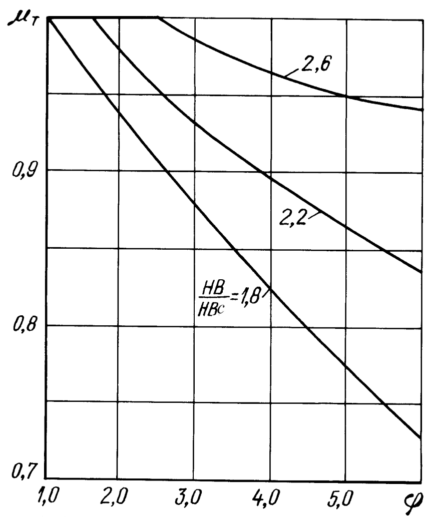


Fig. 4.2.2.8 Diagram for determining the factor μ_T versus φ and HB/HBc

parameter

$$\varphi = \frac{h_t \cdot 10^4}{\rho_c HBc}$$

where

$\rho_c = \frac{\alpha_\chi \sin\alpha_{tw}}{\cos\beta_b}\frac{u}{(u \pm 1)^2}$ — equivalent radius of curvature at the pitch point.

The minimum safety factor for depth strength $S_{Hd\min} = 1{,}4$.

4.2.3 Shafts.

4.2.3.1 The shaft diameter of a larger wheel shall not be less than 1,1 of the intermediate shaft diameter when the driving pinions are set at an angle of 120° and more and not less than 1,15 of the intermediate shaft diameter in all other cases, the mechanical properties of the wheel shaft and intermediate shaft being taken into consideration.

4.2.3.2 For ice class ships, the shafts, pinions and wheels of main gearing shall be calculated for a torque

$$T = K'_A T_1$$

where for K'_A, refer to Table 4.2.3.2 (refer also to 2.1.2, Part VII "Machinery Installations").

Table 4.2.3.2

Factor	Ice category					
	Ice3	**Arc4**	**Arc5**	**Arc6**	**Arc7** to **Arc9** **Icebreaker6** to **Icebreaker7**	**Icebreaker8** to **Icebreaker9**
K'_A	1,15	1,25	1,5	1,75	2,0	2,5

To check the static strength of main propulsion gearing in ships with ice-strengthening categories **Arc6** to **Arc9** and icebreakers the maximum load $T_{1\max}$ shall be taken on agreement with the Register, having regard to relative strength of the "propeller-shafting" system elements and availability of devices restricting the torque transmitted.

4.2.4 Lubrication.

4.2.4.1 Provision shall be made for forced lubrication of the toothing and sleeve bearings of main gears. The possibility of oil pressure regulation shall be provided. A safety device shall be fitted to exclude oil pressure rise above the permissible value.

4.2.4.2 Lubricating oil shall be delivered to the toothing through sprayers.

The sprayers shall provide an oil feed in the form of a fanned-out compact jet with the adjacent jets overlapping.

The sprayers shall be so arranged that, while running ahead or astern, oil is captured in the toothing.

Oil supply to and withdrawal from the bearings and sprayers shall be so arranged that there is no oil foaming or emulsification.

4.2.4.3 Lubricating oil system shall comply with the requirements of Section 14, Part VIII "Systems and Piping".

4.2.5 Control, protection and regulation.

4.2.5.1 Control stations shall comply with the requirements of 3.2, Part VII "Machinery Installations".

4.2.5.2 Provision shall be made for pressure meters at the inlet to the gearing lubrication systems and for temperature meters at inlet and outlet, as well as for a meter of oil level within the reduction gear casing.

4.2.5.3 Each sleeve and thrust bearing shall be provided with a temperature measuring device. For transferring power of less than 2250 kW, oil temperature measurement at outlet may be permitted for journal bearings. When required by the Register, the temperature measuring device may also be provided for rolling bearings.

4.2.5.4 To prevent an inadmissible rise of lubricating oil temperature in bearings or drop of the lubricating oil pressure, provision shall be made for a warning alarm system.

4.3 ELASTIC AND DISENGAGING COUPLINGS

4.3.1 General.

4.3.1.1 The requirements of the Chapter apply to the elastic and disengaging couplings of main and auxiliary machinery. As far as practical, these requirements apply to electromagnetic and hydraulic disengaging couplings as well.

4.3.1.2 As far as their material is concerned, the rigid components of shafting couplings shall satisfy the requirements of 2.4, Part VII "Machinery Installations".

4.3.1.3 Coupling bolts and coupling flanges shall satisfy the requirements of 5.2 and 5.3 and, keyless-fitted shaft couplings shall satisfy the requirements of 5.4, Part VII "Machinery Installations".

4.3.1.4 The elastic and disengaging couplings intended for ice-strengthened ships shall satisfy the requirements of 4.2.3.2.

4.3.1.5 In ships with one main engine, the shaft coupling design shall ensure, in case of coupling failure, the ship running at a speed sufficient for easy steering.

4.3.2 Elastic couplings.

4.3.2.1 Where 4.3.1.5 cannot be complied with, the ultimate static moment of the elastic component material, i.e. rubber or similar synthetic material, being in shear or tension shall be at least eight times the torque transmitted by the coupling.

4.3.2.2 For the purpose of main machinery and diesel generator sets analysis, additional loads due to torsional vibrations shall be considered (refer to Section 8, Part VII "Machinery Installations").

4.3.2.3 The elastic couplings of diesel generator sets shall withstand moments arising as a result of short-circuit. Where no such information is available, the maximum torque shall be at least 4,5 times the nominal torque transmitted by the coupling.

4.3.2.4 The possibility shall be provided of fully loading the elastic components, made of rubber or another similar synthetic material, of main machinery plant and diesel generator sets couplings within the temperature range 5 to 60 °C.

4.3.3 Disengaging couplings.

4.3.3.1 The disengaging couplings of main machinery shall be provided with devices to prevent slipping during appreciable periods of time.

4.3.3.2 It shall be possible to control the disengaging couplings of main machinery from the stations from which the main machinery is controlled.

Directly at the disengaging couplings, local emergency control arrangements shall be provided.

4.3.3.3 Where two or more engines devoted to a common propeller shaft are driving it through disengaging couplings, their control arrangement shall make a simultaneous engagement of the engines impossible when running in opposite directions.

4.4 TURNING GEAR

4.4.1 A power-driven turning gear shall be provided with an interlocking to preclude the possibility of the drives and couplings engagement when the turning gear is engaged (besides, refer to 3.1.6, Part VII "Machinery Installations" and 2.11.1.4 of the present Part).

5 AUXILIARY MACHINERY

5.1 POWER-DRIVEN AIR COMPRESSORS

5.1.1 General.

5.1.1.1 The air inlets of compressors shall be fitted with strainers.

5.1.1.2 The compressors shall be so designed that the air temperature at the outlet of the compressor last stage air cooler is not in excess of 90 °C and they shall be provided with a signalling device or warning alarm system for exceeding of the maximum temperature.

5.1.1.3 The compressor cooling water spaces shall be fitted with drain arrangements.

5.1.2 Safety devices.

5.1.2.1 Each compressor stage or directly after it shall be fitted with a safety valve preventing the pressure rise in the stage above 1,1 of the rated pressure when the delivery pipe valve is closed.

The safety valve design shall prevent any possibility of its adjustment or disconnection after being fitted on the compressor.

5.1.2.2 The compressor crankcases of more than 0,5 m^3 in volume shall be fitted with safety valves meeting the requirements of 2.3.5.

5.1.2.3 The casings of the coolers shall be fitted with safety devices providing for a free escape of air in case the pipes are broken.

5.1.3 Crankshaft.

5.1.3.1 The calculation method specified in 5.1.3.3 and 5.1.3.4 applies to the steel crankshafts of ship air compressors and refrigerant compressors with in-line, V- and W-shaped arrangements of cylinders and with single- and multi-stage compression.

Cast iron crankshafts, as well as departures from the dimensions of steel crankshafts calculated by Formulae (5.1.3.3) and (5.1.3.4) may be allowed on agreement with the Register, provided the confirming calculations or test data are submitted.

5.1.3.2 The crankshafts shall be made of steel having tensile strength 410 to 780 MPa.

The use of steel having a tensile strength over 780 MPa is subject to special consideration by the Register in each case.

Cast iron crankshafts shall be manufactured of the spheroidal graphite cast iron of ferrite-perlite structure according to Table 3.9.3.1, Part XIII "Materials".

5.1.3.3 Crankpin diameter d_c, in mm, of the compressor shall not be less than that determined by the formula

$$d_c = 0{,}25k' \sqrt[3]{D_{cal}^2 \; p_c \sqrt{0{,}3L_{cal}^2 \; f + (s\varphi_1)^2}} \qquad (5.1.3.3)$$

where D_{cal} = calculated diameter of the cylinder, mm; for single-stage compression, $D_{cal} = D$;

D = diameter of the cylinder, mm; for two- and multi-stage compression in separate cylinders $D_{cal} = D_{h.p}$;

$D_{h.p}$ = diameter of high-pressure cylinder, mm; for two-stage compression by a tandem piston $D_{cal} = 1{,}4D_{h.p}$; for two-stage compression by a differential piston

$$D_{cal} = \sqrt{D_{l.p}^2 - D_{h.p}^2} \;;$$

$D_{l.p}$ = diameter of low-pressure cylinder, mm;

p_c = delivery pressure of high-pressure cylinder for air compressors, MPa, for refrigerant compressors, the value p_c shall be taken in accordance with 2.2 of Part XII "Refrigerating Plants";

L_{cal} = calculated span between main bearings, mm, equal to: $L_{cal} = L'$, when one crank is arranged between two main bearings; $L_{cal} = 1{,}1\,L'$, when two cranks are arranged between two main bearings;

L' = actual span between centres of the main bearings, mm;

s = piston stroke, mm;

k', f, φ_1 = coefficients taken in accordance with Tables 5.1.3.3-1, 5.1.3.3-2 and 5.1.3.3-3.

Table 5.1.3.3-1

Values of coefficient k'

Tensile strength σ_B, MPa	390	490	590	690	780	900
k'	1,43	1,35	1,28	1,23	1,2	1,18

Table 5.1.3.3-2

Values of coefficient f

Angle between the cylinder axes	0° (in line)	45°	60°	90°
f	1,0	2,9	1,96	1,21

Table 5.1.3.3-3

Values of coefficient φ_1

Number of cylinders	1	2	4	6	8
φ_1	1,0	1,1	1,2	1,3	1,4

5.1.3.4 Thickness of crank web h_c, in mm, shall be not less than that determined by the formula

$$h_c = 0{,}105k_1 D_{cal} \sqrt{(\psi_1\psi_2 + 0{,}4) p_c c_1 f_1 / b} \qquad (5.1.3.4)$$

where $k_1 = a\sqrt[3]{\sigma_B/(2\sigma_B - 430)}$;

σ_B = tensile strength of material, MPa; where the tensile strength exceeds 780 MPa, σ_B equal to 780 MPa shall be adopted for calculation purposes;

a = 0,9 in the case of shafts, the surface of which is nitrided as a whole or hardened by another method approved by the Register;

a = 0,95 in the case of shafts forged by closed-die or continuous grain-flow method;

a = 1,0 in the case of shafts not subjected to hardening;

k_1, ψ_1, ψ_2 = coefficients taken in accordance with Tables 5.1.3.4-1 and 5.1.3.4-2;
p_c = delivery pressure taken in accordance with 5.1.3.3;
c_1 = distance from the centre of the main bearing to mid-plane of the web; for cranks arranged between two main bearings, the distance is taken to the mid-plane of the web remotest from the support, mm;
b = web thickness, mm;
f_1 = coefficient taken in accordance with Table 5.1.3.4-3.
b = web width, mm;
f_1 = factor taken from Table 5.1.3.4-3.

Table 5.1.3.4-1

Values of coefficient ψ_1

r/h	ε/h						
	0	0,2	0,4	0,6	0,8	1,0	1,2
0,07	4,5	4,5	4,28	4,10	3,70	3,30	2,75
0,10	3,5	3,5	3,34	3,18	2,88	2,57	2,18
0,15	2,9	2,9	2,82	2,65	2,40	2,07	1,83
0,20	2,5	2,5	2,41	2,32	2,06	1,79	1,61
0,25	2,3	2,3	2,20	2,10	1,90	1,70	1,40

Note. r = fillet radius, mm; ε = absolute amount of overlapping, mm (Fig. 5.1.3.4); for crankshafts having the distance x between journals and pins the values of coefficient ψ_1 shall be taken valid for ratio ε/h = 0.

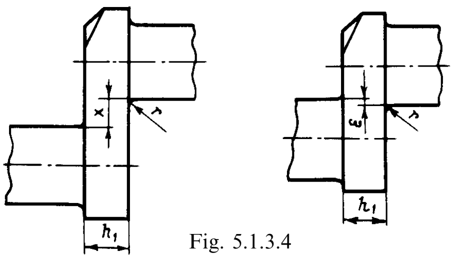


Fig. 5.1.3.4

Table 5.1.3.4-2

Values of coefficient ψ_2

b/d	1,2	1,4	1,5	1,8	2,0	2,2
ψ_2	0,92	0,95	1,0	1,08	1,15	1,27

Table 5.1.3.4-3

Values of coefficient f_1

Angle between the cylinder axes	0° (in line)	45°	60°	90°
f_1	1,0	1,7	1,4	1,1

Intermediate values of coefficients given in the tables are determined by linear interpolation.

5.1.3.5 Shaft designing and manufacturing shall comply with the requirements specified in 2.4.12 to 2.4.13.

5.1.4 Instruments.

5.1.4.1 A pressure gauge shall be fitted after each stage of the compressor.

5.1.4.2 Provision shall be made to measure the air temperature at the delivery pipe immediately after the compressor.

5.1.4.3 The instrumentation of the attached compressors shall be subject to special consideration by the Register in each case.

5.2 PUMPS

5.2.1 General.

5.2.1.1 Provision shall be made to prevent the pumped fluid from penetration to the bearings. However, this does not apply to the pumps where the pumped fluid is employed for lubrication of bearings.

5.2.1.2 The pump glands arranged on the suction side are recommended to be fitted with hydraulic seals.

5.2.2 Safety devices.

5.2.2.1 If the design of the pump does not preclude the possibility of pressure rising above the rated value, a safety valve shall be fitted on the pump casing or on the pipe before the first stop valve.

5.2.2.2 In pumps intended for transferring flammable liquids, the by-pass from safety valves shall be effected into the suction side of the pump or to the suction portion of the pipe.

5.2.2.3 Provision shall be made to prevent hydraulic impacts; use of the by-pass valves for this purpose is not recommended.

5.2.3 Strength calculations.

5.2.3.1 The critical speed of the pump rotor shall not be less than 1,3 of the rated speed.

5.2.3.2 The pump elements shall be checked for strength under the stresses corresponding to the pump rated parameters. In this case, the reference stresses in the elements shall not exceed $0{,}4R_{eH}$ of the element material.

5.2.4 Self-priming pumps.

5.2.4.1 The pumps provided with self-priming devices shall ensure operation under "dry suction" conditions and shall be fitted generally with arrangements preventing the self-priming device from operating with contaminated water.

5.2.4.2 The self-priming pumps shall have the place for connecting a vacuum pressure gauge.

5.2.5 Additional requirements for the pumps transferring flammable liquids.

5.2.5.1 Sealing of the shaft shall be such that the leakages occurred will not cause the formation of vapours and gases in the amount sufficient to produce the flammable air/gas mixture.

5.2.5.2 The possibility of excessive heating and ignition in sealing of the rotating parts due to friction energy shall be excluded.

5.2.5.3 When the materials of low electrical conductivity (plastics, rubber, etc.) are used in the pump structure, provision shall be made for removal of the electrostatic charges by insertion of the conductive additives into them or use of the devices for removal of the charges and for their transfer to the body.

5.2.6 Additional requirements for cargo, stripping and ballast pumps of oil tankers.

The casings of pumps installed in the cargo pump rooms in accordance with 4.2.5, Part VII "Machinery

Installations" shall be provided with temperature sensors.

5.3 FANS, BLOWERS AND TURBOCHARGERS

5.3.1 General.

5.3.1.1 The requirements of the present Chapter shall be complied with when designing and manufacturing fans intended to complete the systems specified in Part VIII "Systems and Piping", as well as boiler fans and internal combustion engine turboblowers.

5.3.1.2 The rotors of fans and air blowers with couplings as well as turbocharger rotor assemblies shall be dynamically balanced in accordance with 4.1.2.

5.3.1.3 The suction pipes of fans, blowers and turbochargers shall be protected against entry of foreign objects.

5.3.1.4 The lubricating oil system of the turbocharger bearings shall be so arranged as to prevent the oil from getting into the supercharging air.

5.3.2 Strength calculation.

The impellers of the turbines and blowers shall be so dimensioned that at a speed equal to 1,3 of the rated speed the reference stresses at any section are not in excess of $0{,}95R_{eH}$ of the element material.

The impellers of the turbines and blowers shall be also tested for strength during at least 3 min at a speed equal to 1,2 times of the designed speed.

Such testing of the prototype of the turbine and blower impellers is mandatory.

Series specimens may not be subjected to such testing, provided each impeller forging shall be tested by one of the approved non-destructive methods.

On agreement with the Register other safety factors for the turboblowers may also be permitted if the calculation procedures are used taking account of the stress concentrations and plasticity (finite element method).

5.3.3 Additional requirements for the ventilators of cargo pump rooms in oil tankers, spaces intended for the carriage of dangerous goods and spaces in which motor vehicles are carried with fuel in their tanks.

5.3.3.1 The air gap between the impeller and the casing shall not be less than 0,1 of the impeller shaft bearing diameter, but not less than 2 mm (it is permitted to be not more than 13 mm).

5.3.3.2 Protection screens of not more than 13 mm square mesh shall be fitted in the inlet and outlet of ventilation ducts at the weather deck to prevent the entrance of objects into the fan housing.

5.3.3.3 To prevent electrostatic charges both in the rotating body and casing, they shall be made of antistatic materials. Furthermore, the installation on board of the ventilation units shall be such as to ensure their safe bonding to the ship's hull according to requirements of Part XI "Electrical Equipment".

5.3.3.4 The impeller and the housing (in way of the impeller) shall be made of materials, which are recognized as being sparkproof.

The following combinations of materials of impeller and housing are considered sparkproof:

.1 non-metallic antistatic materials;

.2 non-ferrous-based alloys;

.3 austenitic stainless steel;

.4 impeller is made of aluminium alloy or magnesium alloy and housing is made of cast iron steel (austenitic stainless steel included), if a ring of suitable thickness of non-ferrous materials is fitted inside the housing in way of impeller;

.5 any combination of cast iron and steel impellers and housings (including the case when impeller or housing is made of austenitic stainless steel), provided the tip clearance is not less than 13 mm.

5.3.3.5 Other combinations of materials of impellers and housings, not specified in 5.3.3.4, may also be permitted if they are recognized as non-sparking by appropriate tests.

5.3.3.6 The following combinations of materials of impeller and housing are not permitted:

.1 impellers are made of aluminium alloy or magne-sium alloy and housings are made of ferrous-based alloys;

.2 impellers are made of ferrous-based alloys and housings are made of aluminium or magnesium alloys;

.3 impellers and housings are made of ferrous-based alloys with less than 13 mm tip clearance.

5.4 CENTRIFUGAL SEPARATORS

5.4.1 General.

5.4.1.1 The separator design shall preclude the leakage of oil products and vapours thereof under any conditions of the separation.

5.4.1.2 The separator bowls shall be dynamically balanced. The position of the removable parts shall be marked. The design of the disc holder and bowl shall preclude the possibility of misassembly thereof.

5.4.1.3 "Rotor-stator" systems shall be so designed that the critical speed exceeds the operating speed both in empty and in filled condition.

The critical speed less than the rated speed may be allowed only provided that proofs of continuous safe operation of the separator are submitted.

5.4.1.4 The design of coupling shall preclude the possibility of sparking and impermissible heating under all conditions of the separator operation.

5.4.2 Strength calculation.

5.4.2.1 Besides, the strength of rotating separator parts shall be checked under stresses arising at rotational speeds exceeding the design speed at least by 30 per cent; in this case, the total stresses in the parts shall not exceed $0{,}95R_{eH}$ of the material, of which they are made.

5.4.2.2 At the manufacturer's test bench, the strength of the rotating parts of the prototype separator shall be tested by a rotation speed exceeding the design speed by 30 per cent at least.

5.4.3 Instrumentation and protection.

5.4.3.1 A device for the control over the separation process shall be provided.

5.4.3.2 It is advisable that the separators be provided with a device automatically shutting off the drive and stopping the separator when inadmissible vibration occurs.

5.5 NATURAL GAS (METHANE) COMPRESSORS

5.5.1 Compressors installed on board the gas carriers carrying methane and used for supply of methane to dual-fuel internal combustion engines (refer to 9.1.1) shall be capable of rising pressure from the atmospheric pressure up to 25 to 30 MPa at the suction temperature not higher than -163 °C.

6 DECK MACHINERY

6.1 GENERAL

6.1.1 The brake straps and their fastenings shall be resistant to sea water and petroleum products. The brake straps shall be heat-resistant at temperatures up to 250 °C.

The permissible heat resistance of connections between the brake strap and the frame shall be above the temperature of heating of the connections for all possible operating conditions of the machinery.

6.1.2 The machinery having both manual and power drives shall be provided with interlocking arrangements preventing their simultaneous operation.

6.1.3 The deck machinery control arrangements shall be so made that heaving-in is performed when the handwheel is turned to the right or when the lever is shifted backwards while veering out is carried on when the handwheel is turned to the left or the lever is shifted forwards. Locking of brakes shall be carried out by turning the handwheels to the right while releasing is effected by turning to the left.

6.1.4 The control devices, as well as the instrumentation shall be so arranged as to provide the observation of them from the control place.

6.1.5 The machinery with the hydraulic drive or control shall additionally comply with the requirements of Section 7.

6.1.6 Winch drums having the multilayer rope winding with the ropes that can be subjected to the load in several layers shall have flanges protruding above the upper layer of winding by not less than 2,5 times the rope diameter.

6.1.7 If used for oil-recovery operations, cargo winches and topping of derricks, cargo-lifting appliances, luffing gear, slewing and travelling machinery of cranes and hoists, and other deck machinery installed in danger zones 0, 1 and 2 shall be intrinsically safe, and relevant safety certificates shall be issued for them by a competent body (for the definition of danger zones refer to 19.2, Part XI "Electrical Equipment").

6.2 STEERING GEAR

6.2.1 General.

6.2.1.1 Main and auxiliary steering gear (refer to 1.2.9, Part III "Equipment, Arrangements and Outfit") shall be so arranged that a single failure in one of them will not render the other one inoperative.

6.2.1.2 Main steering gear comprising two or more identical power units (refer to 2.9.4, Part III "Equipment, Arrangements and Outfit") shall be so arranged that a single failure in its piping or in one of the power units will not impair the integrity of the remaining part of the steering gear.

In oil tankers, oil tankers ($\geqslant$60 °C), chemical tankers or gas carriers of 10000 gross tonnage and upwards, hydraulic steering gear shall be provided with audible and visual alarms to give the indication of hydraulic fluid leakage in any part of the hydraulic system as well as with the arrangements of automatic isolation of the defective part of the system so that the steering capability shall be regained in not more than 45 s after the loss of the defective port of the hydraulic system.

6.2.1.3 The design of the gears shall provide in emergency for changing from the main steering gear to the auxiliary one during not more than 2 min.

6.2.1.4 Steering gears shall provide for a continuous operation under the most severe service conditions.

The design of the steering gear shall exclude the possibility of its failure with a ship running astern at maximum speed.

6.2.1.5 As a rated torque of the steering gear M_r the torque is taken corresponding to the rudder (steering nozzle) angle equal to 35° for the main steering gear and 15° for the auxiliary steering gear when operating under the nominal parameters (nominal pressure in the inner spaces of hydraulic and electrohydraulic gears, nominal current and voltage in the electric steering gear motors, etc.). In this case, the torque corresponding to the rudder angle 0° shall not be less than 0,82 M_r.

6.2.1.6 The requirements of equipping the ships with the steering gears are specified in 2.9, Part III "Equipment, Arrangements and Outfit".

6.2.1.7 In case of the hydraulic steering gear, provision shall be made for the fixed storage tank for hydraulic fluid with the capacity sufficient to fill at least one power actuating system, the equalizing tank included. This fixed tank shall be provided with a water level indicator and connected to the hydraulic gear by the piping so as its hydraulic systems can be filled directly from the tiller room.

Each equalizing tank shall be provided with a minimum water level alarm.

6.2.1.8 Every oil tanker, oil tanker (⩾60 °C), chemical tanker or gas carrier of 10000 gross tonnage and upwards shall comply with the following requirements (refer also to 6.2.1.9):

.1 the main steering gear shall be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear excluding the tiller, quadrant or components serving the same purpose as well as seizure of the rudder actuators, steering capability could be regained in not more than 45 s after the loss of one power actuating system;

.2 the main steering gear shall comprise either:

.2.1 two independent and separate power actuating systems each capable of meeting the requirements of 2.9.2, Part III "Equipment, Arrangements and Outfit"; or

.2.2 at least two identical power actuating systems which, acting simultaneously in normal operation, are capable of meeting the requirements of 2.9.2, Part III "Equipment, Arrangements and Outfit".

In this case the interconnection of hydraulic systems shall be provided. Loss of hydraulic fluid from any power actuating system shall be capable of being detected and the defective system automatically isolated so that the other actuating system (systems) is (are) to remain fully operative;

.3 steering gears other than of the hydraulic type shall achieve equivalent standards.

6.2.1.9 Hydraulic steering gear shall comply with the requirements of Section 7 of the present Part, Part III "Equipment, Arrangements and Outfit" and Part XI "Electrical Equipment".

6.2.1.10 The pipes of hydraulic steering gear systems shall comply with the requirements of Part VIII "Systems and Piping" for Class I piping system. The requirements for flexible joints used for the hydraulic steering gear systems are specified in 2.5, Part VIII "Systems and Piping".

6.2.1.11 For oil tankers, oil tankers (⩾60 °C), chemical carriers or gas carriers of 10000 gross tonnage and upwards but of less than 100000 tons deadweight, at the Register discretion, solutions other than those set out in 6.2.1.8, which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided, that an equivalent safety standard is achieved and that:

.1 following loss of steering capability due to a single failure of any part of the piping system or of one of the power units, steering capability shall be regained within 45 s; and

.2 where a steering gear includes only a single rudder actuator, special consideration is given to stress analysis for the design including fatigue and fracture mechanics analysis, as appropriate, to the material used, the installation of sealing arrangements and testing and inspection as well as to the provision of effective maintenance.

6.2.2 Power of steering gear.

6.2.2.1 The main steering gear shall be capable of putting the rudder (steering nozzle) over from 35° on one side to 30° on the other side in not more than 28 s when the rudder stock is affected by a rated torque of the steering engine.

6.2.2.2 The auxiliary steering gear shall be capable of putting the rudder (steering nozzle) over from 15° on one side to 15° on the other side in not more than 60 s under conditions stipulated by 2.9.3, Part III "Equipment, Arrangements and Outfit".

6.2.2.3 The steering gear power units shall permit a torque overload of at least 1,5 times the rated torque for a period of 1 min.

The steering gear electric motors shall comply with the requirements of 5.5, Part XI "Electrical Equipment".

6.2.3 Hand-operated steering gear.

6.2.3.1 The main hand-operated steering gear shall be of self-braking design.

The auxiliary hand-operated steering gear shall be either of self-braking design or shall have a locking device provided that it is reliably controlled from the control station.

6.2.3.2 The main hand-operated steering gear shall meet the requirements of 6.2.2.1 when handled by one man with a force of not over 120 N applied to the steering wheel handles and with the number of rotations, when shifting the rudder from hard over to hard over, not more than $9/R$ during shifting the rudder from hard over to hard over, where R is arm (radius) of the steering wheel handle up to the middle of its length, m.

6.2.3.3 The auxiliary hand-operated steering gear shall meet the requirements of 6.2.2.2 when handled by not more than four men with a force of not more than 160 N per helmsman applied to the steering wheel handles.

6.2.4 Protection against overload and reverse rotation.

6.2.4.1 The main and auxiliary steering gears shall have protection against overloads of the gear elements and assemblies when a rudder stock torque equal to 1,5 times the corresponding rated value arises. In case of hydraulic steering gear the safety valves may be used set to a pressure meeting the above-mentioned requirements, but not in excess of 1,5 times and not less than 1,25 times the corresponding maximum working pressure in the inner spaces of the hydraulic steering gear.

The design of the safety device shall permit its sealing.

The minimum capacity of the relief valves shall exceed the total pump capacity by 10 per cent; in this case, the pressure of the hydraulic steering gear cavities shall not exceed the pressure, to which the relief valves are adjusted.

6.2.4.2 For the main hand-operated steering gear it is sufficient to provide the gear with buffer springs instead of the protection against overload required by 6.2.4.1.

For the auxiliary hand-operated steering gear the fulfilment of the requirement for protection against overload is not compulsory.

6.2.4.3 The pumps of hydraulic steering engines shall be provided with protective devices preventing rotation of the inoperative pump in the opposite direction or with an automatic arrangement shutting out the flow of liquid through the inoperative pump.

6.2.5 Braking device.

6.2.5.1 The steering gear shall be fitted with a brake or some other device, which provides keeping the rudder (the steering nozzle) steady at any position when the latter exerts a rated torque without allowing for the efficiency of the rudder stock bearings.

6.2.5.2 Where the pistons or blades of the hydraulic steering gear can be locked by closing the oil pipeline valves, a special braking device may be omitted.

6.2.6 Limit switches.

Each power-operated steering gear shall be provided with a device discontinuing its operation before the rudder (the steering nozzle) reaches the rudder (the steering nozzle) stops.

6.2.7 Rudder (steering nozzle) indicators.

The steering gear segment rack or the hydraulic steering engine crosshead guide, or the element rigidly coupled with the rudder stock shall be fitted with a dial calibrated in not more than 1° to indicate the actual position of the rudder (the steering nozzle).

6.2.8 Strength calculation.

6.2.8.1 The main and auxiliary steering gear components to be used in flux of force lines shall be checked for strength under the stress corresponding to the rated torque, and the piping and other steering gear components subjected to internal hydraulic pressure — to the rated pressure.

The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions. In this case, at the discretion of the Register fatigue criterion shall be applied for the design of piping and components, taking account of pulsating pressures due to dynamic loads.

In all above cases the reference stresses in the components shall not exceed $0{,}4R_{eH}$ for the steel components and $0{,}18\sigma_B$ for the components of spheroidal cast iron.

6.2.8.2 The stresses in the elements common for both the main and auxiliary steering gears (viz., tiller, segment, reduction gear, etc.) shall not exceed 80 per cent of the stresses tolerable in compliance with 6.2.8.1.

6.2.8.3 The steering gear elements unprotected from overloads by safety devices specified in 6.2.4 shall have strength corresponding to the rudder stock strength.

6.2.9 Connection with rudder stock.

6.2.9.1 The connection of the steering engine or gear with the elements rigidly coupled with the rudder stock shall eliminate the possibility of breakdown on the steering gear when the rudder stock is shifted in the axial direction.

6.2.9.2 Connecting of the tiller hub or segment rack with the rudder stock shall be designed to transmit no less than double rated torque M_r stated in 6.2.1.5. The height of the hubs of loose segment racks and auxiliary tillers shall not be less than 0,8 of the diameter of the rudder stock head. In case of press keyless fitted solid hubs on the rudder stock the friction coefficient shall be taken not more than 0,13.

6.2.9.3 The split hubs shall be fastened with at least two bolts on each side and have two keys. The keys shall be arranged at an angle of 90° to the split joints plane.

6.3 ANCHOR MACHINERY

6.3.1 Drive.

6.3.1.1 The drive engine power of the anchor machinery shall provide for an uninterrupted heaving-in of one anchor chain together with the anchor of the normal holding power at a speed not less than 0,15 m/s for a period of 30 min with the pull on the sprocket P_1, in N, not less than determined from the formula

$$P_1 = ad^2 \quad (6.3.1.1\text{-}1)$$

where a = coefficient equal to:
36,8 for Grade 1 anchor chain,
41,7 for Grade 2 anchor chain,
46,6 for Grade 3 anchor chain;
d = anchor chain diameter, mm. (For chain grades, refer to Part III "Equipment, Arrangements and Outfit").

On agreement with the Register, reduction of coefficient a is permitted for the chain diameters of 28 mm and less.

For supply vessels the pull on the sprocket P_2 shall not be less than

$$P_2 = 11{,}1(gh + G) \quad (6.3.1.1\text{-}2)$$

where g = mass of anchor chain linear metre, kg;
h = specified depth of anchorage, m, but not less than:
200 m for ships with Equipment Number 720 or less;
250 m for ships with Equipment Number over 720 (refer to 3.2, Part III "Equipment, Arrangements and Outfit");
G = anchor mass, kg.

Heaving-in speed of the anchor chain shall be measured on the length of two shackles beginning from the moment when three shackles are in suspended condition.

6.3.1.2 As the anchor approaches the hawse, the drive shall provide for heaving-in speed not over 0,17 m/s. It is recommended that the speed during pulling the anchor into the hawse shall be not more than 0,12 m/s.

6.3.1.3 To break the anchor out, the anchor machinery drive shall build up a pull on a sprocket of at least 1,5 times the rated value in 2 min (refer to 6.3.1.1) without any requirement for speed.

6.3.2 Brakes and clutches.

6.3.2.1 The anchor machinery shall be fitted with clutches arranged between the sprocket and its drive shaft.

The anchor machinery with a non-selfbraking gear shall be provided with automatic brakes switched in when the driving energy disappears or the driving engine fails.

6.3.2.2 The automatic brake shall ensure a braking torque without slip corresponding to a force in the chain on the sprocket not less than $1{,}3P_1$ or $1{,}3P_2$.

6.3.2.3 Each chain sprocket shall be fitted with a brake, the braking torque of which with the sprocket disconnected from the drive shall provide for holding of the anchor chain without slipping of the brake on exposure to the force in the chain:

.1 equal to 0,45 of the breaking load in the chain, where the anchor gear is provided with the anchor chain stopper intended for anchorage;

.2 equal to 0,8 of the breaking load in the chain without the above-mentioned stopper.

The force applied to the brake drive handle shall not exceed 740 N.

6.3.3 Chain sprockets.

6.3.3.1 The chain sprockets shall have not less than five cams. For horizontal shaft sprockets the wrapping angle shall not be less than 115°, while for vertical shaft sprockets, not less than 150°.

6.3.3.2 The chain sprockets shall ensure passing the joining links in both horizontal and vertical positions.

6.3.3.3 The construction of sprocket shall not permit skipping of the links over the cams:

under all conditions of operation of the machinery from the main drive;

when ship is lying at anchorage;

when paying out the anchor with the chain cable through free dropping with periodical braking by the band brake and when the speed of paying out is approximately 4 m/s.

6.3.4 Overload protection.

If the machinery drive is capable of developing a torque building up an effort on the sprocket exceeding 0,5 of the anchor chain test load, provision shall be made for a safety arrangement installed between the drive and the machinery to prevent exceeding the above-mentioned load.

6.3.5 Strength calculation.

6.3.5.1 The machinery elements shall be checked for strength when the sprocket is affected by efforts corresponding to the maximum torque of the drive or to the moment of the extreme protection setting and also by the chain breaking load acting after the hawse, as well as by the wave forces as specified in 1.4.6.1, Part VIII "Systems and Piping" (refer to 6.3.5.3 to 6.3.5.8). The reference stresses in the elements, which may arise from the influence of the above-mentioned loads, shall not exceed $0{,}95R_{eH}$ of the element material. For the purpose of complying with this requirement the use is allowed of the protecting devices (e.g., extreme moment clutch) fitted between the drive and the machinery, provided the requirements of 6.3.1.3 are met.

6.3.5.2 The anchor machinery elements situated in lines of force flow shall be checked for strength when affected by stresses corresponding to the rated pull on the sprocket P_1 or P_2. In this case, the reference stresses in the elements shall not exceed $0{,}4R_{eH}$ of the element material.

6.3.5.3 The following pressures and associated areas shall be applied (refer to Fig. 6.3.5.3):

200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction;

150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area where f is determined by the formula

$$f = 1 + B/H \qquad (6.3.5.3)$$

where B = width of machinery measured parallel to the shaft axis;
H = overall height of machinery

but not more than 2,5.

6.3.5.4 Forces in bolts, chocks and stoppers securing the machinery to the deck shall be calculated. The machinery is supported by N bolt groups, each containing one or more bolts (refer to Fig. 6.3.5.4).

6.3.5.5 The axial force R_i in the bolt group or one bolt, positive in tension, may be determined by the formula

$$R_i = R_{xi} + R_{yi} - R_{si} \qquad (6.3.5.5)$$

where $R_{xi} = P_x h x_i A_i / I_x$;
$R_{yi} = P_y h y_i A_i / I_y$;
P_x = force acting normal to the shaft axis, kN;
P_y = force acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in i bolt group, kN;
h = shaft height above the windlass mounting, cm;
x_i, y_i = x and y coordinates of i bolt group from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force, cm;
A_i = cross sectional area of all bolts in i group, cm^2;
I_x = $\Sigma A_i x_i^2$ for N bolt groups;
Iy = $\Sigma A_i y_i^2$ for N bolt groups;
R_{si} = static reaction at i bolt group, due to weight of windlass.

6.3.5.6 Shear forces F_{xi} and F_{yi} applied to i bolt group, and the resultant combined force F_i may be determined by the formulae:

$$F_{xi} = (P_x - \alpha g M)/N; \qquad (6.3.5.6\text{-}1)$$

$$F_{yi} = (P_y - \alpha g M)/N; \qquad (6.3.5.6\text{-}2)$$

$$F_i = (F_{xi}^2 + F_{yi}^2)^{0,5} \qquad (6.3.5.6\text{-}3)$$

where α = coefficient of friction equal to 0,5;
M = mass of windlass, t;
g = gravity acceleration, m/s^2;
N = number of bolt groups.

6.3.5.7 Axial tensile and compressive forces in 6.3.5.5 and lateral forces in 6.3.5.6 shall be considered in the design of supporting structure.

6.3.5.8 Tensile axial stresses in the individual bolts in each i bolt group shall be calculated. The

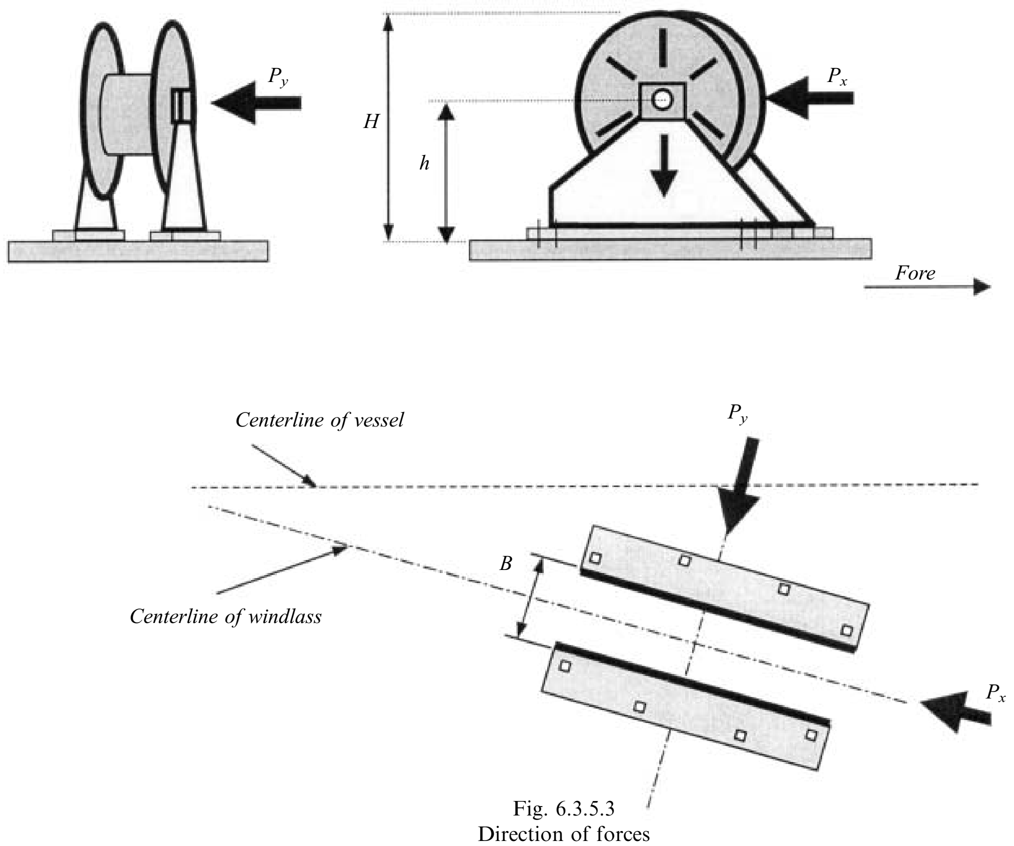


Fig. 6.3.5.3
Direction of forces

N o t e . P_y shall be examined from both inboard and outboard directions separately, refer to 6.3.5.3. The sign convention for y_i is reversed when P_y is from the opposite direction as shown

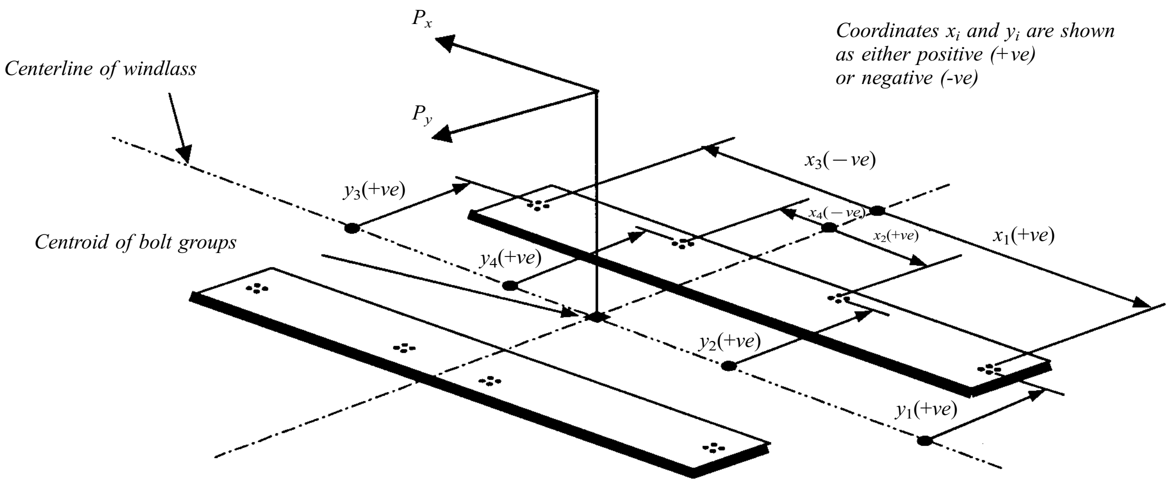


Fig. 6.3.5.4
Sign convention

horizontal forces F_{xi} and F_{yi} shall normally be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, equivalent stresses in the individual bolts shall be calculated, and compared to the allowable stresses. Where synthetic compounds are incorporated in the holding down arrangements, due account shall be taken in the calculations. The safety factor against bolt proof strength shall not be less than 2,0.

6.3.6 Additional requirements.

6.3.6.1 The anchor machinery intended for handling with mooring operations shall comply with the requirements of 6.4, in addition to those of the Chapter.

6.3.6.2 The requirements of the Chapter apply to the remote-controlled anchor machinery chosen in accordance with 3.1.5, Part III "Equipment, Arrangements and Outfit".

6.3.6.3 If the provision is made for remote control of paying out the chain cable with the sprocket disconnected from the anchor machinery drive, a device shall be fitted ensuring an automatic braking by the band brake in order that the maximum speed of paying out will not exceed 3 m/s. In ships with Equipment Number of 400 and less it is permissible not to install a device for an automatic braking by the band brake.

6.3.6.4 The chain sprocket brake shall provide for smooth stopping of the chain cable when paying it out for a period of not more than 5 s and not less than 2 s from the moment of initiation of the signal from the control station.

6.3.6.5 Provision shall be made at the remote control station for an indicator of the length of the chain cable payed out and the indicator of the paying out speed of the cable with the mark of 3 m/s of the maximum permissible speed.

6.3.6.6 Machinery and machinery elements, for which the remote control is provided, shall be manually operated from the local position. The failure of any element or the whole remote control system shall not affect adversely the normal operation of the anchor machinery and equipment manually operated from the local position (refer also to 5.1.3, Part XI "Electrical Equipment").

6.4 MOORING MACHINERY

6.4.1 Drive.

6.4.1.1 The mooring machinery drive shall provide for an uninterrupted heaving-in of a mooring line at a rated pull with the rated speed for a period of not less than 30 min.

The speed, v, of heaving-in of a mooring line on the first rope winding layer on the drum with the nominal pulling force F shall not be less than stated in Table 6.4.1.1.

Table 6.4.1.1

v, in m/s	0,25	0,2	0,16	0,13
F, in kN	Up to 80	81 — 160	161 — 250	Above 250

The speed of heaving-in of a mooring line by the use of a warping drum at the rated pull shall not be over 0,3 m/s. Instructions on the choice of the rated pull are given in 4.4.2, Part III "Equipment, Arrangements and Outfit".

6.4.1.2 Under the rated conditions of the mooring machinery (refer to 6.4.1.1) its drive shall develop the pull on the first rope winding layer on the drum equal at least to 1,5 times the rated value in 2 min.

6.4.2 Overload protection.

If the maximum torque of the drive may bring about a larger load on the mooring machinery elements than that specified in 6.4.4, an overload protection shall be provided.

6.4.3 Brake.

6.4.3.1 The mooring machinery shall be provided with an automatic brake ensuring a hold, without a slip on the mooring line at a pull equal to 1,5 times the rated one when the driving energy disappears or the driving engine fails.

6.4.3.2 The mooring machinery drum shall be provided with a brake, a braking torque of which shall ensure keeping the mooring line from unreeling at a pull in the line equal to 0,8 times the breaking load of the line on the first rope winding layer on the drum.

The force applied to the brake drive handle shall not exceed 740 N.

If the drum is fitted with an arresting or other safety device, the possibility shall be provided for disengaging the drum by an approved means when the mooring cable is under the load.

6.4.4 Strength calculation.

6.4.4.1 The mooring machinery elements situated in lines of force flow shall be checked for strength under the rated pull on the mooring drum. In this case, the reference stresses in the elements shall not exceed $0{,}4R_{eH}$ of the element material.

6.4.4.2 The elements of the mooring machinery and the elements of its fastening to foundation shall be checked for strength under the effect of the maximum torque of the drive and when the drum is affected by an effort equal to breaking force of the mooring cable.

Besides, the strength of the warping drum shaft under the load applied in the middle of its length, equal to the breaking force of the mooring cable shall be checked.

In all above-mentioned cases, the stress in the elements shall not exceed $0{,}95R_{eH}$ of the element material.

The strength of the mooring machinery elements shall allow for all possible kinds and geometrical directions of the loads that may arise during operation.

The strength of the mooring rope intended for operation with the mooring machinery shall be indicated on the machinery.

6.4.5 Automatic mooring winches.

6.4.5.1 The performance characteristics and durability of the automatic mooring winches shall not be inferior to the similar-purpose non-automatic machinery.

6.4.5.2 Automatic winches shall be equipped with the manual control to provide the possibility of non-automatic operation.

6.4.5.3 The following shall be provided:

sound warning alarm operating with the maximum permissible length of the mooring rope veered out;

an indicator of the actual pull in the mooring rope under the automatic operation.

6.5 TOWING WINCHES

6.5.1 Where automatic devices are used for governing the tension of the towline, provision shall be made to enable checking the value of tension at every moment. The tension indicators shall be installed at the towing winch and on the bridge.

6.5.2 Sound warning alarm operating when the maximum permissible length of the towline is veered out shall be provided. It is recommended to install a towline counter.

6.5.3 The drums of the towing winches shall comply with the requirements of 6.1.6 and shall be provided with fairleads. If two or more drums are provided, the fairleads shall be independent. Rope drum shall be fitted with a coupling to ensure its disconnection from the driving machinery.

Geometrical dimensions of the winch heads shall provide the possibility for paying out of the towline.

6.5.4 The design of the winch shall provide for quick releasing of the drum in order to ensure free paying-out of the towing line.

6.5.5 Brakes.

6.5.5.1 The towing winches shall be provided with an automatic brake ensuring holding of a line at a pull equal to at least 1,25 times the rated one when the driving energy disappears or is switched off.

6.5.5.2 The rope drum of the winch shall be provided with the brake capable of holding the drum, when the effort in the rope is not less than the breaking load of the towline without slipping and when the drum is disconnected from the drive. The drum brake controlled by any type of energy shall be provided with manual control as well. The brake design shall ensure the possibility of quick releasing for the purpose of loosing paying out of the towline.

6.5.6 The towing winch elements situated in lines of force flow shall be checked for strength under the rated rope pull applied to the middle layer of winding. The reference stresses in the elements shall not exceed $0{,}4R_{eH}$ of the element material in this case.

6.5.7 The elements shall be checked for strength when the drum is affected by efforts corresponding to the maximum torque of the drive, as well as when the drum is affected by an effort equal to the towline breaking force on the upper layer of winding. The reference stresses in elements, which may be subjected to efforts caused by the above-mentioned loads, shall not exceed $0,95R_{eH}$ of the element material.

7 HYDRAULIC DRIVES

7.1 GENERAL

7.1.1 Connecting of hydraulic steering gear pipelines and those of the hydraulic power systems of CPP to other hydraulic systems is not permitted.

Connecting of pipelines of the engine-room trunk closures hydraulic drive systems to other hydraulic systems is not permitted.

In passenger ships and special purpose ships, the connection of the pipeline systems of power-operated sliding watertight doors to other hydraulic systems is not permitted.

7.1.2 Where the pipeline servicing hydraulic anchor machinery is connected to other hydraulic system pipelines, the latter shall be serviced by two separate pump units, each of which shall ensure the anchor gear operation with nominal pull and at nominal heaving-in speed.

7.1.3 The hydraulic system failure shall not cause the failure of machinery or arrangement.

7.1.4 Fluids to be used in the hydraulic systems shall be selected with regard to temperature conditions that may occur during operation (refer to Table 2.3.1-2, Part VII "Machinery Installations").

7.1.5 In passenger ships and special purpose ships, the hydraulic systems of power-operated sliding watertight doors may be centralized or independent for each door.

The centralized systems shall be provided with a low-level alarm for hydraulic fluid reservoirs serving the system and a low gas pressure alarm for hydraulic accumulators. Other effective means of monitoring loss of stored energy in hydraulic accumulators may be provided. These alarms shall be audible and visual and shall be situated on the operating console at the navigating bridge.

The centralized systems shall be designed to minimize the possibility of a failure in the operation of more than one door caused by damage to a single part of the system.

An independent hydraulic system for each sliding watertight door shall have a low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators, situated at the operating console on the navigating bridge. Loss of stored energy indication shall be provided at each local operating position.

Besides, the hydraulic systems of power-operated sliding watertight doors in passenger ships and special purpose ships shall comply with the requirements of 7.12.5.7, Part III "Equipment, Arrangements and Outfit".

7.1.6 Hydraulic systems of hatch covers drives of holds adapted to the carriage of dangerous goods additionally shall meet the requirements of 7.10.8.6, Part III "Equipment, Arrangements and Outfit".

7.2 STRENGTH CALCULATION

7.2.1 The hydraulic machinery elements situated in lines of force flow shall be checked under the stresses corresponding to the working pressure. In this case, the reference stresses in elements shall not exceed $0,4R_{eH}$ of the element material.

7.2.2 In cases specified in 6.2.4.1, 6.3.4 and 6.4.2, the elements shall be checked for strength under the stresses corresponding to the opening pressure of the safety valves. In this case, the reference stresses in elements shall not exceed $0,95R_{eH}$ of element material.

7.2.3 The pipelines and fittings of the hydraulic systems shall comply with the requirements specified in Sections 2, 4 and 5, Part VIII "Systems and Piping".

7.3 SAFETY AND OTHER ARRANGEMENTS

7.3.1 The hydraulic machinery shall be protected by safety valves, whice operating pressure shall not exceed 1,1 times the maximum rated pressure, except for the cases specified in 6.2.4.1, 6.3.4 and 6.4.2.

7.3.2 The working fluid from the safety valve shall be led to the drain pipeline or to the oil tank.

7.3.3 Arrangements for complete air expulsion when filling the machinery and the pipeline with the working fluid, as well as for leakage replenishment and drainage shall be provided.

7.3.4 The hydraulic systems shall be provided with the filters of appropriate capacity and filtration purity of the working fluid.

For continuously operating hydraulic systems (hydraulic steering gear, hydraulic couplings, etc.)

provision shall be made for filter cleaning without interruption of the system operation.

7.3.5 Oil seals between fixed parts forming a part of external pressure limit shall be of "metal on metal" type.

Oil seals between moving parts forming a part of external pressure limit shall be doubled in such a way that the failure of one seal would not disable the executive actuator.

The alternative arrangements providing the equivalent leakage protection may be accepted upon the special agreement with the Register.

7.3.6 Hydraulic working cylinder rods that are heavity affected by dust and subject to icing shall be protected against such effects.

7.3.7 The hydraulic machinery shall be provided with a sufficient amount of the instruments to monitor its operation.

8 GAS TURBINES

8.1 GENERAL

8.1.1 Requirements of the Section apply to main and auxiliary marine gas turbines of 100 kW power and above. Application of these requirements to gas turbines of less than 100 kW power will be agreed by the Register in each case.

The present requirements cover converted aircraft, marine and stationary gas turbines, if installed aboard sea-going ships.

The field of applying the gas turbines covered by the present requirements is as follows:

displacement ships, high-speed craft;

dynamically supported ships;

mobile offshore drilling units (MODU) and fixed offshore platforms (FOP).

8.1.2 Design output refers to design conditions, i.e. specified values of ambient air and water temperatures, air humidity, atmospheric pressure and exhaust and suction resistance adopted for gas turbine design.

It is recommended that the following parameters shall be adopted as design conditions (in accordance with the requirements of ISO 2314):

air temperature, in °C, at gas turbine inlet — +15;

relative air humidity, in % — 60;

air pressure, in kPa — 100.

8.1.3 In ships of unrestricted service, at least two main gas turbines shall be used, while a possibility shall exist of the ship movement with one gas turbine in operation.

When a single gas turbine is employed, the necessity of application of the emergency device to ensure ship propulsion shall be agreed with the Register in each case.

8.1.4 When water supply to the air cooler is completely shut off, the gas turbine with air intercooling shall develop an output not less than 20 per cent of the design value.

8.1.5 The gas turbine installation with a reversing device shall provide reversing from full ahead to full astern and vice versa (refer to 2.1.4, Part VII "Machinery Installations").

The gas turbine installation without a reversing device may be installed, if the ship is equipped with other means and devices to ensure astern running.

When the astern turbine is employed, the requirements of 3.1.2 and 3.6.2 shall be followed, for reverse-reduction gear, the requirements of 4.1.1 of the Part shall be complied with and in the case of CPP application, the requirements of 6.5.5, Part VII "Machinery Installations" shall be met.

When using the compressed air for the reverse systems, its store shall provide at least 25 resettings of the reverse. Refuelling of the compressed air store shall be performed automatically from at least two sources.

Connection of other consumers to the high pressure compressed air systems providing the operation of the reverse systems, protection of gas turbines, bridge control is prohibited.

8.1.6 The steady operation of the gas turbines without stalling and surging under all possible operating conditions, manoeuvring included, as well as the permissible deposits on gas turbines and under tropical conditions (air temperature not less than 45 °C, relative air humidity of 95 per cent at 35 °C and sea water temperature of 35 °C) shall be proved by calculations and tests.

Increases and drops of load shall be performed at the speed to ensure steady operation of gas turbine compressors throughout the operating range.

The program for testing the steady operation of the gas turbines shall be agreed with the Register in each case, and the control shall be performed both at the manufacturer's bench and after installation of the gas turbine on board.

8.1.7 Throughout the operating starting, there shall be no zones restricting the gas turbine operation due to vibrations. Normal vibrations shall not exceed the permissible values given in Section 9, Part VII "Machinery Installations".

8.1.8 For the gas turbines of ships with ice strengthening categories **Arc6** to **Arc9**, the requirements of 2.1.2, Part VII "Machinery Installations" shall be met, and where these requirements cannot be fulfilled, the loads on units transmitting the power from the gas turbine to the propeller shall be approved by the Register.

8.1.9 As starting devices, a.c. motors shall be used. The application of d.c. motors and starting devices of other types shall be agreed by the Register in each case.

An opportunity shall be ensured of starting each gas turbine from at least two sources of power. The change-over from one source of power to the other for starting up the turbine shall be performed in not more than 60 s. For high-speed and dynamically supported craft, power supply from one source of power is permitted.

At least four successive starts of the gas turbine shall be possible. An opportunity shall be ensured for starting up the turbine before the rotor driven by the starting device has fully stopped.

8.1.10 When doped fuels leaving deposits of combustion products on gas turbine blades are used, provision shall be made for systems and means of cleaning the blading without stopping the turbine. A system for washing the stopped turbine to clean the turbine blades from deposits and the compressor blades from salt deposits shall be also provided.

The gas turbines of high-speed and dynamically supported craft may be cleaned and washed in port by means of shore appliances.

A cleaning or washing of the blading shall result in the restoration of the gas turbine parameters. The cleaning (washing) media shall not have a corrosive effect on the turbine blading and the surface of the exhaust gas boiler installed behind the turbine. The washing waste shall be discharged to special tanks.

The gas turbine washing medium shall be issued with a sanitary approval permitting its application aboard sea-going ships.

8.1.11 The air suction inlets of the gas turbines shall be fitted with filters to preclude speeds of depositing on the compressor blading dangerous for the normal operation of the gas turbines. The filter efficiency shall be tested at the same time as the ship delivery takes place.

The air inlets shall be so located as to prevent the entry of water, exhaust gas vapours and blowout from the fan into the compressor. Provisions shall be made for preventing the suction duct from icing, if the risk of icing exists under the ship operating conditions.

The reserve intake of 60 per cent of air volume shall be provided in case of icing of the suction.

For high-speed and dynamically supported craft, measures against icing and the reserve air intake need not be taken on agreement with the Register.

The air inlets shall not produce eddies at compressor intakes, which would make the compressor operation less stable under any operating conditions.

Drainage systems of air inlets shall be provided with hydroseals.

Quick-operating devices shall be provided for closing the air inlets.

8.1.12 Gas exhaust systems shall be provided with the remote-controlled arrangements to prevent air circulation through the gas turbine both in case of fire and when in port.

If one air duct or exhaust manifold is intended for two or more engines, gas and air recirculation through non-operating engines shall be prevented.

8.1.13 Air suction and gas exhaust trunks, fuel, refrigeration and other piping shall be connected to the engine so that no expansion stresses are transmitted to the place of connection.

Piping shall withstand vibration on levels generated during the gas turbine operation.

8.1.14 All the internal components of air ducts and trunks for air supply to compressors shall be manufactured from corrosion-resistant materials. The dimensions of the components and fastenings shall exclude the possibility of their penetration through the protective grating before the compressor. All inner mountings shall be fixed. The trunks and ducts shall provide the possibility of periodical checking of the condition of inner surfaces.

8.1.15 All turbochargers and gas turbines shall be fitted with a turning arrangement. Provision shall be made for interlocking the shaft-turning gear with the gas-turbine starting device or for an automatic disconnection of the shaft-turning gear.

Quick-disconnecting couplings shall be provided with interlocking excluding the starting up of the gas turbine with the reduction gear being disconnected.

8.1.16 Gas turbines for driving the emergency generator and fire pump shall be fitted with independent fuel, lubricating oil and cooling systems. In addition to automatic starting, manual starting from the local control station shall be provided.

8.1.17 To discharge the liquid fuel (or gas, if gas-operated) remaining in the gas turbine after failed starting or due to fuel leakage in the combustion chamber during standby condition, provision shall be made for "a cold start" (false starting without fuel supply) before each turbine starting.

The duration and number of the "cold starts" shall be sufficient for a complete discharge of unburnt fuel (gas) from the turbine.

8.1.18 To prevent lubricating oil vapour emission to the atmosphere, lubricating oil tanks shall be equipped with special separators discharging air into the exhaust gas duct (to gas vent section).

8.1.19 Each gas turbine shall be covered with a noise- and warmth-insulating case with the inner space aired by a special ventilator or as a result of exhaust gas ejection. The temperature of the outer surface of the case shall be in agreement with the sanitary norms. Shall be also ensured access to principal units and components for maintenance and examination of blading, compressors and combustion chambers with endoscopes.

To comply with sanitary norms for noise level in the machinery space, provision shall be made for noise muffling at air inlet and gas outlet of the turbine.

8.1.20 Each gas turbine shall have a fire extinguishing system independent of the other systems of the kind installed in the machinery space. Where several gas turbines are installed on board, provision shall be made for the transfer of the fire-extinguishing medium from the fire-extinguishing system of one gas turbine to those of the others. The amount of fire-extinguishing medium in the fire-extinguishing system shall be determined on the assumption of the inner volume of each gas turbine and the waste-heat boiler installed thereafter (if any) being filled. The gas turbine shall be equipped with two detectors pertinent to the fire-extinguishing system, one for the temperature of the environment beneath the noise - and warmth-insulating case and the other for the temperature of exhaust gases behind the turbine.

8.1.21 Fuel and lubricating oil piping shall be so arranged or equipped that in case of their rupture the leakage could not get on the hot surfaces of the gas turbine.

8.1.22 The spares available on board shall be in accordance with the requirements of Table 10.2.8, Part VII "Machinery Installations". The gas turbine manufacturer is entitled to furnish his own lists of spare parts proceeding from the operation record of the particular type of unit.

8.1.23 Where the turbines are converted for marine service, checks on service life shall be carried out on agreement with the Register.

8.2 GAS TURBINE ROTORS

8.2.1 The strength analysis of the gas turbine rotors shall be performed for the rated output condition and for conditions when the stresses can reach their maximum values. The check calculation of a turbine with overcapacity shall be made for a rotational speed by 20 per cent higher than the nominal one, and for the other rotors, the check calculation shall be made for a rotational speed exceeding the nominal speed by 10 per cent.

8.2.2 For the rotating parts of the gas turbine, the enlarged torque shall be analysed corresponding to the turbine operation at an ambient air temperature reduced by 20 °C lower as compared to the design temperature.

8.2.3 The strength calculation of rotating parts of the astern gas turbines shall be performed to the maximum torque corresponding to the crush stop from full ahead to full astern at the maximum capacity output of the astern turbine.

8.2.4 The strength calculation of the units transmitting power from the gas turbine to the electric generator drives shall be made on the basis of torque corresponding to the short-circuit condition, unless special sliding couplings are used in the "engine-generator" system.

8.2.5 The critical rotor speed shall be determined with regard to brackets and shall meet the requirements of 3.2.2. For overhanging rotors, precession calculation and additional loads from the gyroscopic moment shall be carried out.

8.2.6 The requirements of 3.2.3 to 3.2.5 shall be also complied with.

8.2.7 The dynamic stresses in the blades of compressors operating in the corrosive medium shall be experimentally determined by the manufacturer throughout operating ranges, including starting ranges, and the blading shall be so set that dangerous vibrations do not occur. The factor of fatigue strength of the blades shall not be less than 3 for the operating ranges or less than 2,5 for transient ranges. This requirement may be waived, if the gas turbine manufacturer supplies data on the reliability of the compressor blades in a corrosive medium with lower fatigue safety factors.

8.3 GAS TURBINE CASINGS

8.3.1 Special sight holes for inspection of the blading shall be provided in the casings of gas turbines and compressors, and the gas turbines shall be equipped with special instruments for inspection (endoscopes).

8.3.2 Where sleeve bearings are applied in the gas turbine, its casing shall be in accordance with the requirements of 3.3.7.

8.3.3 When the internal lagging of the gas turbine casing is applied, it shall be safely fastened and covered with a sheath in order to prevent local stripping of the casing surface and the contacts between the lagging and the blading.

8.3.4 The oil seal design shall be such as to prevent the lubricating oil and oil vapours from entering into the blading of the turbines and compressors, and the blow-out of oil and vapours outside.

8.3.5 Each gas turbine shall have drain holes in the lower point of the casing, which shall have spouts connected to leakage collecting tanks via open funnels so the turbine would not be flooded in case of the leakage collecting tank overfilling.

8.3.6 The casings shall ensure impenetrability for the case of rotor blade break.

8.4 GAS TURBINE BEARINGS

8.4.1 The sleeve bearings of the gas turbines shall comply with the requirements of 3.4.

8.4.2 For marine gas turbines irrespective of type, roller bearings may be used.

8.4.3 Each lubricating oil spout of the gas turbine supports shall be equipped with alarms for the presence of chips and with lubricating oil temperature sensors.

8.4.4 The application of inner bearings for three-bearing shafts shall be subject to consideration by the Register in each case.

8.4.5 In any case, the gas turbine stop shall not damage the bearings. To this end, provision shall be made for lubricating oil supply in case of the turbine stop and for automatic activation of the rotor turning system.

8.5 COMBUSTION CHAMBERS

8.5.1 The arrangement of the combustion chamber design of the gas turbines shall provide the convenience of servicing and the possibility of replacement of burners and flame tubes at sea. The burners shall be inter-changeable without the necessity of a substantial adjustment of the fuel oil supply system.

8.5.2 The possibility of inspection shall be provided for the flame tubes of the combustion chambers with endoscopes without disassembling.

8.5.3 The entering of the fuel into the combustion chambers of the gas turbine, while the engine is out of action, shall be excluded.

8.5.4 High-pressure fuel oil piping and main burners shall be made clean of fuel after the turbine or burner shutdown.

Starting fuel oil piping and starting burners shall be made clean of fuel after the end of the starting condition.

Making clean of fuel shall be achieved by automatic opening of discharge valves on the relevant pipe.

8.5.5 The gas turbine shall be equipped with two igniters at least.

8.6 HEAT EXCHANGERS

8.6.1 The possibility of detection of leakages and the location of the damaged member by means of a pressure test shall be provided in the heat exchangers of the gas turbines (regenerators and gas coolers).

The regenerators shall be tested for tightness both on the gas and the air side. The method and procedure for detecting the leakages and damaged components, as well as disconnection thereof shall be set forth in special instructions.

8.6.2 Dangerous resonance vibrations and self-excited vibrations of the heat exchanger components shall be excluded.

8.6.3 The regenerator shall be provided with a fire-extinguishing system in compliance with the requirements of item 11 of Table 3.1.2.1, Part VI "Fire Protection".

8.6.4 The air coolers of the gas turbines shall comply with the requirements of 1.5.6.

8.6.5 The air coolers shall provide for the possibility of the inspection and cleaning of the tube plates and muffling without removing the covers.

8.6.6 The air coolers shall be provided with arrangements for continuous removal of moisture falling out of the air during the gas turbine operation.

8.6.7 Besides, the heat exchangers shall be in accordance with the requirements of Sections 1, 2 and 6, Part X "Boilers, Heat Exchangers and Pressure Vessels" except for 6.3.1 to 6.3.4, 6.3.6.

8.7 CONTROL, PROTECTION AND REGULATION

8.7.1 The main gas turbine shall be provided with the automatic regulation and remote control systems ensuring the following:

.1 setting the necessary rates and steady maintaining thereof throughout the whole range of operating speeds so that thermal shocks are avoided;

.2 starting and stopping under any operating conditions;

.3 maintaining of steady operation of the compressors and combustion chambers under any transient service conditions and under load;

.4 preventing a sudden increase of gas temperature;

.5 unified control of the gas turbine and propeller by the single lever or hand wheel, preserving the possibility of separate control;

.6 restriction of torque at the power take-off shaft, where necessary;

.7 purging the combustion chambers of turbines and the offtake pipe from liquid or gaseous fuel oil accumulated there before ignition at start or after unsuccessful start (refer to 8.1.17).

The starting devices shall be designed so that the ignition process stops and the main fuel valve is closed at the ignition failure, protection being activated or gas turbine stop.

8.7.2 Each power turbine shall be provided with an overspeed device (on rotation speed) directly connected to the turbine shaft. The oil switch receiving the impulse from the propeller directly driven by the turbine shaft may be used as an overspeed device, but it shall operate so that racing the turbine above the specified "maximum permissible" speed is not allowed.

The maximum permissible speed shall not exceed the rated speed by more than 15 per cent.

8.7.3 Main gas turbines transmitting power directly to the propeller shall have a speed governor besides the overspeed device, which shall limit the speed of the power turbine in case of load fluctuations before the overspeed device is actuated.

The speed governor shall be so adjusted that the power turbine rotation speed would not exceed the rated rotation speed by more than 8 per cent.

If fuel supply is reduced by the governor, stopping of the gas turbine is not permitted.

Generator-driving gas turbines shall have their speed governors in compliance with the requirements of 2.11.3 to 2.11.5.

8.7.4 The main gas turbine shall provide the standby "crush stop" condition ready for immediate use for at least 60 min ensuring beginning of ship's movement immediately after receiving the command. In a "crush stop" condition the speed of the propeller shaft shall not exceed 3 min^{-1}.

Unlimited readiness of the gas turbine for immediate use for at least 20 min shall ensure within this period the possibility for heating of the gas turbine, its starting, as well as beginning of ship's movement.

8.7.5 The requirements of 2.4, Part XV "Automation" shall be met.

8.7.6 Main and auxiliary gas turbines shall be fitted with an arrangement for emergency stopping under any operating conditions by at least two independent means.

When operating from the bridge control at the wheelhouse, provision shall be made for an emergency stopping of the gas turbine from the control station in the engine room in close proximity to the turbine.

8.7.7 The manoeuvring arrangement of the gas turbine installation with an astern turbine shall comply with the requirements of 3.6.1 and 3.6.2. The manoeuvring ahead and astern valves shall be interlocked. Irrespective of the position of manoeuvring valves, the operation of the gas turbine compressors shall be sufficiently stable.

The gas turbine installation shall be provided with a local control console for the astern turbine.

8.7.8 In addition to the overspeed device operation, the gas turbine protection system shall provide full interruption of fuel supply in case of alarm for the following parameters:

.1 lubricating oil pressure drop in the system below the permissible level;

.2 gas temperature rise above the permissible level before or after the turbine;

.3 limit level of vibration;

.4 flame-out;

.5 excess of revolutions of a low pressure compressor exceeding permissible value (for three-shaft gas turbines with a free-propeller turbine and gas reverse);

.6 limiting axial rotor shift;

.7 dangerous air pollution of the machinery and boiler room, if gas-operated.

In case of emergency, the provision shall be made for the manual interruption of fuel supply from the local control station in the vicinity of the gas turbine.

Proceeding from the gas turbine design, the manufacturer may introduce additional types of protection.

8.7.9 Automated main gas turbines shall comply with the requirements of Part XV "Automation".

8.7.10 The gas turbine control system shall also comply with the requirements of 2.5, 3.1 to 3.3, Part VII "Machinery Installations".

8.7.11 The working medium of the control system shall not become viscous at low temperatures or be readily flammable.

The filter and heat exchanger system shall provide the necessary temperature and purity of the working medium.

8.7.12 For main gas turbines, provision shall be made for monitoring the readings of permanent tacho-meters.

8.7.13 The control systems of gas turbines intended for driving generators shall be in compliance with the requirements of 2.11.3 to 2.11.7.

8.8 INSTRUMENTATION

8.8.1 The control station of the main gas turbine shall be provided with instruments for measuring parameters in accordance with 8.7.9, with devices specified in 3.7.2.2 to 3.7.2.4, as well as instruments to carry out thermal check of the gas turbine operation.

8.8.2 The control stations of the auxiliary gas turbines shall be provided with instruments to measure the following parameters:

.1 rotor rotation speed;

.2 lubricating oil pressure at the gas turbine inlet;

.3 fuel oil pressure at the gas turbine inlet;

.4 lubricating oil temperature at the gas turbine inlet;

.5 gas temperature at turbine inlet or outlet.

8.8.3 Where the main gas turbine is provided with a system for monitoring and preventive diagnostics, the number of parameters to be covered by such a system shall be subject for consideration by the Register in each case for each gas turbine type.

8.9 WASTE-HEAT CIRCUIT OF GAS TURBINE

8.9.1 Where the gas turbine units are provided with waste-heat circuits, the steam turbine shall be in compliance with the requirements of Section 3 of the present Part and the waster heat boiler shall comply with the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels".

8.9.2 The waster-heat circuits shall be provided with systems to ensure evacuation in condensers before or during the gas turbine start.

Condensers shall be provided with protection against pressure rising above permissible values.

8.9.3 At the beginning of the rotor rotation, provision shall be made for an automatic disconnection of the shaft-turning gear of the steam turbine.

8.9.4 In case two gas turbines with waste-heat circuits are installed in a twin-shaft ship, an operating mode is permitted with the shaft on one side being driven by the gas turbine and the shaft on the other side being driven by the steam turbine.

In this case, quick disconnecting clutches shall be used, which serviceability shall be tested by the special program approved by the Register.

8.9.5 Steam turbine plants working on waste steam shall comply with the requirements of Sections 17 to 19, Part VIII "Systems and Piping".

8.10 NATURAL GAS FIRED TURBINES

8.10.1 Requirements of the Chapter cover the gas turbines installed on board gas carriers and using the vapours of the natural gas (methane) carried as fuel. For this purpose, the gas carrier shall be provided with an installation to prepare the gas vapours for using in the gas turbine.

8.10.2 Natural gas fired turbines are subject to the requirements of 8.1 to 8.9.

8.10.3 Natural gas is used to start the turbine and operate it in all modes.

8.10.4 The gas fuel supplied to the turbine shall not include any liquid fraction.

8.10.5 Gas fuel supply piping shall comply with the requirements of 13.12, Part VIII "Systems and Piping".

8.10.6 For gas-fired operation, the requirements of 2.4, Part XV "Automation" shall be met.

8.10.7 In case of stop of gas fuel supply, the gas turbine shall be shut down automatically by means of a quick shut-off valve fitted as near to the gas turbine as possible.

8.10.8 A manual gas fuel shut-off device shall be provided directly at the gas turbine. Besides, manual shutdown shall be possible from several locations in the engine room, from a space other than the engine room and from the navigating bridge.

8.10.9 In the engine room, an alarm shall be provided for the maximum permissible gas concentration corresponding to 30 per cent of the lower flammability limit, with an alarm to be installed at the main control station.

The gas supply to the turbine shall be shut off automatically with the gas concentration in the machinery space reaching 60 per cent of the lower flammability limit. The requirement of 8.4.5 shall also be met.

8.10.10 Gas turbine operation using two types of fuel (liquid and gas fuel) requires special fuel equipment to be installed and shall be subject for consideration by the Register in each case.

Requirements for natural gas fired turbines, as given in the Chapter, shall be met in this case.

9 DUAL-FUEL INTERNAL COMBUSTION ENGINES

9.1 GENERAL

9.1.1 The requirements of the present Section are applicable to dual-fuel internal combustion engines (DF-engines) with ignition from compression, operated on liquid fuel and natural gas (methane).

9.1.2 Individual requirements relevant to the application of the DF-engines are given in 4.2.10, Part VII "Machinery Installations" and in 5.5.1 of the present Part.

9.2 CONDITIONS OF OPERATION ON TWO KINDS OF FUEL

9.2.1 When operated on two kinds of fuel DF-engines shall be equipped with the arrangement for supply of starting fuel with further supply of gas fuel. The possibility of quick change-over from gas fuel to liquid fuel shall be provided.

Starting fuel shall be supplied to each cylinder in all operation modes of the DF-engines.

9.2.2 Start of DF-engines, astern operation shall be carried out on liquid fuel only.

9.2.3 When DF-engine is run on variable modes, ships maneuvering, mooring operations, only liquid fuel shall be used.

9.2.4 In case of unexpected gas fuel cut off DF-engine shall continue operation on liquid fuel without stop.

9.2.5 DF-engines shall be provided with sensors for blocking simultaneous feed of gas fuel and complete supply of liquid fuel.

9.3 CRANKCASE PROTECTION

9.3.1 Crankcases of DF-engines shall be fitted with safety valves in way of each crankshaft crank. Design and actuating pressure of the safety valves shall be specified with due regard to the possible explosion of gas fuel leakage accumulated in the crankcase.

9.3.2 When a trunk-piston engine is used as the DF-engine, the crankcase shall be protected as follows:

.1 to prevent accumulation of gas fuel leakage, the ventilation of crankcases shall be provided. Air pipe ends shall be led to safety place and fitted with flame arresters;

.2 detectors of gas fuel leakage or any other equivalent equipment shall be installed. Device for automatic admission of inert gas is recommended for installation;

.3 mounting of oil mist concentration sensor in the crankcase shall be provided.

9.3.3 When a cross-head type engine is used as the DF-engine, the engine crankcase shall be equipped with oil mist concentration sensor or temperature control system of the engine bearings.

9.4 PROTECTION OF SUB-BEARING SPACES OF THE CROSS-HEAD TYPE DF-ENGINES

9.4.1 Sub-bearing spaces shall be provided with gas fuel leakage detectors or any other equivalent devices.

9.5 INTAKE AND EXHAUST GAS SYSTEMS

9.5.1 Intake piping and supercharging air receivers as well as exhaust gas collectors shall be fitted with safety valves or other protective devices.

9.5.2 Exhaust gas pipelines from DF-engines shall not be combined with exhaust gas piping from other engines, boilers or incinerators.

9.5.3 The exhaust gas piping shall be provided with effective means of blowing off.

9.6 STARTING AIR PIPING

9.6.1 Branch pipes of starting air piping laid to each cylinder shall be equipped in compliance with the requirements of 2.9.2.

9.7 COMBUSTION CONTROL

9.7.1 The range of combustion control shall be determined and presented for approval with due regard to the analysis of the origin of failures and their consequences for all the elements of DF-engines affecting the combustion process.

The minimum range of control, types of automatic protection and parameter limit values are given in Table 9.7.1.

Table 9.7.1

No.	Controlled parameter or DF-engine component	Measurement point or monitoring conditions	Parameter limit values (alarm) or fault symptoms	Automatic shut-off of the gas fuel supply valves	Indication in main machinery control room
1	Gas fuel injection valves and starting oil fuel injectors	Each cylinder	Seizing of gas fuel injection valve in open condition	X	Constantly
		At each cylinder outlet	Ignition failure		
2	Exhaust gas temperature	Deviation from average	max	X	Constantly
		In each cylinder	max	X	Constantly
3	Combustion pressure	Deviation from average	max	X	On call
4	Gas fuel supply pressure	At engine inlet	min	X	Constantly

9.8 GAS FUEL SUPPLY

9.8.1 At the inlet of gas fuel supply collector to the DF-engine cylinders the flame arrester shall be fitted.

9.8.2 An arrangement for manual cut-off the gas fuel supply to the DF-engine from the local control station shall be provided.

9.8.3 Gas fuel supply piping shall meet the requirements of 13.12, Part VIII "Systems and Piping".

9.8.4 The connection of the engine gas collector with the ship gas piping shall provide the necessary flexibility.

9.8.5 The connection of the gas fuel supply collector to the gas fuel injection valves shall provide complete coverage by the protection pipes or ducts.

9.9 GAS FUEL SUPPLY CUT-OFF

9.9.1 Gas fuel supply cut-off to DF-engines by means of automatic closing of valves on the engine shall be performed when the DF-engine has stopped due for any unknown reason or in cases stated in 9.3.2.2, 9.3.2.3, 9.3.3, 9.4.1, 9.7.1 of the present Part, and 13.12.2 or 13.12.3, Part VIII "Systems and Piping".

9.9.2 It is advisable that the main cut-off valve for gas fuel supply to the collector could be automatically closed at the failure of gas fuel feed valves to DF-engine combustion chambers (refer to 9.7.1 of the present Part and 13.12.6, Part VIII "Systems and Piping").

9.9.3 Gas fuel supply to DF-engines shall be auto-matically terminated when the concentration of gas in the engine room reaches 60 per cent of the lower inflammability level. The requirements of 9.2.4 shall be met.

PART X. BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to boilers, heat exchangers and pressure vessels, excluding:

.1 water heating boilers (not mentioned in 1.3.2.1 and 1.3.2.3);

.2 manned submersibles and diving systems as regards the construction and strength of their pressure hulls;

.3 non-stationary standard liquefied gas cylinders (refer to 1.3.2.4);

.4 assemblies and components of units that are not self-contained pressure vessels;

.5 units comprising pressure pipe systems and installed outside boilers, heat exchangers or pressure vessels;

.6 air coolers designed to operate at a working pressure less than 0,1 MPa in the air space;

.7 heat exchangers and vessels subjected exclusively to liquid pressure (not mentioned in 1.3.2.1 and 1.3.2.3).

1.1.2 The requirements of the present Part also apply to oil burner units of boilers.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 The definitions and explanations relating to general terminology of the Rules are given in Part I "Classification".

For the purpose of the present Part the following definitions have been adopted.

Automatic boiler oil burner unit is a device for combustion of fuel oil, the operation of which is controlled automatically, without any direct attendance of the operating personnel.

Auxiliary boilers for essential services are boilers, which supply steam to the auxiliary machinery, systems and equipment providing propulsion of the ship, safety of navigation and proper carriage of goods, if no other sources of power being available on board the ship for operating the said machinery, equipment and systems in case the boilers fail to operate.

Working pressure is the maximum permissible pressure under normal conditions on continuous running, excluding permissible short-time pressure rises, such as may be occasioned by the operation of a safety valve or other protective devices.

Design boiler capacity is the maximum amount of steam that can be generated by the boiler at design parameters during 1 h on continuous running.

Design wall temperature is the average wall thickness temperature used in calculation of allowable stresses in dependence upon the temperature of the medium and the heating conditions.

Design pressure is the pressure used in strength calculations.

Walls of boilers, heat exchangers and pressure vessels are the walls of steam and water (gas and liquid) spaces as well as the walls of branch pipes up to the stop valves and the walls of stop valve bodies.

1.3 SCOPE OF SURVEYS

1.3.1 General.

1.3.1.1 The general provisions relating to procedure of classification, survey during construction and in service are given in the General Regulations for the Classification and Other Activity and in Part I "Classification".

1.3.1.2 Boilers, heat exchangers and pressure vessels are classified in accordance with Table 1.3.1.2 depending on the parameters and design features.

Table 1.3.1.2

Item	Class		
	I	II	III
Boilers including waste-heat boilers and water heating boilers designed for water temperature above 115 °C, steam superheaters and steam headers	$p > 0,35$	$p \leqslant 0,35$	—
Thermal fluid boilers, pressure vessels and heat exchangers with toxic, inflammable or explosive working medium	Any parameters	—	—
Steam-heated steam generators	$p > 1,6$	$p \leqslant 1,6$	—
Pressure vessels and heat exchangers	$p > 4$ or $t > 350$ and $s > 35$	$1,6 < p \leqslant 4$ or $120 < t \leqslant 350$ and $16 < s \leqslant 35$	$p \leqslant 1,6$ and $t \leqslant 120$ and $s \leqslant 16$
Symbols: p = design pressure, in MPa t = design wall temperature, in °C s = wall thickness, in mm			

1.3.1.3 Boilers and heat exchangers of Class I and II shall be produced by manufacturers having the Recognition Certificate of the Register.

1.3.2 Scope of surveys.

1.3.2.1 Subject to survey by the Register in the process of construction are:

.1 steam boilers (including waste-heat boilers), steam superheaters and economizers operating at working pressure of 0,07 MPa and upwards;

.2 thermal fluid boilers (with organic working medium), including waste-heat boilers;

.3 heat exchangers and vessels, which under operating conditions are filled fully or partially with gas or vapour at working pressure of 0,07 MPa and over, and which have a capacity of 0,025 m^3 and over, or with the product of pressure, in MPa, by capacity, in m^3, being 0,03 MPa·m^3 and upwards;

.4 desalinating plants;

.5 condensers of main and auxiliary machinery;

.6 oil burning equipment;

.7 water heating boilers designed for water temperatures above 115 °C;

.8 coolers, heaters and filters of fuel and lubricating oil and water for main and auxiliary engines;

.9 automatic devices for control of salinity of boiler feed water;

.10 incinerator boilers.

1.3.2.2 Exempt from the survey by the Register in the process of construction are the heat exchangers and pressure vessels indicated in 1.1.1.2 and 1.1.1.6.

1.3.2.3 Water heating boilers designed for water temperatures above 115 °C shall comply, as regards the materials used and scantlings of elements, with the requirements for steam boilers specified in the present Part.

Filters and coolers of main and auxiliary machinery shall comply, as regards the materials used and scantlings of elements, with the requirements for heat exchangers and pressure vessels specified in the present Part.

1.3.2.4 Cylinders designed for storage of compressed gases and used in various sytems and units for the purposes of ship's operation may be manufactured to the current standards under the supervision of a competent technical supervision body.

1.3.2.5 The scope of survey of the heat exchangers and pressure vessels incorporated into refrigerating plants is specified in 1.1.3, 1.3.2 and 1.3.3, Part XII "Refrigerating Plants".

1.3.3 Components subject to survey.

The components specified in Table 1.3.3 are subject to survey by the Register during manufacture according to the technical documentation approved by the Register, the list of which is given in 1.3.4.

1.3.4 Technical documentation.

1.3.4.1 The following technical documentation shall be submitted to the Register before manufacture of boilers, heat exchangers and pressure vessels is commenced:

.1 construction drawings with sections and descriptions, giving all necessary data for checking the calculations and structures (scantlings, materials, electrodes, location and dimensions of weld seams, fastenings, heat treatment methods to be used, etc.);

Table 1.3.3

Nos	Components of boilers, heat exchangers and pressure vessels	Material	Chapter of Part XIII "Materials"
1	**Boilers, steam superheaters, economizers and steam-heated steam generators**		
1.1	Shells, end plates, tube plates, drums, headers and chambers	Rolled steel	3.3
1.2	Heated and non-heated tubes	Seamless steel	3.4
1.3	Furnaces and elements of combustion chambers	Rolled steel	3.3
1.4	Girders, long and short stays	Forged steel	3.7
		Rolled steel	3.3
1.5	Bodies of mountings and fittings for pressure of 0,7 MPa and over	Forged steel	3.7
		Cast steel	3.8
		Cast iron	3.9
		Copper alloys	4.1
2	**Heat exchangers and pressure vessels**		
2.1	Shells, distributors, end plates, headers and covers	Forged steel	3.7
		Rolled steel	3.3
		Cast steel	3.8
		Copper alloys	4.1
		Cast iron	3.9
2.2	Tube plates	Rolled steel	3.3
		Copper alloys	4.1
2.3	Tubes	Seamless steel	3.4
		Copper alloys	4.1
2.4	Reinforcing elements, long and short stays	Forged steel	3.7
		Rolled steel	3.3
2.5	Bodies of fittings for pressure of 0,7 MPa and over, 50 mm in diameter and over	Forged steel	3.7
		Cast steel	3.8
		Copper alloys	4.1
		Cast iron	3.9
Note. The material shall be selected according to 1.4.			

.2 construction drawings for the components listed in Table 1.3.3, unless all necessary data are shown in the drawings mentioned in 1.3.4.1.1;

.3 valve replacement with technical data;

.4 strength calculations made in accordance with the present Part of the Rules for components subject to pressure other than mountings, fittings, flanges and fastenings if the latter comply with the standards approved by the Register;

.5 calculation of cross-sectional area of safety valves;

.6 welding process;

.7 drawings of oil burning equipment, chambers and arrangements for combustion of oil residues and garbage (for incinerator boilers);

.8 bench test programme.

1.3.4.2 Documentation on automatic control system, protective devices and alarms, as well as on automatic oil burning installations shall be submitted in accordance with the requirements of 3.2.9, Part I "Classification" and 1.4, Part XV "Automation".

1.4 MATERIALS

1.4.1 Materials intended for manufacture of components of boilers, heat exchangers and pressure vessels shall satisfy the requirements of the relevant chapters of Part XIII "Materials" specified in column 4 of Table 1.3.3.

Materials for components of boilers, heat exchangers and pressure vessels of Class III as well as components specified in items 1.5 and 2.5 of Table 1.3.3 may also be selected in accordance with the standards. In this case, the use of materials is subject to agreement with the Register during consideration of the technical documentation.

Materials for components of boilers, heat exchangers and pressure vessels of Class I and Class II, which are listed in Table 1.3.3 (except components specified in items 1.5 and 2.5), are subject to survey by the Register during manufacture.

1.4.2 Carbon and carbon-manganese steels are permitted for manufacture of components of boilers, heat exchangers and pressure vessels at design temperatures up to 400 °C, and low-alloy steel, at design medium temperatures up to 500 °C. The use of these steels for media with temperatures above the specified values may be permitted on condition that their mechanical properties and average stress to produce rupture in 100000 hours satisfy the current standards and are guaranteed by the manufacturer at the specified elevated temperature. For media with temperatures above 500 °C the components, valves and fittings of boilers and heat exchangers shall generally be made of alloy steel.

1.4.3 For heat exchangers and pressure vessels with design medium temperatures below 250 °C, on agreement with the Register, hull structural steel may be used according to the requirements of 3.2, Part XIII "Materials".

For some components of heat exchangers and pressure vessels with working pressures below 0,7 MPa and design medium temperatures below 120 °C semi-killed steel may be used on agreement with the Register.

1.4.4 When the yield stress at the elevated temperature is taken as the design characteristic of the material (refer to 2.1.4.1), tensile tests of the material shall be carried out at the design wall temperature; when the design characteristic is the average stress to produce rupture in 100 000 hours, the data on the average stress at the design wall temperature shall be submitted to the Register.

1.4.5 The use of alloy steel for boilers, heat exchangers and pressure vessels is subject to special consideration by the Register.

In this case, it is necessary to submit to the Register data on mechanical properties, average stress to produce rupture in 100 000 hours at the design wall temperature for steel and welded joints, technological characteristics, welding technique and heat treatment.

The use of cast iron and copper alloys for valves and fittings of thermal fluid boilers is not permitted.

1.4.6 Boiler valves and fittings of nominal diameter frow 50 up to 200 mm designed for working pressure up to 1 MPa and temperatures up to 350 °C may be manufactured from spheroidal or nodular graphite cast iron of entirely ferritic structure meeting the requirements of Table 3.9.3.1, Part XIII "Materials".

For the same mountings and fittings with nominal diameter d below 50 mm, the product $p{\cdot}d$ shall not exceed 250 MPa·mm.

1.4.7 Components and fittings of heat exchangers and pressure vessels with diameters up to 1000 mm and working pressures up to 1 MPa may be manufactured from spheroidal or nodular graphite cast iron of entirely ferritic structure meeting the requirements of Table 3.9.3.1, Part XIII "Materials".

1.4.8 The use of copper alloys for components of boilers, heat exchangers and pressure vessels as well as for their fittings is allowed at design medium temperatures up to 250 °C and working pressures up to 1,6 MPa.

The use of copper alloys for other conditions is subject to special consideration by the Register in each case.

1.4.9 For components specified under items 1.2 and 2.3 of Table 1.3.3, on agreement with the Register, electric welded tubes with longitudinal seams may be used if it is demonstrated that they are equivalent to seamless tubes (refer also to 3.2.14).

1.4.10 Composite materials (structures made of laminated fibrous composite materials and metals, having cylindrical or spherical configuration) may be used in pressure vessels for the design temperatures not higher than 60 °C. The manufacturer or designer shall submit to the Register full details of the materials used (structure and density of reinforcement, moduli of elasticity and shear, yield point, tensile strength, ultimate strains, impact toughness, low cycle fatigue resistance, etc). Moreover, details of product structure, method of manufacture (residual stresses after liner moulding, heat treatment, etc), working environment and service loads shall be submitted as well.

1.5 WELDING

1.5.1 Welding and non-destructive testing of welded joints shall comply with the requirements specified in Part XIV "Welding".

1.5.2 Butt joints shall generally be used.

Structures using fillet joints or joints affected by bending stresses are subject to special consideration by the Register.

Typical examples of allowable welded joints are given in the Appendix.

1.5.3 Arrangement of longitudinal welds in one straight line in structures composed of several sections is subject to special consideration by the Register.

1.6 HEAT TREATMENT

1.6.1 Components, in which the material structure may undergo changes after welding or plastic working, shall be subjected to appropriate heat treatment.

When performing heat treatment of a welded structure, the requirements of 2.4.4, Part XIV "Welding" shall be duly observed.

1.6.2 Heat treatment is required for:

.1 plate-steel elements of boilers, vessels and heat exchangers, which are subjected during manufacture to cold stamping, bending and flanging resulting in plastic deformation of surface fibres exceeding 5 per cent;

.2 tube plates welded of several components (heat treatment, in this case, may be performed before drilling for tube holes);

.3 welded end plates manufactured by cold stamping;

.4 elements subjected to hot forming, with the temperature at the end of this process being lower than that of forging;

.5 welded structures manufactured from steels with a carbon content higher than 0,25 per cent.

1.7 TESTS

1.7.1 On completion of manufacture or assembly all the components of boilers, heat exchangers and pressure vessels shall be subjected to hydraulic tests in accordance with the requirements of Table 1.7.1.

1.7.2 Hydraulic tests shall be carried out on completion of all welding operations and prior to application of insulation and protective coatings.

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

1.7.4 The dimensions of components to be tested under test pressure $p_w + 0{,}1$ MPa and also of components to be tested under test pressure above the value given in Table 1.7.1 shall be checked by calculation to this pressure. The stresses involved shall not exceed 0,9 times the yield stress of the material.

1.7.5 After installation on board the ship the steam boilers shall be steam tested under working pressure.

1.7.6 After installation on board the ship the air receivers shall be air tested under working pressure, with all fittings complete.

1.7.7 Heat exchangers and vessels incorporated in refrigerating plants shall be tested as specified in 12.1, Part XII "Refrigerating Plants".

1.8 BOILER ROOMS AND SPARE PARTS

1.8.1 The boiler rooms shall satisfy the requirements of 4.2 to 4.5, Part VII "Machinery Installations".

1.8.2 The requirements for spare parts are specified in 10.1 and Table 10.2-7, Part VII "Machinery Installations".

Table 1.7.1

Nos	Boilers, heat exchangers, pressure vessels and components	Test pressure p_h, MPa	
		after manufacture or joining of strength shell elements less mountings and fittings	after assembly, with mountings and fittings installed
1	Boilers, steam superheaters, economizers and their components operating at temperatures below 350 °C	$1,5p_w$, but not less than $p_w+0,1$ MPa	$1,25p_w$, but not less than $p_w+0,1$ MPa
2	Thermal fluid boilers	$1,5p_w$, but not less than $p_w+0,1$ MPa	$1,5p_w$, but not less than $p_w+0,1$ MPa
3	Steam superheaters and their components operating at temperatures of 350 °C and above	$1,5p_w \frac{R_{eL/350}}{R_{eL/t}}$	$1,25p_w$
4	Heat exchangers, pressure vessels and their components operating at temperatures below 350 °C and pressure[1,2]:		
	up to 15 MPa	$1,5p_w$, but not less than $p_w+0,1$ MPa	—
	above 15 MPa	$1,35p_w$	—
5	Heat exchangers and their components operating at temperature 350 °C and above and pressure[2]:		
	up to 15 MPa	$1,5p_w \frac{R_{eL/350}}{R_{eL/t}}$	—
	above 15 MPa	$1,35p_w \frac{R_{eL/350}}{R_{eL/t}}$	—
6	Oil burning equipment components subject to fuel oil pressure	—	$1,5p_w$, but not less than 1 MPa
7	Gas spaces of waste-heat boilers	—	To be tested by air pressure at 0,01 MPa
8	Boiler valves and fittings	As per 1.3 of Part IX "Machinery", but not less than $2p_w$	To be tested for tightness of closure at $1,25p_w$
9	Feed valves of boilers and shut-off valves of thermal fluid boilers	$2,5p_w$	Ditto
10	Fittings of heat exchangers and pressure vessels	As per 1.3 of Part IX "Machinery"	Ditto

Symbols:
p_h = test pressure, MPa;
p_w = working pressure, MPa, but not less than 0,1MPa;
$R_{eL/350}$ = lower yield stress of material at 350 °C, MPa;
$R_{eL/t}$ = lower yield stress at operating temperature, MPa.

[1] For testing I.C.E. coolers, refer to Table 1.3.3, Part IX "Machinery".
[2] With $p_w = 15 \div 16,6$ MPa, $p_h \geqslant 22,5$ MPa.

2 STRENGTH CALCULATIONS

2.1 GENERAL

2.1.1 Application.

2.1.1.1 The wall thicknesses obtained by calculation are the lowest permissible values under normal operating conditions.

The standards and methods of strength calculation do not take into account the manufacture tolerances for thicknesses, which shall be added as special allowances to the design thickness values.

Additional stresses due to external loads (axial forces, bending moments and torques) acting upon the element under calculation (in particular, loads due to its own mass, the mass of attached elements, etc.) shall be specially taken into account as required by the Register.

2.1.1.2 The dimensions of structural elements of boilers, heat exchangers and pressure vessels, for which no strength calculation methods are given in the present Rules, shall be determined on the basis of experimental data and proved theoretical calculations, and are subject to special consideration by the Register in each case.

2.1.2 Design pressure.

2.1.2.1 The design pressure to be used for strength calculations of the elements of boilers, heat exchangers and pressure vessels shall generally be taken equal to the working pressure of the medium.

The hydrostatic pressure shall be taken into account in the design pressure calculations when it exceeds 0,05 MPa.

2.1.2.2 For uniflow and forced-circulation boilers the design pressure shall be determined with due consideration for the hydrodynamic resistances in boiler elements at the design steaming capacity.

2.1.2.3 For flat walls subject to pressure on both sides, the design pressure shall be taken as equal to the maximum pressure acting on the walls.

The walls with curved surfaces subject to pressure on both sides shall be designed both for the internal and external pressures.

Where the pressure on one side of the wall with flat or curved surface is below the atmospheric pressure, the design pressure shall be taken as equal to the maximum pressure acting on the other side of the wall plus 0,1 MPa.

2.1.2.4 For economizers the design pressure shall be taken as equal to the sum total of the working pressure in the boiler steam drum and the hydrodynamic resistances in the economizer, tubing, mountings and fittings at boiler design steaming capacity.

2.1.2.5 For heat exchangers and pressure vessels incorporated in refrigerating plants the design pressure shall be taken as specified in 2.2.2, Part XII "Refrigerating Plants".

2.1.3 Design temperature.

2.1.3.1 For the purpose of determining the allowable stresses depending on the temperature of the medium and heating conditions, the design wall temperature shall be taken as not lower than that indicated in Table 2.1.3.1.

2.1.3.2 The design wall temperature t of steam superheater elements with maximum temperature of superheated steam t_H > 400 °C shall be determined for several steam superheater cross-sections with regard to possible operational increase in temperature of separate elements and parts within the range of any possible operational steaming capacity.

The maximum temperature obtained from calculation for the most stressed cross-sections of the steam superheater shall be taken as a design temperature.

The rated design temperature of steam superheater tube walls at t_H > 400 °C (refer to 2.5 of Table 2.1.3.1) is obtained from the formula

$$t = t_a + \Delta t_q + \Delta t \qquad (2.1.3.2\text{-}1)$$

where t_a = mean temperature of steam in the tube cross-section under consideration, °C. t_a is determined from the analysis of thermal conditions of the steam superheater operation and its layouts and also from the results of thermal calculations for the boiler;

Δt_q = mean difference between the design temperature of the tube wall and steam temperature in the tube cross-section under consideration, °C. To determine this difference, it is necessary to calculate or obtain from the boiler thermal calculations the following values:

α_1 = coefficient of heat transfer from flue gases to the tube wall taken as a mean value around the circumference of the tube, W/(m^2·K);

α_2 = coefficient of heat transfer from the tube wall to steam, W/(m^2·K);

α_3 = coefficient of heat transfer by radiator, W/(m^2·K);

t_k = temperature of flue gases in front of the row of tubes under consideration, °C;

Δt_q is determined from Fig. 2.1.3.2-1.

For determination of Δt_q an auxiliary value A_0 is derived from the formula

$$A_0 = k_0 \frac{1{,}6\alpha_1 + \alpha_3}{\alpha_2} \qquad (2.1.3.2\text{-}2)$$

where k_0 = coefficient obtained from Fig. 2.1.3.2-2.

Table 2.1.3.1

Nos	Boiler, heat exchanger, pressure vessel elements and operating conditions thereof	Design wall temperature, °C
1	**Elements exposed to radiant heat**	
1.1	Boiler tubes	$t_M + 50$
1.2	Steam superheater tubes	$t + 50$
1.3	Corrugated furnaces	$t_M + 75$
1.4	Plain furnaces, headers, combustion and other chambers	$t_M + 90$
2	**Elements heated by hot gases but protected against radiant heat effect** [1]	
2.1	Shells, end plates, headers, chambers, tube plates and boiler tubes	$t_M + 30$
2.2	Headers and steam superheater tubes at steam temperatures up to 400 °C	$t_M + 35$
2.3	Headers and steam superheater tubes at steam temperatures above 400 °C	$t_M + x\Delta t + 25$
2.4	Waste-heat boilers operating without flame cleaning of heating surfaces	$t_M + 30$
2.5	Waste-heat boilers operating with flame cleaning of heating surfaces	t_v
3	**Elements heated by steam or fluids**	t_v
4	**Non-heated elements** [2]	t_M

Symbols:
t_M = maximum temperature of heated medium in the element under consideration, °C;
t_v = maximum temperature of heating fluid, °C;
t = rated design temperature of the tube wall determined from 2.1.3.2, °C;
Δt = steam temperature increase in the most heat-stressed tube as against the mean temperature t_a (refer to 2.1.3.2), °C;
x = factor characterizing steam mixing in the steam superheater header:
x = 0 at the concentrated steam supply to the header sides and ends;
x = 0,5 at the uniform dispersed steam supply to the header.

[1] Refer to 2.1.3.4.
[2] Refer to 2.1.3.3.

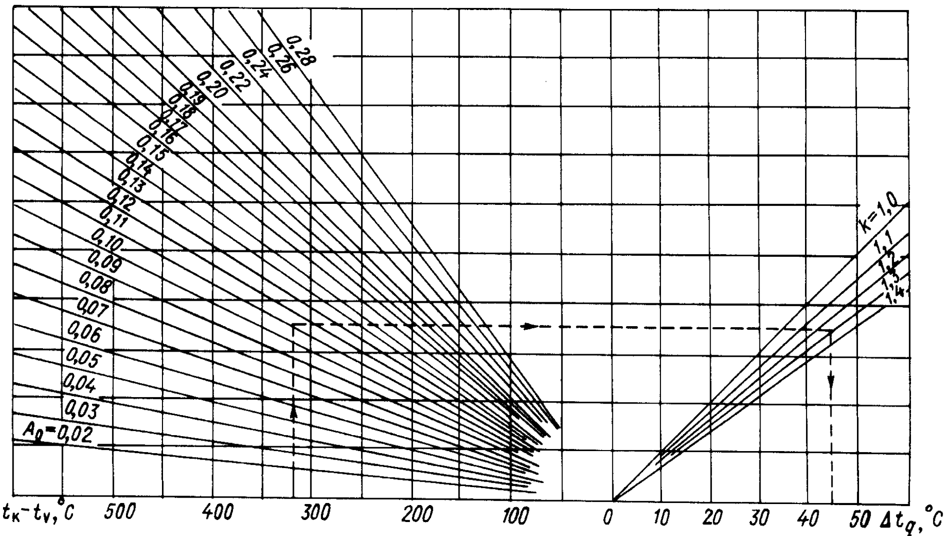


Fig. 2.1.3.2-1

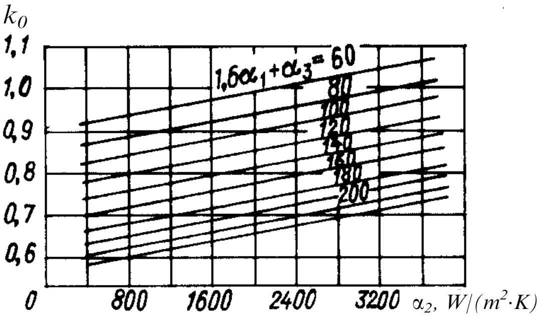


Fig. 2.1.3.2-2

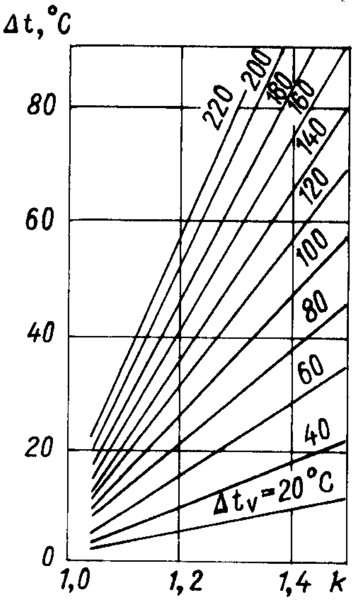


Fig. 2.1.3.2-3

For heated tubes of steam superheaters Δt is dependent upon the coefficient k of uneven heat absorption over the width of the superheater gas flue and upon the steam temperature increment Δt_v at the portion measured from the point of steam entry into the tube to the cross-section under consideration, the value t being obtained from Fig. 2.1.3.2-3.

Coefficient k is taken to be equal to:

1,3 — for vertical water-tube boilers of conventional type with loop or coil superheater;

1,2 — for U-type top-fired boilers with coil superheaters.

Note. In calculation of non-heated headers and tubes of superheaters with t_H > 400 °C the value Δt_v represents the full temperature increment in the superheater step or section under consideration.

2.1.3.3 The walls are considered to be non-heated in the following cases:

.1 the walls are separated from the combustion space or uptake by fire-resistant insulation, the distance between walls and insulation being 300 mm and over, or

.2 the walls are protected with fire-resistant insulation not exposed to radiant heat.

2.1.3.4 The walls are considered to be protected from radiant heat effect in the following cases:

.1 the walls are protected with fire-resistant insulation, or

.2 the walls are protected by a closely spaced row of tubes (with a maximum clearance between the tubes in the row up to 3 mm), or

.3 the walls are protected by two staggered rows of tubes with a longitudinal pitch equal to a maximum of two outside tube diameters or by three or more staggered rows of tubes with a longitudinal pitch equal to a maximum of two and a half outside tube diameters.

2.1.3.5 The design temperature for heated walls of the boiler and non-heated walls of the steam-conducting boiler elements shall not be less than 250 °C.

2.1.3.6 Non-insulated boiler walls measuring over 20 mm in thickness and heated by flue gases may be used only at gas temperatures up to 800 °C. If, with wall thicknesses measuring less than 20 mm and flue gas temperatures running higher than 800 °C, there are areas extending over 8 tube diameters and unprotected by insulation or by tube rows, the design wall temperature shall be determined by thermal stress analysis.

The requirements concerning the wall protection from radiant heat effect are given in 3.2.8.

2.1.3.7 The design wall temperature for heat exchangers and pressure vessels operating under coolant pressure shall be taken as equal to 20 °C if occurrence of higher temperature is not possible.

2.1.4 Strength characteristics of materials and allowable stresses.

2.1.4.1 When determining the allowable stresses in carbon and alloy steels with the ratio of the upper yield stress R_{eH} to tensile strength R_m not exceeding 0,6, the lower yield stress $R_{eL/t}$ or proof stress $R_{p0,2/t}$ and the average stress to produce rupture in 100 000 h $R_{m/t100000}$ at design temperatures shall be adopted as design characteristics.

For steels having the ratio of the upper yield stress to tensile strength above 0,6, the tensile strength $R_{m/t}$ at design temperature shall be adopted additionally.

For steels, the service conditions of which are characterized by creep (at temperatures above 450 °C), irrespective of the value of the ratio R_{eH}/R_m, the creep strength $R_{1\%(10^5)/t}$ at design temperature shall be added to the above characteristics.

Minimum values of $R_{eL/t}$, $R_{p0,2/t}$ and $R_{m/t}$ as stipulated by the steel specifications shall be adopted, while of $R_{m/t}$ and $R_{1\%(10^5)/t}$ average values shall be adopted.

2.1.4.2 For materials having no clearly defined yield stress point, the minimum tensile strength value $R_{m/t}$ at the design temperature shall be taken as the design characteristic.

2.1.4.3 For spheroidal or nodal graphite cast iron and ductile cast iron with ferritic-perlitic and perlitic structure and with elongation less than 5 per cent, the minimum tensile strength value R_v at 20 °C shall be taken as the design strength characteristic.

For cast irons with ferritic structure and elongation more than 5 per cent, the lesser of two values given below shall be taken as the design strength characteristic:

R_v = minimum ultimate strength of material at 20 °C, or

$R_{0,2}$ = proof stress at 20 °C, at which the permanent elongation is 0,2 per cent.

2.1.4.4 When non-ferrous metals and their alloys are used, it shall be taken into account that the heating during working or welding tends to relieve them of the strengthening effects realized under cold conditions. Therefore, the strength characteristics to be used for strength calculations of components and assemblies manufactured from such materials shall be those applied to their heat-treated condition.

2.1.4.5 The recommended values of the design characteristics of steel are given in Tables 7.1 and 7.2.

For the materials omitted from these tables, strength characteristics at higher temperatures are subject to special consideration by the Register.

Strength characteristics of boiler steels are taken according to the standards agreed with the Register.

2.1.4.6 The allowable stress σ, in MPa, used for determining the scantlings shall be adopted equal to the smallest of the following values (bearing the requirements of 2.1.4.1 to 2.1.4.5 in mind):

$$\sigma = \frac{R_{m/t}}{n_t},$$

$$\sigma = \frac{R_{1\%(10^5)/t}}{n_{cr}},$$

$$\sigma = \frac{R_{eL/t}}{n_y} \quad \left(\text{or } \sigma = \frac{R_{p0,2/t}}{n_y}\right), \tag{2.1.4.6}$$

$$\sigma = \frac{R_m/t_{100000}}{n_{av}}$$

where n_t = tensile strength safety factor;
n_{cr} = creep strength safety factor;
n_y = yield stress safety factor;
n_{av} = safety factor for the average stress to produce rupture in 100000 h.

The factors are chosen in accordance with 2.1.5.

2.1.5 Safety factors.

2.1.5.1 For items manufactured of steel forgings and rolled steel, which are under internal pressure, the safety factors shall be chosen of at least:

$$n_y = n_{av} = 1{,}6; \quad n_t = 2{,}7; \quad n_{cr} = 1{,}0.$$

For items under external pressure, the safety factors n_y, n_{av} and n_t shall be increased by 20 per cent.

2.1.5.2 For components of boilers, heat exchangers and pressure vessels of Class II and Class III, which are made of steels having the ratio $R_{eH}/R_m \leqslant 0{,}6$, the safety factors may be adopted as follows:

$$n_y = n_{av} = 1{,}5; \quad n_t = 2{,}6.$$

2.1.5.3 For components of boilers, heat exchangers and pressure vessels, which are made of cast steel and are under internal pressure in service, the safety factors shall be chosen of at least:

$$n_y = n_{av} = 2{,}2; \quad n_t = 3{,}0; \quad n_{cr} = 1{,}0.$$

Table 2.1.6.1-1

Welding	Welded joint	Weld seam	φ
Automatic welding	Butt joint	Double-sided	1,0
		Single-sided on backing strip	0,9
		Single-sided without backing strip	0,8
	Overlap joint	Double-sided	0,8
		Single-sided	0,7
Machine welding and manual welding	Butt joint	Double-sided	0,9
		Single-sided on backing strip	0,8
		Single-sided without backing strip	0,7
	Overlap joint	Double-sided	0,7
		Single-sided	0,6
Notes: 1. In any case, full root penetration shall be provided. 2. For electroslag welding the efficiency factor of welded joints is taken as φ = 1,0.			

For items that are under external pressure in service, the safety factors shall be increased by 20 per cent (except for n_{cr}, which shall remain equal to 1).

2.1.5.4 For essential boiler components being under thermal stress, the safety factors n_y and n_{av} shall be adopted equal to:

3,0 for corrugated furnaces;

2,5 for plain furnaces, combustion chambers, stay tubes, long and short stays;

2,2 for gas uptake pipes subjected to pressure or other similar gas heated walls.

2.1.5.5 When determining scantlings for the items made of grey cast iron, spheroidal or nodular graphite cast iron and ductile cast iron with ferritic-perlitic and perlitic structure having elongation less than 5 per cent, the tensile strength safety factor n_t shall be adopted equal to 4,8 after annealing and to 7,0 without annealing both for the case of internal and external pressure.

For the items made of cast iron with ferritic structure having elongation more than 5 per cent, the tensile strength safety factor n_t shall be adopted equal to 4,0 for the case of internal pressure and 4,8 for the case of external pressure and the proof strength safety factor n_p shall be taken equal to 2,8.

2.1.6 Efficiency factors.

2.1.6.1 Efficiency factor of welded joints shall be selected from Table 2.1.6.1-1 depending on the type of joint and welding method used; efficiency factor of welded joints depending on the class of boilers, heat exchangers and pressure vessels (refer to 1.3.1.2) shall not be below the values given in Table 2.1.6.1-2.

2.1.6.2 The ligament efficiency factor of cylindrical walls weakened by holes of the same diameter shall be taken as equal to the lowest of the following three values:

.1 the ligament efficiency factor of cylindrical walls weakened by a longitudinal row or a field of unstaggered, equally-pitched holes (refer to Fig. 2.1.6.2.1), as determined by the following formula:

Table 2.1.6.1-2

Item	Efficiency factor of welded joints φ depending on class of boilers		
	Class I	Class II	Class III
Boilers, steam superheaters and steam accumulators	0,90	0,80	—
Steam-heated steam generators	0,90	0,80	—
Heat exchangers and pressure vessels	0,90	0,70	0,60

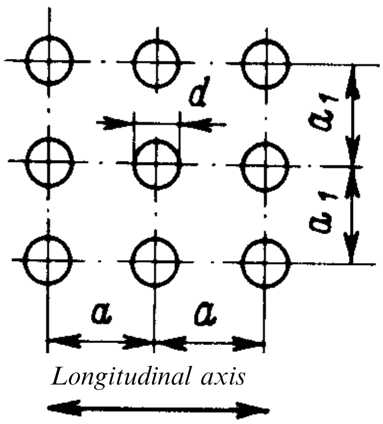


Fig. 2.1.6.2.1

$$\varphi = (a - d)/a; \qquad (2.1.6.2.1)$$

.2 the ligament efficiency factor, reduced to the longitudinal direction, of cylindrical walls weakened by a transverse row or a field of equally-pitched holes (Fig. 2.1.6.2.1), as determined by the following formula:

$$\varphi = 2(a_1 - d)/a_1; \qquad (2.1.6.2.2)$$

.3 the ligament efficiency factor, reduced to the longitudinal direction, of cylindrical walls weakened by a field of staggered and equally-spaced holes (refer to Fig. 2.1.6.2.3), as determined by the following formula:

$$\varphi = k(a_2 - d)/a_2 \qquad (2.1.6.2.3)$$

where d = diameter of the hole for expanded tubes or inside diameter of welded-on tubes and upset nozzles, mm;

a = pitch between two adjacent hole centres in the longitudinal direction, mm;

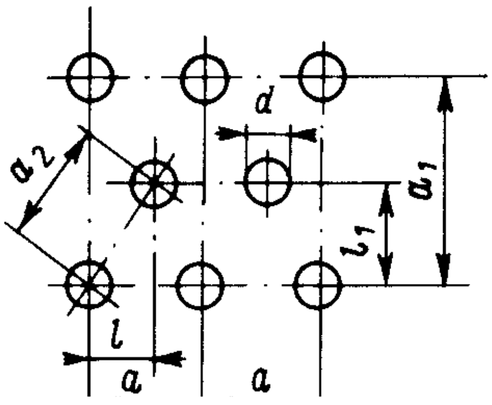


Fig. 2.1.6.2.3

a_1 = pitch between two adjacent hole centres in the transverse (circumferential) direction (taken as a mean circumference arc), mm;
a_2 = pitch between two adjacent hole centres in the diagonal direction, in mm, as determined by the following formula:

$$a_2 = \sqrt{l^2 + l_1^2}\ ;$$

l = centre-to-centre distance between two adjacent holes in the longitudinal direction (refer to Fig. 2.1.6.2.3), mm;
l_1 = centre-to-centre distance between two adjacent holes in the transverse (circumferential) direction (refer to Fig. 2.1.6.2.3), mm;
k = factor selected from Table 2.1.6.2.3 in dependence upon the ratio of l_1/l.

Table 2.1.6.2.3

l_1/l	k	l_1/l	k	l_1/l	k	l_1/l	k
5,0	1,76	3,5	1,65	2,0	1,41	0,5	1,00
4,5	1,73	3,0	1,60	1,5	1,27	—	—
4,0	1,70	2,5	1,51	1,0	1,13	—	—
Note. Intermediate values of k are determined by interpolation.							

2.1.6.3 Where rows or fields of equally-pitched holes contain holes of alternate diameters, in Formulae (2.1.6.2.1), (2.1.6.2.2) and (2.1.6.2.3) for ligament efficiency factor determination value d shall be replaced by a value equal to the arithmetic mean of two largest adjacent hole diameters.

In the case of unequal pitch between holes of equal diameter, the formulae for ligament efficiency factor determination shall be used with the lowest values of a, a_1 and a_2.

2.1.6.4 Where a welded joint has a hole or where the distance between the edge of a hole nearest to the welded joint centre is less than 50 mm or less than one-half the width of the mostly local opening affected zone, Q, in mm, determined by Formula (2.1.6.4), the efficiency factor shall be taken as equal to the product of the efficiency factor of welded joint by the ligament efficiency factor of the wall weakened by holes. In cases where the hole edge is at a distance more than 0,5Q and more than 50 mm from the welded joint centre the lowest of the values determined for the ligament efficiency factors of the wall weakened by holes and the efficiency factor of welded joint shall be taken as the efficiency factor. The width of the mostly local opening affected zone, Q, in mm, is calculated by the formula

$$Q = \sqrt{D_m(s-c)} \qquad (2.1.6.4)$$

where s = wall thickness, in mm;
c = corrosion allowance, in mm, taken according to 2.1.7;
D_m = mean diameter of the weakened wall, in mm;
For cylindrical walls and dished ends
$D_m = D + s$ or $D_m = D_a - s$.
For conical walls
$D_m = (D_a/\cos\alpha) - s$ or $D_m = (D/\cos\alpha) - s$
where D_a = outside diameter;
D = inside diameter.
For conical walls D and D_a are measured across a section, which passes through the centre of the weakening hole;
α = angle between conical wall and central axis (refer to Fig. 2.3.1-1).

2.1.6.5 For seamless cylindrical walls not weakened by welds or rows/fields of holes, the ligament efficiency factor shall be taken equal to 1. In no case shall the factor be taken higher than 1.

2.1.6.6 The ligament efficiency factor of walls weakened by holes for expanded tubes shall be taken as not less than 0,3 as determined by Formulae (2.1.6.2.1), (2.1.6.2.2) and (2.1.6.2.3).

Calculations involving lower ligament efficiency factor values are subject to special consideration by the Register in each case.

2.1.6.7 Where cylindrical walls are manufactured from plates of various thickness, jointed together by longitudinal welds, wall thickness calculation shall be made for each plate separately, taking into account the weakenings.

2.1.6.8 For longitudinally welded tubes the efficiency factor of welded joints is subject to special consideration by the Register in each case.

2.1.6.9 The ligament efficiency factors for cylindrical and conical walls and dished ends weakened by isolated openings shall be determined by the formulae:

for single non-reinforced openings:

$$\varphi_{in} = \frac{2}{d/Q + 1{,}75}\ , \qquad (2.1.6.9\text{-}1)$$

for single reinforced openings:

$$\varphi_{ir} = \varphi_{in}\left(1 + \frac{\Sigma f}{2(s-c)Q}\right) \qquad (2.1.6.9\text{-}2)$$

where Σf = the sum of compensating reinforcement areas, in mm^2, determined according to 2.9;
d = opening diameter, in mm;

s = wall thickness, in mm;
c = corrosion allowance, in mm, taken according to 2.1.7;
Q = determined according to 2.1.6.4.

2.1.6.10 When determining the permissible thicknesses of cylindrical, spherical, conical elements and dished ends, the lowerst of the values determined for a row or a field of non-reinforced openings in accordance with 2.1.6.2 to 2.1.6.7 and for single reinforced and non-reinforced openings determined according to 2.1.6.9 shall be taken as the design efficency factor.

2.1.6.11 The ligament efficiency factor of flat tube plates shall be determined for tangential and radial pitches by Formula (2.1.6.2.1). The lower of the values thus obtained shall be used for calculating the tube plate thickness.

2.1.7 Design thickness allowances.

2.1.7.1 In all cases where the design wall thickness allowance c is not expressly specified, it shall be taken as equal to at least 1 mm. For steel walls over 30 mm in thickness as well as for walls manufactured from corrosion-resistant non-ferrous alloys or high alloy materials, and for materials adequately protected against corrosion, e.g. by plastic covering or facing, no allowance need be provided for the design wall thickness value, on agreement with the Register.

2.1.7.2 For heat exchangers and pressure vessels, which are inaccessible for internal inspection, or the walls of which are heavily affected by corrosion or wear, the allowance c may be increased if required by the Register.

2.2 CYLINDRICAL AND SPHERICAL ELEMENTS AND TUBES

2.2.1 Elements subject to internal pressure.

2.2.1.1 The requirements given below cover the following conditions:

at $D_a/D \leqslant 1{,}6$ for cylindrical walls;

at $D_a/D \leqslant 1{,}7$ for tubes;

at $D_a/D \leqslant 1{,}2$ for spherical walls.

Cylindrical walls with $D_a \leqslant 200$ mm are regarded as tubes.

2.2.1.2 The thickness s, in mm, of cylindrical walls and tubes shall not be less than:

$$s = \frac{D_a p}{2\sigma\varphi + p} + c \qquad (2.2.1.2\text{-}1)$$

or

$$s = \frac{Dp}{2\sigma\varphi - p} + c \qquad (2.2.1.2\text{-}2)$$

where p = design pressure (refer to 2.1.2), MPa;
D_a = outside diameter, mm;
D = inside diameter, mm;
φ = efficiency factor (refer to 2.1.6);
σ = allowable stress (refer to 2.1.4.6), MPa;
c = allowance (refer to 2.1.7), mm.

2.2.1.3 Spherical wall thickness shall not be less than:

$$s = \frac{D_a p}{4\sigma\varphi + p} + c \qquad (2.2.1.3\text{-}1)$$

or

$$s = \frac{Dp}{4\sigma\varphi - p} + c\ . \qquad (2.2.1.3\text{-}2)$$

The symbols used are the same as in 2.2.1.2.

2.2.1.4 Irrespective of the values obtained from Formulae (2.2.1.2-1), (2.2.1.2-2), (2.2.1.3-1) and (2.2.1.3-2), the thicknesses of spherical and cylindrical walls and tubes shall not be less than:

.1 5 mm for seamless and welded elements;

.2 12 mm for tube plates with radial hole arrangement for expanded tubes;

.3 6 mm for tube plates with welded-on or soldered tubes;

.4 values given in Table 2.2.1.4, for tubes.

Table 2.2.1.4

D_a, mm	s, mm	D_a, mm	s, mm
< 20	1,75	> 95 ⩽ 102	3,25
> 20 ⩽ 30	2,0	> 102 ⩽ 121	3,5
> 30 ⩽ 38	2,2	> 121 ⩽ 152	4,0
> 38 ⩽ 51	2,4	> 152 ⩽ 191	5,0
> 51 ⩽ 70	2,6	> 191	5,4
> 70 ⩽ 95	3,0		

Note. Reduction in wall thickness due to bending or expansion shall be compensated by allowances.

The thickness of tube walls heated by gases with temperatures exceeding 800 °C shall not be more than 6 mm.

2.2.1.5 On agreement with the Register, the minimum thicknesses of the walls of tubes of non-ferrous alloys and stainless steels may be taken less than those specified in 2.2.1.4, but not less than determined by Formulae (2.2.1.2-1), (2.2.1.2-2), (2.2.1.3-1) and (2.2.1.3-2).

2.2.2 Elements subject to external pressure.

2.2.2.1 The requirements specified below refer to cylindrical walls at $D_a/D \leqslant 1{,}2$. The thickness of tubes with $D_a \leqslant 200$ mm shall be determined from 2.2.1.2.

2.2.2.2 Plain cylindrical walls with or without stiffening members, including plain furnaces of boilers, shall have a thickness s, in mm, not less than

$$s = \frac{50(B + \sqrt{B^2 + 0{,}04AC})}{A} + c \qquad (2.2.2.2\text{-}1)$$

where $A = 200\frac{\sigma}{D_m}(1 + \frac{D_m}{10l})(1 + \frac{5D_m}{l})$; (2.2.2.2-2)

$B = p(1 + 5\frac{Dm}{l})$; (2.2.2.2-3)

$C = 0{,}045pD_m$; (2.2.2.2-4)

p = design pressure (refer to 2.1.2), MPa;
D_m = mean diameter, mm;
σ = allowable stress (refer to 2.1.4.6 and 2.1.5.3), MPa;
c = allowance (refer to 2.1.7), mm;
l = design length of cylindrical portion between stiffening members, mm.

Assumed as stiffening members may be end plates, furnace connections to end plates and combustion chamber as well as reinforcing rings shown in Fig. 2.2.2.2, or similar structures.

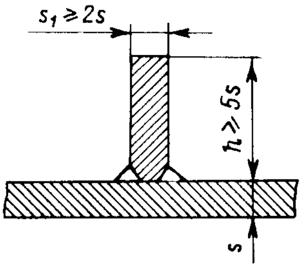


Fig. 2.2.2.2

2.2.2.3 Corrugated furnaces shall have a wall thickness s, in mm, not less than

$$s = \frac{pD}{2\sigma} + c \quad (2.2.2.3)$$

where p = design pressure (refer to 2.1.2), MPa;
D = minimum inside diameter of the furnace over the corrugated portion, mm;
σ = allowable stress (refer to 2.1.4.6 and 2.1.5.3), MPa;
c = allowance (refer to 2.1.7), mm.

2.2.2.4 Where the length of the straight portion of a corrugated furnace from the front end wall to the commencement of the first corrugation exceeds the corrugation length, the wall thickness over this portion shall be obtained from Formula (2.2.2.2-1).

2.2.2.5 The thickness of plain furnaces shall not be less than 7 mm nor more than 20 mm. The thickness of corrugated furnaces shall not be less than 10 mm nor more than 20 mm.

2.2.2.6 Plain furnaces up to 1400 mm in length need not generally be fitted with reinforcing rings.

Where a boiler has two or more furnaces, the reinforcing rings of adjacent furnaces shall be arranged in alternate planes.

2.2.2.7 Holes and openings in cylindrical and spherical walls shall be compensated for as per 2.9.

2.2.2.8 The thickness s_1, in mm, of the ogee rings (refer to Fig. 2.2.2.8) connecting furnace bottoms of the vertical boilers to the shell and bearing vertical loads shall not be less than that determined by the following formula:

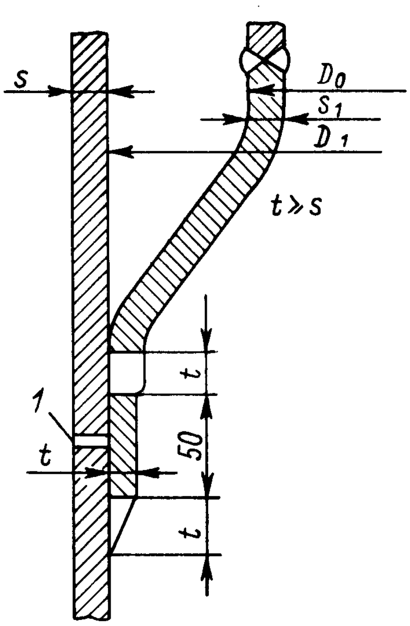


Fig. 2.2.2.8:
1 — at least 4 openings 10 mm in diameter equispaced over the shell

$$s_1 \geqslant \frac{3{,}7}{\sigma}\sqrt{pD_1(D_1 - D_0)} + 1 \quad (2.2.2.8)$$

where σ = allowable stress (refer to 2.1.4.6), MPa.
p = design pressure (refer to 2.1.2), MPa;
D_1 = inside diameter of the boiler wall, mm;
D_0 = outside diameter of combustion chamber where it joins the ogee ring.

2.3 CONICAL ELEMENTS

2.3.1 The wall thickness s, in mm, of conical elements subject to internal pressure shall not be less than:

.1 at $\alpha \leqslant 70°$

$$s = \frac{D_a p y}{4\sigma\varphi} + c \quad (2.3.1.1\text{-}1)$$

$$s = \frac{D_c p}{2\sigma\varphi - p}\frac{1}{\cos\alpha} + c; \quad (2.3.1.1\text{-}2)$$

.2 at $\alpha > 70°$

$$s = 0{,}3[D_a - (r + s)]\sqrt{\frac{p}{\sigma\varphi}\frac{\alpha}{90°}} + c \quad (2.3.1.2)$$

where D_c = design diameter (Figs. 2.3.1-1 to 2.3.1-4), mm;
D_a = outside diameter (Figs. 2.3.1-1 to 2.3.1-4), mm;
p = design pressure (refer to 2.1.2), MPa;
y = shape factor (refer to Table 2.3.1);
$\alpha, \alpha_1, \alpha_2, \alpha_3$ = angles (refer to Figs. 2.3.1-1 to 2.3.1-4), deg.;
σ = allowable stress (refer to 2.1.4.6), MPa;
φ = efficiency factor (refer to 2.1.6); in Formulae (2.3.1.1-1) and (2.3.1.2) the efficiency factor of a circumferential

Table 2.3.1

α, deg.	Shape factor y at r/D_a equal to:											
	0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
20	2,0	1,8	1,7	1,6	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1,1
30	2,7	2,4	2,2	2,0	1,8	1,7	1,6	1,4	1,3	1,1	1,1	1,1
45	4,1	3,7	3,3	3,0	2,6	2,4	2,2	1,9	1,8	1,4	1,1	1,1
60	6,4	5,7	5,1	4,7	4,0	3,5	3,2	2,8	2,5	2,0	1,4	1,1
75	13,6	11,7	10,7	9,5	7,7	7,0	6,3	5,4	4,8	3,1	2,0	1,1
Note. For fillet joints, the shape factor y is determined at r/D_a=0,01.												

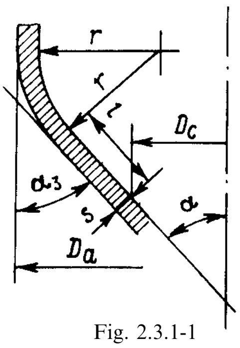


Fig. 2.3.1-1

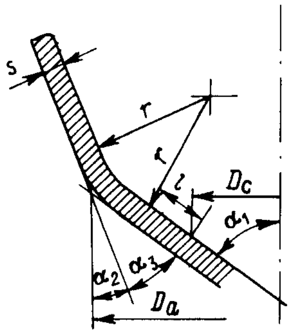


Fig. 2.3.1-2

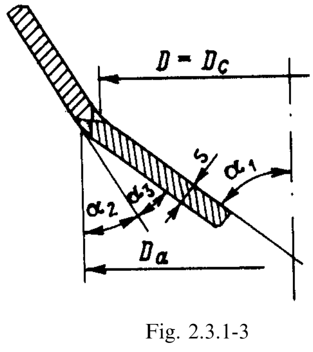


Fig. 2.3.1-3

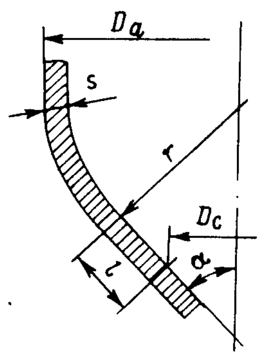


Fig. 2.3.1-4

welded joint shall be used, and in Formula (2.3.1.1-2) that of a longitudinal welded joint; for seamless shells, as well as in situations where circumferential weld is removed from the edge to a distance exceeding $0{,}5\sqrt{D_a s/\cos\alpha}$ the efficiency factor of the welded joint shall be taken equal to 1;

c = allowance (refer to 2.1.7), mm;

r = radius of edge curvature (refer to Figs. 2.3.1-1, 2.3.1-2 and 2.3.1-4), mm.

In Figs. 2.3.1-1, 2.3.1-2 and 2.3.1-4, l is the distance, in mm, from the edge of the wide end of the conical shell, parallel to the generatrix of the conical shell assumed equal to 10 thicknesses, but not larger than half the length of the conical shell generatrix.

2.3.2 The wall thickness s, in mm, of conical elements subject to external pressure shall be determined from 2.3.1 having regard to the following conditions:

.1 efficiency factor of welded joints φ shall be taken equal to 1;

.2 allowance c shall be taken equal to 2 mm;

.3 design diameter D_c is determined by the following formula:

$$D_c = \frac{d_1 + d_2}{2} \frac{1}{\cos\alpha} \qquad (2.3.2.3)$$

where d_1 and d_2 = cone maximum and minimum diameters, mm;

.4 at $\alpha < 45°$ it shall be demonstrated that no elastic concave deformation of the walls occurs. The pressure p_1, in MPa, at which the elastic concave deformation of the walls occurs, shall be determined by the following formula:

$$p_1 = 26E\cdot 10^{-6}\frac{D_c}{l_1}\left[\frac{100(s - c)}{D_c}\right]^2\sqrt{\frac{100(s - c)}{D_c}} \quad (2.3.2.4)$$

where E = modulus of elasticity, MPa;
l_1 = cone maximum length or distance between reinforcements, mm.

The condition for absence of elastic concave deformation is $p_1 > p$ where p = design pressure, MPa.

2.3.3 Fillet welded joints (refer to Fig. 2.3.1-3) are allowed only at $\alpha_3 \leqslant 30°$ and $s \leqslant 20$ mm. The joint shall be welded on both sides. For conical shells with $\alpha \geqslant 70°$, fillet joints may be welded without edge preparation if the requirements of 2.3.2 are met.

It is recommended that fillet joints shall not be used on boilers.

2.3.4 Holes and openings in conical walls shall be reinforced according to 2.9.

2.4 FLAT WALLS, END PLATES AND COVERS

2.4.1 Flat end plates and covers.

2.4.1.1 The thickness s, in mm, of flat end plates unsupported by stays, as well as that of covers (Figs. 2.4.1.1-1 to 2.4.1.1-8 and 1.2 of the Appendix) shall not be less than

$$s = kD_c\sqrt{\frac{p}{\sigma}} + c \quad (2.4.1.1\text{-}1)$$

where k = design factor according to Figs. 2.4.1.1-1 to 2.4.1.1-8 and 1.1 to 1.6 of the Appendix;
D_c = design diameter (refer to Figs. 2.4.1.1-2 to 2.4.1.1-7 and 1.6 of the Appendix), mm, determined as follows:
for end plates shown in Figs. 2.4.1.1-1 and 1.1 of the Appendix the design diameter shall be

$$D_c = D - r; \quad (2.4.1.1\text{-}2)$$

for rectangular or oval covers (refer to Fig. 2.4.1.1-8) the design diameter shall be

$$D_c = m\sqrt{\frac{2}{1 + (m/n)^2}}; \quad (2.4.1.1\text{-}3)$$

D = inside diameter, mm;
r = inside conjugation radius of the end plate, mm;
n and m = major and minor sides or axis of the openings, measured to the centre of the gasket (refer to Fig. 2.4.1.1-8), mm;
p = design pressure (refer to 2.1.2), MPa;
σ = allowable stress (refer to 2.1.4.6), MPa;
c = allowance (refer to 2.1.7), mm.
D_b = circle diameter of fastening bolts (refer to Fig. 2.4.1.1-6), mm;

In Figs. 2.4.1.1-1 and 1.1 of the Appendix, l is the length, mm, of cylindrical portion of end plate.

2.4.1.2 The thickness s, in mm, of the end plates shown in Fig. 1.2 of the Appendix shall not be less than that determined by Formula (2.4.1.1-1).

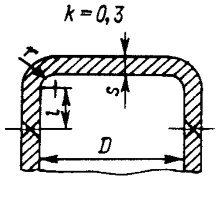


Fig. 2.4.1.1-1

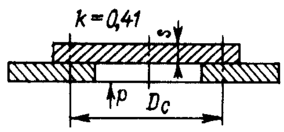


Fig. 2.4.1.1-2

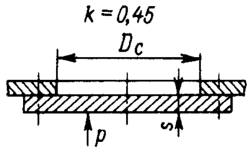


Fig. 2.4.1.1-3

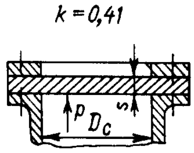


Fig. 2.4.1.1-4

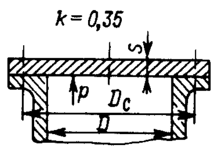


Fig. 2.4.1.1-5

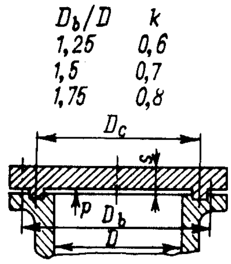


Fig. 2.4.1.1-6

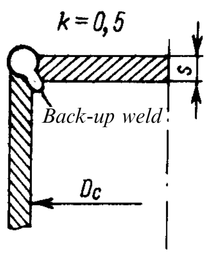


Fig. 2.4.1.1-7

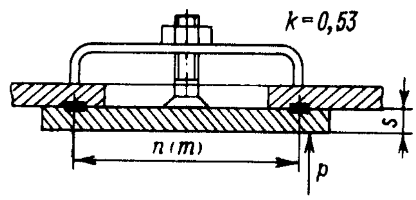


Fig. 2.4.1.1-8

Additionally, the following conditions shall be satisfied:

.1 for circular end plates

$$0{,}77s_1 \geqslant s_2 \geqslant \frac{1{,}3p}{\sigma}\left(\frac{D_c}{2} - r\right); \quad (2.4.1.2.1)$$

.2 for rectangular end plates

$$0{,}55s_1 \geqslant s_2 \geqslant \frac{1{,}3p}{\sigma}\,\frac{mn}{m+n} \qquad (2.4.1.2.2)$$

where s_1 = thickness of the shell, mm;
s_2 = thickness of the end plate in the relieving groove area, mm.

Other symbols used are the same as in 2.4.1.1. In no case shall the value s_2 be less than 5 mm.

The above conditions are applicable to end plates not more than 200 mm in diameter or side length.

The dimensions of relieving grooves in end plates with diameters or side length over 200 mm are subject to special consideration by the Register in each case.

2.4.2 Walls reinforced by stays.

2.4.2.1 Flat walls (Figs. 2.4.2.1-2 and 2.4.2.1-3) reinforced by long and short stays, corner stays, stay tubes or other similar structures shall have a thickness s, in mm, not less than

$$s = kD_c\sqrt{\frac{p}{\sigma}} + c \qquad (2.4.2.1\text{-}1)$$

where k = design factor (refer to Figs. 2.4.2.1-1, 2.4.2.1-2 and 2.4.2.1-3 and also Figs. 5.1, 5.2 and 5.3 of the Appendix).
If the wall area in question is reinforced by stays having different factor k values, Formula (2.4.2.1-1) is used with the arithmetic mean of these factor values;
D_c = design assumed diameter (Figs. 2.4.2.1-2 and 2.4.2.1-3), mm.
In case of uniform distribution of stays

$$D_c = \sqrt{a_1^2 + a_2^2}\,. \qquad (2.4.2.1\text{-}2)$$

In case of non-uniform distribution of stays

$$D_c = (a_3 + a_4)/2. \qquad (2.4.2.1\text{-}3)$$

In all other cases, the value D_c shall be taken equal to the diameter of the largest circle, which can be drawn through the centres of three stays or through the centres of stays and the commencement of the curvature of flanging if the radius of the latter is as specified in 2.4.3. The flanging, in this case, is regarded as a point of support. A manhole flanging shall not be regarded as a point of support;
a_1, a_2, a_3, a_4 = pitch or stay-to-stay distance (Fig. 2.4.2.1-1), mm.
Other symbols used are the same as in 2.4.1.1.

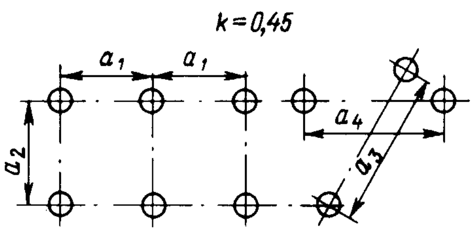


Fig. 2.4.2.1-1

2.4.3 Flanging of flat walls.

2.4.3.1 In flat wall and end plate calculations, the flanging is only taken into account when the flanging radii are not less than those given in Table 2.4.3.1.

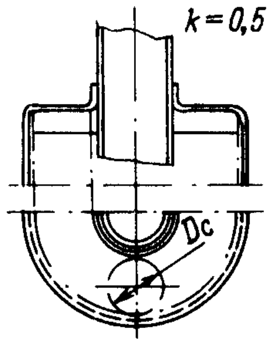


Fig. 2.4.2.1-2

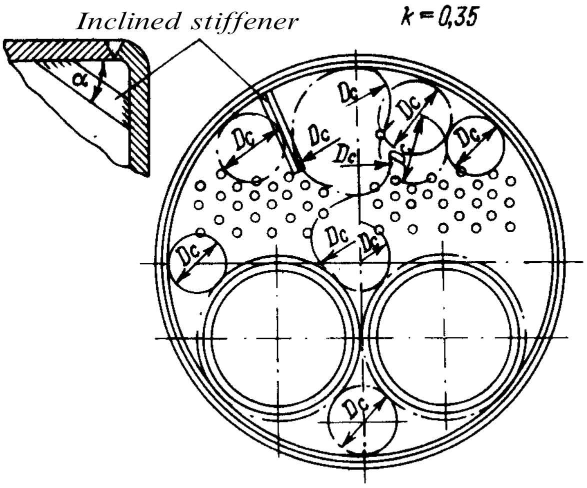


Fig. 2.4.2.1-3

Table 2.4.3.1

Radius of flanging, mm	Outside diameter of end plate, mm
25	$\leqslant$350
30	351 to 500
35	501 to 950
40	951 to 1400
45	1401 to 1900
50	> 1900

The minimum flanging radius shall not be less than 1,3 times the wall thickness.

2.4.3.2 The cylindrical portion of a flanged flat end plate shall have a length l not less than $0{,}5\sqrt{Ds}$ (refer to Fig. 2.4.1.1-1).

2.4.3.3 End plates with a relieving groove shall have a groove curvature radius r according to 1.2 of the Appendix.

2.4.4 Reinforcement of openings.

2.4.4.1 Openings in flat walls, end plates and covers measuring over four thicknesses in diameter shall be reinforced by means of welded-on nozzles, branch pieces and pads, or by increasing the design wall thickness. Openings shall be arranged at a distance of not less than 1/8 of the size of the opening from the design diameter outline.

2.4.4.2 If the actual wall thickness is larger than that required by Formulae (2.4.1.1-1) and (2.4.2.1-1), the maximum diameter *d*, in mm, of a non-reinforced opening shall be determined by the following formula:

$$d = 8s_f\left(1{,}5\frac{s_f^2}{s^2} - 1\right) \qquad (2.4.4.2)$$

where s_f = actual wall thickness, mm;
s = design wall thickness obtained from Formulae (2.4.1.1-1) and (2.4.2.1-1), mm.

2.4.4.3 Edge reinforcement shall be provided for openings of larger dimensions than those indicated in 2.4.4.1 and 2.4.4.2.

The dimensions of reinforcing elements (nozzles and branches), in mm, shall satisfy the expression

$$s_r(h^2/s_f^2 - 0{,}65) \geqslant 0{,}65d - 1{,}4s_f \qquad (2.4.4.3)$$

where s_r = width of reinforcing element (Fig. 2.4.4.3), mm;
h = height of reinforcing element (Fig. 2.4.4.3), mm.
Other symbols used are the same as in 2.4.4.2.

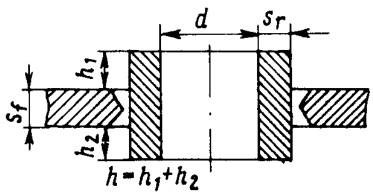


Fig. 2.4.4.3

2.4.4.4 The design heights h_1 and h_2, in mm, of reinforcing elements (nozzles and branches) (refer to Fig. 2.4.4.3) shall be determined by the following formula:

$$h_1(h_2) \leqslant \sqrt{(d + s_r)s_r}\,. \qquad (2.4.4.4)$$

The symbols used are the same as in 2.4.4.2 and 2.4.4.3.

2.5 TUBE PLATES

2.5.1 The thickness s_1, in mm, of flat tube plates of heat exchangers shall not be less than

$$s_1 = 0{,}9kD_B\sqrt{\frac{p}{\sigma\varphi}} + c \qquad (2.5.1)$$

where p = design pressure (refer to 2.1.2), MPa;
σ = allowable stress (refer to 2.1.4.6), MPa.
For heat exchangers of rigid construction the allowable stress may be reduced by 10 per cent when the materials of the shell and tubes have different linear expansion coefficients;
c = allowance (refer to 2.1.7), mm;
k = factor depending on the ratio of the shell thickness s to the tube plate thickness s_1 (s/s_1).
For tube plates welded to the shell along the perimeter the factor k is determined from Fig. 2.5.1. The preset value of the thickness s_1 shall be used. When the difference between the preset value of the thickness s_1 and that obtained from Formula (2.5.1) is more than 5 per cent, the recalculation shall be made.
For tube plates fastened between the flanges of the shell and cover by bolts and studs, k is equal to 0,5;
D_B = inside diameter of the shell, mm;
φ = ligament efficiency factor of the tube plate weakened by holes (refer to 2.5.2).

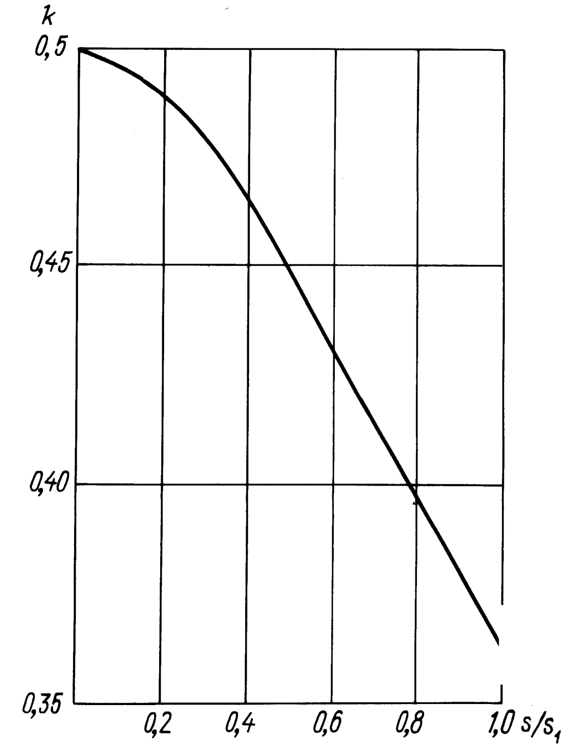


Fig. 2.5.1

2.5.2 The ligament efficiency factor of the tube plate at $0{,}75 > d/a > 0{,}4$ and $D_B/s_1 \geqslant 40$ shall be determined by the following formulae:

for spacing of holes on an equilateral triangle

$$\varphi = 0{,}935 - 0{,}65d/a\,; \qquad (2.5.2\text{-}1)$$

for unstaggered and staggered spacing of holes

$$\varphi = 0{,}975 - 0{,}68d/a_2 \qquad (2.5.2\text{-}2)$$

where d = diameter of the hole in the tube plate, mm;
a = pitch between hole centres for spacing of holes on an equilateral tringle, mm;
a_2 = the lesser pitch for unstaggered or staggered spacing of holes (including concentric rows of holes), mm.

2.5.3 For ratios $d/a = 0{,}75 \div 0{,}80$ the thickness of the tube plates, calculated by Formula (2.5.1), shall also satisfy the following condition:

$$f_{\min} \geqslant 5d \qquad (2.5.3)$$

where $f_{\min}$ = minimum permissible cross-sectional area of the tube plate portion between holes, mm^2.

For other values of d/a and D_B/s_1 and also for heat exchangers of rigid construction having the difference of mean temperatures of exchanging media in excess of 50 °C, the thickness of tube plates is subject to special consideration by the Register in each case.

2.5.4 The thickness of tube plates with expanded tubes, apart from Formula (2.5.1), shall satisfy the following condition:

$$s_1 = 10 + 0{,}125d\,. \qquad (2.5.4)$$

The expansion joints of tube plates shall also satisfy the requirements of 2.10.2.2, 2.10.2.3 and 2.10.2.4.

2.5.5 If the tube plates are reinforced by means of welded-on or expanded tubes in such a way that the requirements of 2.10 are satisfied, the calculations for such tube plates may be made according to 2.4.

2.6 DISHED ENDS

2.6.1 Dished ends, unpierced or pierced, subject to internal or external pressure (Fig. 2.6.1) shall have a thickness s, in mm, not less than

$$s = \frac{D_a p y}{4\sigma\varphi} + c \qquad (2.6.1)$$

where p = design pressure (refer to 2.1.2), MPa;
D_a = outside diameter of the end, mm;
φ = efficiency factor (refer to 2.1.6);
σ = allowable stress (refer to 2.1.4.6), MPa;
y = shape factor selected from Table 2.6.1 depending on the ratio of the height to the outside diameter and on the nature of weakening of the end.
For elliptical and torispherical ends R_B is the maximum radius of curvature. For intermediate values of h_a/D_a and $d/\sqrt{D_a s}$ the shape factor y is determined by interpolation.
The flanged area of the end is assumed to commence at a distance of not less than $0{,}1D_a$ from the outside outline of the cylindrical portion (refer to Fig. 2.6.1).
To choose y using Table 2.6.1 the value s shall be selected from a number of standard thicknesses. The finally accepted value s shall not be less than that determined by Formula (2.6.1);
c = allowance to be taken equal to:
2 mm at internal pressure and
3 mm at external pressure.

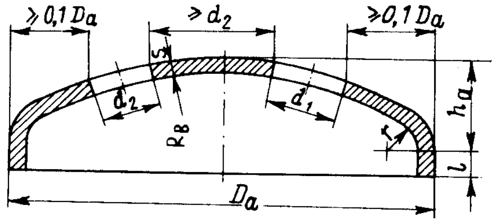


Fig. 2.6.1

At wall thickness exceeding 30 mm the above allowance values may be reduced by 1 mm;
d = the larger dimension of the non-reinforced opening, mm.

The symbols for dished end elements are shown in Fig. 2.6.1.

2.6.2 Formula (2.6.1) is valid where the following relations are observed:

$$h_a/D_a \geqslant 0{,}18;$$

$$(s - c)/D_a \geqslant 0{,}0025;$$

$$R_B \leqslant D_a; \quad r \geqslant 0{,}1D_a;$$

$$l \leqslant 150 \text{ mm};$$

$$l \geqslant 25 \text{ mm} \quad \text{at } s \leqslant 10 \text{ mm};$$

$$l \geqslant 15 + s \quad \text{at } 10 < s \leqslant 20 \text{ mm};$$

$$l \geqslant 25 + 0{,}5s \quad \text{at } s > 20 \text{ mm}.$$

2.6.3 By unpierced end is meant an end, which has no openings or one with openings located at a distance of not less than $0{,}2D_a$ from the outside outline of the cylindrical portion and measuring not more than $4s$ in diameter and never more than 100 mm. In the flanged area of the end, non-reinforced openings are allowed, with diameters less than the wall thickness but not more than 25 mm.

2.6.4 The wall thickness of dished ends in combustion chambers of vertical boilers may be

Table 2.6.1

Dished end shape	$\frac{h_a}{D_a}$	Shape factor y							
		y — for flanged area of end and for unpierced ends	y_A — for dished part of end with non-reinforced openings, for which $d/\sqrt{D_a s}$ is equal to:						y_0 — for dished part of end with reinforced openings
			0,5	1,0	2,0	3,0	4,0	5,0	
Elliptical or torispherical, with $R_B = D_a$	0,20	2,9	2,9	2,9	3,7	4,6	5,5	6,5	2,4
Elliptical or torispherical, with $R_B = 0{,}8D_a$	0,25	2,0	2,0	2,3	3,2	4,1	5,0	5,9	1,8
Hemispherical, with $R_B = 0{,}5D_a$	0,50	1,1	1,2	1,6	2,2	3,0	3,7	4,35	1,1

calculated as for unpierced ends, also where the flue-gas outlet branch passes through the end.

2.6.5 Dished ends subject to external pressure, except for those of cast iron, shall be checked for stability by calculation based on the following relation:

$$\frac{36{,}6E_t}{R_B^2}\,\frac{(s - c)^2}{100p} > 3{,}3 \qquad (2.6.5)$$

where E_t = modulus of elasticity at design temperature, MPa; for modulus of elasticity for steel, refer to Table 2.6.5; for non-ferrous alloys, values of E_t shall be agreed with the Register;
R_B = maximum inside radius of curvature, mm.
Other symbols used are the same as in 2.6.1.

Table 2.6.5

Design temperature t, °C	Modulus of elasticity for steel E_t, MPa
20	$2{,}06\cdot10^5$
250	$1{,}86\cdot10^5$
300	$1{,}81\cdot10^5$
400	$1{,}72\cdot10^5$
500	$1{,}62\cdot10^5$

2.6.6 The minimum wall thickness of steel dished ends shall not be less than 5 mm. For ends manufactured from non-ferrous alloys and stainless steels, the minimum wall thickness may be reduced on agreement with the Register.

2.6.7 The use of dished ends of welded construction is subject to special consideration by the Register.

2.6.8 Where the results of a calculation made according to 2.9.2 call for the reinforcement of openings in dished ends, the reinforcement shall be made in compliance with the requirements of 2.9.3.

2.7 FLANGED END PLATES

2.7.1 Unpierced flanged end plates (refer to Fig. 2.7.1) subject to internal pressure shall have a thickness s, in mm, not less than

$$s = (3pD)/\sigma + c \qquad (2.7.1)$$

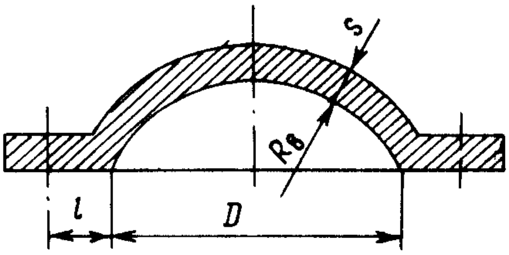


Fig. 2.7.1

where p = design pressure (refer to 2.1.2), MPa;
D = inside diameter of the end plate flange to be equal to the inside diameter of the shell, mm;
σ = allowable stress (refer to 2.1.4.6), MPa;
c = allowance (refer to 2.1.7), mm.

In Fig. 2.7.1, l is the distance, in mm, from the inside diameter edge to the centre line of holding bolts.

2.7.2 Flanged end plates are allowed within the range of diameters up to 500 mm and for working pressures not more than 1,5 MPa. The radius of curvature R_B of the end plate shall not be more than 1,2D, and the distance l not more than 2s.

2.8 HEADERS OF RECTANGULAR SECTION

2.8.1 The wall thickness s, in mm, of rectangular headers (Fig. 2.8.1-1) subject to internal pressure

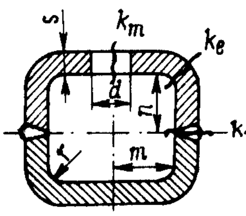


Fig. 2.8.1-1

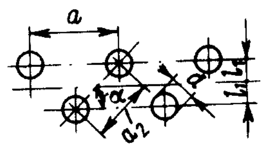


Fig. 2.8.1-2

shall not be less than that determined by the following formula:

$$s = \frac{pn}{2{,}52\sigma\varphi_1} + \sqrt{\frac{4{,}5kp}{1{,}26\sigma\varphi_2}} \qquad (2.8.1\text{-}1)$$

where p = design pressure (refer to 2.1.2), MPa;
n = half the width in the clear of the header side normal to that being calculated, mm;
σ = allowable stress (refer to 2.1.4.6), MPa;
φ_1 and φ_2 = efficiency factors of headers, weakened by holes determined as follows:
φ_1 = by Formula (2.1.6.2.1);
φ_2 = by Formula (2.1.6.2.1) at $d < 0{,}6m$; at $d \geqslant 0{,}6m$ by the following formula:

$$\varphi_2 = 1 - 0{,}6m/a \qquad (2.8.1\text{-}2)$$

where m = half the width in the clear of the header side being calculated, mm;
where the holes are arranged in a staggered pattern, a_2 (Fig. 2.8.1-2) shall be substituted for a in Formula (2.8.1-2);
where the rectangular headers have longitudinal welded joints (refer to Fig. 2.8.1-1), the efficiency factors φ_1 and φ_2 are assumed to be equal, respectively, to the efficiency factor of welded joints selected as per 2.1.6. Longitudinal welded joints shall be arranged, as far as possible, within the area l_1 for which $k = 0$;
where the header wall is weakened in several different ways, the calculations shall be based on the lowest efficiency factor value;
k = design factor for bending moment at the centre of the side wall or at the centre line of the row of holes, mm^2, determined by the formulae:

for the centre line of the header wall

$$k=\frac{1}{3}\,\frac{m^3+n^3}{m+n}-\frac{m^2}{2}\,; \qquad (2.8.1\text{-}3)$$

for rows of holes or longitudinal welded joints

$$k=\frac{1}{3}\,\frac{m^3+n^3}{m+n}-\frac{m^2+l_1^2}{2}\,. \qquad (2.8.1\text{-}4)$$

If the above formulae yield negative values, the absolute numerical values shall be used;
where the holes are arranged in a staggered pattern, factor k shall be multiplied by $\cos\alpha$;
α = angle of the diagonal pitch to the longitudinal axis, deg.;
l_1 = distance between the row of holes under consideration and the centre line of header wall (refer to Fig. 2.8.1-2), mm;
d = diameter of the hole, mm.
For oval holes, d shall be taken as equal to the size of the holes on the longitudinal axis, but in Formulae (2.1.6.2.1) and (2.8.1-2) the size on the axis normal to the header centre line shall be taken as d for oval holes.

2.8.2 Where fillet welded joints are allowed in headers on agreement with the Register, the wall thickness of such headers shall not be less than

$$s=\frac{p\sqrt{m^2+n^2}}{2{,}52\sigma\varphi_1}+\sqrt{\frac{4{,}5k_e p}{1{,}26\sigma\varphi_2}} \qquad (2.8.2\text{-}1)$$

where k_e = design factor for bending moment at the edges, mm^2, determined by the following formula:

$$k_e=\frac{1}{3}\,\frac{m^3+n^3}{m+n}\,. \qquad (2.8.2\text{-}2)$$

Other symbols used are the same as in 2.8.1.

2.8.3 The radius of curvature of rectangular header side shall not be less than 1/3 of the wall thickness and never less than 8 mm. The minimum thickness of header walls designed to accommodate expanded tubes shall not be less than 14 mm. The width of ligaments between holes shall not be less than 0,25 times the pitch between hole centres. The wall thickness in the area of curvature shall not be less than that determined by Formulae (2.8.1-1) and (2.8.2-1).

2.9 REINFORCEMENT OF OPENINGS IN CYLINDRICAL, SPHERICAL, CONICAL WALLS AND IN DISHED ENDS

2.9.1 General.

2.9.1.1 For the purpose of the present Rules openings are subdivided into the following types:

.1 openings reinforced by means of welded-on disc-shaped reinforcing plates (refer to Fig. 2.9.1.1.1);

.2 openings reinforced by means of welded-on tubuler elements such as nozzles, sleeves, branch pieces, flanging, etc (refer to Figs. 2.9.1.1.2-1 to 2.9.1.1.2-3);

.3 openings reinforced by combinations of reinforcing elements listed above (refer to Fig. 2.9.1.1.3);

.4 openings having no reinforcing elements (nozzles, sleeves, branch pieces, flanging and welded-on disc-shaped reinforcing plates), i.e. non-reinforced openings. The dimensions of non-reinforced openings shall not exceed those given in 2.9.2.

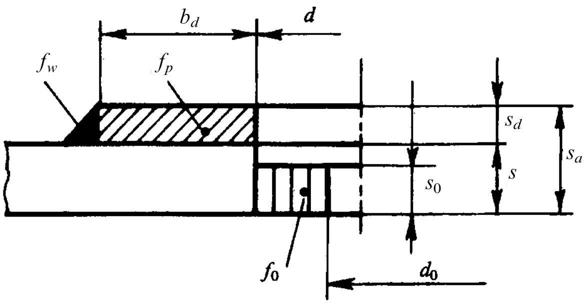


Fig. 2.9.1.1.1

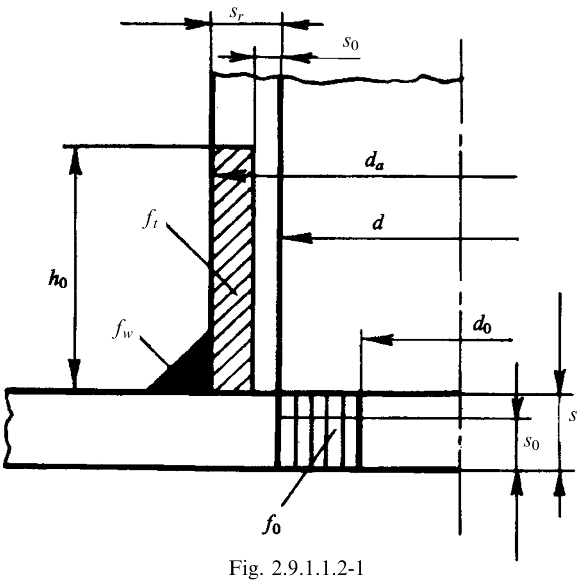


Fig. 2.9.1.1.2-1

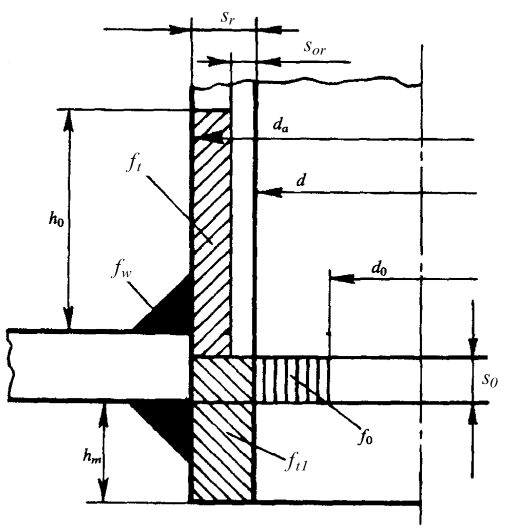


Fig. 2.9.1.1.2-2

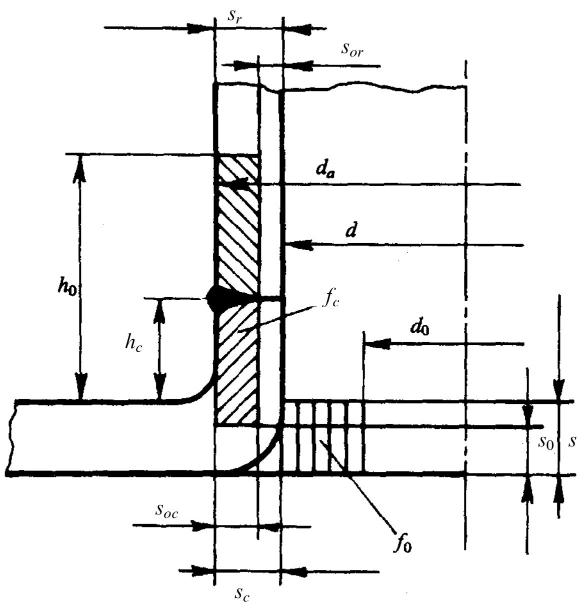


Fig. 2.9.1.1.2-3

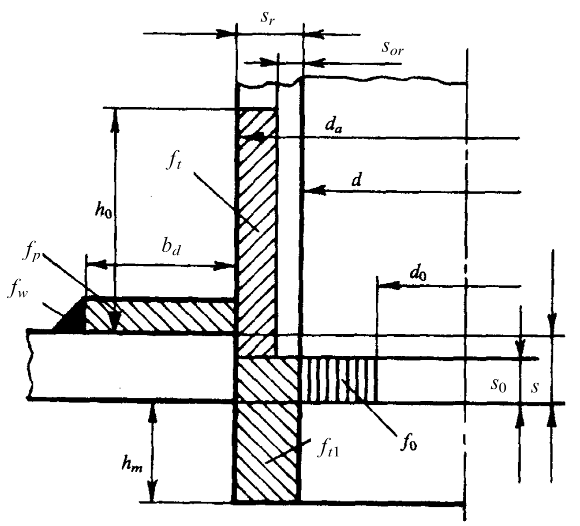


Fig. 2.9.1.1.3

2.9.1.2 The materials used for the wall to be reinforced and for reinforcing elements shall have identical strength characteristics as far as possible. Where reinforcing materials with inferior strength characteristics compared to those of the wall to be reinforced are used, the area of reinforcing sections shall be increased proportionally to the ratio of permissible material stress of the wall to be reinforced to that of the reinforcing material. The higher strength of the reinforcing element shall be neglected.

2.9.1.3 As a rule, openings in walls shall be located at the distance of at least $3s$ (where s is the thickness of the wall to be reinforced), but not less than 50 mm away from welded joints. The arrangement of openings at the distance of less than 50 mm from welded joints is subject to special consideration by the Register in each case. The efficiency factor in this case shall be taken according to 2.1.6.4.

2.9.1.4 Regardless of reinforcing the largest dimension of a reinforced opening shall not exceed 500 mm.

Openings measuring over 500 mm are subject to special consideration by the Register in each case.

2.9.1.5 The minimum thickness of reinforcing tubular elements (branch pieces, sleeves, nozzles) attached by welding to the walls of boilers, heat exchangers or pressure vessels shall be generally taken not less than 5 mm; thicknesses less than 5 mm are subject to special consideration by the Register in each case.

2.9.1.6 The maximum thickness of a tubular element or reinforcing plate taken in the reinforcement calculation shall not generally exceed the thickness of the wall to be reinforced.

The use of reinforcing elements with a thickness up to two thicknesses of the wall to be reinforced may be accepted if required by technological process, but such an increased thickness is disregarded in the reinforcement calculation.

2.9.2 The maximum permissible diameter of a non-reinforced opening.

A single opening is an opening, the edge of which is at a distance of at least $2Q$ from the edge of the nearest opening (where Q is the width of the mostly local opening affected zone, determined by the Formula (2.1.6.4)).

The maximum permissible diameter of a single non-reinforced opening in cylindrical, spherical and conical walls and dished ends is determined by the formula

$$d_0 = (2/[\varphi_{in}] - 1,75)Q \qquad (2.9.2\text{-}1)$$

where Q = the width of the mostly local opening affected zone determined by Formula (2.1.6.4);

$[\varphi_{in}]$ = minimal permissible efficiency factor value of a component weakened by opening, equal to:

for cylindrical wall

$$[\varphi_{in}] = \frac{P(D_a - s + c)}{2(s-c)\sigma}, \qquad (2.9.2\text{-}2)$$

for ellipsoidal, torospherical and semi-spherical ends

$$[\varphi_{in}] = \frac{P(D^2/2h_a + s - c)}{4(s-c)\sigma}, \qquad (2.9.2\text{-}3)$$

for conical walls

$$[\varphi_{in}] = \frac{P(D_c + s - c)}{2(s-c)\sigma\cos\alpha}, \qquad (2.9.2\text{-}4)$$

where D_a, D = outside and inside diameter of the wall to be reinforced, in mm, respectively;

D_c = inside diameter of large base of the conical wall, in mm;

σ = permissible stress, in MPa;

h_a = height of the dished part of end, in mm;
α = cone angle equal to half the angle at the conical wall vertex, in deg;
s = wall thickness, in mm;
c = corrosion allowance, in mm, taken according to 2.1.7.

2.9.3 Reinforcement of openings.

2.9.3.1 When reinforcing single openings in cylindrical, conical walls and dished ends, the sum of compensating areas of reinforcements Σ_f shall exceed the required area of reinforcement f_0:

$$\Sigma_f = f_t + f_{t1} + f_p + f_w + f_c > f_0 \quad (2.9.3.1)$$

where f_t and f_{t1} = compensating areas of exterior and interior parts of a tubular reinforcing element (refer to Figs. 2.9.1.1.2-1, 2.9.1.1.2-2, 2.9.1.1.2-3, 2.9.1.1.3), determined according to 2.9.3.2;
f_p = compensating area of disc-shaped reinforcing plate (refer to Figs. 2.9.1.1.1, 2.9.1.1.3), determined according to 2.9.3.3;
f_w = total compensating area of welded joints equal to the sum of deposited areas without regard weld reinforcement, mm^2;
f_c = compensating area of flanged collar metal (refer to Fig. 2.9.1.1.2-3), determined according to 2.9.3.4;
f_0 = minimum required area of reinforcement, determined according to 2.9.3.5.

2.9.3.2 Compensating areas of tubular elements (nozzles) are determined by the following formulae:

for exterior part of a tubular reinforcing element

$$f_t = 2h_0(s_r - s_{or} - c),\ \text{mm}^2 \quad (2.9.3.2\text{-}1)$$

for interior part of a tubular reinforcing element

$$f_{t1} = 2h_m(s_r - c),\ \text{mm}^2 \quad (2.9.3.2\text{-}2)$$

where s_r = wall thickness of a tubular element, in mm, taken according to the drawing with consideration for recommendations of 2.9.1.5 and 2.9.1.6;
s_{or} = minimum design wall thickness of a tubular element determined according to 2.2.1.2 at $\varphi = 1{,}0$ and $c = 0$, in mm;
c = corrosion allowance, in mm (refer to 2.1.7);
h_0 = height of the exterior part of a tubular element, mm which shall be taken according to the drawing in case it does not exceed the value determined by the formula

$$h_0 = 1{,}25\sqrt{(d_a - s_r)(s_r - c)} \quad (2.9.3.2\text{-}3)$$

where d_a = outside diameter of a tubular element, in mm;
h_m = height of the interior part of a tubular element, which shall be taken according to the drawing in case it does not exceed the value determined by the formula

$$h_m = 0{,}5\sqrt{(d_a - s_r)(s_r - c)}\ . \quad (2.9.3.2\text{-}4)$$

2.9.3.3 Compensating areas of a disc-shaped reinforcing plate are determined by the formula

$$f_p = 2b_d s_d \quad (2.9.3.3)$$

where s_d = thickness of disc-shaped plate taken according to the drawing and with consideration for the requirements of 2.9.1.6;
b_d = a reinforcing plate width (refer to Figs. 2.9.1.1.1 and 2.9.1.1.3), which shall be taken according to the drawing but shall not exceed the width of the mostly opening affected area, Q, determined according to 2.1.6.4.

2.9.3.4 The compensating area of the flanged collar metal (refer to Fig. 2.9.1.1.2-3) is determined by the formula

$$f_c = 2h_{c1}(s_c - s_{oc} - c) + 2(h_0 - h_c)(s_r - s_{or} - c) \quad (2.9.3.4\text{-}1)$$

where h_0, c, s_{or}, s_r = the same as for Formula (2.9.3.2-2);
h_{c1} = height of collar taken equal to the dimension according to the drawing but not more than

$$h_c \leqslant 0{,}5\sqrt{(d - s_c)(s_c - c)} \quad (2.9.3.4\text{-}2)$$

where s_c = thickness of the extended throat or flanged collar taken according to the drawing but not more than wall thickness s, in mm;
s_{oc} = the minimal design wall thickness of a collar or expanded throat, in mm, determined by the formula:

$$s_{oc} = \frac{P(d + 0{,}25r)}{2\sigma - P} \quad (2.9.3.4\text{-}3)$$

where r = curvature radius of a collar or throat, which shall be taken according to the drawing but shall not be less than 5 mm;
d = diameter of an opening to be reinforced, in mm.

2.9.3.5 The minimum required area of a reinforcement f_0 is determined by the formula

$$f_0 = (d - d_0)s_0 \quad (2.9.3.5)$$

where s_0 = the minimum required design wall thickness at $\varphi = 1$ and $c = 0$ determined according to 2.2.1.2, 2.2.1.3, 2.3.1 and 2.6.1. In calculation of wall thickness s_0 by Formula (2.6.1), the value y_a obtained from Table 2.6.1 shall be substitued for y.
d_0 = the maximum permissible diameter of an isolated non-reinforced opening, in mm (refer to 2.9.2-1);
d = diameter of an opening to be reinforced, in mm.

2.9.3.6 In case where combined reinforcing elements are used (refer to Fig. 2.9.1.1.3) the condition of strength according to Formula (2.9.3.1-1) shall be satisfied and the dimensions of reinforcing elements shall meet the requirements of 2.9.1.6 to 2.9.1.7.

2.9.4 Interdependence of openings.

2.9.4.1 The interdependence of openings shall be taken into account if the distance between the edges of adjacent openings determined according to the drawing (refer to Fig. 2.9.4.1) is smaller than two Q, that is the following condition shall be satisfied:

$$l + s_{r1} + s_{r2} \geqslant 2Q, \quad (2.9.4.1\text{-}1)$$

where Q = width of the mostly local opening affected zone determined by Formula (2.1.6.4).

If the above condition (2.9.4.1-1) is not satisfied, it is necessary to check the stress occurring in the

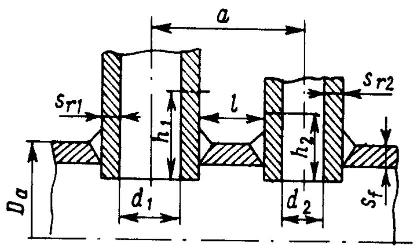


Fig. 2.9.4.1-1

section between the openings due to design pressure. The stress involved shall not exceed, both longitudinally and transversely, the allowable values according to the relation:

$$F/f_c \leqslant \sigma \qquad (2.9.4.1\text{-}2)$$

where σ = allowable stress (refer to 2.1.4.6), in MPa;
F = load caused by the design pressure upon the section between the openings (refer to 2.9.4.2), in N;
f_c = design sectional area between the openings (refer to 2.9.4.3), in mm^2.

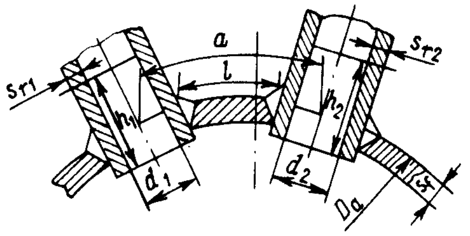


Fig. 2.9.4.1-2

2.9.4.2 The load caused by the design pressure, in N, affecting the section between two openings shall be determined as follows:

.1 for openings arranged longitudinally along a cylindrical wall

$$F_a = Dpa/2; \qquad (2.9.4.2.1)$$

.2 for openings arranged circumferentially in cylindrical or conical walls as well as for openings in spherical walls

$$F_b = Dpa/4; \qquad (2.9.4.2.2)$$

.3 for openings in dished ends

$$F_b = Dpya/4 \qquad (2.9.4.2.3\text{-}1)$$

where D = inside diameter (for conical walls measured at the centre of the opening), mm;
p = design pressure (refer to 2.1.2), MPa;
y = shape factor (refer to 2.6.1);
a = pitch between two adjacent openings on the circumference (determined on the outside of the wall as shown in Fig. 2.9.4.1-2), mm.

Where openings are arranged in cylindrical walls at a diagonal pitch, the load involved is determined by Formula (2.9.4.2.2), the results being multiplied by a factor

$$k = 1 + \cos^2\alpha \qquad (2.9.4.2.3\text{-}2)$$

where α = angle of inclination of the line through the opening centres to the longitudinal axis, deg.

2.9.4.3 The design sectional area f_c, in mm^2, between two adjacent openings with tubular reinforcements shall be determined by the following formula:

$$f_c = l(s - c) + 0{,}5[h_1(s_{r1} - c) + h_2(s_{r2} - c)] \qquad (2.9.4.3)$$

where h_1 and h_2 = heights of the reinforcement, mm, determined by the following formulae:
$h_1(h_2) = h_0 + s$ for non-through reinforcements and $h_1(h_2) = h_0 + s + h_m$ for through reinforcements;
l = width of the ligament between two adjacent reinforcements (refer to Figs. 2.9.4.1-1 and 2.9.4.1-2), mm;
s = thickness of the wall to be reinforced, mm;
s_{r1} and s_{r2} = thicknesses of the tubular reinforcements (refer to Figs. 2.9.4.1-1 and 2.9.4.1-2), mm;
c = allowance (refer to 2.1.7), mm;
h_0 = design height of the tubular reinforcement (refer to Formula (2.9.3.2-3));
h_m = height of inward projecting portion of the tubular reinforcement (refer to Formula (2.9.3.2-4)), mm.

For openings to be reinforced by other methods (combined or disc-shaped reinforcements, etc.) the design sectional area f_c shall be determined in a similar manner.

2.10 STAYS

2.10.1 Scantlings of stays.

2.10.1.1 The cross-sectional area f, in mm^2, of long and short stays, corner stays and stay tubes subject to tensile or compressive stresses shall not be less than

$$f = pf_s/(\sigma \cos\alpha) \qquad (2.10.1.1)$$

where p = design pressure (refer to 2.1.2), MPa;
σ = allowable stress (refer to 2.1.4.6), MPa;
α = angle between the corner stay and the wall, to which the stay is attached (refer to Fig. 2.4.2.1-3), deg.;
f_s = maximum surface area per stay of the wall to be reinforced, bounded by lines passing at right angles through the centres of the lines joining the centre of the stay with the adjacent points of support (stays), mm^2. The cross-sectional area of the stays and tubes within this area may be deducted from the surface area per stay.

2.10.1.2 For stays subject to longitudinal bending, the allowable bending stresses shall be taken with a safety factor not less than 2,25.

2.10.1.3 For end plates with a separate reinforcing stay (Fig. 2.10.1.3), the latter shall be so designed that it may take up at least half the load upon the end plate. An end plate of this type shall have a thickness in compliance with the requirements of 2.4.2.1.

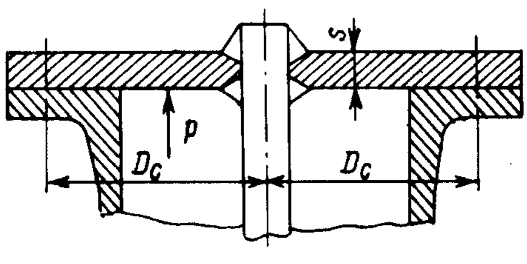


Fig. 2.10.1.3

2.10.1.4 Stay and ordinary fire tubes shall have a thickness not lower than that indicated in Table 2.10.1.4.

Table 2.10.1.4

Outside diameter of tube, mm	Working pressure p, MPa, at wall thickness, mm			
	3,0	3,5	4,0	4,5
50	1,1	1,85	—	—
57	1,0	1,65	—	—
63,5	0,9	1,5	2,1	—
70	0,8	1,35	1,9	—
76	0,75	1,25	1,75	2,25
83	—	1,15	1,6	2,1
89	—	1,05	1,5	1,9

The thickness of stay tubes with diameters over 70 mm shall not be less than:

6 mm for peripheral tubes;

5 mm for tubes arranged inside the tube nest.

2.10.2 Attachment of stays.

2.10.2.1 The cross-sectional area of welded joints of welded-on stays shall be such as to satisfy the following condition:

$$\pi d_a e/f \geqslant 1{,}25 \qquad (2.10.2.1)$$

where d_a = stay diameter (for tubes — outside diameter), mm;
e = weld thickness (Figs. 5.1 to 5.3 of the Appendix), mm;
f = cross-sectional area of the stay (refer to 2.10.1.1), mm^2.

2.10.2.2 For expanded tubes the length of the expansion joint in the tube plate shall not be less than 12 mm.

Expansion joints for working pressures above 1,6 MPa shall be made with sealing grooves.

2.10.2.3 Expansion joints shall be checked for secure seating of the tubes in the tube plates by axial testing loads. The tubes may be considered securely seated, if the inequality is effected

$$pf_s/20sl \leqslant A \qquad (2.10.2.3)$$

where A is equal to:
15 for joints of plain tubes,
30 for joints with sealing grooves,
40 for joints with flanging of tubes.
s = thickness of the tube wall, mm;
p and f_s, refer to 2.10.1.1;
l = length of the expansion belt, mm.
l shall be taken as not more than 40 mm.

2.10.2.4 The expansion of the plain tubes shall ensure secure seating of the tubes $q \geqslant 250$ N/mm according to the formula

$$q = F/l \qquad (2.10.2.4\text{-}1)$$

where q = secure seating of the tube in the opening per 1 mm of the expansion belt length, N/mm; in case of automatic expansion, this value shall be taken as 250 N/mm; in other cases, it shall be obtained experimentally. Where lower values are obtained, the thickness of the tube plate shall be proportionally increased;
F = tension necessary for rupture of the expansion joint, N;
l = expansion belt length, in mm, which shall not be less than that determined by the formula

$$l = pf_s k_r/q \qquad (2.10.2.4\text{-}2)$$

where k_r = safety factor for the expansion joint, which shall be taken as 5,0.

Other symbols used are the same as in 2.10.1.1.

2.11 TOP GIRDERS

2.11.1 The section modulus W, in mm^3, of top girders of rectangular section shall not be less than

$$W = 1000M/(1{,}3\sigma z) \qquad (2.11.1\text{-}1)$$

where σ = allowable stress (refer to 2.1.4.6), MPa;
z = coefficient of rigidity of the wall to be reinforced; for the structure shown in Fig. 2.11.1, z = 1,33;
M = bending moment of the girder, N·m;
for a rectangular section

$$M = pal^2/8000\,; \qquad (2.11.1\text{-}2)$$

s_1 = width of the girder, mm;
h = height of the girder, which shall not be more than $8s_1$, mm;
l = design length of the girder, mm;
p = design pressure (refer to 2.1.2), MPa;
a = spacing of girders, mm.

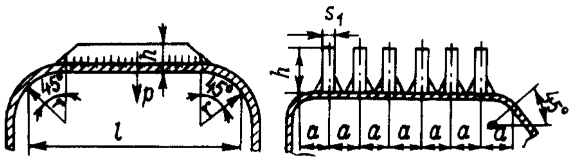


Fig. 2.11.1

3 BOILERS

3.1 GENERAL

3.1.1 The general provisions concerning surveys, technical documentation, manufacture, materials and general requirements for boilers and also strength calculation standards for boiler elements are set forth in Sections 1 and 2.

3.1.2 The boilers shall remain operative under the environmental conditions specified in 2.3, Part VII "Machinery Installations".

3.1.3 Where the failure of an auxiliary boiler for essential services involves the stop of main engine or ship deenergizing or results in the deviation from the specified requirements for proper carriage of goods, two boilers may be required by the Register, the capacity of each being sufficient to ensure normal ship operation.

3.2 CONSTRUCTION REQUIREMENTS

3.2.1 The thickness of tube walls thinned in the process of bending shall not be less than the design values.

3.2.2 The use of long and short stays shall be avoided, and also that of stay tubes exposed to bending or shearing stresses. Stays, strength walls, reinforcements, etc. shall have no abrupt changes in cross-sections.

Control drilled holes shall be provided for at short-stay ends as shown in Fig. 5.3 of the Appendix.

3.2.3 For walls reinforced by short stays and exposed to flame and high-temperature gases, the distance between stay centres shall not be larger than 200 mm.

3.2.4 Corner stays of gas-tube boilers shall be arranged at a distance of not less than 200 mm from the furnaces flues. Where flat walls are reinforced with welded-on girders, this shall be done so that the load involved is transferred as far as possible to the boiler shell or the most rigid parts.

3.2.5 The distance between furnaces flues and boiler shell shall not be less than 100 mm. The distance between any two furnaces shall not be less than 120 mm.

3.2.6 Branches and nozzles shall be of rigid construction and minimum length sufficient for fixing and dismantling boiler mountings and fittings without removing the insulation. Branch pieces shall not be subjected to excessive bending stresses and shall be reinforced by stiffening ribs if so required.

3.2.7 Pads intended for installation of mountings, fittings and pipes as well as branches, sleeves and nozzles passing through the entire thickness of the boiler wall shall generally be attached by welding from both sides. Branches and nozzles may also be welded by a fillet joint, with single-edge preparation, using removable backing strip, or by some other method that ensures penetration throughout the thickness of the part being attached.

3.2.8 Boiler drums and headers having a wall thickness greater than 20 mm and also superheater headers shall be protected from direct heat radiation as indicated in 2.1.3.4. The heating surface components of boilers and oil burner unit tuyeres subject to direct heat radiation shall have no projecting portions or edges on the fire side.

3.2.9 Where use is made of non-metal sealing gaskets, manhole and handhole closures shall be so designed as to prevent the possibility of the gasket being forced out.

3.2.10 Manholes, sight holes and other openings in boiler walls shall be reinforced as specified in 2.4.4 and 2.9.

3.2.11 Structural measures shall be taken to prevent steam generation in economizers of boilers.

3.2.12 A nameplate indicating all principal technical data of boilers shall be provided in a conspicuous place.

3.2.13 The fastening elements of the boiler, apart from those which are not stressed, shall not be attached by welding directly to the boiler walls (shell, ends, headers, drums, etc.) but shall be attached by means of welded-on plates.

3.2.14 The tubes securely seated in the headers and tube plates by expansion of their ends shall be seamless.

3.2.15 Water-tube finned-tube boilers and all waste-heat boilers with forced circulation shall be equipped with an effective fire-resistant soot-cleaning system and their heating surfaces shall have access for inspection and cleaning as well as for sediments removal.

3.2.16 Waste-heat boilers with forced circulation connected to exhaust gas systems of two stroke diesels with inlet gas temperature of 270 °C and lower shall meet the following requirements:

.1 hydraulic resistance of the boiler gas duct shall be such that during operation the gas flow velocity at the pipes of heating surfaces is not less than 10 m/s;

.2 for disconnection of the boiler heating when the engine is operated at partial loads the automated or remotely controlled arrangement providing full gas transfer shall be provided;

.3 the boilers shall be equipped with the system of washing and sediments removal. At the same time measures shall be taken to exclude washing products entering in the engine gas duct. It is advisable to use special additive-injection arrangements to facilitate removal of sediments from the heating surfaces.

3.2.17 The design of waste-heat boilers with forced circulation shall provide for the fixed fire-extinguishing systems to be connected, as stipulated in item 11 of Table 3.1.2.1, Part VI "Fire Protection".

3.3 FITTINGS AND GAUGES

3.3.1 General.

3.3.1.1 All boiler valves shall be fitted on special welded-on branches, nozzles and pads, and shall generally be secured thereto by studs or bolts. The studs shall have a full thread holding in the pad for a length of at least one external diameter.

The bore of threaded nozzle fitted mountings is allowed to be not greater than 15 mm, special pads being used for attaching them to the boiler.

The construction of pads, branches and nozzles shall comply with the requirements of 2.9.

3.3.1.2 The valve covers shall be secured to valve cases by studs or bolts. Valves with bore diameters of 32 mm and less may have screwed covers provided that they are fitted with reliable stops.

3.3.1.3 The valves and cocks shall be fitted with open and shut position indicators.

Position indicators are not required where the design allows to see without difficulty whether the fittings are open or shut. All valves shall be arranged to be shut with a clockwise motion of the wheels.

3.3.2 Feed valves.

3.3.2.1 Each main boiler and each auxiliary boiler for essential services shall be equipped with at least two feed valves. Auxiliary boilers for other services, and also waste-heat boilers may have one feed valve each.

3.3.2.2 The feed valves shall be of a non-return type (check valves). A shut-off valve shall be installed between the check valve and the boiler. The check and shut-off valves may be housed in one casing. The shut-off valve shall be fitted directly on the boiler.

3.3.2.3 The requirements concerning the feed water system are given in Section 17, Part VIII "Systems and Piping".

3.3.3 Water level indicators.

3.3.3.1 Each boiler with free water evaporating surface shall be provided with at least two independent water level indicators with transparent faces (refer to 3.3.3.3). On agreement with the Register, one of these indicators need not be installed when provision is made on the boiler for the lowest water level protective devices, as well as the lowest and highest water level alarms (the transducers of protective and signalling systems shall be independent and shall have different measuring points), or for lowered or remote water level indicator of an approved type with separate measuring points.

Boilers with a steaming capacity of 750 kg/h and less as well as all steam-heated steam generators, waste-heat boilers with free water evaporating surface and steam headers of waste-heat boilers may be provided with one water level indicator having a transparent face.

3.3.3.2 Forced circulation boilers shall be provided, instead of water level indicators, with two independent alarms to signal a shortage of water supply to the boiler.

When the boiler is serviced by an automatic oil burner unit, complying with the requirement of 5.3.3.4, a second alarm is not required.

This requirement is not applicable to waste-heat boilers.

3.3.3.3 Flat prismatic glass shall be used in water level indicators for boilers having a working pressure of less than 3,2 MPa. For boilers having a working pressure of 3,2 MPa and upwards, sets of mica sheets shall be used instead of glass, or else plain glass with a mica layer to protect the glass from water and steam effects, or other materials resistant to destructive action of the boiler water.

3.3.3.4 The water level indicators shall be fitted on the front of the boiler, at an equal height and, as far as possible, at an equal distance from the vertical centre line of the drum/boiler shell.

3.3.3.5 All water level indicators shall be provided with shut-off devices both on the water and steam sides.

Shut-off devices shall have safe drives for disconnection of the devices in case of glass breakage.

3.3.3.6 Water level indicators shall have the possibility of separately blowing off the water and steam spaces. Blow-down ducts shall have an inside diameter of not less than 8 mm. The design of water level indicators shall prevent the gasket materials from being forced into the ducts, and allow of cleaning the blow-down ducts, as well as of replacing the glasses while the boiler is in operation.

3.3.3.7 Water level indicators shall be so installed that the lower edge of the gauge slot is positioned below the lowest water level in the boiler by not less than 50 mm, however, the lowest water level shall not be above the centre line of the visible portion of the water level indicator.

3.3.3.8 Water level indicators shall be connected to the boiler by means of independent branch pieces. No tubes leading to these branches are allowed inside the boiler. The branches shall be protected from exposure to hot gases, radiant heat and intense cooling. If the gauge glasses are fitted on the additional small vessels, the space inside such vessels shall be divided by partitions.

Water gauges and connecting pipes between them shall not be allowed to carry nozzles or branch pieces to be used for other purposes.

3.3.3.9 The branch pieces for attachment of water level indicators to boilers shall have an inside diameter not less than:

32 mm for bent branches of main boilers,

20 mm for straight branches of main boilers and for bent branches of auxiliary boilers,

15 mm for straight branches of auxiliary boilers.

3.3.3.10 The design, dimensions, number, location and lighting of water level indicators shall provide for adequate visibility and reliable control of the boiler water level. Where water level visibility is inadequate, irrespective of the height of water level indicator location, or where the boilers are remotely controlled, provision shall be made for highly reliable remote water level indicators (placed at a lower position) or other types of water gauges approved by the Register and installed in the boiler control stations.

This requirement is not applicable to waste-heat boilers and their steam accumulators (steam separators).

3.3.3.11 Remote water level indicators for boilers may have a tolerance not exceeding ± 20 mm as compared to water level indications of gauge glasses fitted on the boiler while the relevant delays in level indications at the highest possible rate of change shall not exceed 10 per cent of difference between the upper and lower levels.

3.3.4 Lowest water level and highest heating-surface point.

3.3.4.1 Each natural circulation boiler with free water evaporating surface shall have its lowest water level marked on the boiler water level indicator with a reference line drawn on the gauge frame or body. Additionally, the lowest water level shall be marked on a plate with a reference line and an inscription "lowest level". The plate shall be attached to the boiler shell close to the water level indicators.

The reference line and the plate shall not be covered over with boiler insulation.

3.3.4.2 In all cases the lowest water level in the boiler shall not be less than 150 mm above the highest heating-surface point. This distance shall also be maintained when the ship is listed up to 5 degress either side and under all possible service trim conditions.

In the case of boilers with design steaming capacity less than 750 kg/h, the said minimum distance between the lowest water level and the highest heating-surface point may be reduced down to 125 mm.

3.3.4.3 The position of the upper ends of the uppermost downcomers is assumed to be the highest point of the heating surface of water-tube boilers.

For vertical gas-tube boilers with the fire tubes and gas uptake pipes passing through the steam space of the boiler, the position of the highest heating-surface point is subject to special consideration by the Register in each case.

3.3.4.4 Gas-tube boilers shall be fitted with a position indicator for the highest heating-surface point, which shall be securely attached to the boiler wall, close to the lowest water-level plate, and to have an inscription "highest heating-surface point".

3.3.4.5 The requirements for the position of the highest heating-surface point and the relevant position indicator do not apply to waste-heat boilers, forced circulation boilers, economizers and steam superheaters.

3.3.5 Pressure gauges and thermometers.

3.3.5.1 Each boiler shall have at least two pressure gauges connected with the steam space by separate pipes fitted with stop valves or stop cocks. Three-way valves or cocks shall be provided between the pressure gauge and the pipe to make it possible to shut off the pressure gauge from the boiler, connect it to the atmosphere, blow off the connecting pipe and install the control pressure gauge.

3.3.5.2 One of the pressure gauges shall be installed on the front of the boiler, the other at the main engine control station.

3.3.5.3 Boilers with design steaming capacity below 750 kg/h and waste-heat boilers are allowed to have one pressure gauge.

3.3.5.4 A pressure gauge shall be provided at the water outlet from the economizer.

3.3.5.5 Pressure gauges shall have a scale sufficient to allow of boiler hydraulic testing. The pressure gauge scale shall have a red line to mark the working pressure in the boiler.

3.3.5.6 Pressure gauges fitted on boilers shall be protected from the heat emitted by the hot boiler surfaces.

3.3.5.7 The pressure gauges shall be calibrated by a competent body.

3.3.5.8 Steam superheaters and economizers shall be equipped with thermometers. Remote temperature control does not obviate the need for providing local thermometers.

3.3.6 Safety valves.

3.3.6.1 Each boiler shall have not less than two spring-loaded safety valves of identical construction and equal size, to be installed on the drum, as a rule, on a common branch piece and one valve to be fitted on the superheater outlet header. The superheater safety valve shall be so adjusted as to open before the safety valve installed on the drum.

Safety valves of the impulsive action type are recommended for steam boilers having a working pressure of 4 MPa and more.

One safety valve is sufficient for steam boilers with design steaming capacity below 750 kg/h as well as steam accumulators (steam separators).

3.3.6.2 The aggregate cross-sectional area f, in mm^2, of safety valves shall not be less than:

for saturated steam

$$f = k\frac{G}{10{,}2p_w + 1}; \qquad (3.3.6.2\text{-}1)$$

for superheated steam

$$f = k\frac{G}{10{,}2p_w + 1}\sqrt{\frac{V_H}{V_s}} \qquad (3.3.6.2\text{-}2)$$

where G = design steaming capacity, kg/h;
p_w = working pressure, MPa;
V_H = specific volume of superheated steam at the appropriate working pressure and temperature, m^3/kg;
V_s = specific volume of saturated steam at the appropriate pressure, m^3/kg;
k = coefficient of hydraulic resistance is assumed to be equal to: d/h at $h/d \leqslant 0{,}25$; $1{,}25d/h$ at $h/d > 0{,}25$;
d = minimum valve diameter, mm;
h = height of valve lifting, mm.

Spring safety valves shall not be less than 32 mm and not more than 100 mm in diameter.

If specially approved by the Register, the use of valves with smaller cross-sectional areas than required by Formulae (3.3.6.2-1) and (3.3.6.2-2) may be allowed, provided it is proved experimentally that each of these valves has a discharge capacity not lower than the design steaming capacity of the boiler.

3.3.6.3 The cross-sectional area of the safety valve installed on the non-disconnectable superheater may be included in the aggregate cross-sectional area of the valves to be determined from Formulae (3.3.6.2-1) and (3.3.6.2-2). This area shall not amount to more than 25 per cent of the aggregate area of the valves.

3.3.6.4 The safety valves shall be so adjusted that the maximum pressure during their operation shall not exceed the working pressure by more than 10 per cent. When lifted, the safety valves of main and auxiliary boilers for essential services shall fully interrupt the outgoing steam flow in case of the pressure drop in the boiler not below 0,85 of the working pressure.

3.3.6.5 Economizers shall be provided with spring-loaded safety valves not less than 15 mm in diameter.

3.3.6.6 Where safety valves are fitted on a common branch, the cross-sectional area of the branch shall not be less than 1,1 times the aggregate cross-sectional area of the valves installed.

3.3.6.7 The cross-sectional area of the waste-steam branch of the safety valve and of the pipe connected thereto, shall not be less than twice the aggregate cross-sectional area of the valves.

3.3.6.8 To remove the water of condensation, a drain pipe without any stopping devices shall be provided for on the valve body or on the waste-steam pipe (if the latter is located below the valve).

3.3.6.9 The safety valves shall be connected directly to the boiler steam space without any stopping devices. Supply pipes leading to the safety valves are not allowed to be installed inside the boiler. No provision shall be made on the safety valve bodies or their connections for steam extraction devices for other purposes.

3.3.6.10 The safety valves shall be so arranged that they can be lifted by a special hand-operated easing gear. The easing gear of one of the valves shall be operated from the boiler room, and that of the other valve from the upper deck or any other readily accessible place outside the boiler room.

The remote control gear for safety valves of steam superheaters, waste-heat boilers and their steam headers (separators) may be operated only from the boiler room.

3.3.6.11 The safety valves shall be so designed that they could be sealed or provided with an equivalent safeguard to prevent the valves from being adjusted without the knowledge of the operating personnel.

The springs of the safety valves shall be protected from direct exposure to steam and shall be manufactured from heat- and corrosion-resistant materials, as also are the sealing surfaces of seats and valves.

3.3.7 Shut-off valves.

3.3.7.1 Each boiler shall be separated from all pipelines leading to it by means of shut-off valves secured directly to the boiler.

3.3.7.2 In addition to local control, the shut-off valves shall be provided with remote control gears for the operation from the upper deck or from other readily accessible position outside the boiler room.

3.3.7.3 Where there is one main boiler or an auxiliary boiler for essential services installed on board the ship complete with a superheater or an economizer, the superheater and economizer shall be so arranged as to be shut off from the boiler.

3.3.7.4 The requirements for steam lines and boiler blow-down pipes are set forth in Section 18, Part VIII "Systems and Piping".

3.3.8 Blow-down valves.

3.3.8.1 Boilers, their steam superheaters, economizers and steam accumulators shall be fitted with blow-down arrangements and, where so required, with drain valves.

Blow-down and drain valves shall be fitted directly to the boiler shell. At working pressures below 1,6 MPa these valves may be installed on welded-on profiled branch pieces.

3.3.8.2 The inside diameter of blow-down valves and pipes shall not be less than 20 mm and not more than 40 mm. For boilers with design steaming capacity below 750 kg/h the inside diameter of the valves and pipes may be reduced to 15 mm.

3.3.8.3 In boilers with free water evaporating surface the scum arrangements shall ensure scum and sludge removal from the entire evaporating surface.

3.3.9 Salinometer valves.

Each boiler shall be provided with at least one salinometer valve or cock. The fitting of such valves or cocks on pipes and branches intended for other purposes is not allowed.

3.3.10 Valves for deaeration.

Boilers, steam superheaters and economizers shall be equipped with sufficient number of valves or cocks for deaeration.

3.3.11 Openings for internal inspection.

3.3.11.1 Boilers shall be provided with manholes for inspection of all internal surfaces. Where the provision of manholes is not possible, arrangements shall be made for hand holes.

3.3.11.2 Manhole openings shall have dimensions in the clear not less than:

300×400 mm for oval openings, and 400 mm for round openings.

In separate cases, if specially approved by the Register, the dimensions of manhole openings may be reduced to 280×380 mm and to 380 mm for oval and round openings, respectively. The oval manholes in cylindrical shells shall be so positioned that the minor axis of the manhole is arranged longitudinally.

3.3.11.3 Vertical gas-tube boilers shall have at least two hand holes arranged in the shell opposite to each other in the area of the working water level.

3.3.11.4 All boiler parts such as may prevent or hinder free access to, and inspection of, internal surfaces shall be of a removable type.

3.4 INCINERATOR BOILERS

3.4.1 The present requirements apply to ship auxiliary boiler units used for burning garbage, oil residues and sludge having a flush point above 60 °C.

3.4.2 The strength calculations and requirements for design, valves and fittings, oil burning installations, control and protection are specified in Sections 2 to 5.

3.4.3 Control and monitoring systems of incinerator boilers designed for unattended operation and their elements shall satisfy the requirements of Part XV "Automation".

3.4.4 In order to burn garbage, oil residues and sludge, provision shall, as a rule, be made for a special chamber complying with the following requirements:

.1 the chamber shall be separated from the boiler furnace and shall be covered with refractory lining, which is not chemically affected by combustion products;

.2 the ducts connecting the furnace and the chamber shall have a sufficient cross-sectional area. In any case, the working pressure in the chamber shall not exceed the pressure in the furnace by more than 10 per cent;

.3 provision shall be made for a safety device set to operate when the working pressure is exceeded by more than 0,02 MPa. The safety device shall be so arranged that no flame ejection is possible into the engine and boiler room;

.4 the aggregate cross-sectional area of the safety device shall be at least 115 cm^2 per 1 m^3 of the volume and not below 45 cm^2. Garbage may be burned in chambers located within the fire space of the boiler. Incinerator boilers shall be provided with a charging facility fitted with covers, which are so interlocked that they cannot be opened simultaneously. For incinerator boilers having no charging facility, provision shall be made for an interlock between the charging door being opened and the temperature in the combustion chamber so as to exclude the self-ignition of cargo during loading.

In case of any restrictions concerning the materials charged, this shall be indicated on a warning plate.

3.4.5 A specially designed system shall generally be used for burning of oil residues and sludge. The use of the boiler fuel supply system and oil burning installation is only permitted if smokeless combustion is ensured.

3.4.6 The incinerator boilers shall be provided with an effective system of soot removal.

3.5 THERMAL FLUID BOILERS

3.5.1 The requirements of the present Chapter apply to thermal fluid boilers.

3.5.2 General provisions relating to surveys, technical documentation, construction, strength calculation standards and also general requirements are set forth in Sections 1 and 2 and in 3.2.1, 3.2.6 to 3.2.10, 3.2.12, 3.2.13.

3.5.3 Boilers shall generally be installated in separate spaces provided with exhaust ventilation sufficient to give at least 6 air changes per hour.

3.5.4 The boiler shall be designed so that no temperature increase of the tube wall on the thermal fluid side above the permissible value is possible in any part of the boiler.

3.5.5 Each boiler shall be equipped with:

.1 shut-off devices at the thermal fluid inlet and outlet. The devices shall be arranged in a readily accessible position where safe maintenance is ensured and shall be both locally and remotaly controlled from positions outside the boiler space, or provision shall be made for an arrangement for emergency drainage of the thermal fluid from the system being operated both locally and remotely from positions outside the boiler space. Provision shall be made to ensure, in case where the emergency thermal fluid drain valves become open, delivery of sufficient amount of air (in an open system) or inert gas (in a closed system) to the expansion tank. The thermal fluid shall be drained from the system into a drain or reserve tank;

.2 at least one spring-loaded safety valve of encased type. The total capacity of safety valves fitted shall be at least not less than the increment of the thermal fluid amount at the maximum heating intensity. Safety valves shall not be less than 25 mm and not more than 130 mm in bore diameter. The safety valve may be dispensed with if the boiler is directly connected to the expansion tank and cannot be disconnected therefrom. The opening pressure of a safety valve shall not exceed the maximum working pressure by more than 10 per cent;

.3 pressure gauge;

.4 arrangement for complete emptying;

.5 arrangement for emergency drainage of the thermal fluid and remote shut of circulation pumps;

.6 manholes or hand holes for inspection of the furnace;

.7 manholes for inspection of the heating surface of a waste-heat boiler at the gas inlet and outlet;

.8 a nameplate provided in a conspicuous place according to 3.2.12.

3.5.6 Electrically heated boilers are subject to the same requirements as oil-fired boilers.

3.5.7 Each waste-heat boiler and oil-fired boiler shall be provided with an effective system of soot blow down.

3.5.8 Boiler tubes shall be attached to drums and headers by welding.

3.5.9 Boilers shall be equipped with valves having bellow seals. The use of gasketed valves is subject to special consideration by the Register in each case.

3.5.10 Boilers shall be equipped with temperature sensors at the outlet of gases, fire alarms and limiting temperature protection at the outlet of thermal fluid.

3.5.11 Waste-heat boilers installed downstream of the main two-stroke engines shall be provided with a shut-off device to stop gas supply thereto in case of operation of protective devices. This device shall not interfere with the operation of the engine when gas admission to the boiler is shut off.

3.5.12 Thermal fluid boiler installations shall be provided with automatic combustion controls, audible and visual alarms in compliance with 4.3.10, Part XV "Automation", interlocking specified in 5.3.2 and protective devices according to 5.3.3.

3.5.13 Thermal fluid boilers shall be provided with a fixed fire extinguishing system. The use of drenching systems employing large quantities of water may be accepted. Gas duct under the waste-heat boiler shall be equipped with a drainage system used for carrying away such water in order to preclude penetration thereof into the engine.

4 CONTROLS, GOVERNORS, PROTECTIVE DEVICES AND ALARMS FOR BOILERS

4.1 GENERAL

4.1.1 The requirements of the present Section apply to continuously attended steam boilers and thermal fluid boilers.

Additional requirements for controls, governors, protective devices and alarms for boilers comprising unattended automated boiler plants are specified in 4.3, Part XV "Automation".

4.1.2 Automation systems, their elements and devices shall comply with the requirements of Section 2 and 3, Part XV "Automation".

4.2 GOVERNORS AND CONTROLS

4.2.1 The oil-fired boilers (main and auxiliary boilers for essential services) shall be equipped with automatic combustion controls. Oil-fired steam boilers shall be also equipped with feed water governors.

For other types of boilers these controls and governors are recommended.

4.2.2 Governors and controls shall be capable of maintaining the prescribed parameters within the predetermined limits over the entire steaming or heating (for thermal fluid boilers) load range.

4.3 PROTECTIVE DEVICES

4.3.1 All the boilers, except for the forced circulation boilers, the design of which allows operation with no water, and the headers of the secondary systems of the double-pressure boilers, shall be equipped with non-disconnectable protective devices for the lowest water level limit in the boiler (refer to 3.3.4).

4.3.2 Boilers with automatic burner units shall be protected according to the requirements of 5.3.

4.4 ALARMS

4.4.1 Boilers with automatic feed water governors and automatic burner units shall be equipped with visual and audible alarms at the local boilers control stations in accordance with 4.4.2.

4.4.2 Light and sound alarms shall function in case of:

water level reaching its lowest limit;

water level reaching its highest limit;

failures in the automatic control systems and protective devices, in particular, at power failure;

failure in the burner units (refer to 5.3.3);

fire in the air ducts and uptakes of the boiler.

4.4.3 The lowest level limit alarms shall function prior to the operation of the protective devices.

4.4.4 Provision shall be made for manual disconnection of the sound alarm after its operation.

5 OIL BURNER UNITS OF BOILERS

5.1 GENERAL

5.1.1 The general provisions concerning the technical supervision, technical documentation, manufacture and general requirements for oil burning installations are set forth in Section 1.

5.1.2 All the equipment to be used in oil burner units, such as pumps, fans, quick-closing valves, electric drives, shall be of a type approved by the Register and shall be manufactured under supervision of the Register or other competent authorities recognized by the Register.

Control, protective, interlocking and signalling devices shall comply with the requirements of Part XV "Automation".

5.1.3 The electrical equipment for oil burner units shall comply with the requirements of Part XI "Electrical Equipment".

5.1.4 Fuel oil used for boilers shall have a flash point in accordance with 1.1.2, Part VII "Machinery Installations".

5.1.5 Pipes and fittings of oil burner units shall comply with the requirements of Part VIII "Systems and Piping".

5.1.6 Sight devices shall be provided for observation of the burning process.

5.1.7 Suitable devices shall be provided for extinguishing of manual igniters.

5.2 BURNERS

5.2.1 The burners shall be so designed as to ensure the possibility of controlling the size and shape of the flame jet.

5.2.2 In case of variable-delivery burners provision shall be made for controlling the combustion air supply.

5.2.3 It is recommended that the inlets of boiler fans be protected against penetration of moisture or solids.

5.2.4 Structural measures shall be provided to prevent the burners from being turned or removed from the working position before oil supply thereto has been stopped.

5.2.5 Where steam or air atomizing burners are used, structural measures shall be provided to prevent air or steam from penetration in the oil and vice versa.

5.2.6 Where boiler oil is heated, structural measures shall be taken to prevent oil overheating in heaters in case steam-generating capacity of the boiler is reduced or burners are shut-off.

5.2.7 Trays shall be provided in places where oil may leak.

5.3 AUTOMATIC BURNER UNITS

5.3.1 The requirements of the present Chapter apply to the burner units of continuously attended steam boilers and thermal fluid boilers.

5.3.2 Burner units shall be interlocked for fuel supply to the boiler furnace to be possible only under the following conditions:

.1 the burner is in the operating position;

.2 all the electrical equipment is connected to sources of electrical power;

.3 pre-ventilation of the boiler furnace is completed;

.4 the pilot burner is alight or electrical ignition is switched on (when the main burner is being set alight);

.5 water level in the boiler is above the lowest limit (for steam boilers);

.6 the heat-transfer medium flow through the boiler is within the normal range (for forced-circulation steam boilers and thermal fluid boilers).

5.3.3 Burning installations shall be equipped with non-disconnectable protective devices to operate within 1 s maximum (for pilot burner — not more than 10 s) and to shut off automatically fuel supply to the burner in the cases of:

.1 loss or low head of air flow to the furnace;

.2 flame-jet cut-off at the burner;

.3 water level in the boiler reaching its lowest limit;

.4 heat-transfer medium flow going below the minimum allowable limit (for forced-circulation steam boilers and thermal fluid boilers).

5.3.4 Fuel supply shall be cut off by two self-closing series-connected valves or by a single valve if all the tanks, from which fuel is supplied, are arranged below the burning installation.

5.3.5 Burning installations shall be equipped with a burner flame-jet monitor. Such a monitor shall respond only to the flame jet of the burner under control.

5.3.6 The capacity of the pilot burner shall be such that the burner itself could not maintain the boiler under pressure with the steam consumption completely stopped (for thermal fluid boilers — at the working temperature of the thermal fluid in case where all consumers are cut off).

Where the pilot and main burners are simultaneously in operation and the protection devices are caused to function under conditions specified in 5.3.3, the pilot burner shall cease operation in the same time as the main burner.

5.3.7 Automatic burning installations of main and auxiliary boilers for essential services shall be capable of being manually controlled. Manual controls shall be provided directly at the boiler. In this case, all automatic devices required in 5.3.2 and 5.3.3 shall function.

5.3.8 Provision shall be made for the burning installation to be shut off from two places, one of which shall be situated outside the boiler room.

6 HEAT EXCHANGERS AND PRESSURE VESSELS

6.1 GENERAL

6.1.1 The general provisions concerning the surveys, technical documentation, manufacture, materials and general requirements for pressure vessels and heat exchangers as well as strength calculation standards are set forth in Sections 1 and 2.

6.1.2 The elements of heat exchangers and pressure vessels, which come in contact with sea water or other aggressive media, shall be manufactured from corrosion-resistant materials. If other materials are used, their protection against corrosion shall be subject to special consideration by the Register in each case.

6.1.3 The heat exchangers and pressure vessels shall preserve their serviceability under environmental conditions specified in 2.3, Part VII "Machinery Installations".

6.1.4 The design and scope of tests of the heat exchangers and pressure vessels are subject to special consideration by the Register in each case.

6.2 CONSTRUCTION REQUIREMENTS

6.2.1 The requirements of 3.2.1, 3.2.2, 3.2.4, 3.2.6, 3.2.7, 3.2.9, 3.2.10 and, where necessary, 3.2.13 also apply to pressure vessels and heat exchangers.

6.2.2 The construction shall provide, where necessary, for thermal elongation of the shells and various parts of heat exchangers and pressure vessels.

6.2.3 The shells of heat exchangers and pressure vessels shall be provided with suitable lugs for reliable attachment to the foundations. Overhead attachments shall be provided for, where necessary.

6.2.4 Additional requirements are given in 4.4, Part VII "Machinery Installations".

6.2.5 Manholes shall be provided to enable inspection of the internal surfaces of heat exchangers and pressure vessels. Where provision of manholes is not possible, hand holes shall be fitted in suitable places. Where the length of the heat exchanger or pressure vessel is over 2,5 m, hand holes shall be provided at both ends.

Manholes or hand holes are not required where the equipment is of dismountable construction or where corrosion and contamination of internal surfaces is completely eliminated.

Provision of manholes or hand holes is not necessary in heat exchangers and pressure vessels, which construction excludes the possibility of inspection through such holes.

For the dimensions of manhole openings, see 3.3.11.2.

6.3 FITTINGS AND GAUGES

6.3.1 Each heat exchanger, pressure vessel or their banks in permanent communication shall be fitted with non-disconnectable safety valves. Where there are several non-communicating spaces, safety valves shall be provided for each space.

Hydrophores shall be fitted with a safety valve to be installed on the water side.

In separate cases, on agreement with the Register, the variations from the above requirements may be permitted.

6.3.2 Safety valves shall generally be of a spring-loaded type. In fuel and oil heaters it is allowed to use safety diaphragms of a type approved by the Register and installed on the fuel and oil side.

6.3.3 The discharge capacity of safety valves shall be such that under no conditions the working pressure is exceeded by more than 15 per cent.

6.3.4 The safety valves shall be so designed as to allow of their being sealed or fitted with an equivalent safeguard to prevent valve adjustment without the knowledge of the operating personnel.

The materials used for springs and sealing surfaces of valves shall be capable of withstanding the corroding effect of the medium.

6.3.5 Level indicators and sight glasses may only be installed on heat exchangers and pressure vessels where the conditions of control and inspection so require. Level indicators and sight glasses shall be of a reliable design and shall have an adequate protection.

Flat glass plates shall be used for indicators of water, fuel oil or refrigerant level. Shut-off devices shall be installed between the level indicators and pressure vessels.

In deaerators cylindrical glasses may be used.

6.3.6 Heat exchangers and pressure vessels shall be provided with welded-on pads or short rigid connecting pieces for mounting fittings. Use of threaded connections is permitted for hydrophores.

Fittings shall be mounted taking into consideration the requirements of 3.3.1.1.

6.3.7 Pressure vessels and heat exchangers shall be equipped with blow-down and drainage devices.

6.3.8 Each heat exchanger, pressure vessel or their banks in permanent communication shall be equipped with pressure gauges or compound gauges. Where heat exchangers have several spaces, pressure gauges shall be provided for each space.

Pressure gauges shall comply with the requirements set forth in 3.3.5.1, 3.3.5.5 and 3.3.5.7.

6.4 SPECIAL REQUIREMENTS FOR HEAT EXCHANGERS AND PRESSURE VESSELS

6.4.1 Air receivers.

6.4.1.1 When lifted, the safety valves on air receivers of main and auxiliary engines and of fire extinguishing systems shall fully stop the air bleeding in case of the pressure drop in the air receiver not below 85 per cent of the working pressure.

6.4.1.2 Where compressors, reduction valves or pipelines intended for air supply to air receivers are provided with safety valves, which are so installed that the air supply to air receivers under pressure exceeding the working pressure is excluded, the installation of safety valves on air receivers is not necessary. In this case, the air receivers shall be equipped with fusible plugs instead of safety valves.

6.4.1.3 The fusible plug shall have a fusion temperature from 100 °C to 130 °C. The fusion temperature shall be punched out on the fusible plug.

Air receivers having a capacity over 700 l shall be fitted with plugs not less than 10 mm in diameter.

6.4.1.4 Each air receiver shall be equipped with a device for moisture removal. In case of air receivers arranged horizontally, the moisture removal devices shall be provided at both ends of the receiver.

6.4.2 Condensers.

6.4.2.1 The construction of the condenser and its location on board the ship shall be such as to enable tube replacement.

The shell of the main condenser shall generally be of steel welded construction.

Baffles shall be provided inside the condenser, at excess pressure steam inlets, to protect the tubes from direct steam impact.

The tube attachments shall be so designed as to prevent sagging and hazardous vibration of the tubes.

6.4.2.2 The covers of the condenser water chambers shall be fitted with manholes in number and position as may be required for ensuring access to the tubes in any part of the tube nest for the purpose of expansion, packing replacement, or plugging.

Cathodic protection shall be provided for the water chambers, tube plates and tubes for prevention of electrolytic corrosion.

6.4.2.3 The main condenser shall ensure the operation under damage conditions with any casing of the turbine set being disconnected.

6.4.2.4 The condenser shall be so designed as to enable the instrumentation specified in 19.4, Part VIII "Systems and Piping" to be connected to it.

6.4.3 Heat exchangers and pressure vessels of refrigerating plants and fire-fighting installations.

The heat exchangers and pressure vessels of refrigerating plants and fire-fighting installations shall comply with the requirements of Section 5, Part XII "Refrigerating Plants" and Section 3, Part VI "Fire Protection", respectively.

6.4.4 Pressure vessels of processing equipment for sea products.

6.4.4.1 Pressure vessel covers, which are periodically opened, shall be provided with devices preventing their incomplete closing or spontaneous opening. It is also necessary to safeguard against the cover opening in case of excessive pressure or vacuum in the pressure vessel as well as against pressurization of the vessel in case of incomplete closing of the cover.

6.4.4.2 Inside arrangements of pressure vessels (mixers, coils, disks, diaphragms, etc.), which interfere with the internal examination, shall be of a removable type.

6.4.4.3 Sight glasses not more than 150 mm in diameter intended for observation of the mixer working space may be fitted on pressure vessels having the pressure not exceeding 0,25 MPa.

6.4.4.4 For pressure vessels having the pressure in excess of 0,25 MPa closing appliances of the loading holes shall be so constructed that in case of loss of cover sealing hot medium is removed in direction safe for operating personnel.

6.4.4.5 Pressure vessels operating under vacuum and heated by steam or hot water with a temperature of more than 115 °C shall be fitted with safety valves to prevent, in case of the heating system leakage, an excessive pressure in the space operating under vacuum, which is over 0,85 times the test pressure. In strength calculations of these vessels the design pressure equal to that of safety valve opening shall be taken. In this case, the design stresses in the pressure vessel walls shall not exceed 0,8 times the yield stress of material at the design temperature.

6.4.4.6 For mixers heated by steam or water and also for walls of pressure vessel mixing chambers, which are in contact with the processed sea products, allowance c to the design wall thickness shall be taken as not less than 2 mm.

6.4.5 Cylinders.

6.4.5.1 The present requirements apply to standard fixed cylinders with the capacity of not more than 150 l with the outside diameter not exceeding 420 m and length not exceeding 2000 mm, which are filled with gas at special stations and are then delivered on board for storage and recovery of liquefied gases, refrigerant, carbon dioxide and air.

6.4.5.2 Where the outside diametr and wall thickness of a steel cylinder are predetermined, the maximum permissible pressure p_D shall not exceed that determined by the following formula:

$$p_D \leqslant \frac{2\sigma\varphi(S - c)}{D_a - (S - c)} \qquad (6.4.5.2)$$

where σ = permissible stress, MPa (refer to 2.1.4.6 with $n_T = 1{,}5$ and $n_B = 2{,}6$);
φ = efficiency factor (refer to 2.1.6);
S = wall thickness, mm;
D_a = outside diameter of the cylinder, mm.
c = allowance for corrosion ($c = 1$ mm — for air; $c = 0{,}3$ mm — for liquefied gases; $c = 0$ — without corrosive effect).

In case the design pressure p for particular gas is above the maximum permissible p_D, it is allowed to reduce pressure p to the value $p < p_D$ at the expense of the reduction of the filling ratio of gas in the cylinder.

The design ambient temperature in the space for cylinder storage at the design pressure shall be kept below the critical value for the particular gas and shall be equal to:

50 °C — for ships of unrestricted service;

40 °C — for ships of restricted area of navigation in temperate zones;

45 °C — for liquefied carbon dioxide cylinders regardless of the area of navigation.

The design pressure and the filling ratio of carbon dioxide cylinders shall be chosen in compliance with the requirements of 3.8.2.1, Part VI "Fire Protection".

6.4.5.3 Each cylinder and its valve head shall be fitted with a non-disconnectable safety device (breaking diaphragm, safety valve or fusible plug) preventing the cylinder from inadmissible temperature increase.

Safety valves and fusible plugs of the cylinders except for the liquefied carbon dioxide cylinders shall satisfy the requirements of 6.3.3, 6.4.1.1, 6.4.1.3. The opening pressure of breaking diaphragms shall be $1{,}1p$ where p is the design pressure.

Safety devices of liquefied carbon dioxide cylinders shall satisfy the requirements of 3.8.2.6.1, Part VI "Fire Protection".

6.4.5.4 For cylinders less than 100 l in capacity (except liquefied carbon dioxide cylinders) the safety devices may be omitted on agreement with the Register provided the following requirements are met:

.1 cylinders shall not be located in the strength hull of the ship below the upper deck;

.2 temperature in spaces where the cylinders are installed shall not be above the value indicated in 6.4.5.2;

.3 spaces containing the cylinders shall be well removed from accommodation and service spaces and also from places and spaces where the equipment essential for safety of the ship is installed or flammable materials and fuel are stored.

6.4.5.5 Provision shall generally be made for enclosed gas outlet from the safety devices to the atmosphere. Gas outlet from the safety devices directly to the spaces containing the cylinders is subject to special consideration by the Register.

In case of free air discharge from the safety valves of air receivers the requirements of 3.1.2.5, Part VI "Fire Protection" shall be observed.

Gas discharge from safety devices of cylinders of carbon dioxide smothering system shall be provided in accordance with 3.8.2.7, Part VI "Fire Protection".

6.4.5.6 For cylinders filled without the use of the shipboard equipment (ship's compressors, etc.) installation of pressure gauges is not obligatory. However, in any case the pressure control in any cylinder shall be possible.

6.4.5.7 The cylinders shall be equipped with blow-down and drainage devices, if required.

6.4.5.8 Spaces for storage of the cylinder containing explosive gases shall have an access from the weather deck.

7 STRENGTH CHARACTERISTICS OF BOILER STEEL

7.1 LOWER YIELD STRESS AS A FUNCTION OF DESIGN TEMPERATURE, MPa

Table 7.1

Kind of steel	R_m, MPa	Design temperature, °C							
		20	100	200	250	300	350	400	450
Carbon steel Ст.10	330	195	186	177	162	147	127	108	78
Carbon steels 12K & 15K	350	205	196	181	167	142	118	98	78
Carbon steel Ст.3	370	205	196	186	177	157	—	—	—
Carbon steels 16K, 20 & 20K	400	235	226	206	186	157	137	118	98
Carbon steel 18K	430	255	245	226	206	177	157	137	118
Alloy steel 15XM	440	225	226	221	216	216	206	196	191
Alloy steel 12X1MФ	440	255	255	250	245	235	226	216	206
Alloy steels 16ГС & 09Г2С	450	265	255	235	226	196	177	157	123
High-manganese steel 22ГК	530	335	324	304	284	275	255	245	235

7.2 AVERAGE STRESS TO PRODUCE RUPTURE IN 100 000 HOURS AS A FUNCTION OF DESIGN TEMPERATURE, MPa

Table 7.2

Kind of steel	R_m	R_{eH}	Design temperature, °C							
	MPa		370	380	390	400	410	420	430	440
Carbon steels 10, 12K and 15K	330 — 350	195 — 205	186	157	137	118	103	88	74	64
Carbon steels 16K, 18K, 20 and 20K	400 — 430	235 — 255	216	186	162	142	127	108	98	83
Alloy steel 15XM	440	225	—	—	—	—	—	—	—	—
Alloy steel 12X1MФ	440	255	—	—	—	—	—	—	—	—
Alloy steels 16ГС and 09Г2С	450	265	255	216	186	167	147	127	113	98
High-manganese steel 22ГК	530	335	245	226	206	186	167	157	137	118

Table 7.2 — continued

Kind of steel	R_m	R_{eH}	Design temperature, °C								
	MPa		450	460	470	480	490	500	510	520	530
Carbon steels 10, 12K and 15K	330 — 350	195 — 205	59	—	—	—	—	—	—	—	—
Carbon steels 16K, 18K, 20 and 20K	400 — 430	235 — 255	69	—	—	—	—	—	—	—	—
Alloy steel 15XM	440	225	265	245	226	196	157	137	118	103	88
Alloy steel 12X1MФ	440	255	—	—	—	196	186	177	167	152	137
Alloy steels 16ГС and 09Г2С	450	265	88	78	69	—	—	—	—	—	—
High-manganese steel 22ГК	530	335	103	93	83	74	69	59	49	34	25

APPENDIX

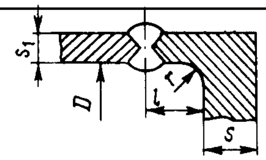
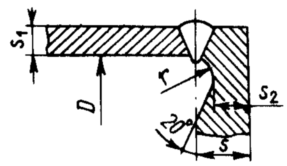
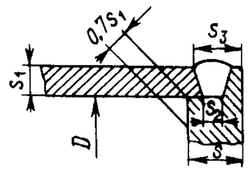
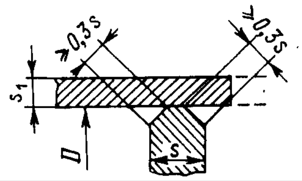
TYPICAL EXAMPLES OF ALLOWABLE WELDED JOINTS FOR BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

Dimensions of structural elements of the prepared edges of welded parts and dimensions of welds shall be taken according to national standards, having regard to the welding method used.

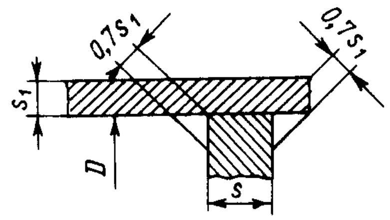
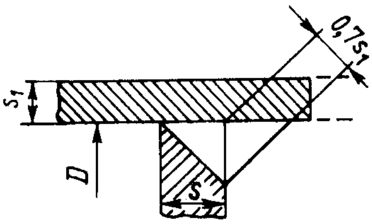
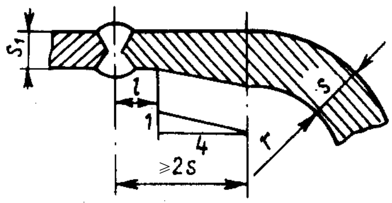
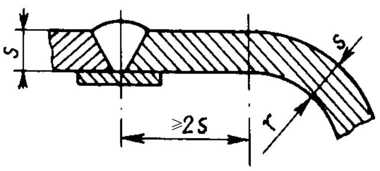
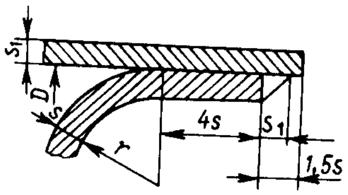
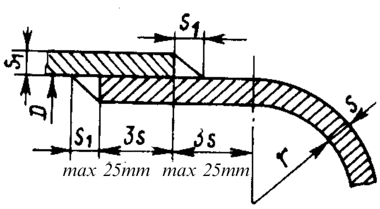
The typical examples of allowable welded joints are given in the present Appendix. Different types of welded joints shall not be considered as equivalents, and the order in which they are presented is not indicative of their strength characteristics. The types of welded joints shown for the elements shall be used on condition that adequate strength of the structure is ensured.

Depending on the caracteristics of the materials used and also on further improvement of the welding procedure, other types of welded joints may also be allowed. In this case and also in case the typical examples of the welded joints cannot be used in whole, the type of the welded joint shall be agreed with the Register.

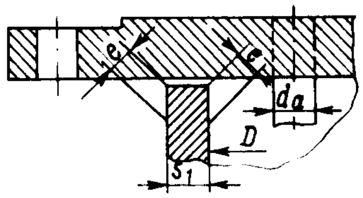
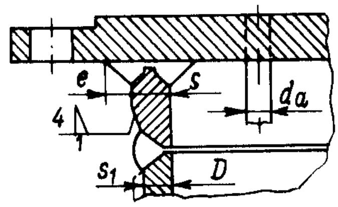
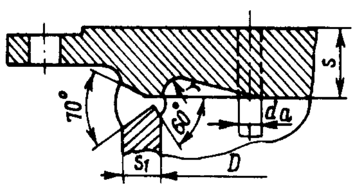
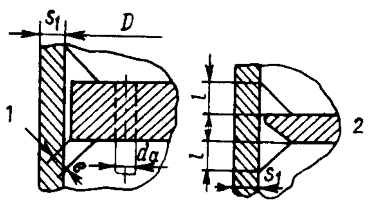
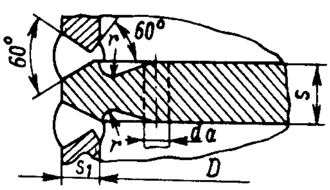
ALLOWABLE WELDED JOINTS

1 Flat end plates and covers		
1.1		$k=0{,}38$, $r \geqslant s/3$, but not less than 8 mm, $l \geqslant s$
1.2		$k=0{,}45$, $r \geqslant 0{,}2s$, but not less than 5 mm, $s_2 \geqslant 5$ mm Refer to Note 1
1.3		$k=0{,}5$, $s_2 \leqslant s_1$, but not less than 6,5 mm, $s_3 \geqslant 1{,}25s_1$ Refer to Note 1
1.4		$k=0{,}45$ Refer to Note 1

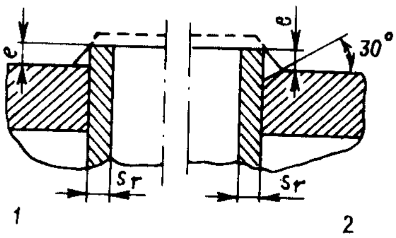
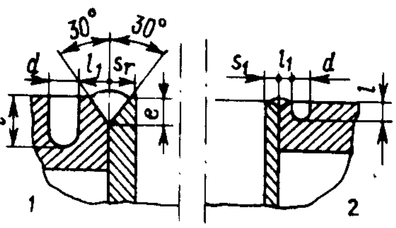
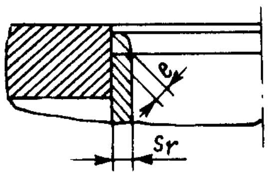
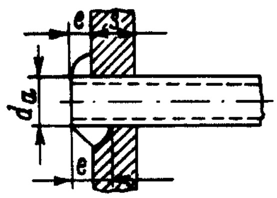
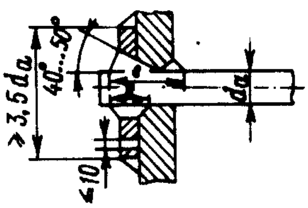
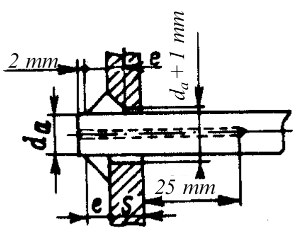
Appendix — continued

1.5		$k = 0{,}55$ Refer to Note 1
1.6		$k = 0{,}57$
	2 Dished ends	
2.1		It is permitted for boilers and pressure vessels of Classes I, II and III Refer to Notes 2, 17
2.2		It is permitted for boilers and pressure vessels of Classes II and III
2.3		This joint shall be avoided. It is permitted only for pressure vessels of Class III where no danger of corrosion exists $s_1 \leqslant 16$ mm, $D \leqslant 600$ mm
2.4		It is permitted only for pressure vessels of Class III $s_1 \leqslant 16$ mm, $D \leqslant 600$ mm

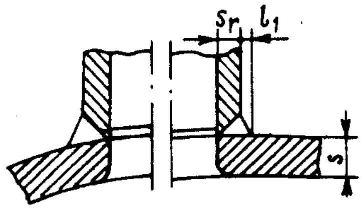
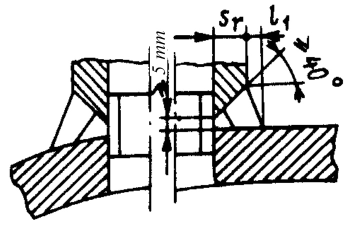
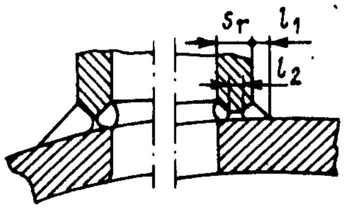
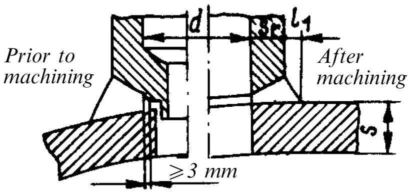
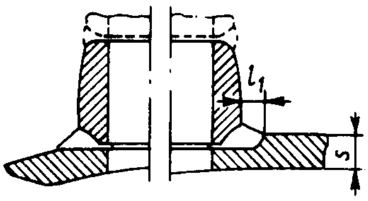
Appendix — continued

3 Tube plates		
3.1		$k=0{,}45$, $e=0{,}71s_1$, $s_1 \leqslant 16$ mm Refer to Notes 3, 4
3.2		$k=0{,}45$, $e=s_1/3$, but not less than 6 mm, $s_1>16$ mm Refer to Notes 5, 6
3.3		$k=0{,}45$, $r \geqslant 0{,}2s$, but not less than 5 mm
3.4		$k=0{,}45$ Type 1: $e \geqslant 0{,}71s_1$, but at $e>13$ mm Type 2 is preferable, where $l=s_1/3$, but not less than 6 mm Refer to Note 7
3.5		$k=0{,}45$, $r \geqslant 0{,}2s$, but not less than 5 mm

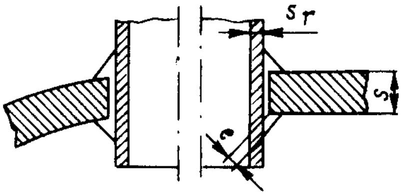
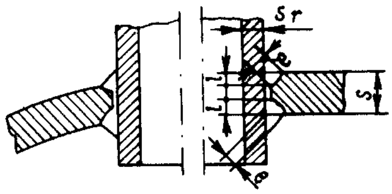
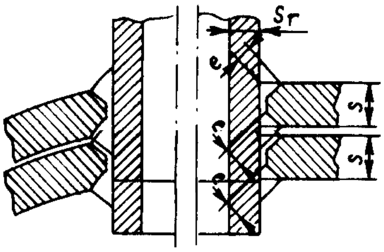
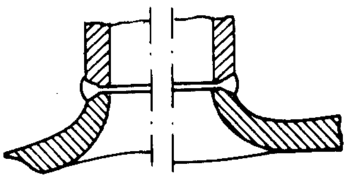
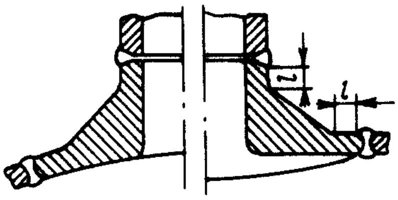
Appendix — continued

	4 Tubes	
4.1		$e = s_r$ $e \geqslant 5$ mm, $s_r \geqslant 2{,}5$ mm Refer to Notes 8, 9, 10
4.2		$d = s_r$; $l_1 = s_r$; $1{,}5s_r < l < 2s_r$. Type 1: $s_r \geqslant 5$ mm; $l = s_r$ Type 2: $s_r < 5$ mm Refer to Note 11
4.3		$e = 0{,}7s_r$ $s_r \geqslant 3$ mm Refer to Note 12
	5 Long and short stays, stay tubes	
5.1		$k = 0{,}42$
5.2		$k = 0{,}34$
5.3		$k = 0{,}38$ Short stays (Refer to 3.2.2)

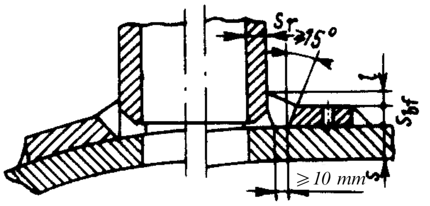
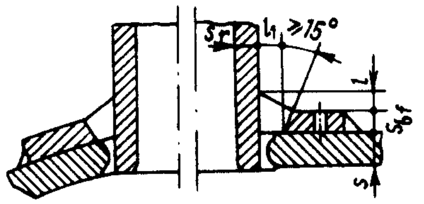
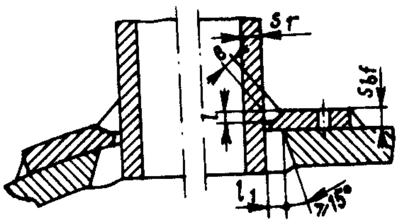
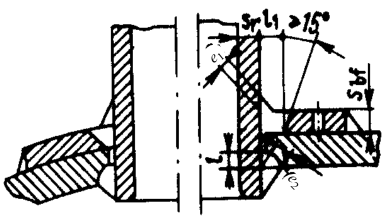
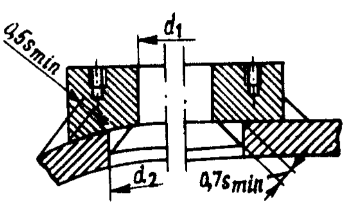
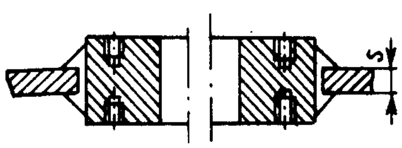
Appendix — continued

6 Branches, nozzles, pads 6.1 Welded-on branches, non-through		
6.1.1		$s_r \leqslant 16$ mm, $l_1 = s_r/3$, but not less than 6 mm
6.1.2		$l_1 \geqslant s_r/3$, but not less than 6 mm Refer to Note 13
6.1.3		$l_2 = 1{,}5...2{,}5$ mm $l_1 \geqslant s_r/3$, but not less than 6 mm Refer to Note 14
6.1.4		$l_1 \geqslant s_r/3$, but not less than 6 mm Refer to Notes 15, 16
6.1.5		$l_1 = 10...13$ mm Refer to Note 15

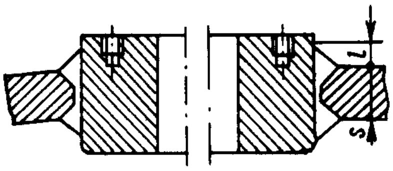
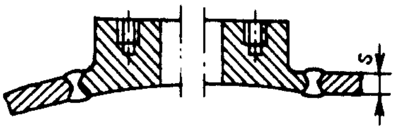
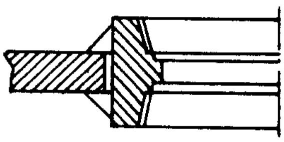
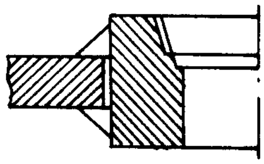
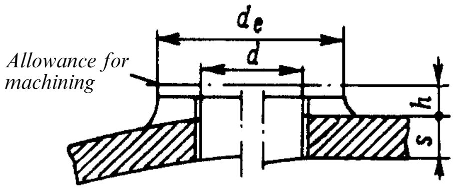
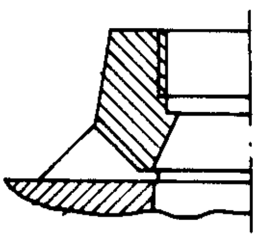
Appendix — continued

	6.2 Welded-on branches, through	
6.2.1		The joint is mainly used at $s_r < s/2$, $e = s_r$
6.2.2		The joint is mainly used at $s_r = s/2$, $e = 6...13$ mm, $e + l = s_r$
6.2.3		The joint is mainly used at $s_r > s/2$, $e \geqslant s/10$, but not less than 6 mm
	6.3 Upset nozzles	
6.3.1		
6.3.2		Refer to Note 17

Appendix — continued

	6.4 Branches with disc-shaped reinforcing plates	
6.4.1		$l \geq s_r/3$, but not less than 6 mm
6.4.2		$l \geq s_r/3$, but not less than 6 mm, $l_1 \geq 10$ mm
6.4.3		$e + l = s_r$ or $e + l = s_{bf}$, whichever is the less, $l_1 \geq 10$ mm
6.4.4		$e_2 + l \geq s_r$, $l_1 \geq 10$ mm, $2s_r \leq (e_2 + l)$ + the lesser of the values $(s_{bf} + e_1)$ or l_1
	6.5 Pads and nozzles for studs	
6.5.1		$d_2 \leq d_1 + 2s_{\min}$ Refer to Note 18
6.5.2		$s \leq 10$ mm Refer to Notes 19, 20

Appendix — continued

6.5.3		$l \geqslant 6$ mm, $s \leqslant 20$ mm
6.5.4		$s \geqslant 20$ mm
	6.6 Pads and nozzles for threaded joints	
6.6.1		
6.6.2		
6.6.3		$d \leqslant s$, $d_e = 2d$, $h \leqslant 10$ mm, $h \leqslant 0{,}5s$ Refer to Note 21
6.6.4		

Appendix — continued

N o t e s : 1. The welded joints are applicable to boilers having a shell diameter up to 610 mm.
For pressure vessels they may be used without restrictions in case $R_m \leqslant 460$ MPa or $R_{eH} \leqslant 365$ MPa.
2. Reduction in thickness of the shell or flange part of the end may be effected either on the inside or on the outside.
3. This type of the welded joint is used when both sides of the shell are accessible for welding.
4. For shells over 16 mm in thickness the fillet welds are effected with the edge preparation of the shell according to Fig. 3.2.
5. This type of the welded joint is used when the shell is accessible for welding only on the outside.
6. For shells less than 16 mm in thickness the fillet welds may be effected without the edge preparation of the shell. The height of the ring shall not be less than 40 mm.
7. Clearance between inside diameter of the shell and the outside diameter of the tube plate shall be minimized as far as possible.
8. The end of the tube protruding outside the weld seam is removed by milling or grinding.
9. The distance between tubes shall not be less than $2{,}5s_r$, but never below 8 mm.
10. In case of the manual electric arc welding it is necessary that the thickness shall be $s_r \geqslant 2{,}5$ mm.
11. It is recommended when the tube plate deformations resulting from welding shall be minimized.
12. Attachment of tubes is effected by manual electric arc welding.
13. The backing ring shall be tightly fitted and removed after welding.
14. It is used when welding is possible on the inside of the branch.
15. It is used for branches of small sizes as compared to those of pressure vessels.
16. After welding the branch is machined to the final size *d*.
17. The dimensions of cylindrical portions *l* shall be such that the radiography could be carried out, if necessary.
18. The clearance between the pads and the pressure vessel shall not exceed 3 mm.
19. The clearance between the opening and the outside nozzle diameter shall be minimal and in no case shall it exceed 3 mm.
20. The upper holes for studs shall be displaced in relation to the lower ones.
21. The total thickness of the pressure vessel shell and the weld metal shall be sufficient for provision of the required number of threads.

PART XI. ELECTRICAL EQUIPMENT

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules applys to electrical installations in ships subject to the Register survey, as well as to individual types of electrical equipment in accordance with 1.3.

1.1.2 It is recommended that the relevant requirements of the present Part shall be also applied to electrical equipment, which is installed in ships not specified in 1.3.2 and 1.3.3.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to the general terminology of the Rules are given in Part I "Classification".

For the purpose of the present Part of the Rules the following definitions and explanations have been adopted.

Emergency lighting is lighting of ship's spaces and zones by means of lighting fixtures fed from the emergency source of power or from the transitional emergency source of power.

Emergency source of electrical power is a source of electrical power intended to supply necessary ship's services in case of power failure on the main switchboard.

Emergency transitional source of electrical power is a source of electrical power intended to supply necessary ship's services from the moment of the power failure on the main switchboard busbars until the emergency generator is switched on to supply the emergency switchboard busbars.

Emergency switchboard is a switchboard intended to be supplied directly from the emergency or emergency transitional source of electrical power in case of failure of the main source of electrical power and to supply the emergency services.

Antistatic earthing is electrical connection to ensure grading of static electricity potentials of the structural parts of equipment and ship's hull due to their direct contact or through antistatic earthing conductors.

The antistatic earthing conductors are:

metal conductors connecting equipment subject to antistatic earthing, cable shields, piping, etc, to one another and/or to ship's hull or other equipment earthed;

layers of conductive substances applied onto equipment surfaces, such as: metal coatings, conductive plastics, compounds, mastics, antistatic paint coatings, etc.

Safety voltage is any voltage not dangerous to the personnel. This condition is considered to be satisfied if the windings of transformers, converters, and other devices to step down voltage are electrically separated and if the value of stepped-down voltage across these devices or sources of electrical power does not exceed:

50 V between poles for direct current;

50 V between phases or between phases and the ship's hull for alternating current.

Shaft generators are generators driven by the main machinery and supplying the ship's mains or separate consumers.

Galvanic intrinsic safety is such a state of the ship equipment and systems, under which the possibility of fire or explosion due to electric sparking in case of galvanic contact of the ship with a shore structure or another ship caused by electrochemical phenomena and stray currents in surrounding sea water and ground is excluded.

Main switchboard is a switchboard intended to be supplied directly from the main source of electrical power and to supply the ship services.

Earthing is electrical connection of a part of electrical equipment to be earthed to ship's hull.

Lightning protection zone is the area, within the limits of which the ship's space is protected against direct lightning strokes.

Uninterruptible power system (UPS) is combination of converters (rectifier-inverter), switches (bypass) and energy storage means, for example, batteries, constituting a power system for maintaining continuity of load power in case of input power failure.

Competent body is an organization possessing appropriate knowledge and experience in a specific area, which documents are recognized by the Register.

Ship's hull means all ship's metal parts, which have a reliable electrical connection to the outer metal shell plating. For ships with non-conducting hull, it is a special copper sheet with the area of not less than 0,5 m^2 and the thickness not less than 2 mm, which is fixed to the outside of the ship's shell plating at a level below the light load waterline and is used for earthing all the equipment installed on board the ship.

Air termination network is the upper part of the lightning protection device intended for the perception of atmospherics.

Non-essential services are services, the temporary disconnection of which does not impair the safety of navigation, the safety of human life and the safety of cargo on board.

Main electrical power plant is a space where the main source of electrical power is placed.

Main electrical power source is a source of electrical power intended to supply all electrical equipment and systems essential for maintaining the ship in normal operational and habitable condition, without resorting to the emergency source of electrical power.

Essential services are services normal operation whereof ensures safe navigation, safety of human life and safety of cargo on board ship; essential services are divided into primary and secondary services.

Primary essential services are the services, which need to be in continuous operation to maintain propulsion and steering of the ship. Such services are those listed in 1.3.2.1.

Secondary essential services are the services, which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the ship safety. These services shall be ready for the immediate activation. Such services are those listed in 1.3.2.2.

Down conductor is a conductor, which electrically connects the air termination network to the earth termination network.

Special electrical spaces are spaces or locations intended expressly for electrical equipment and accessible only to operating personnel.

Not readily ignitable electrically insulating material is a material, which sustaines the tests specified in the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

Electrical installation of low power is an electrical installation of a ship with the total power of supply sources up to 50 kW (kVA).

Electrostatic intrinsic safety is such a state of the ship equipment and systems, under which the possibility of fire or explosion due to static electricity discharges is excluded.

1.3 SCOPE OF SURVEYS

1.3.1 General.

General provisions applicable to the classification procedure, survey during ship's construction and manufacture of the equipment are stated in the General Regulations for the Classification and Other Activity and in Part I "Classification".

1.3.2 Survey of ship's electrical equipment.

Main and emergency sources of electrical power, power and lighting transformers and converters (both rotating and static), main and other switchboards, cable network, as well as electrical equipment, systems and arrangements listed in 1.3.2.1 to 1.3.2.4 are subject to survey on board the ship.

1.3.2.1 Primary essential services are:

.1 steering gear;

.2 pumps of hydraulic systems of CP-propellers;

.3 scavenging air blower, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines necessary for propulsion;

.4 forced draught fans, feed water pumps, water circulating pumps, vacuum pumps and condensate pumps for steam plants on steam turbine ships, and also for auxiliary boilers on ships where steam is used for equipment supplying primary essential services;

.5 oil burning installations for steam plants on steam turbine ships and for auxiliary boilers where steam is used for equipment supplying primary essential services;

.6 electrical equipment for azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps;

.7 electrical equipment for electric propulsion plant and azimuth electric propulsion plant with lubricating oil pumps, cooling water pumps and forced draught systems;

.8 electric generators and associated power sources supplying the above equipment;

.9 hydraulic pumps supplying the above equipment;

.10 viscosity control equipment for heavy fuel oil;

.11 navigation lights, aids and signals;

.12 internal communication devices/systems;

.13 lighting system;

.14 control, monitoring, alarm and safety devices/systems for equipment to primary essential services;

.15 other primary essential services needed to ensure that the ship is used in compliance with its purpose and class notation, as required by the Register.

1.3.2.2 Secondary essential services are:

.1 windlass;

.2 fuel oil transfer pumps and fuel oil treatment equipment;

.3 lubrication oil transfer pumps and lubrication oil treatment equipment;

.4 pre-heaters for heavy fuel oil;

.5 starting air and control air compressors;

.6 bilge, ballast and heeling pumps;

.7 fire pumps and other fire extinguishing medium pumps;

.8 ventilating fans for engine and boiler rooms;

.9 services considered necessary to maintain dangerous spaces in a safe condition, including services for hull earthing on oil tankers, lightning protection and services ensuring electrostatic and galvanic intrinsic safety;

.10 fire alarm systems;

.11 electrical equipment for watertight closing appliances;

.12 electric generators and associated power sources supplying the above equipment;

.13 hydraulic pumps supplying the above equipment;

.14 tunnel and azimuth thrusters;

.15 inert gas devices/systems in oil tankers;

.16 control, monitoring, alarm and safety devices/systems for cargo containment systems;

.17 electric drives for refrigerating plants, specified in 1.1, Part XII "Refrigerating Plants";

.18 control, monitoring, alarm and safety devices/systems for equipment to secondary essential services;

.19 other secondary essential services needed to ensure that the ship is used in compliance with its purpose and Class notation, as required by the Register.

1.3.2.3 Services for habitability are those services, which need to be in operation for maintaining the vessel's minimum comfort conditions for the crew and passengers. Examples of equipment for maintaining conditions of habitability are as follows:

.1 cooking;

.2 heating;

.3 domestic refrigeration;

.4 domestic ventilation;

.5 sanitary and fresh water;

.6 electric generators and associated power sources supplying equipment specified in 1.3.2.3.1 to 1.3.2.3.5.

1.3.2.4 Other electrical services are:

.1 electrical equipment of processing machinery of ships used for processing the living resources of the sea and not engaged in their catching (refer to 19.4.4.1);

.2 electrical equipment of fishing and processing machinery of fishing vessels (refer to 19.10.1.1);

.3 other mechanisms and devices not listed above as required by the Register.

1.3.2.5 Electrical equipment of domestic services is subject to survey on board ship only in respect to:

.1 influence exerted by the operation of this equipment on the quality of electrical power produced by the shipboard electrical power plant;

.2 selection of the types and sections of cables and wires, as well as the methods of cable installation;

.3 insulation resistance, earthing and protective devices, refer also to 10.1.11, 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.

1.3.3 Survey during manufacture of electrical equipment.

1.3.3.1 The following kinds of electrical equipment intended for use in installations and systems listed in 1.3.2 are subject to survey during manufacture:

.1 generating sets;

.2 electric machines;

.3 transformers;

.4 switchboards;

.5 control and monitoring panels;

.6 electric slip couplings and brakes;

.7 apparatus and devices for electrical protection, starting, control and switching;

.8 apparatus and devices of internal communication and signalling;

.9 power semiconductor converters and other similar power units;

.10 fuel and oil heaters;

.11 accumulator batteries;

.12 cables and wires;

.13 fixed electrical measuring instruments;

.14 electrical apparatus and facilities to measure non-electrical values;

.15 space heating and cooking appliances;

.16 lighting switches and accessories;

.17 stationary lighting fixtures;

.18 control and monitoring devices;

.19 other equipment not listed above as required by the Register.

1.3.3.2 The safe type electrical equipment shall be surveyed (with respect to its safety) by a special authority whose documents are recognized by the Register, irrespective of whether or not this equipment is subject to survey according to the requirements of 1.3.3.1.

1.3.3.3 Scope of tests of electrical equipment after manufacture is subject to special consideration by the Register and the requirements for tests are given in the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

1.4 TECHNICAL DOCUMENTATION

1.4.1 General provisions applicable to the procedure of approval of technical documentation are set forth in the General Regulations for the Classification and Other Activity. The scope of technical documentation on electrical equipment for the entire ship to be submitted to the Register for consideration is stated in 3.2, Part I "Classification".

1.4.2 Prior to starting the survey of the electrical equipment manufacture, the following documentation shall be submitted to the Register for consideration:

.1 description of the principle of operation and main characteristics;

.2 specification (list of items), which indicates all the components, instruments and materials used and their technical characteristics;

.3 general view drawing with sectional views;

.4 circuit diagram;

.5 programme of tests;

.6 results of rotor shaft (armature) calculation and drawing of fastening of poles, active iron core, commutator, etc., as well as welded joints of the spoke rib and the shaft, for electric machines with rated current in excess of 1000 A;

.7 busbar calculation of electrodynamic and thermal short circuit strength — for switchboards, if rated current of the generators operating separately or total current of the generators operating in parallel exceeds 1000 A;

.8 data concerning immunity to static or dynamic interference or method of electromagnetic compatibility testing;

.9 measures to be taken for interference suppression.

When necessary, the Register may require supplementary technical documentation and data on reliability to be submitted.

2 GENERAL REQUIREMENTS

2.1 OPERATING CONDITIONS

2.1.1 Influence of climatic conditions.

2.1.1.1 The rated ambient air and cooling water temperatures for electrical equipment shall be those specified in Table 2.1.1.1.

2.1.1.2 Electrical equipment shall be capable of reliable performance at a relative air humidity of 75±3 per cent and a temperature of +45±2 °C or at a relative air humidity 80±3 per cent and a temperature of +40±2 °C, as well as at a relative humidity of 95±3 per cent and a temperature of +25±2 °C.

2.1.1.3 Where electrical equipment is installed within environmentally controlled spaces the ambient temperature, for which the equipment shall be suitable, may be reduced as against the value given in Table 2.1.1.1 and maintained at a value not less than +35 °C, provided:

.1 the equipment is not for use for emergency services and is located outside the machinery spaces;

.2 temperature control is achieved by at least two cooling units so arranged that in the event of loss of one cooling unit, the remaining unit is capable of satisfactorily maintaining the design temperature;

.3 the equipment installed in such spaces shall be able to work safely at temperature of +45 °C until the nominal working ambient temperature may be achieved; the cooling equipment shall be rated for +45 °C ambient temperature;

.4 audible and visual alarms shall be provided at a continually manned control station to indicate any malfunction of the cooling units.

2.1.2 Mechanical effects.

2.1.2.1 Electrical equipment shall be capable of reliable performance at vibrations with frequency of 2 to 80 Hz, i.e. with an amplitude of displacements of ±1 mm for frequency range of 2 to 13,2 Hz and an acceleration of ±0,7 g for frequency range of 13,2 to 80 Hz.

Electrical equipment located on the sources of vibrations (diesel engines, compressors, etc.) or in the steering gear room shall be capable of reliable performance at vibrations of 2 to 100 Hz, i.e. with an amplitude of displacement of ±1,6 mm for frequency range of 2 to 25 Hz and an acceleration of ±4,0 g for frequency range of 25 to 100 Hz.

Electrical equipment shall also be capable of reliable performance at shocks having an acceleration of ±5,0 g and at a frequency of 40 to 80 shocks per minute.

2.1.2.2 Electrical equipment shall be capable of reliable performance with the ship having continuous list up to 15° and trim up to 5°, as well as with the

Table 2.1.1.1

Nos	Location of equipment	Ambient air and cooling water temperature, °C			
		Unrestricted service		Navigation outside the tropical zone	
		Air	Water	Air	Water
1	Machinery and special electrical spaces, galleys	+45 ... 0	+32	+40 ... 0	+25
2	Weather decks	+45 ... −25	—	+40 ... −25	—
3	Other spaces	+40 ... 0	—	+40 ... 0	—

Note. Electronic elements and devices designed for mounting in the switchboards, panels or casings shall be capable of reliable performance at an ambient air temperature up to 55 °C.
Temperature up to 70 °C shall not lead to failure of the elements, devices and systems.

ship rolling up to 22,5° with period of rolling of 7 — 9 s and pitching up to 10°.

Emergency equipment shall also be capable of functioning reliably with the ship having continuous list up to 22,5° and trim up to 10°, or within the same limits of simultaneous list and trim.

In gas carriers and chemical tankers, the emergency electrical power sources shall be capable of reliable performance with the ship having list up to 30°.

2.1.2.3 Electrical equipment shall possess the relevant mechanical strength and shall be so located as to avoid the risk of mechanical damage (refer also to 2.7.4).

2.1.3 Permissible variations of supply parameters.

2.1.3.1 Electrical equipment shall be so designed that it remains operative in all cases, except as noted in 10.8.2, 14.1.3.2 to 14.1.3.3 at all variations from the supply voltage and frequency as specified in Table 2.1.3.1 (refer also to 3.1.2.2 and 16.8.3.3).

Table 2.1.3.1

Parameters	Variations from rated values		
	for long periods, %	for short periods	
		%	time, s
Voltage (A.C) Frequency	+6...-10 ±5	±20 ±10	1,5 5
Voltage (D.C.)	±10	5 10	cyclic variations ripple

Note. When the services are fed from accumulator battery:
long-period voltage variation within + 30 to −25 per cent for the equipment fed from the accumulator battery connected to the charging unit;
long period voltage variation within + 20 to −25 per cent for the equipment, which is not connected to the charging unit.

2.1.3.2 In ships of restricted area of navigation **R3**, it is allowed to use for machinery and gear of non-essential services the electrical equipment (of general commercial type) not fully complying with the above requirements, which is subject to special consideration by the Register in each case.

2.2 ELECTROMAGNETIC COMPATIBILITY

2.2.1 General.

2.2.1.1 The present requirements are applicable to electrical equipment and automation equipment to ensure electromagnetic compatibility on board.

2.2.1.2 Failure-free performance of the equipment shall be ensured under conditions of interference having the following parameters:

.1 static and variable (50 Hz) magnetic field in accordance with Table 2.2.1.2.1.

Installation of equipment is permitted:

class 1 — at a distance of 2 m and more from a powerful field source (busbar, group transformer);

Table 2.2.1.2.1

Class of equipment	Intensity, A/m	
	static field	variable field (50 Hz)
1	100	100
2	400	400
3	1000	1000

class 2 — at a distance of 1 m and more from a powerful field source;

class 3 — irrespective of the distance from field source of any kind;

.2 harmonic components of voltage in supply circuits in accordance with the higher harmonics diagram for ship mains to be found in Fig. 2.2.1.2.2 on a logarithmic scale;

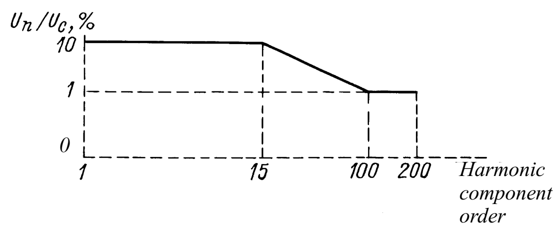


Fig. 2.2.1.2.2
Diagram of higher harmonic components for ship mains

.3 electrostatic discharges with a voltage amplitude of 8 kV;

.4 radio frequency electromagnetic fields within a range of 30 — 500 MHz with a root-mean-square value of field intensity of 10 V/m;

.5 nanosecond voltage pulse with an amplitude of 2 kV for the power supply circuit and of 1 kV for signalling and control cables with a duration of 5/50 ns;

.6 radio frequency interference in conductivity circuits within a range of 0,01 to 50 MHz with a root-mean-square voltage of 1 V and 30 per cent modulation at a frequency of 1 MHz;

.7 microsecond voltage pulse in supply circuits with an amplitude of 1 kV for symmetrical pulse feed and of 2 kV for non-symmetrical pulse feed with a duration of 1,2/50 μs.

2.2.1.3 The voltage curve harmonic distortion factor shall not exceed 10 per cent and shall be determined by the formula

$$K_u = \frac{1}{U_c} \sqrt{\sum_{n=2}^{200} U_n^2} \cdot 100\% \qquad (2.2.1.3)$$

where U_c = actual circuit voltage;
U_n = n — harmonic component voltage;
n = higher harmonic component order.

The value of K_u is specified for the complete electrical power system of a ship.

On special agreement with the Register, busbars with $K_u > 10$ % may be used for power supply to powerful sources of the harmonic components of voltage and to electrical equipment not sensitive to such harmonic components, provided that the busbars are connected to the main busbars through isolating devices (refer to 2.2.2.2).

2.2.1.4 The intensity levels of radio interference from equipment in the power supply circuits shall not exceed the following values within the frequency bands given below:

for the equipment installed on open deck and navigating bridge:

10 — 150 kHz – 96 — 50 dB;

150 — 350 kHz – 60 —50 dB;

350 kHz — 30 MHz – 50 dB;

for the equipment installed in machinery and other enclosed spaces:

10 — 150 kHz – 120—69 dB;

150 — 500 kHz – 79 dB;

500 kHz — 30 MHz – 73 dB.

Artificial mains network and quasi-peak measuring receiver shall be used for measuring the intensity level of radio interference. The receiver bandwidth when measurements are taken within the frequency band from 10 to 150 kHz shall be 200 Hz and within the frequency band from 150 kHz to 30 MHz — 9 kHz.

2.2.1.5 On ships, for which the level of radio interference from power semiconductor converters cannot be limited in conformity with 2.2.1.4, the mains of automation, radio and navigational equipment shall be galvanically isolated from the mains of those converters so that at least 40 db are damped within the frequency range 0,01 — 30 MHz.

The power supply cables of equipment having the radio interference levels in excess of those stipulated by 2.2.1.4 shall be laid at least 0,2 m away from the cables of other equipment groups where the common cable run is longer than 1 m (refer to 2.2.2.8).

2.2.1.6 The levels of the radio interference electromagnetic field induced at a distance of 3 m from the equipment shall not exceed the following values within the frequency bands given below:

for the equipment installed on open deck and navigating bridge:

150 — 300 kHz – 80 — 52 dB;

300 kHz — 30 MHz – 52 — 34 dB;

30 — 2000 MHz – 54 dB, except for the band 156 — 65 MHz where the level shall be equal to 24 dB.

for the equipment installed in machinery and other enclosed spaces:

150 kHz — 30 MHz – 80 — 50 dB;

30 — 100 MHz – 60 — 54 dB, except for the band 156 — 165 MHz where the level shall be equal to 24 dB.

Quasi-peak measuring receiver shall be used to take measurements. The receiver bandwidth within the frequency band from 150 kHz to 30 MHz and from 156 to 165 MHz shall be 9 kHz and within the frequency band from 30 to 156 MHz and from 165 MHz to 1 GHz – 120 kHz.

2.2.2 Measures to ensure electromagnetic compatibility.

2.2.2.1 To ensure protection of radio equipment against electromagnetic interference, the requirements of Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships shall be considered.

2.2.2.2 For the purpose of dividing the supply system of the ship, rotary converters, special transformers and filters shall be used.

2.2.2.3 Power cable screens or metal armour shall be connected to the metal casing of relevant equipment and shall be earthed as frequently as possible, at each end as a minimum.

2.2.2.4 The screens of signal cables shall be earthed at one point on the side of the initial signal processing block. The cable shall have an external insulating sheath.

2.2.2.5 Continuous screening shall be ensured, and for this purpose cable screens shall be connected to equipment casings, and it shall also be ensured in cable branch boxes and cable distribution boxes, and in way of cable penetrations through bulkheads.

2.2.2.6 The earthing installed for the purpose of interference protection shall have an electric resistance not greater than 0,02 ohm, minimum length possible, shall be resistant to vibration and corrosion, and shall be readily accessible for inspection.

2.2.2.7 Cable screens shall not be used as return conductors.

2.2.2.8 By the type of signals conveyed, ship cables are subdivided in groups as follows:

.1 coaxial cables of radio receivers and conveying video signals with the level of signals 0,1 μV to 500 μV;

.2 screened or coaxial cables conveying analogue or digital signals with a level 0,1 to 115 V;

.3 screened cables of telephone and radio broadcasting apparatus, control and signalling network with the level of signals 0,1 to 115 V;

.4 unscreened and located below the deck or screened and located above the deck cables of power and lighting network with the level of signals 10 to 1000 V;

.5 coaxial or screened cables of the transmitting aerials of radio transmitters, radar installations and echo sounders, power semiconductor converters with the level of signals 10 to 1000 V.

2.2.2.9 Cable of the same group may be laid in the same cable run provided interference-sensitive equipment is not influenced by the difference in the levels of signals conveyed. Where cable lengths laid in parallel are in excess of 1 m, the cables (cable runs) of different groups shall be laid at least 0,1 m apart and their intersections shall be effected at right angles. The radar installation and echo sounder cables mentioned in 2.2.2.8.5 shall either be double-screened or, if they are coaxial, laid inside a metal pipe. The outer screen shall be earthed, as well as the principal screen of the cable.

2.2.2.10 When electrical equipment is installed or cables are laid in the vicinity of magnetic compasses and to ensure protection against interference from other navigational equipment, the requirements of Part V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships shall be consi-dered.

2.2.2.11 On all ships constructed from non-conductive materials, for which radio equipment is required by the Rules, all cables located within 9 m from the aerials shall be shielded or otherwise protected from radio interference, and all the equipment on board those ships shall be fitted with devices for radio interference suppression (refer to curve *1* in Fig. 2.2.1.4).

2.3 MATERIALS

2.3.1 Structural materials.

2.3.1.1 The structural parts of electrical equipment shall be fabricated of durable materials, rated at least as having low flame-spread characteristics, resistant to sea air, oil and fuel wapour effects, or reliably protected against such effects.

For equipment installed or intended for use in dangerous spaces and zones, the structural parts of electrical equipment shall be fabricated of materials ensuring electrostatic and galvanic intrinsic safety.

2.3.1.2 Screws, nuts, hinges and similar items designed to fasten enclosures of the electrical equipment to be installed on weather decks or in spaces with increased humidity shall be made of corrosion-resistant materials or have effective corrosion-resistant covering.

2.3.1.3 All current-carrying parts of electrical equipment shall be of copper, copper alloys or other materials of equivalent qualities, with the exception of:

.1 rheostat elements, which shall be made of mechanically strong materials having high resistivity and capable of withstanding high temperatures;

.2 short-circuit rotor windings of asynchronous and synchronous motors, which may be made of aluminium or its alloys resistant to sea conditions;

.3 carbon brushes, cermet contacts and other similar parts when the properties specified so require;

.4 parts of electrical equipment directly connected to the ship's hull in case of hull-return single-wire system.

The use of other materials for current-carrying parts is subject to special consideration by the Register in each case.

2.3.2 Insulating materials.

2.3.2.1 Insulating materials of live parts shall have adequate dielectric strength and resistance to creepage currents, moisture and oil, as well as sufficient mechanical strength, or else be suitably protected.

The heating temperature of current-carrying parts and their connections shall not exceed the permissible heating temperature of the insulating materials at the rated load.

2.3.2.2 Non-flammable liquids may be used for cooling uninsulated parts of electrical equipment.

The use of flammable oils for this purpose is subject to special consideration by the Register in each case.

2.3.2.3 The insulating materials used for winding insulation in machines, apparatus and other equipment for essential services shall comply with the agreed standards.

The use of insulating materials not inferior to Class E is recommended.

2.3.2.4 Conductors used in electrical devices for internal connections shall have insulation made of materials rated at least as having low flame-spread characteristics and for apparatus with increased heating and also indicated in Section 15 — of non-combustible materials.

2.3.2.5 For insulation materials used for the manufacture of cables, refer to 16.3.

2.4 STRUCTURAL REQUIREMENTS AND PROTECTION OF ELECTRICAL EQUIPMENT

2.4.1 General.

2.4.1.1 Such parts as require replacement while in service shall be easily dismountable.

2.4.1.2 Where screw fastenings are employed, provision shall be made of exclude self-loosening of screws and nuts or, where dismantling and opening are a frequent occurrence, loss of same.

2.4.1.3 Gaskets used in components of electrical equipment (such as doors, covers, sight holes, packing glands, etc.) shall ensure adequate protection when in service.

The gaskets shall be secured to the covers or casings.

2.4.1.4 If the casings, panels and covers of electrical equipment, installed where unspecialized personnel has access to it, render lived parts inaccessible, they shall be opened with tools only.

2.4.1.5 Suitable water drainage arrangements shall be provided in electrical equipment where condensation is likely to occur. Channels shall be fitted inside the equipment to provide for condensate drainage from all equipment components. The windings and live parts shall be so arranged or protected that they are not exposed to the effects of such condensate as may accumulate inside the equipment.

2.4.1.6 Electrical equipment with forced ventilation, designed for installation in bottom parts of damp spaces, shall be provided with a ventilation system so as to avoid, as far as possible, suction of moisture and oil vapours inside the equipment.

2.4.1.7 Where measuring instruments with oil, steam or water supply are fitted in the control panel or desk, measures shall be taken to prevent these agents from making contact with the live parts in case of damage to the instruments or pipelines.

2.4.2 Insulation clearances.

Clearances between live parts at different potentials, or between live parts and earthed metal parts or outer enclosure, both in air and across the insulant surface shall be in conformity with the operating voltage and operating conditions of the installation, with the properties of the insulating materials used duly taken into account.

2.4.3 Internal wiring.

2.4.3.1 Stranded wires shall be used for internal wiring of electrical equipment throughout.

The use of solid wires is subject, in each case, to special consideration by the Register.

2.4.3.2 For internal wiring of switchboards, control desks, other distribution and switching arrangements, etc., wires of not less than 1 mm^2 in cross-sectional area shall be used.

For systems of control, protection, measurement of different parameters, signalling and internal communication the use of wires having a cross-sectional area not less than 0,5 mm^2 is permitted.

For electronic and electrical devices for transformation and transmission of low-power signals wires less than 0,5 mm^2 in cross-sectional area may be used, which is subject to special consideration by the Register in each case.

2.4.3.3 Current-carrying parts shall be so attached that they will not have to sustain any additional mechanical stresses; such parts shall not be attached by screws fitted directly into insulating materials.

2.4.3.4 Stranded cores, cables and wires shall have their ends fitted out to suit the type of terminal used, or shall be provided with lugs.

2.4.3.5 Insulated wires shall be laid up and secured in such a manner that the method used for their attachment and arrangement does not lead to reduced insulation resistance and that they are not exposed to damage due to electrodynamic loads, vibrations or shocks.

2.4.3.6 Arrangements shall be made to ensure that the temperatures allowed for insulated wires under normal service conditions or for the duration of short-circuit current breaking are not exceeded.

2.4.3.7 Insulated wires shall be so connected to terminals or busbars that the wire insulation shall not be exposed to the overheating temperature under rated operating conditions.

2.4.4 Protection of electrical equipment.

2.4.4.1 Depending on location, the use shall be made of electrical equipment in appropriate protective enclosure, or other suitable measures shall be taken to protect the equipment from harmful effect of the environment and to protect the personnel from electric shock hazards.

2.4.4.2 The minimal degree of protection of electrical equipment installed in ship's spaces and zones shall be chosen from Table 2.4.4.2.

2.5 PROTECTIVE EARTHING OF METAL PARTS, WHICH DO NOT CARRY CURRENT

Metal enclosures of electrical equipment operated at a voltage exceeding the safety level or having no double or reinforced insulation shall be fitted with an earth terminal marked with the symbol .

Provision shall be made for earthing inside and outside of the electrical equipment enclosure dependent on its purpose.

2.5.1 Parts to be earthed.

2.5.1.1 Metal parts of electrical equipment, which are likely to be touched under service conditions and which may become live in the event of damage to the insulation (except for those mentioned under 2.5.1.2), shall have a reliable electric contact with a component fitted with an earth terminal (refer also to 2.5.3).

2.5.1.2 Protection earthing is not required for:

.1 electrical equipment supplied with current at safety voltage;

.2 electrical equipment provided with double or reinforced insulation;

.3 metal parts of electrical equipment fastened in non-conducting material or passing therethrough and separated from the earthed and live parts in such a manner that under normal operating conditions these parts cannot become live or come in contact with earthed parts;

.4 bearing housings isolated to guard against circulating currents;

.5 lamp caps and fasteners for luminescent lamps, lamp shades, reflectors and guards supported on lamp holders or lighting fixtures constructed of, or shrouded in non-conducting material;

.6 cable clips, cleats, etc.;

.7 individual consumer — under voltage up to 250 V supplied through an isolation transformer.

2.5.1.3 The shields and metal armour of cables shall be earthed.

2.5.1.4 The secondary windings of all instrument transformers for current and voltage shall be earthed.

Table 2.4.4.2

Spaces, in which electrical equipment is installed		Type of electrical equipment				
		Electric machines, transformers	Switchboards, control gear, starters	Communication and signalling equipment, accessories (switchers, sockets, junction boxes)	Space heating and cooking appliances	Lighting fixtures
1		2	3	4	5	6
Spaces and zones, in which explosive mixtures of vapours, gases or dust with air are likely to occur		*Ex* (refer to 2.9, 19.2.4)	—	*Ex* (refer to 2.9, 19.2.4)	—	*Ex,* (refer to 2.9, 19.2.4)
Dry spaces, dry accommodation spaces		IP20	IP20	IP20	IP20	IP20
Navigating bridge, radio room		IP22	IP22	IP22	IP22	IP22
Service spaces, steering gear rooms, refrigerating plant rooms (except for ammonia equipment), emergency diesel generator rooms, general purpose stores. Pantries, provision stores		IP22	IP22	IP22	IP22	IP22
Engine and boiler rooms	Above plating	IP22	IP22	IP44	IP22	IP22
	Below plating	IP44	—	IP44	IP44	IP44
	Control stations (dry)	IP22	IP22	IP22	IP22	IP22
	Enclosed separator rooms	IP44	IP44	IP44	IP44	IP44
Refrigerated spaces, galleys, laundries, bathrooms and showers		IP44	IP44	IP55	IP44	IP44
Catch processing spaces[1], shafting tunnels, cargo holds		IP55	IP55	IP55	IP55	IP55
Open decks		IP56	IP56	IP56	IP56	IP56

[1] For the electrical equipment installed in the catch processing spaces an additional protection is recommended to enable sanitarization of the equipment with sea water.

N o t e . Where the enclosure of equipment does not guarantee the necessary protection, alternative methods of protection or alternative arrangement of equipment shall be applied to ensure the degree of protection stipulated by the Table.

2.5.2 Earthing of aluminium structures in steel ships.

Superstructures of aluminium alloys fastened to the ship steel hull but insulated therefrom shall be earthed by at least two special wires, which will not start electrolytic corrosion at the points of their contact with the superstructure and the hull. The conductivity of each wire shall not be lower than the equivalent conductivity of a copper wire having a cross-sectional area of 16 mm^2. Such earthing connections shall be provided at different locations around superstructure perimeter, shall be accessible for inspection and protected from damage.

2.5.3 Earth terminals and conductors.

2.5.3.1 Bolts for fastening the earthing conductor to the ship's hull shall have a diameter not less than 6 mm. For cables and wires having a cross-sectional area of 2,5 mm^2 and 4 mm^2 it is permitted to use bolts (screws) 4 mm and 5 mm in diameter, respectively. Such bolts shall not be used for other purposes.

The bolts screwed into material (without nuts) shall be manufactured of brass or other corrosion-resistant material.

Ship's hull in places of earthing conductor connections shall be cleaned to metal and properly protected against corrosion.

2.5.3.2 Fixed electrical equipment shall be earthed by means of external earthing conductors or an earthing core in the feeding cable.

When earthing is effected with a special core of the feeding cable, it shall be connected to the earthing device inside the enclosure of the electrical equipment.

Such earthing effected with external earthing conductors need not be provided in case the arrangement of equipment ensures a reliable electrical contact between the equipment enclosure and the metal ship's hull under all operating conditions.

For earthing effected with an external earthing conductors, the use shall be made of copper conductors, as well as conductors of any other corrosion-resistant metal provided the resistance of these conductors does not exceed that of the required copper conductor. The cross-sectional area of copper earthing conductor shall not be less than that specified in Table 2.5.3.2.

In case earthing is effected with a special core, the cross-sectional area of this core shall be equal to the nominal area of the feeding cable core for cables, having a cross-sectional area up to 16 mm^2 and at least half the cross-sectional area of the feeding cable core, but not less than 16 mm^2 for cables having a cross-sectional area over 16 mm^2.

2.5.3.3 Earthing of movable, loose and portable consumers shall be effected through and earthed jack in the socket outlet or other earthed contact device and a copper earthing core of the feeding flexible cable. The cross-sectional area of the earthing core shall not be less than the nominal cross-sectional area of the feeding flexible cable core for cables up to 16 mm^2 and at least half the cross-sectional area of the feeding flexible cable core, but not less than 16 mm^2, for cables over 16 mm^2.

2.5.3.4 Earthing of the fixed equipment shall be non-disconnectable.

2.5.3.5 Earthing of shields and metal armour of cables shall be effected in one of the following ways:

.1 using a copper earth wire of a cross-section not less than 1,5 mm^2 for cable conductors with a cross-sectional area up to 25 mm^2 and not less than 4 mm^2 for cable conductors with a cross-sectional area over 25 mm^2;

.2 by adequate attachment of the shields and metal armour to the hull;

.3 by means of cable gland rings provided these are characterized by corrosion resistance, good conductivity and elasticity.

Except for cables of end branches of circuit, which may be earthed at the supply end only, earthing can be effected at both cable ends. Cable shields and metal armour may be earthed in another approved way, provided these methods do not hamper the operation of equipment.

2.5.3.6 The external earthing conductors shall be accessible for inspection and protected against getting loose and mechanical damage.

2.6 LIGHTNING PROTECTION

2.6.1 General.

2.6.1.1 In ships provision shall be made for lightning protection devices covering the zone to be protected.

2.6.1.2 In ships, where consequential effects of lightning strokes may cause a fire or explosion, lightning protection earthing devices shall also be fitted to preclude consequential sparking.

2.6.1.3 Lightning protection device shall consist of an air termination, down conductor and earth termination. On metal masts no special lightning protection device need be fitted if provision is made for reliable electrical connection of the mast to the metal hull or earthing point.

2.6.2 Air termination network.

2.6.2.1 In metal ships the ship's vertical structures (masts, derrick posts, superstructures, etc.) may be used as air termination if provision is made for reliable electrical connection of these structures to the metal hull.

Additional air terminations shall be used only when ship's structural elements proper do not provide for reliable lightning protection.

2.6.2.2 If electrical equipment is installed on the top of the metal mast, provision shall be made for an air termination network, which is effectively earthed.

2.6.2.3 On each mast or top mast of non-conducting material an effectively earthed air termination shall be provided.

2.6.2.4 The air termination shall be made of a rod at least 12 mm in diameter. The rod may be of copper, copper alloys or steel protected against corrosion. For aluminium masts aluminium rods shall be used.

2.6.2.5 The air termination shall be fitted to the mast in such a manner that it projects at least 300 mm above the top of the mast or above any device fitted on its top.

2.6.3 Down conductor.

2.6.3.1 The down conductor shall be made of a rod, strip or multiwire cable having a cross-sectional area not less than 70 mm^2 for copper or its alloys and not less than 100 mm^2 for steel. Steel down conductors shall be protected against corrosion.

Table 2.5.3.2

Cross-sectional area of cable core connected to consumer, mm^2	Cross-sectional area of earthing conductor of fixed electrical equipment, mm^2, min	
	solid	stranded
Up to 2,5	2,5	1,5
2,5 to 120	Half the cross-sectional area of cable core connected, but not less than 4	
Over 120	70	

2.6.3.2 Down conductors shall run on the outer side of masts and superstructures with a minimum number of bends, which shall be gradual and have as large radius as possible.

2.6.3.3 Down conductors shall not run through dangerous spaces and zones.

2.6.3.4 In ships with non-metal hull the down conductor of the lightning protection device shall be laid separately throughout its length (including its connection to the earth termination network), without connecting to the busbars of the protective and operation earthing circuits.

2.6.4 Earth termination network.

2.6.4.1 In composite ships the metal stem or other metal structures immersed in water under any navigation condition may be used as earth termination.

2.6.4.2 Means shall be provided on board the ship to allow for connecting the ship's steel hull or the earth termination network to the shore-based lightning protection device earthing when the ship is in a dock or on a slipway.

2.6.4.3 Earthing of ships with non-conducting hulls shall be in accordance with 1.2 (refer to the definition "Ship's hull").

2.6.5 Connections in lightning protection device.

2.6.5.1 Connections between the air termination network, down conductor and earth termination network shall be welded or bolted with clamps.

2.6.5.2 The contacting surface area between the down conductor, air termination network and earth termination network shall not be less than 1000 mm^2.

The connecting clamps and connecting bolts shall be made of copper, copper alloys or steel protected against corrosion.

2.6.6 Lightning protection earthing devices.

2.6.6.1 Lightning protection earthing referred to in 2.6.1.2 shall be provided for isolated metal structures, flexible connections, pipes, screens of power and com-munication lines, pipeline entries into dangerous spaces.

2.6.6.2 All pipelines conveying petroleum products and other pipelines associated with dangerous spaces and zones and located on open decks or in spaces free from electromagnetic screening shall be earthed to the ship's hull at least at 10 m intervals throughout their length.

All pipelines, which are located on the upper deck where explosive gases may be present and which are not associated with dangerous spaces and zones, shall be earthed to the ship's hull at least at 30 m intervals throughout their length.

2.6.6.3 Metal parts near down conductors shall be earthed if they are not fixed to earthed structures and have no other metal connection to the ship's hull. In so doing, facilities or metal parts located at a distance of up to 200 mm from the down conductor shall be so connected to the down conductor that consequential sparking is excluded.

2.6.6.4 The joints of earthing elements shall be accessible for inspection and protected from mechanical damage.

2.7 ARRANGEMENT OF ELECTRICAL EQUIPMENT

2.7.1 Electrical equipment shall be installed in such a manner as to provide convenient access to controls and to all parts that require maintenance, inspection and replacement.

2.7.2 The horizontal-shaft electric machines shall be so installed that the shaft is positioned parallel to the centre line of the ship. Installation of machines with the shaft positioned in another direction is permitted only in those cases when the design of the machine ensures its normal operation under conditions specified in 2.1.2.2.

2.7.3 The air-colled electrical equipment shall be so located that cooling air is not taken from bilges or other spaces wherein the air may be contaminated with substances having a harmful effect on insulation.

2.7.4 The electrical equipment placed in locations subject to vibration and shocks, which are heavier than those specified in 2.1.2.1 and which are impossible to eliminate, shall be so designed as to ensure its normal operation under these conditions or to mounted on relevant shock absorbers.

2.7.5 Electrical equipment shall be fixed in position in such a manner that the strength of decks, bulkheads and skin is not impaired as a result of this.

2.7.6 Open live parts of electrical equipment shall not be situated closer than 300 mm horizontally and 1200 mm vertically to non-protected combustible materials.

2.7.7 When the enclosures of electrical equipment are made from different material than the structures on which they are installed, care shall be taken, if necessary, to prevent electrolytic corrosion.

2.7.8 Where electrical equipment is within the coverage of fixed local application fire extinguishing systems, the requirements of 7.13.3 and 7.13.4 shall be met.

2.8 SPECIAL ELECTRICAL SPACES

2.8.1 The doors of special electrical spaces shall be locked. These doors shall open on the outside.

In case the doors face corridors and passageways in accommodation and service spaces, it is permitted that these doors open on the inside on condition that protection guards and stops are provided. A warning notice shall be placed on the door. From the inside of the space the door shall open without a key.

2.8.2 Special electrical spaces shall not be adjacent to the tanks filled with flammable liquids. If this requirement is not feasible from the structural point of view, measures shall be taken eliminating the possibility of flammable liquid penetration into these spaces.

2.8.3 No exits, side scuttles of the opening type or other openings are permissible from special electrical spaces into dangerous spaces.

2.8.4 Handrails of non-conducting material shall be installed in special electrical spaces, in passageways and servicing areas when the open-type electrical equipment is used.

2.9 SAFE-TYPE ELECTRICAL EQUIPMENT

2.9.1 The requirements of the paragraph are applicable to all ships, in which enclosed or semi-enclosed spaces and zones explosive mixtures of vapours, gases or dust with air are likely to occur in dangerous concentrations.

The following spaces and zones fall under this category: paint rooms, lantern rooms (for oil lanterns), battery compartments and spaces, which contain machinery, pipes and tanks for flammable liquids having a flash point of 60 °C and below.

Additional requirements for installation of electrical equipment in oil tankers are specified in 19.2; in ships intended for the carriage of motor vehicles with fuel in their tanks — in 19.3; in ships intended for the carriage of dangerous goods — in 19.11.

2.9.2 Safe type of the equipment shall be confirmed by a certificate issued by a competent body.

2.9.3 In dangerous spaces and zones, only safe type electrical equipment may be installed, the protection of which corresponds to the category and group of the most dangerous gas mixture. In accumulator spaces, the electrical equipment shall be installed in accordance with 13.6, in paint rooms — in accordance with 2.9.16.

Depth-sounder oscillators and associated cables shall be installed in compliance with the requirements of 3.7.4 and 3.8.3, Part V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships, and ventilator motors shall be installed in spaces adapted for the carriage of dangerous cargoes in compliance with 12.7.4, Part VIII "Systems and Piping".

2.9.4 In spaces where explosive mixture of dust or fibre with air may accumulate electrical equipment with the degree of protection not below IP65 shall be installed.

Electrical equipment of IP55 type may be permitted where the occurrence of explosive mixture of dust or fibre with air is temporary, resulting from the damage or infiltration from processing equipment in operation or ventilation cutoff.

Electrical equipment installed in these spaces shall have such protective enclosure that the temperature of its upper horizontal surfaces or those inclined more than 60° to the horizontal is, under conditions of continuous operation, by 75 °C below the smouldering point of dust accumulated in these spaces (the smouldering point shall be determined for a layer of dust 5 mm thick).

2.9.5 Lighting fixtures of safe type shall be so installed that a free space around them is not less than 100 mm, excluding the place of the fastenings.

2.9.6 Any equipment installed in dangerous spaces and zones, except for fire detectors, shall be provided with switches fitted at a safe position outside dangerous spaces and zones to disconnect all live conductors.

2.9.7 Fastening of electrical equipment directly to the walls of tanks intended for flammable liquids is not allowed. In any case, electrical equipment shall be fastened at a distance not less than 75 mm from the tank walls.

2.9.8 In enclosed and semi-enclosed spaces where an explosive mixture of gas or vapour with air is not likely to occur, but direct openings lead to dangerous spaces, electrical equipment of safe type shall be generally installed.

Installation of electrical equipment of non-safe type, is permitted if the following conditions are observed:

.1 operation of alarms (light and sound) and automatic disconnection of power supply (in sound cases with time delay) to electrical equipment if the ventilation is shut off;

.2 interlocking to provide for possible connection of electrical equipment only after adequate ventilation of the space (at least 10 air changes).

2.9.9 In compartments/holds intended for carriage of flammable cargoes the electrical equipment, which is essential for the safety and control of the ship, shall be completely isolated and protected against unauthorised actuation. The equipment shall be isolated from locations outside the dangerous zones by removing special disconnectors or by switches with interlocking device.

If provision of such equipment is necessary for the safety and control of the ship, the equipment shall be of certified safe type: intrinsically safe (*Exia* or *Exib*), pressurised enclosure (*Exp*), flameproof (*Exd*), increased safety (*Exe*).

2.9.10 In dangerous spaces and zones only those cables may be laid, which serve the electrical equipment fitted in such spaces and zones subject to the requirements of 2.9.11.

The through runs of cables may be permitted in the above spaces and zones provided the requirements of 2.9.11 to 2.9.15 are met.

No connections of cables laid in dangerous zones are permitted. In cases where the connections are inevitable, they shall be subject to special consideration by the Register. In such cases, the connections shall be made using metal-reinforced/shock-resistant plastic junction boxes of certified safe type or using thermocontractable/capsulated cable sleeves of approved type.

2.9.11 Cables installed in dangerous spaces and zones shall have protective covering of one of the following types:

.1 metal armour or braid with additional insulation covering;

.2 lead sheath with additional mechanical protection;

.3 copper or stainless steel sheath (only for cables with mineral insulation).

2.9.12 Cables passing through dangerous spaces and zones shall be suitably protected against mechanical damage.

Penetrations of cables through decks and bulkheads shall be sealed to avoid ingress of flammable gases or vapours.

2.9.13 All shields and metal braids of cables of power circuits for electric motors and lighting systems, which pass through dangerous spaces and zones or supply the electrical equipment installed in these spaces, shall be earthed at both ends at least.

2.9.14 Cables of intrinsically safe circuits shall not be used for more than one intrinsically safe device and shall be laid separately from other cables.

2.9.15 Cables of portable electrical equipment, except for cables of intrinsically safe circuits, shall not pass through dangerous spaces and zones.

2.9.16 Additional requirements for electrical equipment installed in paint stores.

2.9.16.1 Electrical equipment shall be installed in paint stores and in ventilation ducts serving such spaces only when it is essential for operational services.

Safe type equipment of the following type is acceptable: intrinsically safe (*Exi*), pressurized (*Exp*), flameproof (*Exd*), increased safety (*Exe*), special protection (*Exs*).

2.9.16.2 The minimum requirements for the safe type equipment are as follows: explosion group IIB, temperature class T3.

2.9.16.3 In paint stores and spaces mentioned under 2.9.16.4, cables (through-runs or terminating cables) of armoured type or installed in metallic conduits shall be used.

2.9.16.4 In the areas on open deck within 1 m of inlet and exhaust ventilation openings or within 3 m of exhaust mechanical ventilation outlets, the following electrical equipment may be installed: safe type equipment permitted by 2.9.16.1, equipment of protection class (*Exn*), appliances, which do not generate arcs or sparks in service and which surface does not reach unacceptably high temperature under normal conditions.

2.9.16.5 Enclosed spaces giving access to the paint store may be considered as non-hazardous, provided that:

.1 the door to the paint store is a gastight door with self-closing devices without holding-back arrangements;

.2 the paint store is provided with an acceptable, independent, natural ventilation system ventilated from a safe area;

.3 warning notices are fitted adjacent to the paint store entrance stating that the store contains flammable liquids.

2.10 ANTISTATIC EARTHING

2.10.1 Antistatic earthing is a mandatory mean of ensuring electrostatic intrinsic safety for all types of ships having dangerous spaces and zones.

2.10.2 Equipment to be installed on board, in enclosed and semi-enclosed spaces and zones where explosive mixtures of vapours, gases or dust with air likely to occur (refer to 2.9.1), as well as any portable equipment to be brought and installed in such spaces shall be antistatically earthed.

2.10.3 At all entrances to dangerous spaces and zones conditions shall be provided to remove electrostatic charge from entering people through installation of metal earthed plates, handrails or handles to remove charge when touched with the hand or by placing wet mats (rugs) at entry.

2.10.4 The following equipment does not require use of the antistatic earthing conductors:

.1 fixed and portable electrical equipment shields and metal armour of cables earthed in accordance with 2.5;

.2 pipes and conduits for installation of cables earthed in accordance with 16.8.8;

.3 electrical equipment, automation equipment, radio equipment and navigational equipment earthed in accordance with 2.2.2;

.4 equipment and structures provided with lightning protection earthing in accordance with 2.6.6.

2.10.5 Arrangement and monitoring of antistatic earthing.

2.10.5.1 Unless otherwise specified, the design of the antistatic earthing conductors shall comply with the requirements of 2.5.

The method of connecting the antistatic earthing conductors to non-metal equipment, such as plastic piping shall be specified by the equipment manufacturer.

2.10.5.2 Design of the antistatic earthing conductors being the component part of the equipment delivered to the ship shall meet the requirements of relevant parts of the Rules or the standards approved by the Register.

2.10.5.3 Resistance of the antistatic earthing shall be monitored by portable instruments of any type with control d.c. voltage of not more than 10 V. The resistance value measured between the equipment, component, structure being monitored and ship's hull shall not exceed 10^6 Ohm with the area of contact between the measure electrode and the equipment surface being no more than 20 mm^2.

3 MAIN ELECTRICAL POWER SOURCE

3.1 COMPOSITION AND CAPACITY OF MAIN ELECTRICAL POWER SOURCE

3.1.1 In every ship, a main electric power source shall be provided with a capacity sufficient to supply all the electrical equipment on board under conditions specified in 3.1.5. Such a source shall consist of two independently driven generators at least.

In ships of 300 gross tonnage and below (except for passenger ships), accumulator batteries may be the main power source.

3.1.2 The number and capacity of independently driven generators and electric converters, of which the main electrical power source is composed, shall be such that if any of them failed the rest would ensure:

.1 supply to electrical equipment necessary under conditions specified in 3.1.5 with normal habitable conditions on board guaranteed;

.2 start of the most powerful electric motor with the greatest starting current. The motor start shall not involve a voltage and frequency drop in the mains that could result in a fall out of synchronism, stop of generator engine or disconnection of machinery and apparatus being in operation;

.3 supply to consumers necessary to start the propulsion plant when the ship is de-energized. For this purpose, emergency electrical power source may be used if its capacity proper or in association with the capacity of any other electrical power source would ensure a simultaneous supply of consumers listed under 9.3.1 to 9.3.3 or under 19.1.2.1 to 19.1.2.3 (refer also to 2.1.6, Part VII "Machinery Installations"), for this purpose their parallel operation may be provided.

3.1.3 Where the main electrical power source is needed to ensure propulsion and steering of the ship, provision shall be made that the power supply to the equipment essential for propulsion and steering and to ensure safety of the ship is maintained continuously or restored immediately in case of failure of any generator being in operation.

Along with that, in ships where electrical power is normally supplied by two or more generators running in parallel, provision shall be made for automatic switching-off of less essential consumers without any overloading of the remaining generators, with retention of power supply to consumers essential for propulsion, steering and to ensure safety of the ship.

In ships where electrical power is normally supplied by one generator, in case of its failure and deenergization of the main switchboard, provision shall be made for:

automatic starting of stand-by generator of sufficient capacity and its connection to busbars of the main switchboard within 30 s;

automatic re-starting, in the necessary sequence, of essential devices ensuring propulsion, steering and safety of the ship.

3.1.4 Instead of one independently driven generator as mentioned under 3.1.1, a generator driven by the main engine (shaft generator) may be used if it complies with 3.2.3 under conditions listed below:

.1 the shaft generator operates practically at a constant speed under different operating conditions of the ship;

.2 provision is made for actuation of the ship's propulsion plant in case of failure of any generator with an independent prime mover.

The use of shaft generators operating at different speeds of main engines and shafts and forming part of the main electrical power source is subject to special consideration by the Register.

3.1.5 The number and power output of generators forming the main source of electrical power shall be determined with regard to the following operating conditions of the ship:

.1 running conditions;

.2 manoeuvring;

.3 in case of fire, hole in the ship's hull or other conditions affecting the safety of navigation, with the main sources of electrical power in operation;

.4 other operating conditions according to ship's purpose.

3.1.6 Where accumulator batteries are the main source of electrical power, their capacity shall be sufficient to satisfy the requirements of 3.1.2.1 for 8 hours without recharging; provision shall be made for charging of accumulator batteries from the source of electrical power installed on board.

3.1.7 In ships of restricted area of navigation **R3** (except passenger ships) with a low-power electrical installation as the main source of electrical power, only one generator with an independent prime mover or accumulator batteries may be installed.

3.2 ELECTRIC MACHINE SETS

3.2.1 General.

3.2.1.1 Engines designed for use as generator prime movers shall comply with the requirements set forth in Sections 2, 3 and 8, Part IX "Machinery", and, additionally, with the requirements of the Chapter.

3.2.1.2 Electric machine sets shall be designed for continuous duty, with regard to the power reduction during ship's service under conditions specified in 2.1.1.1.

3.2.1.3 Under short circuit in the ship's mains the generators shall provide for the value of the sustained short-circuit current sufficient for the operation of protective devices.

3.2.1.4 The voltage of generators shall be regulable within the range specified in 10.6 and 10.7 of the present Part, and speed frequency shall be regulable within the range specified in 2.11.3, Part IX "Machinery".

3.2.2 Load sharing between sets running in parallel.

3.2.2.1 Alternating-current sets intended to run in parallel shall be provided with such a reactive-voltage drop compensating system that when the sets run in parallel the reactive load sharing between the generators does not differ from a value proportional to their output by more than 10 per cent of the rated reactive load of the largest generator involved or by not more than 25 per cent of the rated output of the smallest generator if this value is lower than the above one.

3.2.2.2 When the alternating-current sets run in parallel at 20 to 100 per cent of the total load, load sharing shall be within the limits specified in 2.11.3, Part IX "Machinery".

3.2.3 Shaft generator sets.

3.2.3.1 Where shaft generators are used for feeding the ship mains, automatic connection of one or more independently driven generators to the ship mains shall be provided, or an alarm shall be activated in the engine room or at the main machinery control room in case the network frequency is below the permissible value.

3.2.3.2 Shaft generators intended for supply of particular consumers may, on agreement with the Register, operate under parameters, which differ from those specified in 3.2.1.4.

3.2.3.3 Shaft generators and semiconductor transducers (inverters) supplying the ship mains shall not be damaged by short circuits at the main distribution board busbars. In this case, a steady short-circuit current shall be ensured, sufficient for protection to be activated.

3.2.3.4 As a minimal requirement, shaft generators shall be designed for short periods of parallel running with other types of generator sets so that manual or automatic (if available) switch-over of the load is possible.

3.2.3.5 For shaft alternators, automatic devices shall be provided to preclude the current overload of their excitation system components when running at a speed below 90 per cent of the nominal speed during more than 5 s. In this case, a proportional voltage lowering across the generator terminals is permitted.

3.2.3.6 For each shaft generator, a de-excitation device shall be provided at the main distribution board, and measuring instruments as listed under 4.6.4.3.

3.2.3.7 When the shaft generator is connected into the ship mains, a visual warning signal shall be activated at the navigating bridge indicating that a change in the mode of main machinery operation might bring about a deviation in the ship main parameters beyond the limits stipulated by 10.6 and 10.7 of the present Part and 2.11.3, Part IX "Machinery".

3.2.3.8 A generator with an independent prime mover may be used in shaft generators with semiconductor converters as a synchronous condenser. In such cases, a disengaging clutch shall be fitted between the generator and its prime mover.

3.2.4 Exhaust-heat turbogenerators.

3.2.4.1 Exhaust-heat turbogenerators supplying particular consumers may, if approved by the Register, have performance characteristics different from those stated under 3.2.1.4.

3.2.4.2 The exhaust-heat turbogenerators used for feeding the ship mains shall be designed for parallel operation with generators having an independent prime mover. In this case, the distribution of load between the generator sets shall be in accordance with 3.2.2.

3.3 NUMBER AND CAPACITY OF TRANSFORMERS

3.3.1 In ships, where lighting and other circuits of essential services are powered through transformers, not less than two transformers shall be provided of such a capacity that in case of failure of the largest unit, the remaining transformers are capable of satisfying the complete need in electrical power under all operating conditions of the ship.

Where subdivided system of busbars is used, transformers shall be connected to different sections of the main switchboards.

In ships of less than 300 gross tonnage (other than passenger ships) of restricted areas of navigation **R2**, **R2-RSN** and **R3-RSN**, with the electrical installation of low power as well as in ships of restricted area of navigation **R3**, if approved by the Register, depending on specific area of navigation, installation of only one transformer is allowed.

3.4 POWER SUPPLY FROM AN EXTERNAL SOURCE OF ELECTRICAL POWER

3.4.1 If provision is made for ship's mains to be supplied from an external source of electrical power, an external supply switchboard shall be installed in the ship (refer also to 4.6.4.6).

For ships with the electrical installation of low power it is allowed that cables for supply of the ship's mains from an external source of electrical power shall be connected to the main switchboard directly.

3.4.2 At the external supply switchboard, the following facilities shall be provided:

.1 terminals for flexible cable connection;

.2 switch gear and protection devices for connecting and protection of permanently laid cable of the main distribution switchboard; where the cable length between the external supply switchboard and the main distribution switchboard is less than 10 m, no protection devices may be fitted;

.3 voltmeter or pilot lamps to indicate the presence of voltage from an external source across the terminals;

.4 device or facilities for connecting a device to control polarity and phase sequence;

.5 terminal for earthing a neutral wire from an external source;

.6 plate to indicate voltage, type of current and frequency;

.7 arrangement for mechanical fixation of the end of flexible cable connected to the switchboard and a hanger for the cable, which shall both be provided at the external supply switchboard or in its vicinity.

3.5 CONNECTION OF ELECTRICAL POWER SUPPLY UNITS

3.5.1 Where the electrical power supply units are not adapted for long operation in parallel to feed common busbars, it is necessary to use a connection circuit ensuring their switching-on for parallel operation for the duration of load transfer from one unit to another.

3.5.2 Direct current compound-wound generators designed for parallel operation shall have equalizing connections.

3.5.3 Where alternating-current generators are intended to operate in parallel, a synchronizer shall be installed in the main switchboard.

Where synchronizing is arranged to operate automatically, a standby manual synchronizer shall be provided.

Irrespective of the provision of synchronoscopes for manual and automatic synchronizing, in all cases the lamps for manual synchronizing shall be installed.

3.5.4 Where several direct-current generators are installed, a magnetizing device shall be fitted in the main switchboard.

Such device may be also allowed for synchronous alternating-current generators if it is necessary for initial excitation.

3.5.5 Where the ship's and external sources of electrical power are not intended to operate in parallel to the common busbars of the ship's electrical installation, the system of connections shall be so interlocked, in this case, as to prevent their possible switching-on for parallel operation.

3.5.6 Where the main source of electrical power is necessary for propulsion of the ship, the main busbar shall be subdivided into at least two parts, which shall normally be connected by circuit breakers or other approved means (e.g. circuit breaker without release or disconnector). Bolted links between the main switchboard sections, by which the busbars can be split, are not acceptable.

So far as it is practicable, the connection of generating sets and other duplicated equipment shall be equally divided between the parts.

4 DISTRIBUTION OF ELECTRICAL POWER

4.1 DISTRIBUTION SYSTEMS

4.1.1 The following systems of electrical power distribution are acceptable:

.1 for alternating current up to and including 1000 V:

.1.1 three-phase three-wire insulated system;

.1.2 three-phase three-wire system with neutral earthed through high-value resistor or reactor (compensated-resistored neutral);

.2 additionally for current up to and including 500 V:

.2.1 three-phase four-wire insulated system;

.2.2 three-phase four-wire system with neutral earthed according to 4.1.1.1.2;

.2.3 single-phase two-wire insulated system;

.2.4 single-phase two-wire system with neutral earthed according to 4.1.1.1.2;

.2.5 single-phase single-wire system with hull return for voltage up to 50 V (in ships of less than 1600 gross tonnage), except stated in 6.8.4, provided that any possible current will not pass directly through any of the dangerous spaces;

.3 for direct current:

.3.1 two-wire insulated system;

.3.2 single-wire system with hull return for voltage up to 50 V (in ships of less than 1600 gross tonnage), except stated in 6.8.4, provided that any possible current will not pass directly through any of the dangerous spaces.

Where a hull return system is used, all final circuits shall be two-wire and the insulated return wire shall be earthed by connecting to the earthing busbar of the distribution board supplying the circuit, at the place accessible for inspection. In this case devices shall be provided for isolating the earthing busbars from the hull to test insulation condition.

In ships of 1600 gross tonnage and upwards the use of local earthed systems is accepted for supplying the following consumers (provided that any possible current will not pass directly through any of the dangerous spaces and zones):

.1 electrical (battery) starter systems of internal combustion engines;

.2 impressed-current cathodic protection systems;

.3 insulation resistance monitoring and measuring systems (refer to 4.6.4.7).

The use of other distribution systems is subject to special consideration by the Register in each case (refer also to 18.2.1 and 19.2.2).

4.2 PERMISSIBLE VOLTAGE

4.2.1 Proceeding from the electrical power distribution system used, the permissible voltage across the terminals of power generating sets of electrical power sources with frequencies of 50 and 60 Hz shall be found under 4.1. Additonal requirements for apparatus designed for a voltage in excess of 1000 V shall be found in Section 18.

4.2.2 Permissible voltage across the terminals of sources of electrical power and direct current sources shall not exceed the values below:

500 V for power systems;

250 V for lighting and heating systems, and socket outlets.

4.2.3 Permissible voltage across the terminals of alternating-current consumers shall not exceed the values specified in Table 4.2.3.

Table 4.2.3

Nos	Consumers	Permissible voltage, V
1	Permanently installed power consumers, cooking and heating appliances permanently installed in spaces other than those specified in item 2	1000
2	Portable power consumers supplied from socket outlets fixed in position when used, heaters in cabins and passenger accommodation (refer to 15.2.5)	500
3	Lighting, signalling and internal communication, socket outlets for portable consumers with double or reinforced insulation or isolated electrically by isolating transformer	250
4	Socket outlets fitted in locations and spaces with increased humidity, and in extra humid spaces, and intended for supply of consumers having no double or reinforced insulation and not isolated electrically	50

4.2.4 Permissible voltage across the terminals of direct-current consumers shall not exceed the values specified in Table 4.2.4.

Table 4.2.4

Nos	Consumers	Permissible voltage, V
1	Permanently installed power consumers	500
2	Cooking, heating, etc. appliances	250
3	Lighting, socket outlets[1]	250

[1] In spaces with increased humidity and extra humid spaces, notices shall be provided at socket outlets with voltage exceeding the overrating voltage to notify of the use of consumers with double or reinforced insulation or those electrically isolated from overrating voltage.

4.3 POWER SUPPLY OF ESSENTIAL SERVICES

4.3.1 The following services shall be supplied by separate feeders from the main switchboard busbars:

.1 steering gear electric drives (refer also to 5.5.2);

.2 anchor gear electric drives (refer also to 4.3.3);

.3 fire pump electric drives;

.4 bilge pump electric drives;

.5 electric drives of sprinkler system compressors and pumps;

.6 gyrocompass;

.7 refrigerating plant switchboard for cargo holds;

.8 electric drives of exciter sets of propulsion plant;

.9 section main-lighting switchboards;

.10 radio station switchboard;

.11 navigational equipment switchboard;

.12 navigation light switchboard;

.13 section switchboards and distribution gear for supplying other essential services combined on the principle of uniformity of their functions;

.14 switchboards of integrated bridge control console (refer also to 4.5);

.15 switchboard of automatic fire detection system;

.16 electric drives of auxiliaries ensuring the operation of main machinery;

.17 switchboards of electric drives for cargo, mooring, boat and other gears, ventilation and heating appliances;

.18 control devices of controllable pitch propeller;

.19 charging facilities of starter accumulator batteries and batteries supplying essential consumers;

.20 switchboards of electric drives for closure of watertight doors and devices holding fire doors in open position and closure of watertight and fire doors;

.21 switchboard of refrigerating plant for the low pressure carbon dioxide extinguishing system;

.22 lighting switchboards for hangars and helicopter deck illumination;

.23 other services not listed above as required by the Register.

It is permitted to supply services indicated in 4.3.1.4, 4.3.1.10 to 4.3.1.12, 4.3.1.15, 4.3.1.16, 4.3.1.18 to 4.3.1.20, from switchgear indicated in 4.3.1.13 or 4.3.1.14 by separate out-going feeders provided with adequate switching and protective devices.

4.3.2 In case one-purpose machinery with electric drives indicated in 4.3.1 is installed in double or greater number, except for specified in 4.3.1.1, 4.3.1.5 and 4.3.1.8 at least one of these drives shall be energized by a separate feeder from the main switchboard. Electric drives of the rest of such machinery are allowed to be supplied from section switchboards or special distribution devices intended for supply of essential services.

When the collecting busbars in the main switchboard are subdivided into sections having intersectional disconnecting devices, the electric drives, section switchboards, special distribution devices or boards installed in double or greater number or supplied by two feeders shall be connected to different sections of the main switchboard.

4.3.3 In cargo ships of restricted areas of navigation **R2**, **R2-RSN**, **R3** and **R3-RSN**, and in particular cases in ships of unrestricted service and ships of restricted area of navigation **R1**, the supply feeder of anchor gear may be connected to the distribution board of cargo winches or to another distribution board, on special approval of the Register, provided the boards are supplied directly from the main distribution board and adequate protection is available.

4.3.4 Final sub-circuits having a current rating in excess of 16 A shall supply not more than one consumer.

4.4 POWER SUPPLY OF ELECTRICAL (ELECTRONIC) AUTOMATION SYSTEMS

4.4.1 Power supply of electrical (electronic) automation systems shall satisfy the requirements of Part XV "Automation".

4.4.2 Power supply of automation devices necessary for starting and operating the emergency diesel generator shall be taken from a starter battery or another independent accumulator battery installed in the emergency diesel generator space.

4.5 POWER SUPPLY TO INTEGRATED BRIDGE CONTROL CONSOLE

4.5.1 When locating in the integrated bridge control console the electrical equipment, navigational equipment, radio equipment, electrical automatic and remote-control equipment for the main and auxiliary machinery, such equipment shall be supplied by separate feeders as required in the present Chapter and other parts of the Rules.

It is allowed to feed the equipment specially listed in 4.3.1 from the switchboards of the integrated bridge control console, provided the requirements of 4.5.2 to 4.5.6 are met (refer to 9.4.3 as well).

4.5.2 The switchboards of the integrated bridge control console shall be fed from the main switchboard directly or through the transformers by two independent feeders connected to different sections of the main switchboard busbars, where busbars are subdivided.

When the emergency generator is provided on board the ship, the switchboards of the integrated bridge control console shall be supplied by one feeder from the main switchboard and by one feeder from the emergency switchboard.

4.5.3 In addition, the switchboards of the integrated bridge control console shall be independently supplied by a separate feeder from other source or sources of power, if necessary, basing on the requirements for the equipment fed from these switchboards.

4.5.4 The switchboard shall be provided with a change-over switch for feeders specified in 4.5.2.

If an automatic change-over switch is used, manual switching of feeders shall be also ensured. In this case, provision shall be made for necessary interlocking.

4.5.5 Each consumer specially listed in 4.3.1 fed from the switchboards of the integrated bridge control console shall be supplied by a separate feeder (refer to 9.4.3 as well).

4.5.6 In the integrated bridge, control console a light signalling device indicating the presence of voltage shall be fitted.

4.6 SWITCHBOARD AND SWITCHGEAR

4.6.1 Switchboard design and construction.

4.6.1.1 Frames, front panels and enclosures of main, emergency, section and distribution switchboards shall be constructed of metal or some other durable non-combustible material.

Where the aggregate capacity of generators intended for parallel operation exceeds 100 kW, barriers shall be installed between the generator sections and adjacent sections for protection against the effects of arcs.

4.6.1.2 Switchboards shall be of rigid construction capable of withstanding the mechanical stresses liable to occur under service conditions or as a result of short circuits.

4.6.1.3 Switchboards shall at least be protected from drip. This protection is not required if the switchboards shall be located in spaces where the conditions are such that no vertically falling drops of liquid can get into the switchboard (refer also to 4.6.6.2).

4.6.1.4 Switchboards intended to be installed in places accessible to unauthorized persons shall be provided with doors to be opened by means of a special key, the same for all the switchboards in the ship.

4.6.1.5 The design of switchboard doors shall be such that with the doors opened access is assured to all parts which require maintenance, and the live parts located on the doors shall be protected against inadvertent touching.

Opening panels and doors, which are used for mounting electrical control gear and measuring instruments, shall be securely earthed with at least one flexible connection.

4.6.1.6 Handrails shall be fitted to main, emergency and section switchboards and to control panels on their front sides. Switchboards accessible from the rear shall be provided with horizontal handrails fitted at the back.

The materials, which may be used for manufacture of handrails, are insulating material, wood or earthed metal pipes with insulating covering.

4.6.1.7 The generator panels of main switchboards shall be illuminated with lighting fixtures supplied on the generator side before the circuit breaker of the generator or not less than from two different systems of busbars in case these systems are provided according to 3.5.6.

4.6.1.8 The lighting of the front side of switchboard panels shall not interfere with instrument observation or produce a blinding effect.

4.6.1.9 The design of switchboards, which have no space at the rear, shall be such that the access is ensured to all parts, which require maintenance.

Arrangements shall be provided for doors of switchboards to fix them in the open position.

Withdrawable blocks and instruments shall be fitted with devices to prevent their fall-out in the withdrawn position.

4.6.1.10 Each distribution device designed for voltage over the safe, with switchgear and protective devices and without a voltmeter, shall be furnished with a pilot lamp, which indicates the presence of voltage on busbars.

4.6.2 Busbars and uninsulated conductors.

4.6.2.1 The maximum permissible temperature for switchboard busbars and uninsulated conductors at the rated load and short-circuit current or at the permissible one-second short-circuit load for copper busbars shall be determined according to national standards.

4.6.2.2 Equalizer busbars shall be designed for at least 50 per cent of the rated current of the largest generator connected to the main switchboard.

4.6.2.3 Where the busbar is in contact with or close to insulated parts, its heat effects shall not cause under operating or short-circuit conditions a temperature rise in excess of that allowable for a given insulating material.

4.6.2.4 Busbars and uninsulated conductors in switchboards shall have adequate electrodynamic and thermal strength during short-circuit currents occurring at relevant points in the circuit.

Such electrodynamic loads as occur in busbars and uninsulated conductors due to short circuit shall be as specified in the relevant national standards.

4.6.2.5 Insulators and other parts designed to support busbars and uninsulated conductors shall be capable of sustaining the loads due to short circuits.

4.6.2.6 The natural frequency of copper tier busbars shall be outside the ranges of 40 to 60 Hz and 90 to 110 Hz for rated frequency of 50 Hz, 50 to 70 Hz and 110 to 130 Hz for rated frequency of 60 Hz.

4.6.2.7 Busbars and uninsulated conductors of different polarity shall be marked with the following distinguishing colours:

.1 red for positive pole;

.2 blue for negative pole;

.3 black or green and yellow for earth connections;

.4 light blue — for middle wire.

The equalizer connection shall be marked with white transverse bands in addition to the appropriate colour as given above.

4.6.2.8 Busbars and uninsulated conductors of different phases shall be marked with the following distinguishing colours:

.1 yellow for phase 1;

.2 green for phase 2;

.3 violet for phase 3;

.4 light blue for neutral wire;

.5 green and yellow for earth connections.

4.6.2.9 Busbars shall be connected so as to prevent corrosion in way of connections.

4.6.3 Calculation of short-circuit currents and selection of electrical switch apparatus.

4.6.3.1 Electrical switch apparatus shall at least comply with the national standards and shall be so selected that:

under normal service conditions their rated voltages, currents and temperature rise limits are not exceeded;

they are capable of withstanding, without damage or exceeding temperature limits, such overloads as specified for transient conditions;

their characteristics under short-circuit conditions are consistent with the actual short-circuit power factor as well as with the behaviour of the sub-transient and transient short-circuit current.

4.6.3.2 The rated breaking capacity of electrical swith apparatus designed to break short-circuit currents shall not be less than the prospective short-circuit current at the point of its installation at the moment of breaking.

4.6.3.3 The rated making capacity of circuit breakers or switches, which may be incorporated in a shorted electric circuit, shall not be less than the prospective maximum making current under short-circuit condition at the point of installation.

4.6.3.4 The elctrodynamic strength current of electrical apparatus not intended for interrupting short-circuit currents shall not be less than the prospective peak short-circuit current at the point of installation.

4.6.3.5 The thermal strength current of electrical apparatus under short-circuit condition shall be consistent with the prospective short-circuit current at the point of installation taking into account the duration of short-circuit based on the dicriminative action of the protection.

4.6.3.6 The use of a circuit breaker with inadequate breaking and/or making capacities relative to the prospective peak short-circuit current at the point of installation is admissible, provided that it is protected on the generator side by means of fuses and/or a circuit breaker with at least necessary ratings for short-circuit currents, which is not used as a generator automatic switching device.

The characteristics of the protection arrangement thus composed shall be such that:

.1 while breaking the prospective peak short-circuit current, the circuit breaker on the load side will not be so damaged as to become unfit for further service;

.2 making the circuit breaker on the prospective peak short-circuit current will not result in damage to the remaining part of the electrical arrangement, while it is allowed for the circuit breaker on the load side not to be immediately fit for further operation.

4.6.3.7 In electric circuits having a current rating in excess of 320 A circuit breakers shall be fitted for overload protection.

The use of circuit breakers is recommended at the current exceeding 200 A.

4.6.3.8 In direct current compound generator circuits where the generators are intended for parallel operation, circuit breakers shall have a pole for a common-wire mated mechanically with the other poles of the circuit breaker so it would switch on before the other poles are connected to the busbars and switch off after their disconnection.

4.6.3.9 Short-circuit currents shall be calculated on the basis of the standards or calculation methods approved by the Register.

4.6.3.10 In calculations of peak short-circuit currents short-circuit current source shall contain all generators including synchronous condensers, which may be connected in parallel and all electric motors running simultaneously. Currents from generators and electric motors shall be calculated on the basis of their characteristics.

When the precise information is lacking, the following ratios of the effective value of current contribution of the short-circuit point shall be taken for alternating current electric motors:

at the instant of short-circuit occurence — $6{,}25I_r$;

at the instant T, i.e. after one cycle from short-circuit inception — $2{,}5I_r$;

at the instant $2T$, i.e. after two cycles from short-circuit inception — I_r;

for peak current — $8I_r$ (I_r = total rated current of all the electric motors running simultaneously under design conditions).

For the evaluation of the maximum value of short-circuit current in direct current systems the value of current contribution of electric motors is taken to be equal to the six-fold sum of the rated currents of electric motors running simultaneously under design conditions.

The calculation of short-circuit currents shall be made for all design short-circuit points, required for the selection and test of the power electric circuit elements.

In any case, the calculation of short-circuit currents shall be made for the following design points:

on the generator side — on the automatic circuit breaker terminals;

on the main switchboard collecting busbars;

on the emergency switchboard busbars;

on the terminals of the consumers and the busbars of the switchboards supplied directly from the main switchboard.

The calculation of the minimum short-circuit current shall be made if it is required for the assessment of the protection sensitiveness.

The calculation of short-circuit currents shall contain the list of all the switching devices fitted, with indication of their characteristics, and also the prospective short-circuit current at the points of their installation.

4.6.4 Position and arrangement of electrical switch apparatus and measuring instruments.

4.6.4.1 Apparatus, measuring and indicating instruments used in connection with generators and other large essential installations shall be fitted on the switchboards associated with the appropriate generators and installations.

This requirement may be dispensed with in the case of generators where there is a central control console with switch gear and measurements for several generators.

4.6.4.2 One ammeter and one voltmeter shall be provided for each direct-current generator on the main and emergency switchboards.

4.6.4.3 The following instruments shall be provided for each alternating current generator on the main switchboard and for emergency generator on the emergency switchboard:

.1 an ammeter with a selector switch for current measurements in each phase;

.2 a voltmeter with a selector switch for measuring phase or line voltages;

.3 a frequency indicator (use of one double frequency indicator is permissible for generators opera-ting in parallel with change-over to each generator);

.4 a wattmeter (for output upwards of 50 kVA);

.5 other instruments as required.

4.6.4.4 In ships having a low-power electrical installation, in which the generators are not expected to operate in parallel, one set of instruments as stipulated by 4.6.4.2 and 4.6.4.3 may be installed at the main and emergency switchboards, which would ensure a possibility of taking measurements at each generator installed.

4.6.4.5 Ammeters shall be installed in the circuits of essential consumers rated at 20 A and over. These ammeters may be installed on the main switchboard or at the control stations.

It is allowed to install ammeters with selector switches but not more than for six consumers.

4.6.4.6 In the main switchboard the feeder energized from the external power source shall be provided with:

.1 switchgear and protective devices;

.2 a voltmeter or a pilot lamp;

.3 means of protection against phase breaking.

4.6.4.7 A change-over arrangement or a separate device for each network of isolated systems for measuring and indicating insulation resistance shall be installed on the main and emergency switchboards.

In any case, the hull leakage current due to the operation of the measuring device shall not exceed 30 mA.

Provision shall be made for audible and visual alarms to warn of inadmissible decrease in the insulation resistance.

In ships with unattended machinery spaces this signalling shall be also provided at the ship's main control station.

4.6.4.8 Measuring instruments shall have scales with a margin of divisions in excess of the rated values of quantities to be measured.

The upper scale limits of the instruments used shall not be less than:

.1 for voltmeters — 120 per cent of the rated voltage;

.2 for ammeters associated with generators not operating in parallel and with current consumers — 130 per cent of the rated current;

.3 for ammeters associated with parallel-operating generators — 130 per cent of the rated current for load-current scale and 15 per cent of the rated current for reverse-current scale (the latter refers only to direct-current generators);

.4 for wattmeters associated with generators not operating in parallel — 130 per cent of the rated output;

.5 for wattmeters associated with generators opera-ting in parallel — 130 per cent for power scale and 15 per cent for reverse power scale;

.6 for frequency indicator — ± 10 per cent of the rated frequency.

The specified scale limits may be changed on agreement with the Register.

4.6.4.9 Voltage, current and power ratings of electric power plant and generators shall be clearly indicated on the scales of electrical measuring instruments.

4.6.4.10 Wherever possible, switchgear shall be installed and connected to busbars in such a way that none of the movable elements and protective or control devices associated with switchgear are energized in the open position.

4.6.4.11 When switches with fuses are installed in outgoing circuits of switchboards, the fuses shall be positioned between the busbar and the switch.

Other pattern of the fuse installation is subject to special consideration by the Register in each case.

4.6.4.12 Where switchboards are installed on a foundation at the floor level, the fuses shall be located not lower than 150 mm and not higher than 1800 mm from the floor level.

Live open parts of switchboards shall be located at a height of not less than 150 mm above the floor level.

4.6.4.13 Fuses shall be so installed in switchboards that they are easily accessible and the fuse link replacement is not dangerous for the operating personnel.

4.6.4.14 The fuses protecting the poles or phases of the same circuit shall be installed in a row, horizontally or vertically depending on the fuse design. The fuses in an a.c. circuit shall be positioned to follow the sequence of phases from left to right or from top to bottom.

In a d.c. circuit the positive-pole fuse shall be on the left, at top, or closer to reach.

4.6.4.15 The manual actuators of voltage regulators installed in main or emergency switchboards shall be positioned close to the measuring instruments associated with the respective generators.

4.6.4.16 The ammeters of direct current compound generators intended for operation in parallel shall be included in the hole circuit not connected to the common wire.

4.6.4.17 For connecting portable and semi-portable instruments, flexible-stranded conductors shall be used.

4.6.4.18 Switch electrical apparatus controls, panels and outgoing circuits on the switchboards shall have their designations marked. The apparatus switching positions shall be also indicated. Besides, markings shall be provided to indicate the rated currents of the installed safety devices and switches, settings of circuit breakers and electrothermal trips.

4.6.4.19 Each outgoing circuit in a switchboard shall be provided with an appropriate circuit breaker to disconnect all poles and phases. Switches or circuit breakers may be dispensed with in lighting branch boxes provided with a common switch and also in the circuits of instruments inter-locking devices, alarms and local lighting of switchboards protected by fuses.

4.6.5 Light signals.

4.6.5.1 Light signals shall be of the colour specified in Table 4.6.5.1.

4.6.5.2 The use of light signalling methods other than specified in Table 4.6.5.1 (for example, letter code) is subject to special consideration by the Register in each case.

4.6.6 Arrangement of distribution gear.

4.6.6.1 The switchboards shall be placed in locations where the possible concentration of gases, water vapours, dust and acid evaporations is eliminated.

4.6.6.2 If the switchboard having protective enclosure of IP10 type and below is located in a special space, cabinet or recess, then such spaces shall be made of non-combustible material or shall have a lining of such material.

Table 4.6.5.1

Colour	General meaning	Type of signal	Condition of device
Red	Danger	Blinking Permanent	Alarm in dangerous conditions where immediate action is necessary Alarm in dangerous conditions,detected, but not yet rectified
Yellow	Attention	Blinking Permanent	Abnormal conditions where immediate action is not required Intermediate condition between abnormality and safety Abnormal condition already detected, but not yet rectified
Green	Safety	Blinking Permanent	Standby machinery is put into operation Rated conditions of running and operation
Blue	Information	Permanent	Machinery and gear are ready to be started Voltage in mains. Everything is in order
White	General information	Permanent	Signals activated when necessary Notations relating to automatic control conditions Other auxiliary signals

4.6.6.3 Arrangement of pipelines and tanks near the switchboards shall conform to the requirements of 5.5, Part VIII "Systems and Piping".

4.6.6.4 The navigation lights switchboard shall be located in the wheelhouse where it is readily accessible and visible to the personnel on watch.

4.6.6.5 The main switchboard and generating sets shall be positioned in close proximity to each other, in the same engine room and within the boundaries of the same "A-60" class vertical and horizontal fire-resistant constructions. The enclosure situated within the main boundaries of machinery space, provided for the engine control room where the main switchboard is positioned, is not considered as separating the main switchboard from the generating sets.

Where essential services for stearing and propulsion of ship are supplied from section switchboards these switchboards and any transformers, converters and similar equipment forming the essential part of the system supplying these services shall be also positioned in the same space as generating sets.

4.6.7 Access to switchboards.

4.6.7.1 In front of the switchboard, a passageway shall be provided not less than 800 mm wide for switchboards up to 3 m long, and not less than 1000 mm wide for switchboards 3 m long and over.

In ships of less than 500 gross tonnage, the width of the passageway may be reduced to 600 mm.

4.6.7.2 Behind the free standing switchboards, it is necessary to provide a passageway not less than 600 mm wide for switch boards up to 3 m in length and not less than 800 mm wide, for longer switchboards.

Between the free standing switchboards with open live parts located in special electrical spaces a passageway shall not be less than 1000 mm wide.

4.6.7.3 The space behind the free standing switchboards with open live parts shall be enclosed and fitted with doors in accordance with 2.8.1.

4.6.7.4 For switchboards more than 3 m in length mentioned in 4.6.7.3 at least two doors shall be provided leading from the space where the switchboard is installed to the space behind the switchboard. These doors shall be as widely spaced as possible.

It is allowed that one of these doors shall lead to the adjacent space having at least another exit.

4.6.7.5 Passageways specified in 4.6.7.1 and 4.6.7.2 are measured from the most protruding parts of apparatus and structure of the switchboard to the protruding parts of equipment or hull structures.

5 ELECTRIC DRIVES FOR SHIPBOARD MECHANISMS AND EQUIPMENT

5.1 GENERAL

5.1.1 The control stations of the drives shall meet the relevant requirements of Part VII "Machinery Installations", while the power supply of electrical (electronic) automation systems shall meet the requirements specified in Part XV "Automation".

5.1.2 Electrically-driven mechanisms shall be provided with light signals to indicate switching-on of the electric drive.

5.1.3 Equipment provided with automatic, remote and local control shall be so designed that the automatic control is switched off as well as the remote control when the change-over to the local control occurs. The local control shall be independent both of the automatic and remote control.

5.2 INTERLOCKING OF MACHINERY OPERATION

5.2.1 The machinery provided with electric and manual drives shall be fitted with an interlocking device that will prevent simultaneous operation of the drives.

5.2.2 If the machinery is required to operate in a certain sequence, appropriate interlocking devices shall be used, the diagram and design of which are subject to special consideration by the Register in each case.

5.2.3 A device may be installed that will switch off the interlocking on condition that this device is protected from switching off the interlocking inadvertently. Informative inscription shall be placed in close proximity to this device that will indicate its application and forbid its use by unauthorized personnel.

Such a device is not permitted for machinery specified in 5.2.1.

5.2.4 Starting of the machinery, which electric motors or switchgear require additional ventilation in normal operation, shall be possible only with ventilation in action.

5.3 SAFETY ISOLATION DEVICES

5.3.1 Control systems of mechanisms, which operation under certain conditions may endanger human or ships safety, shall be provided with push-buttons or other safety isolation devices that will ensure disconnection of the electric drive from the power supply.

These push-buttons and/or other safety isolation devices shall be suitably protected against inadvertent actuation.

5.3.2 Push-buttons or other safety isolation devices shall be located near the control stations or in other places with a view to ensure safety of operation.

5.3.3 Electric drives of arrangements and machinery which require restriction of motion to prevent damage or break-down shall be provided with terminal switches to ensure reliable isolation of the electric motor.

5.4 SWITCHGEAR AND CONTROL GEAR

5.4.1 The switchgear in the circuits of electric drives, which in itself does not provide for short-circuit protection shall withstand the short-circuit current that may flow at the point of its installation during the time required for operation of a special protection device.

5.4.2 Starting of the engine shall be possible only from the zero position of the control gear.

5.4.3 A discharge protection device shall be provided for the control gear that permits isolation of the shunt-field windings.

5.4.4 For directly started alternating-current electric motors, the requirements of 3.1.2.2 and 16.8.3.3 shall be taken into consideration.

5.4.5 For each electric motor rated at 0,5 kW and more and its control gear, provision shall be made for fitting a device to isolate the power supply. If the control gear is mounted on the main switchboard or on any other switchboard in the same compartment and its visibility is ensured from the place of installation of the electric motor, then for this purpose it is permitted to use a switch mounted on the switchboard.

If the requirements in respect of location of machine control gear stated above are not met, the following shall be provided:

.1 a device interlocking the switch on the switchboard in the "off" position, or

.2 an additional disconnecting switch near the electric motor, or

.3 fuses in each pole or phase of the control gear arranged in such a manner that they could be readily removed or replaced by the personnel.

5.5 ELECTRIC DRIVES AND CONTROL OF STEERING GEAR

5.5.1 In addition to the requirements of 6.2, Part IX "Machinery" and 2.9, Part III "Equipment, Arrangements and Outfit", steering gear shall comply with the requirements of the present Part of the Rules.

5.5.2 Main electric or electro-hydraulic steering gear comprising one or more power units shall be supplied by two separate feeders laid directly from the main switchboard in two different runs (refer also to 16.8.4.13).

When the collecting busbars in the main switchboard are subdivided, each feeder shall be supplied from different sections (refer also to 4.3.2). One of these feeders may be supplied through the emergency switchboard.

In case the auxiliary electric or electro-hydraulic steering gear is provided according to 2.9, Part III "Equipment, Arrangements and Outfit", it may be supplied from the feeders of the main electric steering gear.

5.5.3 Each feeder shall be selected so as to supply all the electric motors, which are normally connected thereto and operate simultaneously.

5.5.4 If a change-over arrangement is provided to supply any electric motor or a combination of motors from one or the other feeders, such feeders shall be designed for operation under the most severe loads, and the change-over arrangement shall be installed in the steering gear compartment.

5.5.5 In case a steering gear power unit becomes inoperative, another unit required by 2.9.4, Part III "Equipment, Arrangements and Outfit" shall be actuated manually from the bridge control station. Provision may be made for an additional automatic actuation of the power unit.

5.5.6 In every ship provided with steering gear according to 2.9.6, Part III "Equipment, Arrangements and Outfit" in the event of failure of the main source of electric power of the steering gear power unit provision shall be made for automatic connection within 45 s to the emergency source of electrical power or an other independent source located in the steering gear compartment and intended only for this purpose.

For ships of 10000 gross tonnage and over the power of this source shall be sufficient for continuous supply of the steering gear, associated control system and rudder angle indicators within at least 30 min and for all other ships, within at least 10 min.

5.5.7 The operating conditions for the electric motors of the drives for the active means of the ship's steering shall conform to the conditions prescribed for the entire gear, but the motors shall at least satisfy the short-term operating conditions during not less than 30 min.

5.5.8 The electric or electrohydraulic drive of a steering gear shall ensure:

.1 putting the rudder from hard over to hard over within the time and angle stated in 6.2.2, Part IX "Machinery";

.2 putting the rudder continuously from hard over to hard over during 30 min for each set at the maximum service speed ahead corresponding to the draught at which the rudder is fully immersed (refer also to 2.9.2 and 2.9.3, Part III "Equipment, Arrangements and Outfit");

.3 continuous operation during one hour at the maximum service speed ahead with putting the rudder over through an angle so as to ensure 350 puttings over per hour;

.4 possible stalling of the electric motor in "on" position for one minute from hot state (only for rudders fitted with the direct electric drive);

.5 sufficient strength of electric drive in the presence of mechanical forces arising at maximum speed astern.

It is recommended that a possibility shall be provided for putting the rudder over at the average speed astern.

5.5.9 Starting and stopping of the steering gear electric motors, other than electric motors of rudders with direct electric drive, shall be effected from the steering room and from the wheelhouse.

5.5.10 The starting devices shall ensure automatic restarting of electric motors as soon as the voltage is restored after a discontinuity in power supply.

5.5.11 In the wheelhouse and main machinery control station audible and visual alarms shall be given in the event of:

.1 voltage loss, phase break-off or power circuit overload of each power unit;

.2 voltage loss in the power circuit of the control system;

.3 low oil level in any tank of the hydraulic system.

Besides, means shall be provided to indicate operation of the electric motors of the steering gear power units.

5.5.12 The steering gear control systems specified in 2.9.14 and 2.9.15, Part III "Equipment, Arrangements and Outfit" shall be supplied by separate feeders laid in different runs from the power circuits of the steering gear in the steering gear compartment or directly from the busbars of the switchboard serving these power circuits.

5.5.13 In the steering gear compartment means shall be provided for disconnecting any bridge control system from the steering gear it serves.

5.5.14 Each remote control system specified in 2.9.14 and 2.9.15, Part III "Equipment, Arrangements and Outfit" shall have its own independent circuit, including all electrical components, for transmission of orders to the steering gear actuator.

5.5.15 The direction of rotation of the rudder wheel or the direction of motion of the control gear handle shall agree with the direction of putting the rudder over.

In the push-button control system, the push-buttons shall be arranged in such a manner that the switching on of the push-button located to the right causes the rudder blade to move rightward, while the button to the left its motion leftward.

5.6 ELECTRIC DRIVES OF ANCHOR AND MOORING MACHINERY

5.6.1 In addition to the requirements of 6.3 and 6.4, Part IX "Machinery", the drives of windlasses, anchor and mooring capstans and mooring winches shall comply with this Part of the Rules.

5.6.2 When alternating current squirrel-cage electric motors are used, the electric drives of the anchor and mooring machinery shall ensure, after 30-minute operation at the rated load, possible stalling of the electric motor in "on" position at the rated voltage for at least 30 s for the anchor machinery and 15 s for the mooring machinery. For reconnecting stator winding motors this requirements is applicable to operation of the motors with the windings producing maximum starting torque.

The direct-current electric motors and alternating current wound-rotor electric motors shall withstand the above-stated stalling conditions but at the torque twice that of the rated value; in this case, the voltage may be below the rated value.

After stalling conditions the temperature rise shall not be over 130 per cent of the permissible value for the insulation used.

5.6.3 In anchor and mooring capstans and mooring winches at the speed steps intended only for mooring operations provision shall be made for overload protection of the electric motor.

5.6.4 The supply of electric drives of anchor capstans shall be effected in conformity with 4.3.1 and 4.3.3.

5.7 ELECTRIC DRIVES OF PUMPS

5.7.1 The electric motors of fuel and oil transfer pumps and separators as well as of organic coolant circulation pumps shall be provided with remote disconnecting switches located outside the space wherein these pumps are placed and outside the machinery casings, but in close vicinity of the exits from these spaces.

5.7.2 The electric motors of the pumps transferring the liquids overboard through the drain holes above the lightest waterline at locations where lifeboats or liferafts are lowered shall be provided with disconnecting switches located near the control stations of the driving machinery for lowering the relevant boats or rafts.

5.7.3 The electric motors of emergency fire pumps and submersible bilge pumps (refer to 7.1.4, Part VIII "Systems and Piping") shall be provided with remote starting devices located above the bulkhead deck (refer to 3.2.3.9, Part VI "Fire Protection").

A remote starting device shall be provided with a light signal indicating the "on" condition of the electric drive.

5.7.4 Disconnecting switches of electric drives specified in 5.7.1 shall be located in conspicuous positions covered with glass and provided with explanatory inscriptions. The disconnecting switches shall de-energize feeders of those electric drives.

5.7.5 Local starting of fire and bilge pumps shall be possible even in case of failure of their remote control circuits, including protection equipment.

5.7.6 The electric motors of oily and sewage water transfer and discharge pumps shall be provided with remote cut-off arrangements located in the vicinity of discharge manifolds, provided no telephone or radio communication is available between the discharge observation position and discharge control position.

5.8 ELECTRIC DRIVES OF FANS

5.8.1 The electric motors of ventilation fans in machinery spaces shall be provided with at least two disconnecting switches, one of which shall be located outside these spaces and their casings, but in close vicinity of the exits from these spaces. It is recommended that these disconnecting switches be positioned together with similar switches referred to in 5.7.1.

5.8.2 The electric motors of ventilation fans of cargo holds and galley fans shall be provided with disconnecting switches at locations readily accessible from the main deck, but outside the machinery casings.

Electric motors of exhaust ventilation from galley ranges shall be provided with a disconnecting switch located inside the galley, regardless of the number of disconnecting switches.

5.8.3 The electric motors for general shipboard ventilation shall have at least two switches for remote disconnection of the motors, one of the switches being fitted in the wheelhouse and the other accessible from the open deck.

For ships with electrical installation of low power (other than passenger ships) it is permitted to use one disconnecting switch located in the wheelhouse or in a position readily accessible from the main deck.

5.8.4 The electric motors of fans in the spaces protected by a smothering system shall be provided with a disconnecting switch operating automatically when fire extinguishing medium is discharged into the space.

5.8.5 The disconnecting switches of the electric motors of fans listed in 5.8.1 to 5.8.3 shall be so grouped on board the ship that all these electric motors could be stopped from not more than three positions. The disconnecting switches shall de-energize feeders of those electric motors of fans.

5.9 ELECTRIC DRIVES OF BOAT WINCHES

5.9.1 The electric drives of boat winches shall comply with the requirements of 6.20, Part II "Life-Saving Appliances" of the Rules for the Equipment of Sea-Going Ships.

5.9.2 The winch electric drive controls shall be provided with self-return to the "stop" position.

5.9.3 A switch in power circuit of the electric motor shall be installed near the boat winch control station.

5.10 ELECTRIC DRIVES OF WATERTIGHT AND FIRE DOORS

5.10.1 The electric drives of watertight doors shall meet the requirements of 7.12, Part III "Equipment, Arrangements and Outfit".

5.10.2 Power supply of electric drives and indicators of position and closure of the watertight doors shall be taken from the main, emergency and emergency intermediate sources of electrical power in accordance with 4.3.1, 9.3 and 19.1.2.

5.10.3 The electric drives of devices for holding the fire doors in the open position (refer to 2.1.3.4, Part VI "Fire Protection") shall:

.1 be supplied from the main and emergency sources of electrical power;

.2 be remotely controlled from the wheelhouse for closing the doors individually, in groups or all doors simultaneously;

.3 automatically close all the doors simultaneously in case of the supply voltage loss;

.4 be so designed that any damage in the mechanism of closing any door could not render inoperative the systems of supply and operation of other doors.

5.11 ELECTRIC DRIVES FOR OIL BURNER UNITS OF BOILERS AND INCINERATORS

5.11.1 Electric drives for oil burner units of boilers and incinerators shall be provided with remote shut off devices located outside the spaces where they are installed (refer also to 5.3.8, Part X "Boilers, Heat Exchangers and Pressure Vessels" and 4.3.5, 4.10.3.4 and 6.2.3, Part XV "Automation").

5.11.2 Where the spaces in which the incinerators and boilers are installed are protected by aerosol fire-extinguishing system, the electric drives for oil burner units of boilers and incinerators shall be automatically shut off when the said system is activated.

6 LIGHTING

6.1 GENERAL

6.1.1 In all ship's spaces, places and zones where the illumination is essential for safety of navigation, control of machinery and gear, habitability and evacuation of passengers and crew, stationary main lighting fixtures shall be provided, which are supplied from the main source of electrical power.

The list of spaces, places and zones where the emergency lighting fixtures shall be installed in addition to the main ones is given in 9.3.1.1 and 19.1.2.1.1.

6.1.2 Lighting fixtures installed in spaces and zones where mechanical damage is possible to the glass hoods shall be provided with protection gratings.

6.1.3 Lighting fixtures shall be installed in such a manner as to prevent heating of cables and adjacent materials up to a temperature exceeding the permissible level.

6.1.4 In spaces or spaces illuminated with luminescent lamps where visible rotating parts of machinery are located, all measures shall be taken to prevent stroboscopic effect.

6.1.5 External-illumination lighting fixtures shall be so installed that no light interference with ship's navigation could occur.

6.1.6 In spaces and zones illuminated with discharge lamps, which do not ensure continuity of burning at voltage variations according to 2.1.3, provision shall be also made for lighting fixtures with incandescent lamps.

6.1.7 Battery and other dangerous compartments shall be illuminated with lighting fixtures located in adjacent safe spaces through gastight windows, or with safe-type lighting fixtures located inside the compartment (refer also to 2.9).

6.2 POWER SUPPLY OF MAIN LIGHTING ELECTRIC CIRCUITS

6.2.1 The switchboards of the main lighting shall be supplied by separate feeders. The main lighting switchboards may supply the electric drives of non-essential services rated up to 0,25 kW and individual cabin heaters rated up to 10 A.

6.2.2 The protective devices of final lighting circuits shall be set to operate at a current rating not exceeding 16 A, the total load current of the consumers connected shall not exceed 80 per cent of the current setting of the protective device.

The number of lighting fixtures supplied by final lighting circuits shall not exceed that specified in Table 6.2.2. Cabin fans and other appliances may be supplied by final lighting circuits.

Table 6.2.2

Voltage, V	Maximum number of lighting fixtures
Up to 50	10
51 to 120	14
121 to 250	24

6.2.3 Lighting of corridors, machinery spaces, propeller shaft tunnels, boiler water-level indicators, and in passenger ships also the lighting of saloons, stairways, ladders and passageways leading to the boat deck shall be supplied by not less than two independent feeders, with the lighting fixtures arranged in such a manner that even in case of failure of either feeder, as uniform lighting as possible is ensured. These feeders shall be supplied from different distribution boards, which in case of application of the lighting subdivided busbars in the main switchboard, shall be supplied from different busbar sections.

For cargo ships with the electrical installation of low power it is allowed that lighting of the above spaces, except for machinery spaces, be supplied by one feeder from the distribution board or from the main switchboard directly.

6.2.4 Local lighting fixtures in accommodation spaces, as well as socket outlets shall take power from the lighting switchboard by a separate feeder, other than that intended for supplying the common lighting fixtures.

6.2.5 If the ship is divided into main fire zones, then lighting of each zone shall be supplied by two feeders supplying the lighting circuits in other fire zones.

The lighting feeders shall be installed, as far as possible, in such a manner that a fire in one zone cannot damage the feeders supplying the lighting circuits in other zones.

In case of application of the lighting subdivided busbars in the main switchboard, these feeders shall be supplied from different busbar sections.

6.2.6 The main lighting circuits shall be so arranged that fire or any other casualty in the spaces accommoda-ting the main sources of power and/or main lighting transformers, if any, will not cause failure to the emergency lighting.

6.2.7 Permanently installed lighting fixtures in holds shall take power supply from a special switch-board. Apart from the switchgear and protective devices, this switchboard shall be provided with light signals to indicate switching-on of each individual lighting circuit.

For ships with electrical installations of low power the lighting fixtures of holds may be supplied from the switchboard located in the wheelhouse; and in this case, light signals are required to indicate the presence of voltage in the supply circuit of the lighting fixtures installed in holds.

6.3 EMERGENCY LIGHTING

6.3.1 The illumination obtained from the emergency lighting fixtures in separate spaces, locations and zones listed in 9.3.1.1 and 19.1.2.1.1 shall at least be equal to 10 per cent of the general illumination obtained from the main lighting fixtures (refer to 6.7). It is permitted that the illumination from the emergency lighting fixtures in the machinery space is equal to 5 per cent of the main illumination if the socket outlets fed from the emergency lighting circuit are provided.

The illumination shall be sufficient to easily find one's way to the means of escape (or shall be equal to 0,5 lx).

6.3.2 To obtain the illumination required in 6.3.1, the emergency lighting fixtures with incandescent lamps may be combined with luminescent lamps.

6.3.3 The main lighting fixtures are permitted for use as emergency lighting fixtures if they may be also fed from the emergency sources of electrical power.

6.3.4 The emergency lighting circuit shall be so arranged that in case of a fire or other casualty in the spaces containing the emergency sources of electrical power and/or emergency lighting transformers the system of the main lighting will not fail.

6.3.5 For emergency lighting use could be made of the stationary lighting fixtures with built-in accumulators, automatic recharging from the main lighting circuit.

6.3.6 Emergency lighting fixtures and shades of combined lamps shall be marked in red.

6.4 SWITCHES IN LIGHTING CIRCUITS

6.4.1 Two-pole switches shall be used in all lighting circuits.

In dry accommodation and service spaces it is allowed to use single-pole switches in circuits disconnecting individual lighting fixtures or groups of lighting fixtures rated at not more than 6 A and also in lighting fixture circuits designed for safety voltage.

6.4.2 For permanently installed external-illumination lighting fixtures, provision shall be made for switching off all the lighting fixtures from the wheelhouse or from any other permanently watched station on the upper deck.

6.4.3 The switches of lighting circuits of the fire extinction stations shall be located outside these spaces.

6.4.4 The lighting switches behind free-standing switchboards shall be installed near each access door behind the switchboard.

6.4.5 In emergency lighting circuits local switches shall not be used.

The use of local switches is permitted in circuits of such emergency lighting fixtures, which under normal conditions serve as the main lighting fixtures.

A switch shall be provided for emergency lighting in the wheelhouse.

Emergency lighting fixtures of embarkation stations, which under normal conditions serve as main lighting fixtures shall switch on automatically if the ship is de-energized.

6.5 GAS DISCHARGE LAMP INSTALLATIONS

6.5.1 Reactors and capacitors of gas discharge lamp installations shall be protected by securely earthed metal enclosures.

6.5.2 Capacitors of 0,5 μF and over shall be fitted with discharging devices. The discharging device shall be so designed that the voltage of the capacitor does not exceed 50 V in 1 min after disconnection from supply.

6.5.3 Reactors and transformers having a high inductive reactance shall be installed as close as possible to the lighting fixture they serve.

6.5.4 Gas discharge lamp installations supplied at over 250 V shall be provided with warning notices giving the voltage rating. All live parts of such installations shall be suitably protected.

6.6 SOCKET OUTLETS

6.6.1 Socket outlets for portable lighting fixtures shall be installed at least:

on deck near the windlass;

in the gyrocompass room;

in the radio equipment converter room;

in the steering gear compartment;

in the emergency generator set compartment;

in the machinery spaces;

behind the main switchboard;

in special electrical spaces;

in the propeller shaft tunnel;

in the wheelhouse;

in the radioroom;

in the vicinity of winches;

in the vicinity of the log and echo-sounder trunk or recess;

in spaces where centralized ventilation and air conditioning installations are located.

6.6.2 Socket outlets fed with different voltages shall be so designed as to prevent insertion of a plug intended for one voltage into a socket intended for higher voltage.

6.6.3 Socket outlets for portable lighting and other electric appliances installed on the open decks shall be mounted with their face looking downward.

6.6.4 Socket outlets shall not be fitted in machinery spaces below the plating, in enclosed fuel and oil separator rooms or where approved safety-type equipment is required.

6.7 ILLUMINATION

6.7.1 The illumination of particular spaces and zones shall not be below that specified in Table 6.7.1. This requirement is not applicable to ships provided with lighting circuits supplied at a voltage below 30 V.

The general lighting standards stated in Table 6.7.1 refer to a level of 800 mm above the deck (flooring) of the space, while the standards of general plus local lighting, to the level of working surfaces.

6.8 NAVIGATION LIGHTS

6.8.1 The navigation lights switchboard shall supply by separate feeders the masthead lights, sidelights and sternlight, and in towing, pushing, fishing, pilot vessels, vessels restricted in ability to manoeuvre and air-cushion vehicles it shall supply also permanently mounted lights listed in Table 2.4.1, Part III "Signal Means" of the Rules for the Equipment of Sea-Going Ships, and additional masthead and stern lights listed in Table 5.2.1 of the said Part of the Rules.

Table 6.7.1

Nos	Spaces and surfaces		Illumination, lux			
			Luminescent lighting		Incandescent lighting	
			general + local	general	general + local	general
1	Radioroom	At the predetermined level above the deck	—	—	—	100
		Operator tables in radioroom	—	—	200	—
2	Chartroom	At the predetermined level above the deck	—	100	—	50
		Chart tables	150	—	150	—
3	Wheelhouse	At the predetermined level above the deck	—	75	—	50
4	Machinery spaces, spaces for switchboards, manoeuvring and control stations and panels, spaces for automation facilities and gyrocompasses	At the predetermined level above the deck plating	—	75	—	75
		Surfaces of switchgear and control desks	200	100	150	75
		Main engine controls	150	100	150	75
		Passageways between boilers, machinery, ladders, platforms, etc.	—	75	—	30
		In front of boilers	100	75	75	75
5	Battery compartment	At the predetermined level above the deck	—	75	—	50
6	Propeller shaft tunnels, log, echo sounder trunks, chain lockers	At the predetermined level above the deck	—	50	—	20
		Surfaces of shaft bearings and connection flanges, etc.	75	—	50	—
7	Passageways on decks, gangways and lifeboat and liferaft positions	At the predetermined level above the deck	—	50	—	20
8	Overboard spaces in way of lifeboat and liferafts launching	Near the load waterline	—	—	—	5

6.8.2 The navigation lights switchboard shall be supplied by two feeders:

.1 one feeder from the main switchboard through the emergency switchboard;

.2 the second feeder from the nearest distribution board, which is not supplied from the emergency switchboard.

It is permitted to install the navigation lights control devices in the integrated bridge control console and taking the power in accordance with 4.5.2.

Where the main source of power of the ship is an accumulator battery and the main switchboard is installed in the wheelhouse, the navigation lights may be controlled directly from the main switchboard.

6.8.3 Navigation lanterns shall be connected to the fixed supply circuit by a flexible cable with a plug connector.

6.8.4 The supply circuits of navigation lights shall be of two-wire system with a double-pole switch for each circuit to be installed in the navigation light switchboard.

6.8.5 Each navigation light supply circuit shall be provided with protection in both wires and with indication of the navigation light switching in compliance with the requirements of 4.1.4, Part III "Signal Means" of the Rules for the Equipment of Sea-Going Ships.

The indication device of the navigation light switching shall be so designed and installed that its failure does not cause the navigation light disconnection.

The voltage drop at the distribution board supplying navigation lights including the system of indicating the lights operation shall not exceed 5 per cent at rated voltage up to 30 V and 3 per cent at rated voltage above 30 V.

6.8.6 Independent of the navigation light switching indication referred to in 6.8.5, provision shall be made for visual and audible alarms operating automatically in case of failure of any navigation light with the switch in the "on" position.

Alarms shall be supplied from a source or feeder other than that used for power supply to navigation light switchboard or from an accumulator battery.

6.8.7 Lamp holders and lamps used in navigation lanterns shall comply with the requirements of 3.1.7, Part III "Signal Means" of the Rules for the Equipment of Sea-Going Ships.

6.9 LIGHTING AND ILLUMINATION MEANS OF HELIDECKS

6.9.1 General.

6.9.1.1 Lighting and illumination means for landing areas of helidecks shall comply with the applicable requirements of Part III "Signal Means" of the Rules for the Equipment of Sea-Going Ships.

6.9.1.2 The lighting and illumination means for landing areas of helidecks shall at least provide for the following:

indication of the perimeter (boundaries) of the landing area;

illumination of the landing area;

indication of the elevated structures within the landing area.

6.9.1.3 Lights used for this purpose shall be protected to not lower than level IP56 and shall function reliably under environmental effects mentioned in Section 2.

6.9.1.4 All lighting and illumination means as well as other electrical equipment within the landing areas of helidecks, helicopter refuelling stations and hangars shall be of certified safe type and designed to not lower than the temperature class T3 and subgroup II A.

6.9.1.5 In respect to their lighting characteristics, the lights shall meet the requirements of ICAO (International Civil Aviation Organization), which shall be confirmed by the appropriate conclusion or by the Certificate of the Civil Aviation competent body.

6.9.1.6 The lighting and illumination means mentioned in this Section shall be supplied by a separate switchboard fed from the main and emergency power sources with automatic change-over in the event of loss of power.

6.9.2 Perimeter lighting.

6.9.2.1 All-round lights each of not less than 40 W chained up along the boundary of the landing area shall be provided to indicate the perimeter (boundaries) thereof (at least 8 lights).

6.9.2.2 The distance between adjacent lights shall not exceed 3 m. The lights to indicate the perimeter shall be yellow. Use of yellow and blue lights with sequential alternation thereof may be permitted.

6.9.2.3 The lights shall be divided into two independent circuits and supplied in such a manner that when the power to any one circuit fails, 50 per cent of lights to indicate the perimeter remain functioning.

6.9.2.4 After installation, the globes of the lights shall not rise to a height of more than 150 mm above the helideck level.

6.9.3 Illumination of the landing area.

6.9.3.1 The landing area and wind direction indicator shall be properly illuminated. For this purpose, floodlights may be used.

6.9.3.2 Appropriate measures shall be taken when the illumination means are being installed to avoid glare to pilots during take-off, landing and manoeuvering.

6.9.4 Obstruction/warning lights.

6.9.4.1 To provide flight safety, all considerably elevated structures and items such as superstructure components, drill and production strings, etc. shall be marked by special obstruction/warning red lights.

6.9.4.2 Structures and items rising to a height of 15 m and more above the helideck level shall be marked by obstruction lights throughout their full height at 10 m intervals beginning from the uppermost point of the structure.

6.9.4.3 All-round lights of at least 40 W shall be used as obstruction/warning lights.

6.9.4.4 Lights shall be divided into several independent circuits and supplied in such a manner that when power supply to one of the circuits fails, the basic part of the obsruction/warning lights remains functioning.

7 INTERNAL COMMUNICATION AND SIGNALLING

7.1 ELECTRIC ENGINE ROOM TELEGRAPHS

7.1.1 In addition to the requirements of the present Chapter, the engine room telegraphs shall meet the requirements of 3.3.1, Part VII "Machinery Installations".

7.1.2 Engine room telegraphs shall be provided with visual indication of the presence of voltage in the power circuit and audible warning of disappearance of voltage from the power circuit.

7.1.3 Engine room telegraphs installed in the wheelhouse shall be provided with an illuminated dial of regulated illumination.

7.1.4 Engine room telegraphs shall be fed from the main switchboard or from the navigation equipment switchboard.

If the ship is provided with the integrated bridge control console the engine room telegraph may be fed from this control console.

7.1.5 The engine room telegraph transmitter shall be so intalled in the wheelhouse that when orders are given out for ship's motion, the telegraph operating handle is shifted in the same direction with the ship. Vertical position of the handle shall correspond to the "stop" order.

7.1.6 Where engine room telegraphs and devices for remote control of the main engines and the controllable pitch propellers are installed on sloping desks of control panels, the handle in the "stop" position shall be perpendicular to the panel surface and be fixed precisely in this position.

7.1.7 Where two and more engine room telegraphs are located in close proximity to one another (on one deck), they shall ensure the transmission of an order from any telegraph and the reception of order by all of them simultaneously, without additional changing-over.

Change-over to telegraphs located on another deck or in another part of the ship shall be effected with the use of switches fitted on the navigating bridge.

7.1.8 Each engine room telegraph shall be provided with an audible signal arrangement that will ensure the operation of an audible signal on the bridge and transmission of orders and reception thereof in the engine room. In case of a wrong reply, the operation of the audible signal arrangement shall not stop (refer also to 3.3.1, Part VII "Machinery Installations").

7.2 INTERNAL SERVICE COMMUNICATION

7.2.1 In the absence of other types of two-way voice communication facilities, provision shall be made for independent two-way telephone communication between the wheelhouse and the control stations of the main propelling machinery as well as between the wheelhouse and the radioroom.

In the case of an enclosed or non-enclosed main control station, independent two-way voice communication shall be provided between this station and the wheelhouse, and between the wheelhouse and local control stations of main machinery and propellers.

For this purpose, use shall be made of independent two-way telephone communication or two-way telephone communication between the wheelhouse and the main control station with telephones connected in parallel and installed in the local control stations.

7.2.2 In addition to the communication facilities specified in 7.2.1, provision shall be made for separate system of telephone communication between the wheelhouse on one side and the following main service spaces and control stations: forecastle, poop, watch station on the mast, steering gear compartment, compartment containing the emergency switchboard, gyrocompass room, fire smothering station (refer also to 3.1.3.2.6, Part VI "Fire Protection"), spaces containing electric propulsion motors, cargo operations control station (in oil tankers), fire and rescue control station (in ships with distinguishing mark of provision with means for fire fighting aboard other ships in the class notation) and other spaces where equipment is installed ensuring safety of ship's navigation on the other side. Provision shall be made for telephone communication between the main or local control station of the main machinery and the engineers' accommodation.

For this purpose, a two-way loudspeaker device may be used instead of telephones.

When two-way voice communication is provided between the wheelhouse and the above spaces, additional communication facilities need not be installed.

7.2.3 The system of the internal service communication shall ensure signalling to a subscriber and clear voice communication under conditions of specific noise in places of installation of the communication facilities. When the service telephone sets are installed in the spaces of high noise intensity, measures shall be taken for noise absorption or additional earphones shall be provided.

7.2.4 For communication facilities mentioned in 7.2.1 and 7.2.2 use shall be made of sound-powered telephones or provision shall be made for power supply from the main source of electrical power and accumulator battery actuated automatically in case of failure of the main source of electrical power; the battery capacity shall be sufficient for supply of communication facilities during the time specified in 9.3.1.

7.2.5 A damage to or disconnection of one telephone set shall not interfere with operability of other sets.

7.2.6 The telephone sets specified in 7.2.1 for two-way voice communication between the wheelhouse and the main control station located in a separate space or between the wheelhouse and the local control stations of the main machinery and propellers shall be fitted with visual and audible alarms to indicate the call in the main control station and in the machinery space.

7.2.7 The two-way loudspeaker devices may be independent or may be combined with the command broadcast apparatus specified in Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships. The loudspeaker devices shall meet the requirements of 2.1.3, 2.1.4 and 6.22.2, Part II "Life-Saving Appliances" of the Rules for the Equipment of Sea-Going Ships.

7.3 SIGNALLING. GENERAL

7.3.1 The requirements cover the following systems signaling the equipment or ship's condition requiring attention of personnel or passengers, activating an audible and visual alarm:

.1 general alarm and fire alarm systems;

.2 fire detection system;

.3 warning alarm of extinguishing system release;

.4 indication of closure of watertight and fire doors and also the doors indicated in 7.12;

.5 machinery alarm system;

.6 high level of bilge water alarm;

.7 alarm on water presence in cargo holds of bulk carriers;

.8 engineer's alarm;

.9 personnel alarm, cargo control and gas detection alarm;

.10 side port doors condition alarm;

.11 alarm on presence of people inside refrigerated holds: "Man in hold" alarm (for ships used for processing the living resources of the sea and not engaged in their catching).

7.3.2 An opportunity to functionally test each alarm system shall be provided.

Unless otherwise stated, all alarm systems shall be designed on the fail safe principle with provision for power supply failure alarm, alarm on contact-to-frame fault or circuit break, as well as the possibility of checking visual and audible alarms operability.

7.3.3 Audible alarms shall be heard and distinguishable in all the spaces and areas they intended for.

7.3.4 Audible alarms of an alarm system shall be given until their acceptance (acknowledgement) is confirmed, and the visual indication of each separate alarm shall remain until the fault has been corrected.

7.3.5 The sound frequency of audible alarm devices, excepting a bell, shall be within the range of 200 Hz to 2500 Hz.

7.3.6 Where the visual alarm is applied, the colours specified in Table 4.6.5.1 shall be used unless otherwise stated.

7.3.7 The height of inscription text symbols for operating and alarm controls, unless they have been duplicated with symbols/a plate of an established pattern, shall be at least 7 mm, the width is 0,7 symbol height.

This requirement, excepting the visual alarms mentioned in 7.3.1, also applies to the texts of inscriptions above the controls in switchboards, control consoles, starting, protection and control equipment for electric drives of essential machinery listed in 1.3.2.1.5.

7.3.8 The texts of inscriptions above operating and alarm controls not mentioned in 7.3.7, as well as the texts of watch-keeping and other instructions used for the description of a working procedure, starting and control of an object shall have symbols of at least 3,5 mm high, the width is 0,7 symbol height.

7.3.9 Flashing alarms shall emit light within 50 per cent of the entire work cycle, the pulse frequency therewith shall be within the range of 0,5 Hz to 1,5 Hz.

7.4 GENERAL ALARM SYSTEM

7.4.1 Ships in which a general alarm given by voice or by any other means cannot be heard simultaneously in all locations where people may be, shall be fitted with electrical general alarm system that will ensure good audibility of signals in all such places. In addition to the requirements stated above, the general alarm system shall meet the requirements of 2.3.1 and 6.22.1, Part II "Life-Saving Appliances" of the Rules for the Equipment of Sea-Going Ships.

7.4.2 Sound devices shall be installed in the following places:

in machinery spaces;

in public spaces, if their floor area is more than 150 m^2;

in corridors of accommodation, service and public spaces;

on open decks;

in working spaces.

7.4.3 General alarm system shall be supplied from the ship mains and the busbars of the emergency distribution board in conformity with 9.3.1.3 and 19.1.2.1.4.

General alarm system may be energized from the ship mains and from an independent accumulator battery if provision is made for an automatic changeover of general alarm circuits to the battery. In this case, no supply either from the emergency source or from an intermediate emergency source of electrical power is necessary.

7.4.4 The general alarm system shall be energized continuously, no matter if the accumulator battery is set in position for charging or discharging.

7.4.5 In case a separate accumulator battery is used for supply of the general alarm system, it may also energize other internal communication and signalling facilities if the battery capacity is sufficient for simultaneous supply of all consumers for at least 3 hours and also if these facilities are so designed that a damage to one circuit will not interfere with operation of other circuits provided no longer supply time is required for those facilities.

7.4.6 In circuits supplying the general alarm system the protection only from short circuit shall be provided. Protective devices shall be fitted in both conductors of the feeder and also in circuits of each sound device.

Protection of several sound devices by one common protective device is permitted if in spaces where they are installed good audibility of other sound devices provided with independent protection is ensured.

7.4.7 General alarm sound devices shall be so located that a signal is clearly heard against the noise in the given space. Sound devices installed in spaces with high intensity of noise shall be fitted with luminous indicators.

The sound of general alarm devices shall differ in tone from the sounds of all other kinds of signalling. With the exception of bells, audible alarms shall have a sound frequency between 200 Hz and 2500 Hz. Facilities may be provided for regulating the audible signal frequency within the above limits.

7.4.8 The general alarm system shall be actuated by means of a double-pole self-return switch from the wheelhouse and from the space intended for the watch when moored in a port, if such a space is provided.

If the general alarm signal is not heard from the wheelhouse or from the station where it has been given, a pilot lamp shall be fitted after the switch to indicate that the general alarm system is activated.

The switches shall be provided with the inscriptions indicating their purpose.

7.4.9 No switching devices shall be incorporated into the circuits of the general alarm system other than the switch specified in 7.4.8. Where a power supply switch is installed on the general alarm system switchboard, provision shall be made for its interlocking in the "on" position or it shall be otherwise protected against access thereto of unauthorized persons.

It is permitted to use intermediate contactors controlled by the switch, but not more than one contactor in each loop.

7.4.10 Sound devices, switches and distribution devices of the general alarm system shall be provided with readily visible distinctive symbols.

7.4.11 The general alarm system shall consist of at least two loops controlled by one switch. Short-circuit protection shall be provided at both poles of each loop of the general alarm system.

7.4.12 Sound devices connected to different loops of the general alarm system shall be fitted in large area spaces (machinery spaces, boiler rooms, fish-processing shops, etc.).

7.5 FIRE DETECTION SYSTEM

7.5.1 Fire detection systems used on ships shall be of the Register-approved type and, in addition to the requirements of the present Chapter, meet the requirements of 4.2.1, Part VI "Fire Protection" and of the Fire Safety Systems Code (refer to 1.2, Part VI "Fire Protection").

7.5.2 Application of fire detectors located in spaces where explosive vapours may accumulate or in a flow of air sucked out of these spaces is regulated by 2.9, 19.2 and 19.3.

7.5.3 For the fire detection system, at least two sources of electrical power shall be provided. One of these sources shall be the emergency source of electrical power. The power shall be supplied by separate feeders intended solely for this purpose. In case of failure of the main source of electrical power, provision shall be made for an automatic change-over of supply to the emergency source with operation of an audible and visual signal.

Where an accumulator battery is the main source of power supply, two independent accumulator batteries (main and reserve) shall be provided, the capacity of either being sufficient for operation of the fire detection system for at least 3 days without recharging.

7.5.4 The smoke detection system based on air sampling (refer to 4.2.1.6, Part VI "Fire Protection") and the fans of this system shall be fed by separate feeders from the main and emergency sources or another independent source of electrical power.

7.5.5 Indicating units of the fire detection system, other than the those indicated in 7.5.4, shall be designed in such a manner that:

.1 any signal or damage to one circuit does not influence normal operation of other circuits;

.2 a fire-detection signal shall prevail over other signals fed to the indicator and to make it possible to determine the location of the space wherefrom this fire-detection signal has arrived;

.3 contact-type fire detector circuits are normally closed; it is permitted to use detectors with normally open circuits if the contacts are hermetically sealed and permanent damage control of the circuits is effected;

.4 provision is made for monitoring its operation.

7.5.6 Indicating units of the fire detection system shall produce information specified in Table 7.5.6.

A visual signal of fire detection shall be executed in such a manner that is consists of two indicators (two lamps or a double filament), or a special device shall be provided to check the proper condition of signalling lamps. The colour of a light signal shall comply with the requirements of 4.6.5.

Visual signals shall be separate for each kind of information.

Signals intended to determine the location of the space or area wherefrom a pulse has arrived may be common with the signal of fire detection or damage.

Visual signals shall function from the moment a pulse is received till the moment the cause of their operation has been removed; the signal specified in item 1 of Table 7.5.6 shall function continuously irrespective of the nature of supply.

7.5.7 The fire detection system shall meet the following requirements:

.1 the activation of any automatic detector or manually operated call point shall initiate a visual and audible signals at the control panel and indicating units. If the signals have not received attention within 2 min, an audible alarm shall be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of category A. This alarm sounder need not be an integral part of the fire detection system;

.2 the control panel shall be located on the navigating bridge or in the continuously manned engine control room. One indicating unit shall be located on the navigating bridge if the control panel is located in the main fire control station;

.3 indicating units shall, as a minimum, denote the section in which an automatic detector has activated or manually operated call point has operated;

Table 7.5.6

Nos	Signalling of operating conditions and faults	Signal of using temperature fire detection system	Signal of using systems, in which air from protected spaces enters indicating units
1	Operation of device	Visual	Visual
2	Power supply from emergency source	Visual	Visual
3	Signals of fire and location of area or space where outbreak of fire is detected	Audible Visual	Audible Visual
4	No draught in detection chamber	—	Visual Audible
5	No draught in pipelines	—	Visual Audible[1]
6	Disconnection in detector circuits	Visual Audible	—
7	Location of faults in detector circuit	Visual	—
8	Off position of detector circuit[1]	Visual	—
9	Power supply failure	Visual Audible	Visual Audible

[1] Recommended.

.4 clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections.

7.5.8 Fire detection systems with a zone address identification capability shall be so arranged that:

.1 no loop shall pass through a space more than once to prevent its damage at more than one point by a fire. When this is not practical (e.g. for large spaces), the parts of the loop passing through the space for the second time shall be installed at the maximum possible distance from the other parts of the loop;

.2 means are provided to ensure that any fault (e. g. power break, short circuit, earth) occurring in the loop will not render the whole loop ineffective. It means that a fault occurring in the loop only renders ineffective a part of the loop not being larger than a section of a system without means of remotely identifying each detector;

.3 all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (electrical, electronic, informatic);

.4 the first initiated fire alarm will not prevent any other detector to initiate further fire alarms.

7.5.9 The fire detectors containing ionising radiation sources (radioactive isotopes) shall have a certificate confirming their radiation safety issued by a competent body.

7.5.10 Detectors shall meet the following requirements:

.1 automatic detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. The possibility of using automatic detectors operated by other factors indicative of incipient fires may be considered by the Register provided they are no less sensitive than the above detectors. Flame detectors shall only be used in addition to smoke and heat detectors;

.2 smoke detectors required according to 4.2.1.1, Part VI "Fire Protection" shall operate before the smoke density exceeds 12,5 per cent obscuration per metre, but not until the smoke density exceeds 2 per cent obscuration per metre. Smoke detectors fitted in machinery spaces of category A shall operate before the smoke density reaches 50 per cent obscuration per metre;

.3 heat detectors fitted in spaces with a normal air temperature shall operate within the temperature limits of 54 to 78 °C when the temperature is increased to those limits at a rate less than 1 °C per min. The Register may consider the possibility of using heat detectors with higher rates of temperature increase taking into account their sensitivity;

.4 the temperature of heat detectors activation in drying rooms and similar spaces, which are characterized by high temperatures, may be set up to 130 °C inclusive, and in saunas up to 140 °C inclusive;

.5 heat detectors shall reliably operate at a temperature at least by 5 °C in excess of the temperature at which the sensor is set;

.6 in machinery spaces of category A the detectors may be used which reveal a seat of fire on appearing temperature pulsation (heat-pulse detectors). They shall be set to a temperature pulse frequency of 1,9 to 2,3 Hz and above, and operate when an amplitude is exceeded by $(2 \pm 0{,}5)$ °C whatever a space temperature may be;

.7 the type of all automatic detectors shall be so chosen that after the operation test they come back to normal operation without any components being replaced.

7.5.11 Sections and their cables shall meet the following requirements:

.1 automatic detectors and manually operated call points shall be grouped into sections;

.2 a section of automatic fire detectors which covers a control station, a service space or an accommodation space shall not cover a machinery space of category A. In case the fire detection system is fitted with individually identifiable fire detectors, a loop covering sections of automatic fire detectors in accommodation spaces, service spaces and control stations shall not serve machinery spaces of category A;

.3 where the fire detection system is not fitted with individually identifiable fire detectors, no section covering more than one deck within accommodation spaces, service spaces and control stations shall be permitted except the section serving an enclosed stairway. A number of enclosed spaces served by one section shall not exceed 50. In case the fire detection system is fitted with individually identifiable fire detectors, the sections may cover several decks and serve any number of enclosed spaces;

.4 a section shall not contain more than 100 detectors;

.5 cables of sections, including their feeding cables, being part of the system shall be so arranged as to avoid galleys, machinery spaces of category A, and other enclosed spaces of high fire risk except where it is necessary to provide fire detection or fire alarm in such spaces (refer to 16.8.1.8).

7.5.12 A fire detection system for periodically unattended machinery spaces of category A shall be so designed and the automatic detectors so positioned as to quickly detect the fire in any part of those spaces and under any normal operation conditions of machinery and variations of ventilation. Except in spaces of restricted height and where their use is especially appropriate, fire detection systems using only thermal detectors shall not be permitted. The fire detection system shall initiate audible and visual alarms, distinct from those of any other system not indicating fire, in sufficient number of places to ensure that the alarms are heard and observed on the navigating bridge and by a responsible engineer officer. When the navigating bridge is unmanned, the alarm shall sound in a continuously manned place.

7.5.13 A fire detection system for unattended machinery spaces, as required in 4.2.3, Part VI "Fire Protection", shall meet the following requirements:

.1 an indicating unit shall be installed on the navigating bridge, in the fire control station or another accessible place protected against fire in a machinery space of category A;

.2 a visual alarm on the indicating unit shall indicate the location (zone) of fire;

.3 a fire alarm shall initiate visual and audible alarms distinct from those of any other system which shall be provided at the locations sufficient to be heard and observed by the watch officer on the navigating bridge and by the responsible engineer officer;

.4 in case of power supply failure or any fault in the system, the audible alarm shall be initiated in addition to the visual alarm;

.5 the type and arrangement of detectors shall ensure quick detection of fire and prevent misoperation under normal operating conditions of machinery space. Provision shall be made for detectors of at least two types operating by different factors of fire detection. In spaces of less than 2,5 m in height, use of heat detectors may only be permitted on agreement with the Register;

.6 the arrangement of detector sections shall provide for the indication of fire location. An air movement due to machinery operation shall not affect the efficient operation of the fire detection system;

.7 detectors with controlled sensitivity shall have fixing arrangement and an indicator of the preset sensitivity;

.8 where provision is made for temporarily cutting off an individual detector or a section of detectors, this shall be clearly indicated. When a preset period of time expires, the switching-off detector or section of detectors shall automatically switch on;

.9 facilities shall be provided to release the fire alarm from the following locations:

.9.1 corridors having entrances to machinery spaces of category A;

.9.2 a wheelhouse;

.9.3 a control station in the machinery space.

7.6 WARNING ALARM OF EXTINGUISHING SYSTEM RELEASE

7.6.1 The warning alarm system shall comply with the requirements of 4.3, Part VI "Fire Protection".

7.6.2 The warning alarm system shall be energized from the ship's mains and an accumulator battery having a capacity sufficient for feeding the system during 30 min.

Provision shall be made for a device for automatic change-over of power supply for the warning alarm system to the accumulator battery in case of disappearance of voltage from the ship's mains.

7.7 INDICATION OF CLOSURE OF WATERTIGHT AND FIRE DOORS

7.7.1 Indication of closure of watertight doors shall comply with the requirements of 7.1.9, 7.1.11, 7.1.13, 7.4.1.7, 7.12.4 to 7.12.6 and 7.16, Part III "Equipment, Arrangements and Outfit", and indication of position of fire doors, with the requirements of 2.2.3.3, 2.2.4 and 3.1.2.3, Part VI "Fire Protection".

7.8 SOUND SIGNALS IN ENGINEERS' ACCOMMODATION SPACES

7.8.1 In the engineers' accommodation spaces the sound signalling system shall be provided for the emergency call of the engineer, which is actuated manually from the main machinery control station in the engine room or from the main control station, if any.

7.9 PERSONNEL ALARM

7.9.1 In ships where engineering watch is maintained by one person, or in ships with unattended machinery space, personnel alarm shall be provided, and in this case:

.1 the alarm system shall monitor safe and efficient condition of the machinery space personnel at least every 30 min;

.2 the alarm signal shall be transmitted to machinery spaces. If the signal is not acknowledged within 3 min, an appropriate signal shall be transmitted to navigating bridge and to accommodation, service and public spaces where machinery attending personnel might be staying;

.3 the alarm shall be put into operation by personnel attending machinery installation, when one person stays in the machinery space, and shall be disconnected after he leaves the space.

.4 the system shall also meet the requirements in 2.4.1.14, Part XV "Automation".

7.10 CARGO HOLD WATER LEVEL ALARM SYSTEM ON BULK CARRIERS AND SINGLE-HOLD CARGO SHIPS OTHER THAN BULK CARRIERS

7.10.1 Unless otherwise specified in this Chapter, the cargo hold water level alarm system on bulk carriers shall meet the requirements of 7.3 of the present Part, as well as 3.4.12, Part V "Subdivision" and 7.9.9, Part VIII "Systems and Piping".

7.10.2 The alarm system shall provide warning and emergency visual and audible alarms to indicate water level in cargo holds and for the ballast tanks and dry spaces, forward of the collision bulkhead — only emergency visual and audible alarms.

The warning alarm shall be activated when the water reaches the lower level with the emergency alarm activated when the water reaches the upper level as mentioned in 7.9.9, Part VIII "Systems and Piping". It is allowed to use one sensor to initiate warning and emergency alarms.

The error in the water level determination by detectors shall not exceed 100 mm.

The warning and emergency audible alarms shall be dissimilar.

The system shall provide clear identification of spaces from which the alarm has been released.

The audible alarm shall be silenced from the alarm panel installed on the navigating bridge.

7.10.3 The alarm system shall be supplied by the main and emergency sources of electrical power. Instead of the emergency source of electrical power an independent, continuously charged from the shipboard charging facility, accumulator battery complying with the requirements for the emergency source of electrical power and capable of supplying the system during at least 18 hours may be used.

In the event of loss of the main or emergency power and of automatic changeover to the emergency power, an emergency warning alarm shall be released.

7.10.4 The system shall be provided with self-monitoring capability. The alarm signal shall be activated when at least the following faults occur: short circuit, circuit break, contact-to-frame fault. For the computer-based systems, alarm shall be additionally provided to indicate the excess program execution time, central processor fault and input-output unit fault.

The system shall provide a possibility of checking the visible and audible alarms.

7.10.5 Provision shall be made in the system for disabling of the alarm in the events when the cargo holds and forepeak are used as water ballast tanks. In case where such ballast tanks are emptied, disabling shall be automatically released when the water level lowers below the level of the lowest detector fitted in the hold concerned.

7.10.6 The alarm system components fitted in cargo holds, ballast tanks and dry spaces shall be corrosion-resistant and protected to not lower than IP68 degree of protection and those fitted on open deck — to not lower than IP56 degree of protection.

7.10.7 Where the alarm system components are fitted in holds intended for the carriage of dangerous goods as well as other goods causing formation of explosive mixtures in the holds, these components and their circuit shall be of intrinsically safe type and protected to not lower than (*Exi*) standard.

7.11 ALARM OF ULTIMATE CONCENTRATION OF DANGEROUSLY EXPLOSIVE AND NOXIOUS GASES

7.11.1 The alarm systems for ultimate concentration of dangerously explosive and noxious gases shall comply with the requirements of 9.14.3, Part VIII "Systems and Piping" and 7.2.6, Part XII "Refrigerating Plants".

7.11.2 The system shall provide for actuation of audible and visual alarm signal to indicate ultimate gas concentration both in a protected space and in permanently manned stations. When several systems are provided, the alarm shall clearly indicate the particular system.

7.11.3 Two sources of electrical power, one of which shall be an emergency source, shall supply the alarm system. A separate accumulator battery (continuously charged from shipboard charging facility), which meets the requirements for the emergency source of electrical power, may be used as an emergency source.

7.12 INDICATION OF DOOR POSITION IN RO-RO PASSENGER SHIPS AND RO-RO CARGO SHIPS

7.12.1 Visual and audible alarms shall be installed on the navigation bridge and on each operating panel for closing/opening the doors specified in 7.4, 7.15, Part III "Equipment, Arrangements and Outfit" (visor outer bow doors, folding doors, inner bow doors, side shell and stern doors[1]) to provide separate indication of door closed and door fully locked.

The indication panel shall be provided with a lamp test function. The possibility for accidental or unauthorized turning off the indicator light shall be excluded.

7.12.2 The indicator system shall be designed on the fail safe principle and shall include the following:

.1 the indication panels installed on the navigation bridge and at doors' control station shall be provided with:

[1]Hereinafter referred to as "the doors".

power supply failure alarm,
earth fault alarm or open-circuit alarm,
a lamp test,
separate indication for door closed, door not closed, door locked and door not locked;

.2 limit switches (door position sensors) closed when the door is closed (when more limit switches are provided for each door they may be connected in series);

.3 limit switches closed when securing arrangements are in place (when more limit switches are provided for each door they may be connected in series);

.4 circuits for the indication of door closed/not closed and for door locked/not locked shall be independent, but may be designed in one multicore cable;

.5 in case of position of limit switches (door position sensors), indication to show: not closed/not locked, securing device is not in place — as appropriate.

7.12.3 The indicator system shall indicate by visual and by audible alarms in the following cases:

.1 if the door is not fully closed, or not fully locked, or

.2 at least one securing device is open or a locking device is unsecured.

7.12.4 The indication panel on the navigation bridge shall be equipped with a mode selection switch "harbour/sea voyage", so arranged that audible alarm is given on the navigation bridge if the vessel leaves harbour with the doors not closed or with any of the securing devices not in the correct position.

7.12.5 The power supply for the indicator system shall be independent of the power supply for operating and closing the doors and shall be provided with a backup power supply from the emergency source of power or any other reliable source (e.g. uninterruptible power supply).

The sensors of the indicator system shall be protected from water, ice formation and mechanical damages, or they shall have respective design resistant to the action of the above factors.

7.12.6 For ro-ro passenger ships, besides the indicator system of door position, provision shall be made of a water leakage detection system with audible alarm and television surveillance, which shall be so arranged as to provide an indication to the navigation bridge and to the engine control room of any leakage through inner, side shell and stern doors.

For ro-ro cargo ships, it is permitted that television surveillance of water leakage through side shell and stern doors is provided from the navigation bridge only.

7.12.7 To control the bow door and the inner bow door position a television surveillance system shall be fitted with a monitor on the navigation bridge and in the engine control room. The system shall monitor the position of the doors and a sufficient number of their securing devices. Special consideration shall be given for the lighting and contrasting colour of objects under surveillance.

7.12.8 A drainage system (sumps) shall be arranged in the area between the bow door and the ramp, or where no ramp is fitted, between the bow door and inner door. The system shall be equipped with an audible and visual alarm functions to the navigation bridge for the high water level alarm in the sump or for water level in these areas exceeding 0,5 m, proceeding from the type of structure.

7.12.9 For ro-ro passenger ships engaged in international voyages, the special category spaces and cargo spaces, indicated in 1.5.4.3 and 1.5.9, Part VI "Fire Protection", (in the absence of continuous patrolling or other effective means of monitoring) shall be monitored by means of television surveillance, so that any movement of vehicles in adverse weather conditions or unauthorized access of passengers thereto, may be detected whilst the ship is moving.

7.13 RELEASE INDICATION OF FIXED WATER-BASED LOCAL APPLICATION FIRE-FIGHTING SYSTEM

7.13.1 Release indication system shall comply with the requirements specified in 3.12, Part VI "Fire Protection".

7.13.2 The system shall be equipped with an audible and visual alarm functions regarding release of fire-fighting system both in the protected space and in permanently manned stations. Where several fire-fighting systems are installed the indication system shall clearly indicate the particular system activated.

7.13.3 The electrical and electronic equipment shall not be located within protected areas and in adjacent areas. Where the installation of electrical equipment in such areas is essential for safe operation of protected items, the electrical equipment shall have a degree of protection not less than IP44.

7.13.4 The electrical and electronic equipment within adjacent areas not exposed to direct spray, upon agreement by the Register, may have a lower degree of protection, provided relevant measures of the electrical equipment protection are taken (e.g. installation of extra inlet ventilation openings, filters, baffles, etc.).

7.13.5 Indication system shall be supplied from two sources of power, one of the two being emergency power source. A separate accumulator battery (continuously charged from the ship charging device) may be used as emergency power source when it complies with the requirements for emergency power source and provides system supply during not less than 18 hours.

7.14 TELEVISION SURVEILLANCE AND INDICATION SYSTEM

7.14.1 Television surveillance and indication systems shall comply with the requirements specified in 7.12.6, 7.12.7, 7.12.9 of the present Part and 7.15.5, Part III "Equipment, Arrangements and Outfit".

7.14.2 Generally, television surveillance and indication systems shall include the following:

.1 TV cameras;

.2 video displays;

.3 commutation switchboard;

.4 movement detectors;

.5 video recorders.

7.14.3 Television surveillance and indication system shall monitor respective areas and spaces and ensure video transmission to permanently attended control stations. Television surveillance and indication system shall give audible and visual signals when the condition of the monitored item/space is changed.

7.14.4 Television surveillance and indication system shall provide the following alarms:

.1 power failure;

.2 television surveillance and indication system failure;

.3 "TV camera — display" channel failure (short circuit, circuit break);

.4 TV camera(s) failure;

.5 movement detector failure;

.6 video recorder failure.

7.14.5 Television surveillance and indication systems may be of black-and-white or color type. The installation of this or that type depends on the required informative capacity of the system, parameters of the monitored item (location, lighting and other properties) and presumable targets (man, cargo, water and other purposes).

7.14.6 TV cameras transmitting video signals with a "signal/noise" (S/N) ratio not less than 50 dB shall be used in television surveillance and indication systems to minimize the noise on display.

7.14.7 Camera lens projection shall not be less than 480 television lines (tvl) (for color image) or not less than 570 tvl (for black-and-white image).

7.14.8 Proceeding from their location TV cameras used in television surveillance and indication systems shall be protected to not lower than the following levels:

.1 IP22 — for those fitted in the internal service spaces;

.2 IP44 — for those fitted in machinery spaces;

.3 IP56 — for those fitted on ro-ro decks and exposed parts of the weather deck.

7.14.9 The installation of TV cameras shall be such that all dead zones are covered.

7.14.10 Within internal spaces, TV cameras shall be fitted in places with minimum temperature difference to reduce condensate formation on camera lens.

7.14.11 TV cameras fitted on the exposed part of the deck shall have a thermo-casing with a sun visor.

7.14.12 Where the lighting of monitored area is below TV camera sensitivity, the item (item area) shall be equipped at night-time with additional visible or infra-red lighting. Therewith, either camera lens shall be not swamped by the lights, or TV cameras with back light compensation (BLC) function shall be used. Where television surveillance and indication system of color type is used, infrared lighting is impermissible.

7.14.13 Displays with a capacity to operate around the clock over a long period of time with a static picture shall be used to display the data received from TV cameras. The display diagonal for multi-image shall be within 15" — 21" with a resolution not less than 800 tvl for black-and-white image (400 tvl for color image) or within 10" — 14" for full-screen image displays with a resolution not less than 600 tvl for black-and-white image (300 tvl for color image).

7.14.14 Special type video recorders with a capacity to record over long periods of time or digital video data memory shall be used to record TV image.

7.14.15 The recording time for a 180 min videocassette shall not exceed 24 h with the use of special-type video recorder. The use of special-type video recorder with a longer recording time is only allowed if the reorder will automatically change over to real-time recording when alarm is activated by the movement detector.

7.14.16 Commutation switchboard shall provide priority display of areas where alarm has been activated.

8 PROTECTIVE DEVICES

8.1 GENERAL

8.1.1 Outgoing circuits of switchboards shall be protected against short circuits and overloads by means of devices installed at the inception of each circuit.

No overload protection is required for the switchboard supply circuit if the current consumers supplied from this switchboard have individual protective devices, and the cable of the supply circuit is selected on the basis of maximum working current.

8.1.2 Protective devices shall be so adapted to the characteristics of the equipment under protection that they operate under inadmissible overloads.

8.1.3 The electric protection system shall be discriminative with regard to both the overload currents and the short-circuit currents. Such protection system shall be designed so that its operation could not adversely affect the reliable functioning of ship's generating plant and the power supply of essential consumers. Short-circuit and overload protective devices shall not operate at starting currents of the electrical equipment under protection.

8.1.4 Overload protection shall be provided in:

.1 not less than one phase or positive pole in a two-wire system;

.2 not less than two phases in an insulated three-wire three-phase current system;

.3 all phases in a three-phase four-wire system.

8.1.5 Short-circuit protection shall be fitted in each insulated pole of a direct-current system or in each phase of an alternating current system.

Short-circuit current protective devices shall be set to operate at not less than 200 per cent of the rated current of the electrical equipment under protection. Operation of the protective devices may be without time delay or with a time delay necessary for the proper discrimination.

The short-circuit current protective device may be used for the protection of both the electrical equipment itself and its supply cable.

8.1.6 Where cables of reduced cross-sectional area are used in some lengths of a supply circuit, additional protection shall be provided for each of such cables unless the preceding protective device is capable of protecting the cable of reduced cross-sectional area.

8.1.7 Protective devices excluding the possibility of immediate repeated switching after operation of the protection shall not be used in supply circuits of the emergency switchboard, as well as in supply circuits of emergency consumers.

8.1.8 The design of the electronic and computer protection devices of generators and major services shall be such as to ensure easy identification and regulation of their operational settings.

Protection devices shall be equipped with the necessary apparatuses and instruction manuals shall be provided for checking their serviceability and the condition of the settings.

The protection devices of generators and important major services shall be tested once in 5 years to confirm the accuracy of their operation.

8.2 PROTECTION OF GENERATORS

8.2.1 Generators not intended for parallel operation shall be provided with means of protection against overloads and short circuits. Fuses may be used as protective devices for generators rated under 50 kW (kVA).

8.2.2 Generators intended for parallel operation shall be provided at least with the following means of protection:

.1 against overloads;

.2 against short circuits;

.3 against reverse current or reverse power;

.4 against under voltage.

It is necessary that the devices used for generator overload protection shall be provided with light and sound alarms to operate with a time delay of up to 15 min at the loads from 100 to 110 per cent of the rated current, and shall be capable of disconnecting the generator under protection after a time delay to suit the generator thermal time constant at the loads from 110 to 150 per cent of the rated current.

It is necessary that for a setting of the protection to operate at 150 per cent of the rated generator current the time delay shall not exceed 2 min for an alternating-current generator and 15 s for a direct-current generator. An overload exceeding 150 per cent of the rated current may be allowed where it is required by operating conditions and is admitted by the generator construction.

Overload protection settings and time delay shall be selected to suit the overload characteristics of the generator prime mover so that the prime mover is capable of developing the necessary output within the time delay period adopted. The protective devices used for generator overload protection shall not prevent the possibility of re-starting the generator immediately.

8.2.3 Automatic and selective disconnect of non-essential services shall be provided in the event of the generator overload. These services shedding may be carried out in one or several steps, depending on the generator overload capacity.

Therewith:

.1 the automatic disconnect is not allowed for primary essential services;

.2 the automatic disconnect is allowed for secondary essential services, provided disconnection will not prevent services required for safety being immediately available when the power supply is restored to normal operating conditions;

.3 the automatic disconnect is allowed for services needed for maintaining the minimum comfort habitability conditions for the crew and passengers on the ship.

Examples of such services are as follows:

cooking;

heating, domestic refrigeration;

domestic ventilation drives;

sanitary and fresh water, etc.

This requirement may be dispensed with in the case of electrical installations of low power if approved by the Register.

8.2.4 Reverse-current and reverse-power protection of generators intended for parallel operation shall be selected to suit characteristics of generator prime mover. The respective protection settings shall be in accordance with those specified in Table 8.2.4.

Reverse-power protection for alternating-current generators may be replaced by a different, but not less effective, means of protection. With settings specified in the Table the protection of the types in question shall be activated in 10 s.

Reverse-current protection for direct-current generators shall be installed in the pole opposite to that, in which the equalizer lead is connected. Reverse-power or reverse-current protection shall still be capable of operation when the voltage applied is reduced by 50 per cent although reverse current or reverse power may have altered values.

Reverse-current and reverse-power protection shall permit trasfer of power fed from the ship's mains (as, for example, from cargo winches).

8.2.5 Undervoltage protection shall ensure the possibility of a reliable connection of generators to the busbars at a voltage of 85 per cent or more of rated voltage and shall exclude the possibility of generator-to-busbar connection at a voltage less than 35 per cent of rated voltage. Besides, it shall disconnect the generators in case of reduction of voltage across its terminals in the range from 70 to 35 per cent of the rated value.

Undervoltage protection shall operate with a time delay for disconnection of generators from busbars in case of reduction of voltage and shall operate without time delay at the attempt to make connection to the generator busbars before the minimum voltage specified above is reached.

8.2.6 For generators with the ratings of 1000 kVA and above, it is recommended that provision shall be made for protection against internal faults, as well as for the protection of the lead connecting the generator to its switchboard and switch. Where the generator and its switchboard are installed in different spaces, such protection is compulsory.

8.2.7 If a turbine-driven direct-current generator is intended for operation in parallel, provision shall be made for tripping the circuit breaker of the generator when the automatic safety device of the turbine operates.

8.2.8 The current settings of protective devices with time delay shall be chosen in such a way that in any case a reliable interruption of short-circuit current is ensured after the prescribed time delay.

8.2.9 It is permitted to use safety devices in excitation systems of generators as protective devices for semiconductor elements.

8.3 PROTECTION OF ELECTRIC MOTORS

8.3.1 Outgoing feeders from switchboards supplying electric motors rated at over 0,5 kW shall be provided with means of protection against short-circuit currents and overloads, as well as with no-voltage protection if the motor need not be automatically restarted.

It is admissible for overload and no-voltage protective devices to be installed in the motor starting apparatus.

8.3.2 The overload protective devices for continuously running motors shall disconnect the motor under protection when the load is in the range from 105 to 125 per cent of the rated current.

Table 8.2.4

Kind of current	Limits of reverse-current or reverse-power protection settings related to generator prime mover	
	Turbine	Internal combustion engine
Alternating	2-6% of rated output of generator, kW	8 — 15 % of rated output of generator, kW
Direct	2-6% of rated current of generator, A	8 — 15 % of rated current of generator, A

It is admissible for the overload protective devices to be replaced by light and sound alarms, which is subject to special consideration by the Register in each case.

8.3.3 In supply circuits of fire pump electric drives the overload protective devices operating on the principle of electrothermal and temperature relays shall not be used.

The overload protective devices may be substituted by light and sound alarms.

8.4 STEERING GEAR PROTECTION

8.4.1 Only short-circuit current protection shall be provided for electric motors and control systems of electric or electrohydraulic steering gear.

Light and audible warning shall be provided of the motor overload or of any phase failure of the feeder supplying the motor.

8.4.2 Circuit breakers used to protect direct-current motors against short-circuit currents shall be set for release without time delay at currents not lower than 300 per cent and not higher than 400 per cent of the rated current of the motor under protection, while those used with alternating-current motors shall be set for release without time delay at currents not lower than 125 per cent of the peak starting current of the motor under protection.

In case fuses are used as protective devices the rated current for the fuse links shall be one grade of rating higher than it follows from the values specified for the electric motor starting currents.

8.4.3 For electric motors of the drives for the active means of the ship's steering short-circuit and overload protective devices shall be provided.

Overload protective devices of the above mentioned motors shall be fitted with light and sound alarms to warn of the motor overload and shall disconnect the electric motor over the load range specified in 8.3.2.

Short-circuit protection shall be in compliance with the requirements of 8.4.2.

8.4.4 For directly driven electric motors of steering gear, overload protection is permitted for locked rotor periods above 60 s with a setting of not less than twice the full load current of the motor protected.

Where such electric motors obtain their power supply via an electronic converter, e.g. for speed control, and which are limited to full load current are exempt from the requirement to provide overload protection. Alarm at electronic converter overload shall be provided with a setting equivalent to the highest permissible current for the normal operation of steering gear.

8.5 PROTECTION OF TRANSFORMERS

8.5.1 Short-circuit and overload protective devices shall be installed on the supply feeders of transformer primaries.

Transformers rated up to 6,3 kVA may be protected by fuses only.

It is admissible for transformer overload protection to be replaced by light and sound alarms subject to special consideration by the Register in each case.

No overload protection or alarm is required for voltage transformers and supply transformers of the control circuits.

8.5.2 Where transformers are intended for parallel operation, it is necessary that switches shall be provided to disconnect their primaries and secondaries, but not necessarily at the same time.

If such transformers are fed from different main switchboard sections, which may be isolated in service, provision shall be made for an interlock to preclude their parallel operation in case of main switchboard sections isolation.

8.5.3 The switching-over of instrument current transformers shall be so arranged as to prevent the possibility of their secondary windings being on open circuit.

8.6 PROTECTION OF ACCUMULATOR BATTERIES

8.6.1 Means of protection against short-circuit currents shall be provided for accumulator batteries other than those, which are designed to start internal combustion engines.

8.6.2 Each battery charging system shall be provided with protection against battery discharge due to a drop or loss of the charger output voltage.

8.6.3 For accumulator batteries designed for starting internal combustion engines, it is recommended that disconnectors shall be fitted at the start of the circuit on the accumulator side to disconnect the batteries from services (the disconnector may be fitted in one pole).

8.7 PROTECTION OF PILOT LAMPS, VOLTMETERS, CAPACITORS AND VOLTAGE COILS

8.7.1 Pilot lamps, as well as measuring and recording instruments shall be provided with short-circuit protection or short-circuit current limiting devices.

Pilot lamps may have no short-circuit protection of their own, nor short-circuit current limiting devices, provided that all the conditions specified below are met:

.1 the lamps are enclosed together with the device;

.2 the lamps are supplied from circuits inside the enclosure of the device;

.3 the protection of the circuit of the device is rated for current not exceeding 25 A;

.4 a fault in the lamp circuit is not liable to cause an interruption in the operation of an essential service.

Short-circuit protection or current limiting devices shall be located as close as practicable to the terminals of the device under protection on the supply side.

8.7.2 Radio interference suppression capacitors installed in the circuits of main and emergency switchboards, generators, and essential electrical installations shall be protected against short-circuit currents.

8.7.3 The voltage coils of apparatus and devices for control and protection shall be protected against short-circuit current, but they may have no protection of their own, provided that the conditions specified below are met:

.1 the coils are enclosed with the device, are under overall protection and belong to the control system of one device;

.2 the coils are supplied from a device circuit, the protection of which is rated for current not exceeding 25 A.

8.8 PROTECTION OF POWER SEMICONDUCTOR UNITS

8.8.1 Provision shall be made for protecting power semiconductor units from internal and external overvoltage.

8.8.2 Semiconductor element units shall be protected against short-circuit. The overload protection of diodes and semiconductors shall be isolated from the overload protection of power circuits.

8.8.3 Where only one consumer is available, a common overload protection is permitted for diode and semiconductors units, and power circuits.

8.9 RESIDUAL-CURRENT DEVICES (RCD)

8.9.1 To protect personnel against current injury and to protect some kinds of electrical equipment against single-phase earth fault residual-current devices shall be used.

8.9.2 The residual-current devices shall be fitted in the supply circuits of socket outlets intended to feed the portable equipment and in the supply circuits of cabin's socket outlets as well as the socket outlets in public and other spaces with the voltage in excess of the safe one (50 V).

8.9.3 The residual-current devices shall be set to operate at zero sequence current within 10 to 30 mA.

8.9.4 For essential electrical equipment, installation of the residual-current devices is not permitted.

9 EMERGENCY ELECTRICAL INSTALLATIONS

9.1 GENERAL

9.1.1 In each self-propelled ship, an autonomous emergency source of electrical power shall be provided. Such source is not required for ships, in which the main sources of electrical power are accumulator batteries, on condition that at least one of the batteries installed satisfies the capacity and location requirements imposed upon the emergency source of electrical power.

In the case of non-self-propelled ships, the installation of an emergency source of electrical power is subject to the special approval by the Register in each case.

9.1.2 A generator or an accumulator battery may be used as an emergency source of power.

9.1.3 The capacity of the emergency source of power shall be sufficient to supply simultaneously all those services that are essential for the safety of navigation in an emergency. In ships where electrical power is necessary for propulsion, the capacity of the emergency source of electrical power shall be sufficient to restore propulsion to the ship (in conjunction with other machinery, as appropriate) from a dead ship condition within 30 min after blackout.

9.1.4 Facilities shall be provided for functional testing of the complete emergency installation, including testing of automatic starting arrangements of the diesel generator.

9.1.5 An indicator shall be mounted in the main control station or on the main switchboard to show when the battery, which serves as an emergency source of electrical power, is being discharged.

9.1.6 The emergency sources of electrical power shall be provided only with short-circuit protection. If the emergency source of power is a generator, in the main control station or in the main switchboard visual and audible alarms shall be fitted to warn of the generator overload.

9.2 SPACES OF EMERGENCY SOURCES OF ELECTRICAL POWER

9.2.1 The spaces of emergency sources of electrical power and of their transformers (if any), of emergency transitional sources of electrical power, emergency distribution board and distribution board of emergency lighting shall be located above the uppermost continuous deck outside machinery casings and astern from forepeak bulkhead (collision bulkhead). The above mentioned spaces in ships covered by the requirements of Part V "Subdivision" shall be also located, as a minimum, at a height of 300 mm above the deepest (damage) waterline.

The exits from the spaces shall be easily accessible and shall be direct exits to the open deck, on which the emergency source of electrical power is installed.

9.2.2 The arrangement of emergency sources of electrical power and pertinent transformers, if any, of transitional sources of electrical power, emergency distribution board and distribution board of emergency lighting with regard to the main sources of electrical power and pertinent transformers, and with regard to the main distribution board, shall be such that a fire or another emergency in the space of the main source of electrical power, of pertinent transformers, main distribution board or in any machinery space of category A would not hamper the supply, control and distribution of electrical power from the emergency source.

9.2.3 Spaces containing emergency sources of electrical power, pertinent transformers, transitional sources of electrical power, emergency distribution board and distribution board of emergency lighting shall not, where possible, be adjacent to machinery and boiler spaces or to spaces containing the main source of electrical power, pertinent transformers and main distribution board.

In case of adjacent arrangement, the decks and bulkheads separating these spaces shall be constructed in accordance with the requirements of Part VI "Fire Protection" relating to control stations.

9.2.4 Emergency distribution board shall be as close as possible to the emergency source of electrical power.

9.2.5 Where a generator serves as the emergency source of electrical power, the emergency distribution board shall be installed in the same space as the diesel generator except where such an arrangement would adversely affect the distribution board operation.

All starting arrangements, charging facilities and starter accumulator batteries of the emergency unit shall also be installed in this space, provided the requirements of 13.2 are complied with.

9.2.6 The emergency diesel generator space shall be provided with heating appliances to ensure the temperature in the space sufficient for starting, without fail, of the emergency generating set and ventilation in accordance with the requirements of 12.5.3, Part VIII "Systems and Piping".

9.2.7 Where the emergency source of electrical power is an accumulator battery, this battery and the emergency switchboard shall be installed in separate spaces.

The requirements for the battery compartments are given in 13.2.

9.3 EMERGENCY SOURCES OF ELECTRICAL POWER IN CARGO SHIPS

9.3.1 In cargo ships, the emergency sources of electrical power shall supply the following services:

.1 emergency lighting for:

all corridors, stairways and exits from service spaces as well as passenger lift cars and trunks;

machinery spaces, main generating stations;

all control stations, main and emergency switchboards;

emergency diesel generator space;

wheelhouse;

chartroom and radioroom;

stowage positions for emergency and fireman's outfit and also positions where manual fire alarms are fitted;

steering gear compartments;

positions at fire and sprinkler pumps, emergency bilge pump and starting positions of their motors;

cargo pump rooms;

helicopter hangars and landing areas;

gyrocompass space;

medical rooms;

.2 navigation lanterns, lanterns of "Vessel not under command" signal and other lanterns required by Part III "Signal Means" of the Rules for the Equipment of Sea-Going Ships;

.3 internal communication means and general alarm signals;

.4 radio equipment and navigational equipment according to the requirements of Part IV "Radio Equipment" and Part V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships where the emergency source of power is a diesel generator;

.5 fire detection and alarm systems;

.6 daylight signalling lamps, sound signal means (whistles, gongs, etc.), manual calling and other signals required under emergency conditions;

.7 machinery and devices mentioned under 3.2.1.2, 3.4.7, 3.7.3.7, Part VI "Fire Protection";

.8 electric drives of watertight doors with their indicators and alarms;

.9 electric drives of devices holding fire doors;

.10 other systems, the operation of which would be found necessary by the Register to ensure the safety of the ship and the persons on board.

In ships of unrestricted service and restricted area of navigation **R1** of 300 and above gross tonnage, the emergency sources of electrical power shall ensure the supply of services listed under 9.3.1.1 to 9.3.1.9 during 18 hours.

Consumers mentioned under 9.3.1.3 to 9.3.1.6 may be supplied from their own batteries arranged as provided for in 9.2 and having a capacity sufficient to supply those consumers during 18 hours.

For ships of a restricted area of navigation **R3** with gross tonnage of 300 and upwards, the period of 18 hours may be changed to 12 hours.

For ships of less than 300 gross tonnage, the period of 18 hours may be changed to 6 hours in the case of unrestricted service and restricted area of navigation **R1** and to 3 hours in the case of restricted areas of navigation **R2**, **R2-RSN**, **R3-RSN** and **R3**.

9.3.2 The emergency source of electrical power shall ensure, during 3 hours, the emergency lighting of muster and embarkation stations for boarding life-saving appliances on deck and overboard according to 2.3.4 and 2.7.7, Part II "Life-Saving Appliances" of the Rules for the Equipment of Sea-Going Ships.

9.3.3 The supply of steering gear shall be effected from the emergency source of electrical power in accordance with 5.5.6.

9.3.4 Where a generator is used as the emergency source of electrical power, it shall be:

.1 driven by an internal combustion engine (refer to 2.2.5, Part IX "Machinery");

.2 automatically started upon failure of the electrical supply from the main source of electrical power and automatically connected to the emergency switchboard, and consumers stipulated under 9.3.7 shall be automatically supplied by the emergency generator. The total time of starting and load take-over by the generator shall not exceed 45 s;

.3 in case the automatic start of emergency unit stipulated by 9.3.4.2 shall not take place within 45 s, an emergency transitional source of electrical power shall be provided, which shall start immediately on failure of the main source of electrical power.

9.3.5 Where an accumulator battery is used as the emergency source of electrical power, it shall:

.1 operate without recharging with voltage variations across the terminals within 12 per cent of rated voltage during the whole discharge period, where voltage variations across the terminals of accumulator battery connected to an electronic voltage converter are determined by the permissible range of voltage variation across the terminals of the converter;

.2 be automatically connected to emergency distribution board busbars in case of failure of the main source of electrical power and supply at least the consumers mentioned under 9.3.7 during the time stipulated by 9.3.1 excepting electric drives of fire doors with their indicators and alarms, which can be supplied during 30 min.

9.3.6 As transitional emergency source of electrical power stipulated by 9.3.4.3, an accumulator battery shall be used, which shall operate without recharging with voltage variations across the terminals within 12 per cent of rated voltage during the whole discharge period. Voltage variations across the terminals of accumulator battery connected to an electronic voltage converter are determined by the permissible range of voltage variation across the terminals of the converter.

9.3.7 The capacity of the battery serving as the transitional source of electrical power shall be sufficient to supply, during 30 min, the following consumers:

.1 lighting and essential navigating lights according to 9.3.1.1, 9.3.1.2 and 9.3.2;

.2 all internal communications and announcing systems required in an emergency;

.3 general alarm system, fire detection and alarm system and warning system on starting a smothering fire-extinguishing system;

.4 daylight signalling lamps, sound signal means (whistles, gongs, etc.);

.5 command broadcast apparatus in accordance with item 12 of Table 2.3.4, Part IV "Radio Equipment" of the Rules for the Equipment of Sea-Going Ships;

.6 closing gear of watertight doors, their position indicators and signals warning of their closure;

.7 ship's security alarm system and AIS installation required by Part IV "Radio Equipment" and Part V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships.

Services listed under 9.3.7.2 to 9.3.7.7 may not be supplied from the transitional source if they have their own accumulator batteries, by which they are supplied during the required period of time.

9.3.8 For Class **INF2** and Class **INF3** ships, in accordance with the classification given in 2.14.1, Part VI "Fire Protection", regardless of the navigation area and tonnage of the ships, the emergency source of electrical power shall supply the services listed in 2.14.3 and 2.14.5, Part VI "Fire Protection" for a period of 36 hours.

9.4 DISTRIBUTION OF ELECTRICAL POWER FROM EMERGENCY SOURCES

9.4.1 Under normal service conditions, emergency distribution board shall be supplied from the main distribution board. The supply feeder shall have an overload and short-circuit protection fitted at the main distribution board.

At the emergency distribution board, a switch shall be provided, which shall switch off automatically in the case of de-energizing the busbars of the main distribution board.

Where the main distribution board shall be supplied from the emergency distribution board, the automatic switch at the emergency distribution board shall be provided with short-circuit protection at least.

9.4.2 The emergency generator, during the stay of the ship in port, may be used to supply non-emergency consumers (refer also to 2.2.6, Part IX "Machinery"), which is subject to special consideration by the Register in each case. In doing so, the following conditions shall be met:

provision is made for automatic disconnection of non-emergency consumers from the emergency distribution board to prevent overloading of the generator and to ensure the supply of emergency consumers;

damage of any control, protection and alarm circuits intended to maintain operation of the emergency generator during the stay of the ship in port, shall not affect the work of the main and emergency electrical power sources;

arrangements are provided to select the operating modes of emergency generators with a quick change-over to emergency mode being possible;

provision is made for instructions to be available onboard, for bringing all the controls (valves, switches, etc) in a position ensuring independent operation of the emergency generator when the ship is underway, and also containing information on the required oil fuel capacity, on the position of the operating mode switch (if any), on the position of ventilation closures, etc.

9.4.3 Consumers listed under 9.3.1 and 19.1.2 shall be supplied through separate feeders from the busbars of the emergency distribution board fitted up with relevant switch gear and protection. Supply of consumers mentioned under 9.3.1.2 to 9.3.1.6 and 19.1.2.1.2 to 19.1.2.1.6 may be effected from the main control console in the wheelhouse, which is supplied in conformity with 4.5.2.

9.4.4 Where a transitional source of power is available, consumers listed under 9.3.7 and 19.1.2.7 shall be supplied through a special distribution board on the feeders, of which no switches shall be fitted.

9.4.5 The switchboards for emergency services shall be installed above the bulkhead deck.

9.5 STARTING ARRANGEMENTS FOR EMERGENCY DIESEL GENERATORS

9.5.1 The following arrangements may be used as starting arrangements for emergency diesel generators:

.1 electric starter with its own accumulator battery and charging device;

.2 compressed air system with its own independent air receiver;

.3 hydraulic starting system;

.4 manual starting arrangements: starting handle for manual cranking, inertia starters, manually charged hydraulic accumulators or powder charge cartridges.

9.5.2 Each emergency generating set arranged to be automatically started shall be equipped with a starting device of an approved type with a stored energy capability of at least three consecutive starts. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy shall be provided for additional three starts within 30 minutes unless manual starting can be demonstrated to be effective.

9.5.3 Where automatic starting of the emergency diesel generator is not required, manual starting is permissible with the use of one of the starting arrangements specified in 9.5.1.4.

When manual starting is not practicable, the starting arrangements shall comply with the requirements of 9.5.2.

9.5.4 The starting arrangements of the accumulator batteries and the electric drives of the machinery ensuring the functioning of the compressed air or hydraulic systems of the emergency diesel generator starting shall be supplied from the emergency switchboard by separate feeders.

9.6 ALARM SYSTEM AND PROTECTION OF EMERGENCY DIESEL GENERATOR DRIVES

9.6.1 Emergency diesel generator drives having power of 220 kW and above shall be equipped with a protective device ensuring the shutdown of the engine in case of overspeed.

9.6.2 All protective devices that may influence the shutdown of emergency diesel generator drives, except for those preventing overspeed, shall be automatically overridden when the emergency diesel generator is in remote control or automatic mode during navigation. This requirement covers all emergency diesel generators regardless of their drives' output.

9.6.3 In addition to the remote fuel stop control, a local means of emergency shutdown of emergency diesel generator drives shall be provided.

9.6.4 For emergency diesel generator drives alarm system shall be activated at:

fuel oil leakage from high pressure pipes;

lubricating oil pressure below the minimum permissible value;

high temperature of cooling water or cooling air.

9.6.5 For drives having power of 220 kW and above, in addition, provision shall be made for alarm system activating at:

high lubricating oil temperature;

pressure or flow of cooling water below the minimum permissible value;

overspeed.

9.6.6 For drives having power of more than 2250 kW or with cylinder bore of more than 300 mm, in addition, provision shall be made for alarm system activating at excess of the oil mist concentration in crankcase.

9.6.7 Alarm system shall comply with the requirements given in 2.4.1, Part XV "Automation".

9.6.8 Grouped alarms shall be arranged on the navigating bridge.

9.6.9 Proceeding from the power of drives, local indication of the parameters listed in 9.6.4 to 9.6.6 shall be provided (within the same space as the emergency diesel generator) independent of the alarm and safety systems.

9.7 UNINTERRUPTIBLE POWER SYSTEM (UPS)

9.7.1 Uninterruptible power system (UPS), in addition to the requirements set forth below, shall comply with the requirements of IEC 62040 and applicable requirements of national standards.

9.7.2 UPS complying with these requirements may be used as emergency or transitional sources of electrical power as required by the present Part.

9.7.3 UPS type selection shall be appropriate to power supply requirements of the connected load equipment.

9.7.4 UPS shall be provided with a bypass, which ensures power supply to connected load from the ship's mains if the inverter fails.

9.7.5 Each UPS shall be provided with audible and visual alarm to be given in normally manned location for:

.1 power supply failure to the connected load;

.2 earth fault;

.3 operation of battery protective device;

.4 when the battery is being discharged; and

.5 when the bypass is in operation for on-line UPS.

9.7.6 The requirements for location of the UPS shall be similar to the requirements for the location of the emergency or transitional source of electrical power.

9.7.7 UPS utilising sealed batteries may be located in any space other than the accommodation space, provided sufficient ventilation is ensured in the space.

9.7.8 UPS shall maintain rated voltage and frequency on the load side throughout the whole time necessary to supply the connected services.

9.7.9 On restoration of the voltage in the supply circuit, the capacity of the UPS rectifier shall be sufficient to maintain rated voltage and frequency on the load side with simultaneous recharging the battery by the maximum possible charging current.

9.7.10 The accelerated (boost) charging of the UPS batteries by the maximum possible charging current shall be interlocked with the ventilation of the space where the UPS batteries are installed.

10 ELECTRICAL MACHINES

10.1 GENERAL

10.1.1 The materials of propulsion motors shafts, generators and slip coupling built into the shafting shall comply with the requirements of 3.7, Part XIII "Materials".

10.1.2 Alternating-current generators together with voltage correctors shall be capable to sustain, under steady short-circuit conditions, at least three-times the rated current within 2 s.

10.1.3 Electric propulsion generators and electric propulsion motors, or, where justified, also machines of different designation, shall have heating arrangements to maintain their temperature at least 3 °C above the ambient air temperature.

10.1.4 Generators built into the shafting of the main machinery shall have split stators and bearing shields if, due to the shaft arrangement, the stator displacement in the direction of the shaft from the rotor is not possible. Such generators shall have an air gap preventing mechanical contact of the rotor and stator under the most unfavourable service conditions.

10.1.5 Rotors and armatures of alternating and direct-current machines shall be capable of withstanding for 2 min, without damage and permanent set, the following increased speeds of rotation:

.1 generators, rotating coverters and electric slip coupling and brakes: 120 per cent of the rated speed, but at least by 3 per cent more than the maximum speed transient process;

.2 series-wound motors: 120 per cent of the maximum permissible speed as indicated on the rating plate, but not less than 150 per cent of the rated speed;

.3 all motors other than mentioned above: 120 per cent of the maximum no-load speed.

10.1.6 Where a machine is so designed that after installation on board the ship its bottom portion is positioned below floor level, ventilation air intake shall not be through the bottom part of the machine.

10.1.7 Application of external cooling fans is not recommended for machines intended for installation on weather decks.

10.1.8 The power of electric motors supplied from an electrical power source, which does not comply with the requirements of 2.2.1.3, shall be calculated taking into account the additional heating due to the higher harmonic components.

10.2 SLIP RINGS, COMMUTATORS AND BRUSHES

10.2.1 Direct-current machines for driving the propulsion plants and direct-current machines rated at 200 kW and over shall be provided with sight holes to enable observation of the commutator and brushes without removing the lids.

10.2.2 The permissible wear of commutator segments or slip rings shall be indicated on their sides. It shall be taken equal to at least 20 per cent of the commutator segment or slip ring height.

10.2.3 For armatures more than 1000 kg in mass provision shall be made to allow reconditioning of the commutator without removing the armature from the machine.

10.2.4 A flexible copper conductor shall be used for drawing current from brushes. Brush holder springs shall not be used for this purpose.

10.2.5 The position of brushes in direct-current machines shall be clearly and indelibly marked.

10.2.6 Commutator type machines shall be capable of operating practically without sparking at any load from zero to rated value. No sparking shall be possible at the specified overloads, reversals or startups, to such an extent as to cause damage to brushes or commutators.

10.3 BEARINGS

10.3.1 Bearings shall be so designed as to avoid the possibility of oil splashing or leaking along the shaft and coming into contact with the machine windings or live parts.

10.3.2 The casing of the sliding bearing shall be fitted with a hole for excessive lubricating oil drain and with a lid in the upper part of the casing. Oil level indicators shall be provided on machines rated at 100 kW or more.

10.3.3 Pressure lubrication system shall incorporate pressure indicators for oil entering the bearing.

10.3.4 In electric propulsion machinery, or machines of different designation, where so justified, provisions shall be made to prevent flow of shaft currents through sliding friction bearings.

10.3.5 Generators driven by belts or chains from the main machinery of the ship shall be so designed that the effect of the lateral forces is taken into account.

10.4 TEMPERATURE DETECTORS

10.4.1 Stators of alternating-current machines rated at over 5000 kW, or having a core length of more than 1 m, shall be provided with temperature detectors installed where the machine may be expected to develop the highest temperatures.

10.4.2 Embedded temperature detectors are recommended for electric motors with short-time or intermittent operating conditions.

10.4.3 It is recommended that overload protection for windlass-driving electric motors shall be by means of embedded temperature detectors so selected that the protection device will disconnect the motor when the temperature rise limit for the insulation employed is exceeded by more than 30 per cent.

The terminals of the detector shall be located so as to be easily accessible.

10.5 OVERCURRENT

10.5.1 Generators shall be so designed that after reaching the steady-state temperature corresponding to the rated load they shall be capable of sustaining overcurrent as specified in Table 10.5.1.

Table 10.5.1

Type of generator	Overcurrent, %	Duration of overload, s
a.c.	50	120
d.c.	50	15

10.5.2 Electric motors shall be so designed that they are capable of developing, without stopping or sudden rotation frequency changes, the increased torque specified in Table 10.5.2.

Table 10.5.2

Nos	Type of motor	Overload in torque, %	Duration of overload, s	Testing conditions
1	Synchronous motors, as well as squirrel-cage motors with starting current not less than 4,5 times the rated current	50	15	Frequency, voltage and excitation to be maintained at rated levels
2	Induction motors for continuous and intermittent duties	60	15	Frequency and voltage to be maintained at rated levels
3	Motors as specified in item 2, but for short-time and continuous duty with varying load	100	15	Frequency and voltage to be maintained at rated levels
4	Direct-current motors	50	15	Voltage to be maintained at rated level

10.6 ALTERNATING-CURRENT GENERATORS

10.6.1 General.

10.6.1.1 Each alternating-current generator shall have a separate, independent automatic voltage regulation system.

10.6.1.2 Alternating current generators shall possess sufficient excitation capacity to maintain the rated voltage with an accuracy of 10 per cent for 2 min at generator overcurrent equal to 150 per cent of the rated value and at a power factor 0,6.

10.6.1.3 Protection of alternating-current generators shall comply with the requirements of 8.2.

10.6.2 Voltage regulation systems.

10.6.2.1 Alternating-current generators shall have automatic voltage regulation systems ensuring that the voltage may be maintained within (2,5 per cent of the rated value (up to 3,5 per cent for emergency generators) at all load changes from no-load to rated load values at the rated power factor. The speed in this case shall be within the range specified in 2.11.3, Part IX "Machinery".

10.6.2.2 A sudden change in the balanced load of a generator running at rated speed and rated voltage, under given current and power-factor conditions, shall not cause a drop of voltage below 85 per cent or a rise above 120 per cent of the rated value. After the completion of transient processes, the generator voltage shall be restored within not more than 1,5 s with a deviation from the rated value being ± 3 per cent. For emergency sets these values may be increased, respectively, to 5 s and ± 4 per cent of the rated voltage.

Where no precise data are available on peak values of sudden load that may be connected additionally to the existing generator load, these may be taken equal to a load of 60 per cent of the rated current at a power factor of 0,4 or less, which is connected at idle speed and then disconnected. The speed in this case shall be within the range specified in 2.11.3, Part IX "Machinery".

10.6.2.3 For alternating-current generators the deviation from sine voltage shall not be more than 5 per cent of the harmonic component peak value.

10.7 DIRECT-CURRENT GENERATORS

10.7.1 General.

10.7.1.1 Compound-wound and shunt-wound direct-current generators shall be equipped with automatic voltage regulation systems.

10.7.1.2 Protection of direct-current generators shall comply with the requirements of 8.2.

10.7.2 Voltage regulations.

10.7.2.1 Voltage regulators of direct-current compound-wound generators shall enable reduction of no-load voltage, with the generator cold, by not less than 10 per cent below the rated generator voltage, taking into account the increased revolutions of the prime mover running at no load.

10.7.2.2 Manual voltage regulators shall be so designed that the voltage increases when their controls are rotated clockwise.

10.7.2.3 Voltage regulators of direct-current shunt-wound generators shall be so designed that, when the field current is removed, the field winding shall be closed to the discharge circuit.

10.7.2.4 Direct-current compound-wound generators shall have independent devices for voltage regulation within a tolerance of ± 1 per cent for generators rated at up to 100 kW, or within $\pm 0,5$ per cent for generators of rating exceeding 100 kW. The above regulation limits shall be maintained with the generator cold and hot and at any load within the operating load range of generators.

10.7.2.5 Direct-current sets comprising compound-wound generators shall have such external characteristics that the voltage of a hot generator adjusted to the rated value with an accuracy of ± 1 per cent at 20 per cent of the load does not vary at full load by more than $\pm 1,5$ per cent for generators rated at 50 kW or over, and by more than $\pm 2,5$ per cent for generators of lower output.

Voltage variations in a compound-wound generator running at 20 to 100 per cent of the rated load shall not exceed the following limits:

.1 ± 3 per cent for generators rated at 50 kW and more;

.2 ± 4 per cent for generators rated over 15 kW but less than 50 kW;

.3 ± 5 per cent for generators rated at 15 kW and less.

10.7.2.6 Direct-current sets comprising shunt-wound generators shall have such external generator characte-ristics and automatic voltage regulators that voltage is maintained to within $\pm 2,5$ per cent of the rated value at all load variations from zero to the rated load.

10.8 ELECTROMAGNETIC BRAKES

10.8.1 The brake shall operate when the brake operating coil becomes de-energized.

10.8.2 A 30 per cent voltage drop below the rated value shall not cause a hot brake to operate.

10.8.3 Electromagnetic brakes shall allow of manual release.

10.8.4 Electromagnetic brakes shall be fitted with at least two pressure springs.

10.8.5 The shunt windings of a compound-wound electromagnetic brake shall be capable of holding off the brake even when no current flows through the series winding.

10.8.6 The shunt windings of electromagnetic brakes shall be so constructed or protected that they can be safe from damage at overvoltages such as occur when they are being disconnected (refer also to 5.4.3).

11 TRANSFORMERS

11.1 GENERAL

11.1.1 The requirements of the Section apply to power and lighting transformers listed in 3.3.

For additional requirements for transformers with voltages over 1000 V, refer to 18.4.

11.1.2 Dry-type transformers shall be used in ships.

The use of other type transformers is subject to special consideration by the Register.

11.1.3 Transformers shall have electrically separated windings for primary and secondary voltages.

11.2 OVERLOAD, VOLTAGE VARIATION AND OPERATION IN PARALLEL

11.2.1 Transformers cooled by air or dry dielectric shall be so designed as to be capable of withstanding 10 per cent overloads for 1 hour and 50 per cent overloads for 5 min.

11.2.2 For single-phase and three-phase transformers used to supply the ship's mains, voltage variation at an active load between zero and rated load shall not exceed 5 per cent for transformers rated at up to 6,3 kVA per phase and 2,5 per cent for transformers of higher rating.

11.2.3 Transformers intended to operate in parallel shall have their winding connections grouped together, their transformation ratios shall be the same, and their short circuit voltages shall be such that the load on any transformer does not depart from the corresponding proportional part of power output of each transformer by more than 10 per cent of the rated current for a given transformer.

11.2.4 Nominal capacities of transformers for parallel work shall not differ from each other more than twice.

12 POWER SEMICONDUCTOR UNITS

12.1 GENERAL

12.1.1 In power semiconductor units use shall be made of semiconductor elements of silicone type.

Elements of other type are subject to special consideration by the Register in each case.

12.1.2 To prevent condensation in semiconductor units having the dissipation power above 500 W, provision shall be made for heating so that their temperature is at least by 3 °C higher than that of the ambient air.

12.1.3 Power semiconductor units shall be provided with air cooling (natural or artificial).

The use of liquid cooling is subject to special consideration by the Register in each case.

12.1.4 For power semiconductor units with forced cooling, provision shall be made for the protection reducing or disconnecting the load in case of inadequate cooling.

The activation of protection shall be preceded by the activation of light and sound alarms for exceeding the maximum permissible temperature of cooling medium at the system outlet.

12.2 PERMISSIBLE PARAMETERS OF VOLTAGE DISTORTION

12.2.1 The voltage curve harmonic distortion factor for the ship mains depending upon the operation of the power semiconductor units shall not exceed 10 per cent.

The use of power semiconductor units, which cause the harmonic distortion of the voltage curve above 10 per cent, is subject to special consideration by the Register in each case.

The voltage curve harmonic distortion factor shall be determined by the formula given in 2.2.1.3.

12.2.2 The factor of maximum relative deviation of instantaneous voltage value from the first harmonic component shall not exceed 30 per cent.

Factor K_{MD} shall be determined by the formula

$$K_{MD} = \frac{U_m - U_{1m}}{U_{1m}} 100\ \% \qquad (12.2.2)$$

where U_m = peak value of the ship mains voltage;
U_{1m} = peak value of the first harmonic component.

12.3 CONTROL AND SIGNALLING SYSTEMS

12.3.1 Semiconductor arrangements shall be provided with light signals for connection or disconnection of power circuits and control circuits.

12.3.2 The power section of semiconductor arrangements shall be electrically insulated from the control system.

12.3.3 The long-term current deviation in the parallel branches of semiconductor arrangements shall not exceed 10 per cent of average current value.

12.3.4 The operation of semiconductor arrangements shall not be hampered by the failure of particular gates. Where the load upon particular gates exceeds permissible values, it shall be reduced automatically.

When a gate fails, light and sound signals shall be activated.

12.4 MEASURING INSTRUMENTS

12.4.1 Semiconductor arrangements shall be fitted up with measuring instruments in accordance with their purpose.

12.4.2 In the scales of measuring instruments of semiconductor arrangements, maximum permissible parameter values shall be marked off. Where forced cooling is applied, the maximum permissible temperature shall be marked off clearly in the scale of the instrument for measuring the cooling air temperature.

13 ACCUMULATOR BATTERIES

13.1 GENERAL

13.1.1 Accumulator batteries shall be so constructed that the loss of capacity of a fully charged battery due to self-discharge after 28 days out of operation at a temperature of (25 ± 5) °C does not exceed 30 per cent of rated capacity for acid batteries and 25 per cent for alkaline batteries.

13.1.2 Battery containers and closures for holes shall be so constructed and secured as to prevent spilling or splashing of the electrolyte when the container is inclined on any side to an angle of 40° from the vertical.

Closures shall be made from durable material resistant to electrolyte. Closure design shall be such as to avoid building up of excess gas pressure inside the battery.

13.1.3 The mastics used shall not change their properties or deteriorate at ambient temperature changes within -30 to $+60$ °C.

13.1.4 Materials used for fabrication of crates to house battery cells shall be resistant to electrolyte. Individual cells arranged within the crates shall be so secured that it is impossible for them to move relative to one another.

13.1.5 Where batteries are fitted for use for essential and emergency services a schedule of such batteries shall be compiled and maintained. The schedule, which shall be reviewed by the Register, shall include the following information regarding the battery:

type and manufacturer;

voltage and capacity;

location;

equipment and systems served;

maintenance/replacement cycle dates;

date of last maintenance or replacement;

for replacement batteries in storage, the date of permissible shelf life.

Details of the schedule shall be included in the ship's safety management system specified in Chapter IX of SOLAS-74.

13.1.6 Where batteries are replaced, they shall be of an equivalent performance type, which shall be reflected in appropriate instructions.

13.1.7 Where vented type battery replace valve-regulated sealed type at its location, the requirements of the Rules relevant to the location and ventilation of the batteries shall be met.

13.2 ARRANGEMENT OF ACCUMULATOR BATTERIES

13.2.1 Batteries having a voltage in excess of the safety voltage, as well as batteries having a capacity over 2 kW computed from the maximum charging current and the rated voltage, shall be located in special battery compartments accessible from the deck, or in appropriate boxes installed on deck. These spaces shall be special electrical spaces.

Batteries having a charge capacity of 0,2 kW up to 2 kW may be installed in boxes or cabinets located inside the ship's hull.

In ships with low-power electrical installation, except passenger ships, the above batteries may be installed in the machinery space in such a way that their upper section is at least above the margin line in case the ship is flooded.

Accumulator batteries intended for the electric starting of internal combustion engines except for emergency units may be installed in machinery spaces in special cabinets with sufficient ventilation.

Batteries having a charge capacity less than 0,2 kW and unattended batteries giving off no gases in operation are allowed to be installed in any space, other than accommodation spaces, provided they are protected from the action of water and mechanical damage and do not harmfully affect the surrounding equipment.

13.2.2 The acid and alkaline batteries shall not be placed in one compartment or in one box. The vessels and instruments intended for the batteries with different electrolytes shall be placed separately.

13.2.3 The inside part of a battery compartment or cabinet, as well as all structural parts, which may be subjected to harmful effects of electrolyte or gas, shall be suitably protected.

13.2.4 Accumulator batteries and individual cells shall be properly fixed in position. In case they are installed on shelves in two or more rows, all the shelves shall have a clearance of at least 50 mm on the face and back side for air circulation, and the distance from the deck to the plugs in the upper row of cells shall not exceed 1500 mm.

13.2.5 When installing the accumulator batteries or individual accumulators (cells), provision shall be made for fitting linings and spacers between them that will ensure a clearance for circulation of air of not less than 15 mm on all sides.

13.2.6 Warning notices indicating the danger of explosion shall be provided on the doors leading to the battery compartment or nearby, as well as on the boxes containing the accumulators.

13.3 HEATING

13.3.1 The battery compartments and boxes wherein temperature in operation may fall down below $+5$ °C shall be heated. The heating is allowed to be effected by the heat produced in adjacent spaces, as well as with water or steam radiators located inside the battery rooms.

13.3.2 The heating system valves shall be located outside the battery compartments.

13.3.3 The shipboard air conditioning system shall not be used for heating the battery compartments.

13.4 VENTILATION

13.4.1 The battery compartments and boxes shall have sufficient ventilation that will prevent accumulation of explosive air-gas mixture.

The ventilation system shall meet the requirements of 12.10, Part VIII "Systems and Piping".

13.4.2 The battery compartments equipped with mechanical ventilation shall be provided with devices that will prevent charging of accumulator batteries before ventilation has been switched on.

Charging cycle shall be automatically discontinued, shall the ventilators stop.

13.5 CHARGING OF ACCUMULATOR BATTERIES

13.5.1 Provision shall be made for charging facilities to charge the accumulator batteries of essential services within 8 hours.

In case an additional battery is used substituting that being charged, the charging time may exceed 8 hours.

13.5.2 The charging facilities shall have means for measuring the voltage across battery terminals and charging current, as well as discharging current for emergency sources of electrical power.

13.5.3 In ships equipped with portable accumulator-fed lanterns or with spare accumulator-fed navigation lanterns the facilities shall be provided for charging the accumulators of these lanterns.

13.6 INSTALLATION OF ELECTRICAL EQUIPMENT IN BATTERY COMPARTMENTS

13.6.1 Apart from safe-type lighting fixtures and cables led to accumulators and lighting fixtures, no other electrical equipment shall be installed in battery compartments.

Cables led to accumulator batteries and lighting fixtures may run openly, provided they have metal armour or braid covered with non-metal sheath and this metal armour or braid is reliably earthed at both ends.

13.7 ELECTRICAL STARTERS FOR INTERNAL COMBUSTION ENGINES

13.7.1 Number of starter batteries.

13.7.1.1 In a ship equipped with electrically-started internal combustion engines, irrespective of the number of such engines, not less than two starter batteries shall be permanently installed for starting each of the main and auxiliary engines, or not less than two common batteries for starting all the engines. Moreover, provision shall be made for a permanent switching system that will ensure possible use of any battery for starting any of the engines in the group serviced by this battery. In this case parallel connection of the batteries is not allowed.

13.7.1.2 For ships of restricted area of navigation **R3** and also for ships of restricted area of navigation **R2** with the electrical installation of low power (other than passenger ships), it is permitted to have only one starter accumulator battery, provided that it may be used for starting all the engines.

13.7.2 Battery characteristics.

13.7.2.1 Each starter battery shall be designed to withstand the discharging current in starter duty that will correspond to the maximum current through the most powerful starting electric motor.

13.7.2.2 Capacity of each battery shall be sufficient for six starts of the engine in the ready-for-start condition, or in case of two or more engines, for not less than three starts of each engine. Total capacity of the batteries for starting main engines shall provide the required number of starts during 30 minutes.

13.7.2.3 In computing battery capacity, the duration of each start shall be considered not less than 5 s.

13.7.3 Charging facilities.

13.7.3.1 A starter battery charging facility shall be supplied by a separate feeder from the main switchboard even if the battery is charged from the appurtenant generator.

13.7.3.2 For ships of restricted area of navigation **R3** and also for ships of restricted area of navigation **R2** with the electrical installation of low power (other than passenger ships) the starter battery may be charged only from the appurtenant generator.

14 ELECTRICAL APPARATUS AND ACCESSORIES

14.1 ELECTRICAL APPARATUS

14.1.1 General.

14.1.1.1 The design of switchgear with renewable contacts shall be such that renewal of contacts shall be possible by means of standard tools, without dismantling the switchgear or its basic components.

14.1.1.2 All switches, circuit breakers and isolating switches, except those for cabins, shall be provided with mechanical or electrical contact-making position indicators located where the apparatus is actuated by the operator.

14.1.1.3 The positions of controller and master controller drums shall be rigidly locked by mechanical means, location in zero position being more rigid than elsewhere.

Controller and master controlled drums shall be fitted with a scale and an indicator of position.

14.1.1.4 Machine control gear, except such as is used for smooth regulation, shall be so constructed that the end and intermediate fixed positions are easy to feel at various control stages while movement beyond the end positions shall be impossible.

14.1.2 Manually operated controls.

14.1.2.1 The direction of movement of manually operated controls of switchgear or machine control gear shall be such that clockwise rotation of a handle (lever) corresponds to closing of an apparatus, start-up of a motor, increased speed, increased voltage, and so forth.

Where lifting or lowering mechanisms are under control, clockwise rotation of a handle (handwheel) or shifting of a handle (lever) toward the operator shall correspond to lifting movement, and counter-clockwise rotation or shifting away from the operator to lowering movement.

14.1.2.2 Switchgear push buttons shall be so designed that they cannot be actuated accidentally.

14.1.3 Motor-operated gear.

14.1.3.1 Actuators of switches and circuit breakers shall be so designed that in the event of loss of supply to the actuating motor the switch or circuit breaker contacts remain in closed or in open position only.

14.1.3.2 Electric motor actuators shall provide for reliable closing of the apparatus at all changes of the control voltage within 85 to 110 per cent of the rated value and in case of alternating current at frequency deviation within ± 5 per cent of the rated frequency.

14.1.3.3 A drop of control voltage down to 70 per cent of the rated value shall not result in opening the apparatus contacts, or reducing the pressure thereof.

14.1.3.4 The design of a motor-actuated switchgear shall embody a provision for manual operation.

14.1.4 Coils.

14.1.4.1 A conductor or a shoe shall be attached to a coil winding so as to avoid the mechanical stresses of the connection affecting the coil turns. The tapping of voltage coils shall be made from flexible stranded conductor, except where the contact terminals are secured directly to the coil frame.

14.1.4.2 The coils of electromagnetic apparatus shall bear notations giving particulars of their characteristics.

14.1.5 Resistor elements.

14.1.5.1 Resistor elements shall be easily replaceable, in sections or in total.

14.1.5.2 Resistors shall be so disposed and ventilated that they do not heat other devices beyond the permissible limits.

14.1.5.3 The joints between resistor elements or between these and terminals shall be effected by welding or by mechanical press-fitting where there is no need to provide for their dismantling. Soldering is admissible where there is no risk of temperature rise at the point of junction above the limits specified for the solder.

14.1.6 Fuses.

Fuse link housing shall be of totally enclosed type and allow no arc ejection to the outside, or sparking, or any other harmful effect upon the adjacent parts in case the fuse blows.

14.2 ELECTRICAL ACCESSORIES

14.2.1 General.

14.2.1.1 The enclosures of accessories and fittings shall be constructed from materials of adequate mechanical strength, which are corrosion-resistant or adequately protected from corrosion and at least flame-retardant. The enclosures of accessories and fittings designed for installation on weather decks, in refrigerated cargo spaces, fish processing shops, or other humid areas shall be made of brass, bronze, or equivalent alloy, or from plastics of suitable quality. If steel or aluminium alloys are used, anti-corrosive protection shall be provided.

It is inadvisable to use threaded connections or tight-fit mating of parts in accessories and fittings made of aluminium alloys.

14.2.1.2 Insulating parts, to which current-carrying components are fixed, shall be made of materials that do not evolve gases as would ignite from an electric spark at a temperature up to and including 500 °C.

14.2.1.3 The lighting fixtures designed to be mounted on or close to combustible materials shall be so constructed as not to get heated over 90 °C.

14.2.2 Lampholders.

14.2.2.1 The design of lampholders fitted with screw caps shall be such as to effectively prevent the lamps from getting loose in service.

14.2.2.2 No switches are allowed to be fitted in lampholders.

14.2.2.3 Each lighting lampholder shall be marked to indicate rated voltage and allowable current or load.

14.2.3 Plug and socket connector.

14.2.3.1 The pin jacks of socket outlets shall be so constructed as to ensure permanent pressure in contact with the plug pins.

14.2.3.2 Plugs with slotted pins are not allowed for use. The pins of plugs designed for currents in excess of 10 A shall be cylindrically shaped, solid or hollow.

14.2.3.3 Socket outlets and plugs for voltages exceeding the safety level shall have contacts for connecting the earth continuity conductors of the incoming cables from current consumers.

14.2.3.4 Socket outlets having protective enclosures shall be so constructed that the required degree of protection is ensured regardless of whether the plug is in or out of the socket outlet.

14.2.3.5 Socket outlets rated at over 16 A shall be provided with built-in switches. Provision shall be also made for interlocking such socket outlets to prevent the possibility of the plug being inserted or withdrawn when the socket switch is in the "closed" position.

14.2.3.6 Where socket outlets are not interlocked, the clearance between contacts in air or across the insulation surface shall be such that no short circuit is possible due to arcing over when the plug is withdrawn while carrying a load 50 per cent above the rated current at rated voltage.

14.2.3.7 Socket outlets and plugs shall be so designed that it is not possible to insert only one live contact pin into the socket outlet, or insert a live contact pin into the earthing contact. Besides, the design of the outlets intended for connecting the motors (gears), the direction of rotation (operation) of which depends on the change of the sequence of phases or poles connected, shall exclude the possibility of the sequence change. When the plug is inserted into the socket outlet, the earthing part of the plug shall make contact with the earthing part of the socket outlet before connecting the live pins.

14.2.3.8 In socket outlets, plugs and branched pin jacks, no fuses shall be fitted.

15 ELECTRICAL COOKING AND HEATING APPLIANCES

15.1 GENERAL

15.1.1 Only stationary-type electrical cooking appliances are permitted for use.

15.1.2 Electrical cooking appliances shall be supplied from the main switchboard or from distribution boards intended for this purpose and also from the lighting switchboards with regard to the requirements of 6.2.1.

15.1.3 The supporting structural parts of electrical cooking appliances, as well as the internal surfaces of enclosures, shall be fabricated entirely from non-combustible materials.

15.1.4 In heated condition, permissible loss current shall not exceed 1 mA per 1 kW of rated power for a separately connected heating element or 10 mA for the appliance as a whole.

15.1.5 Electric cooking appliances shall be so designed that the temperature of their components, which shall be handled by the personnel or which can be touched inadvertently, does not exceed the value indicated in Table 15.1.5.

Table 15.1.5

Nos	Item	Permissible temperatures, °C
1	Control handles and other parts to be handled during long periods of time	
	Metallic	55
	Non-metallic	65
2	Same, but where short-time contact is possible	
	Metallic	60
	Non-metallic	70
3	Enclosures of electric space heating and cooking appliances at ambient temperature of 20°C	80
4	Air coming out from electric space heating appliances into heated spaces	110

15.2 HEATING APPLIANCES

15.2.1 Electric heating appliances intended for space heating shall be of stationary type. These appliances shall be provided with devices for disconnection of the supply source when the temperature rise of the enclosure exceeds the permissible limit.

15.2.2 If built-in disconnecting devices are not provided in the heating and cooking appliances, such devices shall be installed in the rooms wherein these appliances are located.

Switches shall disconnect power supply at all poles or phases.

15.2.3 The enclosures of electric heating appliances shall be so constructed as to prevent the possibility of any objects being placed upon them.

15.2.4 Stationary heating appliances rated at 380 V and upwards and admitted for use in accordance with Table 4.2.3 shall be protected against access to live parts, except with the aid of special tools. The enclosures shall bear notices giving the voltage value.

15.2.5 Electric cooking appliances forming part of galley equipment shall be so constructed as to avoid the possibility of cooking utensils being brought into contact with live parts, and to prevent short circuits or damage to insulation due to liquid spilling or leakage.

15.2.6 Sauna shall be fitted with the temperature limiter, which shall cut off the electrical heater from the mains (at that, electrical heater control circuits shall also be de-energized), if the temperature in the area of 0,3 m from the ceiling exceeds 140 . In this area the electrical heater control devices (thermostats and temperature limiters) and associated cables withstanding a temperature not less than 170 may only be installed.

15.3 OIL, FUEL AND WATER HEATERS

15.3.1 In addition to the requirements of the Chapter, heaters shall meet the requirements of Section 6, Part X "Boilers, Heat Exchangers and Pressure Vessels".

15.3.2 Oil and fuel having a flash point above 60 °C may be heated by means of electric heaters, provided the requirements of 15.3.3 and 15.3.4 are fulfilled.

15.3.3 Electric heaters for pipelines shall be equipped with devices for temperature control, light signals for indication of operating conditions and also with light and sound signals for indication of fault conditions and inadmissible temperature rise.

15.3.4 Electric heaters for oil and fuel heating in tanks shall be equipped with devices for temperature control of the heated medium, temperature sensors for surfaces of heating coils, low level indicators and means for disconnection of power supply to the heaters in case the upper temperature limit or the lowest permissible level is exceeded.

15.3.5 Oil and fuel heaters shall be fitted up with devices for temperature control of the medium heated. Irrespective of those devices, a manually disengaged device shall be provided for de-energizing the heaters as soon as their surface temperature reaches 220 °C.

15.4 SYSTEMS UTILISING HEATING CABLES

15.4.1 Systems utilising heating cables for removing ice and avoiding icing shall be provided for ship's arrangements, equipment and spaces intended for:

performing by the ship its purpose (descriptive notation in the class notation);

maintaining manoeuvrability;

maintaining stability;

safety of crew (rafts, boats, ladders, guard rails, etc.).

15.4.2 Heating capacity of such systems shall not be less than:

300 W/m^2 for the spaces of open decks, helidecks, ladders and gangways;

200 W/m^2 for superstructures;

50 W/m^2 for guard rails with internal heating.

The heating capacity for other areas and spaces is subject to special consideration by the Register in each particular case.

15.4.3 In the systems utilising electrical heating cables, particular attention shall be paid upon the heat transfer between the cable and the equipment (space) to be heated to provide efficient heating.

15.4.4 The switchboard for the said systems shall be equipped with:

wattmeter or amperemeter to indicate the total load;

name plate indicating the rated load of each circuit and the switchboard as a whole;

device for monitoring the earth fault for each circuit with warning alarm;

load signal lamps for each circuit.

15.4.5 The heating cables shall be protected against overload exceeding 125 per cent of the rated current of the circuit. For cables of self-regulating type the overload protection may be omitted.

15.4.6 Where systems with heating cables are used for pipelines and fittings, the requirements of 5.8, Part VIII "Systems and Piping" shall also be met.

16 CABLES AND WIRES

16.1 GENERAL

16.1.1 The requirements of this Section do not apply to radio frequency, telephone cables, and to power cables designed for voltages above 1000 V.

16.2 CABLE CONDUCTORS

16.2.1 Cables intended for supplying essential services shall have stranded conductors (refer also to 16.8.1.2). Table 16.2.1 specifies the minimum number of wires per conductor.

Table 16.2.1

Nominal cross-sectional area of conductor, mm^2	Minimum number of wires per conductor	
	circular non-tightened conductors	tightened sector and circular conductors
0,5 to 6	7	—
10 to 16	7	6
25 to 35	19	6
50 to 70	19	15
95	37	15
120 to 185	37	30
240 to 300	61	30

Note. The ratio between nominal diameters of any two wires in the mechanically tightened cable conductor shall not exceed 1:1,3, and for conductors formed geometrically, but not

16.2.2 Connections of separate wires of the conductor shall be displaced from one another by not less than 500 mm along the length of the conductor.

Such connections shall not impair the mechanical and electrical properties of the wire nor change the cross-sectional area of wires or the conductor as a whole.

16.2.3 Separate wires of rubber-insulated copper conductors shall be tinned or coated with suitable alloys.

Tinning or other anticorrosive coating of external stranding or of all wires of a rubber-insulated core may be dispensed with, if the manufacturer takes steps to guarantee that the rubber insulation does not affect adversely the metal of the conductor.

No tinning is required for conductors provided with other types of insulation.

16.3 INSULATING MATERIALS

16.3.1 For conductors of cables and wires, insulating materials specified in Table 16.3.1 may be used.

Table 16.3.1

Insulation	Standard types of insulating materials	Permissible service temperature, °C [1]
PVC/A	Standard-type polyvinylchloride	60
PVC/D	Heat-resistant polyvinylchloride	75
EPR	Ethylene-propylene rubber	85
XLPE	Cross-linked polyethylene	85
S 95	Silicone rubber	95

[1] Wire temperature to determine the permissible sustained load of cable.

Application of other insulating materials is subject to special consideration by the Register in each case.

16.4 CABLE SHEATHING

16.4.1 Protective sheathing of cables and wires may be manufactured of non-metallic materials as specified in Table 16.4.1, lead, cooper.

Table 16.4.1

Sheathing	Non-metallic sheathing material of solid type	Maximum permissible cable temperature, °C
SV 1	Standard-type polyvinylchloride	60
SV 2	Heat-resistant polyvinylchloride	85
SP 1	Polychloroprene rubber	85
SH 1	Chlorosulfonated polyethylene	85

Application of alternative sheathing materials is subject to special consideration by the Register in each case.

16.4.2 Sheathing shall be of uniform thickness within allowable limits, throughout the manufacturing length of cable, and shall envelope the cable cores concentrically. The sheaths shall form an impervious covering in tight contact with the protected cores.

16.4.3 Lead cable sheaths shall be made of appropriate alloys specified by the national standards.

Pure lead sheaths may only be used when the lead sheath is covered with an additional protective envelope.

16.5 PROTECTIVE COVERINGS

16.5.1 Metal shielding braid shall be made of tinned copper wire. If plain copper wire is used, it shall be protected by suitable sheath. Non-shielding braids may be made of galvanized steel wires. The braid shall be uniform and its density shall be such that its mass is at least equal to 90 per cent of the mass of tube of equal diameter made of the same material and with a wall thickness equal to the braiding wire diameter.

16.5.2 Metal armour shall be made of annealed and galvanized steel wire or tape, wound helically, with a suitable pitch, over the cable sheath or an intermediate bedding over the sheath in such a way that a continuous cylindrical layer is formed to assure adequate protection and flexibility of the finished cable. On special demand, the armour may be made of non-magnetic metals, using the techniques described above.

16.5.3 Cable armour or braid made of steel tape or wire shall be effectively protected against corrosion.

16.5.4 Armour bedding shall be made of moisture-resistant materials.

16.6 MARKING

16.6.1 Rubber- or polyvinylchloride-insulated cables having a limiting temperature at core 60 °C shall be marked in such a manner as would enable their identification.

16.6.2 Cable cores shall be marked in such a manner as to assure adequate preservation of the markings.

In multi-core cables with cores arranged in several concentric layers at least two adjacent cores in each layer shall be marked with different colours.

16.6.3 Cables of fire resistant type shall be clearly marked.

16.7 HOOKUP WIRES

16.7.1 For internal wiring of distribution boards and electric devices, single-wire insulated conductors may be used (refer also to Table 16.3.1).

16.7.2 Non-insulated wires and busbars are permitted for use only for internal wiring of electrical devices. The external wiring with non-insulated wires or busbars is not allowed unless they are reliably guarded.

16.8 CABLING

16.8.1 General.

16.8.1.1 Use shall be made of non-combustible and flame-retarding cables and conductors with copper cores manufactured and tested in accordance with the requirements of the present Part of the Rules, national standards, as well as complying with IEC 60092, as applicable.

As far as the fire resistance testing of cable is concerned, use shall be made of IEC 60331-31 for cables of outside diameter more than 20 mm and 60331-21 for other diameters.

Use of cables and conductors of other types shall be subject to special consideration. In this case, IEC 60331-23 for data transfer cables and IEC 60331-25 for optical fibre cables may be used.

16.8.1.2 Cables and wires having stranded conductors shall be used, the cross-sectional area of the conductors being not less than:

.1 1,0 mm^2 for power, control and signalling circuits of essential services and for power circuits of other services;

.2 0,75 mm^2 for control and signalling circuits;

.3 0,5 mm^2 with the number of cores in the cable not less than four for instrumentation and internal communication circuits.

For power circuits supplying non-essential services, the use is permitted of cables with single-wire conductors having a cross-sectional area of 1,5 mm^2 and less.

16.8.1.3 In circuits with heavy inductive and capacitive loads, the use shall be made of cables designed for working voltages approximately equal to twice the rated voltage of the circuit.

16.8.1.4 Maximum permissible temperature for the insulating material of the cable cores or wires shall be at least 10 °C higher than the maximum specified ambient temperature.

16.8.1.5 In locations affected by the action of petroleum products or other aggressive medium, the use shall be made of cables having a sheath resistant to such medium. Cables not having such properties may be installed in such locations only fitted in metallic pipes (refer to 16.8.8).

16.8.1.6 In locations where cables may be subjected to mechanical damage, the use shall be made of cables having an appropriate armour, while other types of cables in such locations shall be protected with special reliable covers or shall be installed in metallic pipes (refer to 16.8.8).

16.8.1.7 Cables supplying the electric drives of the sprinkler system and of the fire pump from the emergency source of electrical power and running through casings of machinery spaces of category A, galleys, drying rooms and other similar fire-hazardous spaces, shall be of fire-resisting type or protected from the action of flame.

The above requirements cover the remote-control cables of those devices as well.

16.8.1.8 Cables for essential and emergency services as well as cables for services required for operation under fire conditions, including cables for their power supply shall be routed clear of high fire risk spaces (refer to 16.8.1.9), and in addition to passenger ships, main vertical fire zones, except for cases, when the services themselves are installed in such spaces.

Where such installation of cables is necessary, the cables shall be of fire resistance type according to 16.8.1.1.

16.8.1.9 The high fire risk spaces include:

machinery spaces of category A;

spaces containing fuel treatment equipment and other highly flammable substances;

galleys and pantries containing cooking appliances;

laundries containing drying equipment;

accommodation spaces of high fire risk;

paint rooms, store rooms and similar spaces for storage of flammable liquids;

enclosed and semi-enclosed spaces requiring installation of safe-type electrical equipment.

16.8.1.10 Cables, distribution gear, switch apparatus and protective devices associated with these services shall be so designed or installed that the likelihood of the device failing in case of fire in any one such space or area is minimised.

16.8.1.11 Among the services required for operation under fire conditions are the following:

general alarm;

fire extinguishing systems;

fire detection and alarm systems;

warning alarm of fire extinguishing system release;

controls of fire doors with door-position indicators;

control of watertight doors with door-position indicators and warning alarm;

emergency lighting;

public address system;

low-location lighting;

remote emergency shutdown arrangements for systems, which operation may support the propagation of fire and/or explosion.

16.8.1.12 Use of fire resistant cables for devices listed in 16.8.1.11 is not mandatory provided that:

.1 fail safe functioning of devices is provided by, at least, two-loop or radial laying of cables spaced apart as far as practical so that if one loop or radial section fails, the rest sustain operability of the devices;

.2 the devices are provided with self-monitoring with such damages like a short circuit, an open-circuit fault, earth fault, or trouble-free functioning of these devices is ensured by duplicating cables laid in separate runs spaced apart as far as practical.

16.8.2 Choice of cables and wires for loads required.

16.8.2.1 Permissible continuous loads on single-core cables and wires with different insulation materials shall comply with the values specified in Table 16.8.2.1.

Table 16.8.2.1

Current ratings in continuous service of single-core cables and wires with different insulation materials for ambient temperatures of +45 °C

Nominal cross-sectional area of conductor, mm^2	Insulating material				
	Polyvinylchloride	Heat-resistant polyvinylchloride	Butyl rubber	Ethylene-propylene rubber of cross-linked polyethylene	Silicone rubber or mineral insulation
	Maximum conductor temperature permissible in service, °C				
	60	75	80	85	95
1	8	13	15	16	20
1,5	12	17	19	20	24
2,5	17	24	26	28	32
4	22	32	35	38	42
6	29	41	45	48	55
10	40	57	63	67	75
16	54	76	84	90	100
25	71	100	110	120	135
35	87	125	140	145	165
50	105	150	165	180	200
70	135	190	215	225	255
95	165	230	260	275	310
120	190	270	300	320	360
150	220	310	340	365	410
185	250	350	390	415	470
240	290	415	460	490	—
300	335	475	530	560	—

The current ratings given in the Table are applicable to the following cases of cable installation:

when installing not more than 6 cables in one bunch or in one row closely adhering to one another;

when installing cables in two rows, regardless of the number of cables in one row, on condition that a free space for air circulation is provided between each group or bunch of 6 cables.

When installing more than six cables in one bunch, which may be under rated current simultaneously or when no free space for air circulation between them is provided, the permissible current ratings for the given cross-sectional area shall be reduced by 15 per cent (factor 0,85).

16.8.2.2 Current ratings in amperes for cross-sectional areas given in Table 16.8.2.1 and also for any other cross-sectional areas shall be calculated from the formula

$$I = \alpha S^{0,625} \qquad (16.8.2.2)$$

where α = factor corresponding to the maximum permissible service temperature of the conductor obtained from Table 16.8.2.2;

S = nominal cross-sectional area of conductor.

Table 16.8.2.2

Maximum permissible conductor temperature, °C	Factor α for nominal cross-sectional area S, mm^2	
	⩾2,5	⩽2,5
60	9,5	8
65	11	10
70	12	11,5
75	13,5	13
80	15	15
85	16	16
90	18	20

16.8.2.3 The permissible current ratings for double-, triple- and quadruple-core cables shall be determined by reducing the values given in Table 16.8.2.1 for the given cross-sectional area with the use of correction factors:

0,85 for double-core cables;

0,7 for triple- and quadruple-core cables.

16.8.2.4 The permissible current ratings for cables and wires in circuits of intermittent or shorttime service shall be determined by multiplying the current ratings for continuous service stated in Table 16.8.2.1 or chosen according to 16.8.2.2 by the correction factors given in Table 16.8.2.4.

16.8.2.5 The permissible current ratings given in Table 16.8.2.1 refer to the ambient temperature of +45 °C.

The correction factors for converting the permissible current ratings to be introduced depending on the ambient temperature are stated in Table 16.8.2.5.

16.8.2.6 In choosing the cables for final branch circuits of lighting and cooking appliances correction factors or simultaneity factors are not applicable.

16.8.2.7 The cables shall be so designed that they could withstand maximum short-circuit current occured in the circuit considering time and current ratings of the protective devices and peak value of the prospective short-circuit current of the first onehalf period.

16.8.2.8 Cables installed in parallel and belonging to the same phase or pole shall be of the same type, be laid together and have the same cross-sectional area of at least 10 mm^2 and the same length.

Table 16.8.2.4

Correction factors for cables and wires with or without metal sheathing

Nominal cross-section of conductor, mm^2	Intermittent service, intermittence ratio, 40%		Short-time service, 30 min		Short-time service, 60 min	
	Cable and wire					
	with metal sheathing	without metal sheathing	with metal sheathing	without metal sheathing	with metal sheathing	without metal sheathing
1	1,24	1,09	1,06	1,06	1,06	1,06
1,5	1,26	1,09	1,06	1,06	1,06	1,06
2,5	1,27	1,10	1,06	1,06	1,06	1,06
4	1,30	1,14	1,06	1,06	1,06	1,06
6	1,33	1,17	1,06	1,06	1,06	1,06
10	1,36	1,21	1,08	1,06	1,06	1,06
16	1,40	1,26	1,09	1,06	1,06	1,06
25	1,42	1,30	1,12	1,07	1,06	1,06
35	1,44	1,33	1,14	1,07	1,07	1,06
50	1,46	1,37	1,17	1,08	1,08	1,06
70	1,47	1,40	1,21	1,09	1,09	1,06
95	1,49	1,42	1,25	1,12	1,11	1,07
120	1,50	1,44	1,28	1,14	1,12	1,07
150	1,51	1,45	1,32	1,17	1,14	1,08
185	—	—	1,36	1,20	1,16	1,09
240	—	—	1,41	1,24	1,18	1,10
300	—	—	1,46	1,28	1,20	1,12

Table 16.8.2.5

Correction factors depending on ambient temperature

Maximum conductor temperature, °C	Ambient temperature, °C										
	35	40	45	50	55	60	65	70	75	80	85
60	1,29	1,15	1,00	0,82	—	—	—	—	—	—	—
65	1,22	1,12	1,00	0,87	0,71	—	—	—	—	—	—
70	1,18	1,10	1,00	0,89	0,77	0,63	—	—	—	—	—
75	1,15	1,08	1,00	0.91	0,82	0,71	0,58	—	—	—	—
80	1,13	1,07	1,00	0,93	0,85	0,76	0,65	0,53	—	—	—
85	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	—	—
90	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	—
95	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

16.8.3 Selection of cable cross-sectional areas for permissible voltage drop.

16.8.3.1 Voltage drop on the cable connecting the generators of the main switchboard or the emergency switchboard shall not exceed 1 per cent.

16.8.3.2 Voltage drop between busbars of the main or emergency switchboard and any points of the installation shall not exceed 6 per cent of the rated voltage under normal operating conditions; for consumers supplied from the accumulator battery with the rated voltage up to 50 V this value may be increased to 10 per cent.

For circuits of navigation lights it may be required to limit the voltage drop by a lesser value in order to ensure necessary luminous intensity.

At short-term loads (e.g. when starting the electric motors) the greater voltage drop may be permitted if it does not cause disturbance of normal operation of the ship's electrical installation.

16.8.3.3 The cables used for feeding the directly-started alternating current electric motors shall be computed in such a manner that the voltage drop on motor terminals at starting is not over 25 per cent of the rated voltage.

A possibility of raising the above voltage drop is subject to special consideration by the Register in each case.

16.8.4 Installation of cables.

16.8.4.1 Cables shall be installed in runs, which shall be, as far as possible, straight and accessible.

The cable runs shall pass through locations where cables are not exposed to oil, fuel, water and excessive external heating.

Cable runs shall be installed not closer than 100 mm to sources of heat.

16.8.4.2 No cables shall be installed at a distance less than 50 mm from the double bottom and from the fuel and oil tanks.

Cable runs shall be installed at a distance not less than 20 mm from the shell plating, as well as from fireproof watertight and gastight bulkheads and decks.

16.8.4.3 For bunches of cables consisting of cable types, which have not been subjected to a bunch fire test, the following measures shall be taken during installation to limit the propagation of fire:

.1 fire-retarding divisions shall be used, B-0 class at least, (refer also to 2.1.2.5, Part VI "Fire Protection") where bunches enter the main and emergency switchboards, central control panels and consoles for the main propulsion plant and for important auxiliaries, as well as at each entry and exit point of cable runs in fully enclosed metal conduits (Fig. 16.8.4.3-1);

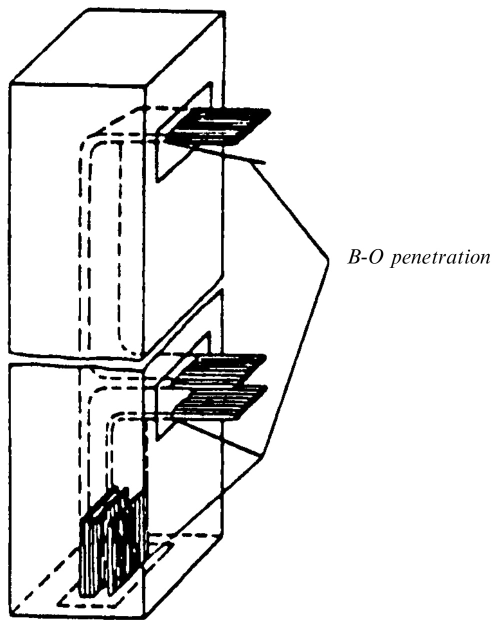


Fig. 16.8.4.3-1
Fully enclosed cable run protected with B-0 fire-retarding divisions

.2 in closed and semi-enclosed rooms and spaces, bunches installed in partly enclosed and open cable runs shall be protected by: flameproof coatings over the entire length of vertical cable runs and over a length of 1 m every 14 m apart on horizontal cable runs (Fig. 16.8.4.3-2); or

B-0 fire-retarding divisions at least at every second deck or every 6 mm apart for vertical cable

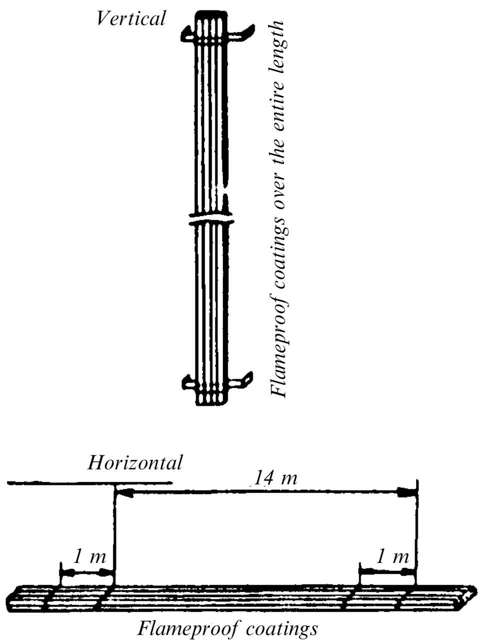


Fig.16.8.4.3-2 Cable runs protected with flameproof coatings

runs and every 14 m apart for horizontal cable runs (Fig. 16.8.4.3-3). Fire-retarding divisions shall be made of steel plates at least 3 mm thick and having dimensions as shown in Fig. 16.8.4.3-3;

.3 bunches installed in cargo holds shall be protected by B-0 fire-retarding divisions at least at the entry and exit points of cable runs.

16.8.4.4 Cables having external metallic sheaths may be installed on structures of light metal or be fastened in position by means of cable clips of light metal only in cases where reliable anticorrosive protection is provided.

16.8.4.5 In the holds of dry cargo ships intended for the carriage of dangerous cargoes, no through runs of cables shall, generally, be installed.

Admissibility and methods of installation of cables in such holds are, in each case, subject to special consideration by the Register.

16.8.4.6 Cables installed in fishing vessels at locations subjected to the action of salt shall be adequately protected with casings or be provided with salt-resistant sheaths.

16.8.4.7 No cables are recommended to be installed under the flooring of machinery spaces. If such installation is required, cables shall be laid in metallic pipes or in closed conduits (refer to 16.8.8).

16.8.4.8 Cables installed across expansion joints in the hull structure shall be provided with expansion loops having a radius adequate for such joint. The inside diameter of a loop shall not be less than 12 outside diameters of the cables.

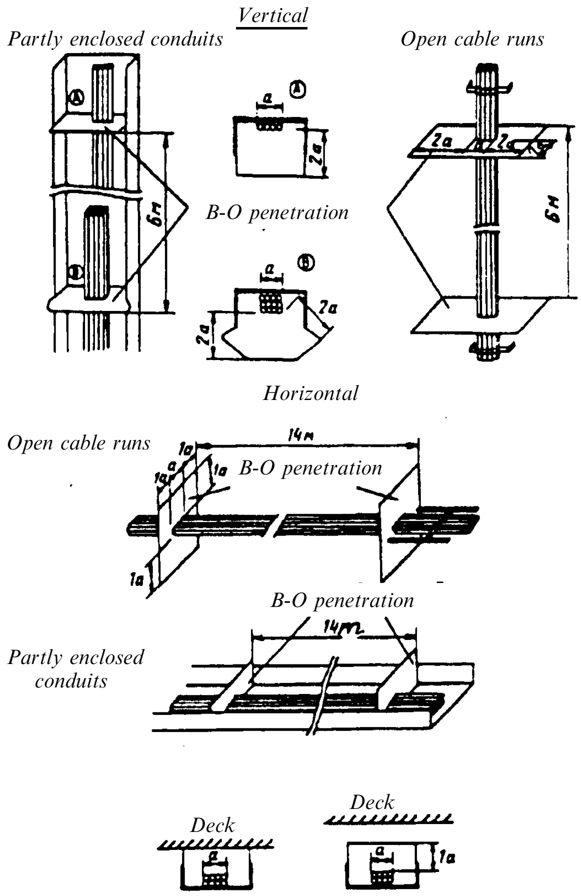


Fig. 16.8.4.3-3 Cable runs protected with B-0 fire-retarding divisions

16.8.4.9 Installation of cables having insulation intended to withstand different permissible temperatures in the common cable runs shall be effected in such a manner that the cables are not heated above their permissible temperature.

16.8.4.10 Cables with different protective coverings the less hard of which may be damaged shall not be installed in one common pipe, one common duct or in other runs of not supported common laying.

16.8.4.11 The main current cables of the electric propulsion machinery shall be installed at least 0,5 m away from cables of lower voltage or those intended for other purposes.

16.8.4.12 Cores in multi-core cables shall not be used for supplying power and control currents to essential services not associated with one another.

Multi-core cables shall not be used simultaneously for safety voltage and service voltages exceeding the safety level.

16.8.4.13 When machinery is energized through two separate feeders, these feeders shall be installed in different runs as far apart as possible in horizontal and vertical directions.

16.8.4.14 When installing cables in ducts or other structures of combustible material, the ways of cable installation shall be protected from igniting by means of suitable fire protection, such as lining, coating or impregnation.

16.8.4.15 Cables shall not be embedded into thermal or acoustic insulation in case it is made of combustible materials. Cables shall be separated from such insulation by the lining of non-combustible materials or shall be installed at a distance at least 20 mm from it.

When cables are laid in thermal or acoustic insulation made of combustible materials, they shall be computed with relevant reduction in current rating.

16.8.4.16 Cables installed in refrigerated spaces shall be provided with protective sheath of metal, polychloroprene composition, or of any other material resistant to the exposure of the cooling agent.

If cables are provided with armour, this armour shall be adequately protected against corrosion.

16.8.4.17 Cables in refrigerated spaces shall be installed on perforated panels or bridges and fastened in position in such a manner that a free space is reserved between the cables and the walls of the room. Panels, bridges and cable clips shall be protected against corrosion.

If cables cross the thermal insulation of a refrigerated space, these cables shall run at right angles through an appropriate gland pocket on both ends.

16.8.4.18 When installing the cables, minimum internal bending radii shall be maintained in accordance with Table 16.8.4.18.

16.8.4.19 Cables and earthing conductors of equipment mounted on shock absorbers shall be installed in such a manner that they cannot be damaged in service.

16.8.4.20 Cables laid on the open parts of the ship and masts shall be protected against direct exposure to sun radiation.

16.8.5 Fastening of cables.

16.8.5.1 Cables shall be adequately fastened in position by means of clips, holders, hangers, etc., manufactured of metal or other non-combustible material.

The fastener surface shall be sufficiently wide and to have no sharp edges. The fasteners shall be selected in such a manner that the cables are securely fastened in position without damage to their protective coverings.

16.8.5.2 Distances between cable fastening points in case of horizontal installation shall not exceed the values given in Table 16.8.5.2.

Table 16.8.5.2

External diameter of cable, mm		Distance between fastening points for cables, mm		
over	up to	without armour	with armour	with mineral insulation
—	8	200	250	300
8	13	250	300	370
13	20	300	350	450
20	30	350	400	450
30	—	400	450	450

For vertical runs of cables these distances may be increased by 25 per cent.

16.8.5.3 Cables shall be fastened in such a manner that mechanical strains in cables, if any, are not transmitted to their inlets or connections.

16.8.5.4 Cable runs and cables installed parallel to shell plating shall be fastened to ship's structures.

On watertight bulkheads and masts, cables shall be fastened on special supports (saddles, tray plates, chocks, etc.).

Table 16.8.4.18

Type of cable		External diameter of cable, in mm	Minimum bending radius of cable
Insulation material of cable	Protective covering of cable		
Rubber or polyvinylchloride	Armoured with metal tape or wire	Any	10*d*
	Protected with metal sheath	Any	6*d*
	Lead alloy and armour	Any	6*d*
	Other sheaths	Up to 9,5	3*d*
		9,5 — 25,4	4*d*
		Over 25,4	6*d*
Varnished cambric	Any	Any	8*d*
Mineral insulation	Metal	Up to 7	2*d*
		7 — 12,7	3*d*
		Over 12,7	4*d*
Ethylene-propylene rubber or cross-linked polyethylene	Semiconducting and/or metal	25 and over	10*d*

16.8.5.5 Cables running parallel to bulkhead subject to sweating shall be installed on bridges or on perforated panels in such a manner that free space is reserved between cables and bulkheads.

16.8.5.6 Cable runs shall be installed with a minimum number of crossings. Bridges shall be used at places where cables cross each other. An air gap of not less than 5 mm shall be left between the bridge and the cable run crossing it over.

16.8.5.7 For ships constructed from non-conducting materials it is permitted, due to the technology of hull construction from these materials, the properties of the materials used, etc., to accept the equivalents to the requirements for the installation, fastening and sealing of penetrations of cables and cable runs specified in the Rules for steel ships.

16.8.6 Cables penetrating decks and bulkheads.

16.8.6.1 Cable penetrations through watertight, gastight and fire-resisting bulkheads and decks shall be sealed.

Sealings where cables penetrate through the above bulkheads and decks shall not reduce their tightness; no force shall be transmitted to cables resulting from elastic deformations of ship's hull.

16.8.6.2 When installing the cable through non-tight bulkheads or elements of ship's structure less than 6 mm thick, linings or bushings that will prevent damage to cables shall be provided.

When bulkheads or ship's structure is 6 mm or more thick, no linings or bushings are required, but the edges of holes shall be rounded.

16.8.6.3 Installation of cables over watertight decks shall be effected by one of the following methods:

.1 in metal pipes (shafts) protruding above the deck to a height of not less than 900 mm in locations where mechanical damage to cable is possible and to a height not less than that of the door sill in spaces where there is no risk of such damage;

.2 in common metal sockets or boxes with additional protection of cables by enclosures having the height specified in 16.8.6.3.1.

Cable boxes shall be packed with cable compound, while the pipes shall be provided with glands or be stuffed with cable compound.

16.8.7 Packing compounds.

16.8.7.1 To fill the cable boxes in watertight bulkheads and decks, the use shall be made of packing compounds having good adhesion to the inside surfaces of cable boxes and cable sheath that will withstand the action of water and oil products, will not shrink and lose its tightness in continuous service under conditions specified in 2.1.1 and 2.1.2.

16.8.7.2 Packings of cable penetrations through fire-resisting bulkheads shall withstand standard fire test specified for the given type of bulkhead in 2.1.2.5, Part VI "Fire Protection".

16.8.7.3 The inside cross-section of each cable penetration shall be filled by cables to not more than 40 per cent.

16.8.8 Installation of cables in pipes and conduits.

16.8.8.1 Metallic pipes and conduits wherein cables are installed shall be protected from corrosion on the inside and the outside surfaces. The inside surface of pipes and conduits shall be even and smooth. Ends of pipes and conduits shall be machined or protected in such a manner that no damage is caused to the cables when they are being pulled in.

Cables with lead sheaths not having any additional protective covering shall not be installed in pipes and conduits.

16.8.8.2 Pipe bending radius shall not be smaller than the permissible radius for cable of the largest diameter installed in this pipe (refer to 16.8.4.18).

16.8.8.3 The total cross-sectional areas of all cables measured on their outside diameters shall not exceed 40 per cent of the inside cross-sectional area of the pipe and the conduit.

16.8.8.4 The pipes and conduits shall be mechanically and electrically continuous and securely earthed if the earthing has not been already effected by the method itself of pipe and conduit installation.

16.8.8.5 The pipes and conduits shall be installed in such a manner that no water can accumulate therein. When required, ventilation holes shall be provided in the pipes and conduits, as far as possible, in the highest and lowest points, so that circulation of air is ensured and vapour condensation is prevented. Holes in pipes and conduits are permissible only at places where it will not enhance the danger of explosion or fire.

16.8.8.6 Cable pipes and conduits installed alongside ship's hull, which can be damaged due to deformation of ship's hull, shall be provided with compensation devices.

16.8.8.7 If in accordance with 16.8.1.1, the use is allowed of cables with combustible covering, these cables shall be installed in metallic pipes.

16.8.8.8 Cables installed in pipes and conduits vertically shall be fastened so that they are not damaged under tension due to gravity.

16.8.8.9 It is allowed to use cable trays/protective casings of the approved type made of reinforced and plain thermoplastic polymeric materials like polyvinylchloride (PVC) or fiber reinforced plastic (FPR).

The protective casing shall have round or other closed cross-section.

16.8.8.10 Cable trays/protective casings made of polymeric materials shall be supplemented by metallic fixing and straps such that in the event of a fire they, and the cables affixed, are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route.

When cable trays/protective casings made of polymeric materials are used on open deck, they shall additionally be protected against UV radiation.

16.8.8.11 The load on the cable trays/protective casings made of polymeric materials shall be within the safe working load (SWL). The support spacing shall not be greater than the manufacturer's recommendation nor in excess of spacing at the SWL test.

In general the spacing shall not exceed 2 m.

The selection and spacing of cable tray/protective casing supports shall take into account:

cable trays/protective casings' dimensions; mechanical and physical properties of their material; mass of cable trays/protective casings; loads due weight of cables, external forces, thrust forces and vibrations; maximum accelerations to which the system may be subjected; combination of loads.

16.8.8.12 The sum of the cables installed in cable trays/protective casings made of polymeric materials total cross-sectional area shall not exceed 40 per cent of the protective casing's internal cross-sectional area. This does not apply to a single cable in a protective casing.

16.8.9 Special precautions for single-core cables for a.c. wiring.

16.8.9.1 A.c. wiring shall not be carried out, as far as possible, in single-core cables. When, however, it is necessary to use single-core cables for circuits rated in excess of 20 A, the following precautions shall be observed:

.1 the cables shall be armoured with non-magnetic material;

.2 cables belonging to one circuit shall be placed in the same run or metal pipe and shall be as short as practicable. Each of such cables may be installed separately under a non-magnetic screen (in a pipe) earthed at one point and isolated from the screens of other cables and from the hull;

.3 cable clamps, unless they are made of non-magnetic material, shall include all the single-core cables of a circuit;

.4 the distance between the cables shall not be greater than one cable diameter.

16.8.9.2 Where single-core cables pass through bulkheads or decks, there shall be no magnetic material between cables belonging to the same circuit. The clearance between the cables and the magnetic material shall not be less than 75 mm.

16.8.9.3 When single-core cables having a current rating greater than 250 A are installed near steel structures, the clearance between the cables and the structure shall be at least 50 mm.

16.8.9.4 When single-core cables of a conductor cross-section of 185 mm^2 or over are installed, a transposition of phases shall be effected at intervals not exceeding 15 m. Where cable length is below 30 m, no transposition is necessary.

16.8.9.5 Multicore cables with conductors in parallel shall be installed as single-core cables, and all the requirements for single-core cables apply in this case.

16.8.10 Connection and tapping of cables.

16.8.10.1 Ends of rubber-insulated cables to be introduced into machines, apparatus, switchgear and other equipment shall be provided with contact, protection and packing terminals that will ensure reliable electrical contact, will not permit moisture to penetrate inside the cable and will protect the insulation of cable cores from mechanical damage and effects of air and oil vapours.

At places of connection, rubber-insulated cable cores shall be provided with protective insulation against damage (wear, etc.).

16.8.10.2 Protective covering of a cable inserted into a device shall enter not less than 10 mm inside.

16.8.10.3 At places of tappings, connection of cables shall be effected in junction boxes by means of clamps.

16.8.10.4 If during the installation of cables it is necessary to make additional connections, these shall be effected in suitable junction boxes provided with clamps. The joint as a whole shall be protected from ambient conditions. The applicability of cable jointing and methods of cable connection other than those mentioned above are subject to special consideration of the Register in each case.

17 ELECTRIC PROPULSION PLANTS

17.1 GENERAL

17.1.1 The requirements of the present Section apply to all electric propulsion plants and their components, as well as to manufacture, installation and tests including:

.1 generators and their prime movers;

.2 switchboards;

.3 transformers/reactors;

.4 semiconductor frequency converters;

.5 electric propulsion motors;

.6 excitation systems;

.7 control systems of electric propulsion plants, monitoring systems (alarm system, indication and logging systems), as well as safety devices;

.8 systems of power bus ducts and cable runs.

17.1.2 The requirements of the present Section do not apply to bow and aft thrusters being auxiliary arrangements for ship's steering.

17.1.3 The requirements of the present Section and applicable requirements of other Sections of the present Part are mandatory for ships with the character of classification supplemented with the mark EPP in compliance with the requirements of 2.2.11, Part I "Classification".

17.1.4 The electrical equipment of the electric propulsion plant shall meet the requirements of other sections and chapters of the present Part unless otherwise specified in the present Section.

17.1.5 In electrical systems of electric propulsion plants, the voltages used shall not exceed those specified in 4.2 and Section 18.

17.1.6 It is recommended to provide electric heating in spaces enclosing electrical machines, switchboards and control panels.

17.1.7 Stationary lighting shall be provided underneath generators and motors of the electric propulsion plant.

17.1.8 Parts of electric propulsion machines (motors and generators) located under the floor shall have the degree of protection not below IP56.

Where they are installed in a dry compartment or protected against the ingress of water by a watertight foundation, and additionally, an alarm operating with the ingress of water in that compartment is provided, degree of protection IP23 may be allowed.

17.1.9 Provisions shall be made for arrangements preventing the generation and accumulation of moisture and condensate, in particular, while being idle for a long time, in casings of electric propulsion motors, generators, semiconductor frequency converters and other electric propulsion plant components. These arrangements may be electric heaters, air dryers, etc.

17.2 DEFINITIONS AND EXPLANATIONS

17.2.1 For the purpose of the present Section the following definitions and explanations have been adopted.

Main control station of the electric propulsion plant — control station of the main propulsion plant which is attended under seagoing condition.

Local control station — control station located where a system is installed intended for selection and input of reference values for semiconductor frequency converters independent from reference values for remote control system and any external limitations.

Azimuth drive — drive which moves the propulsion unit around the vertical axis.

Podded drive — propulsion system in which the electric propulsion motor is located in a dedicated, submerged unit (pod housing) of the ship.

Double sensor — a sensor with two sensor elements in one housing.

Redundant sensor — two single sensors in separate housings to control the same parameter.

17.3 CONFIGURATION OF ELECTRIC PROPULSION PLANTS

17.3.1 The electric propulsion plant includes:

.1 main generators of the electric propulsion plant — at least 2;

.2 main switchboard separated into two parts with a section circuit breaker or break switch;

.3 power transformers for conversion of the main switchboard voltage to that of semiconductor converters — one per each converter;

.4 power semiconductor converters to supply the electric propulsion motor – at least 2;

.5 electric propulsion motor with two systems of stator windings, each being supplied from its semiconductor converter;

.6 control system.

17.3.2 For electric propulsion plants with one electric propulsion motor, synchronous and induction main propulsion motors shall have two systems of stator windings which can independently be disconnected from the relevant semiconductor frequency converter. Each converter shall be designed for at least 50 per cent of the rated power of the electric propulsion plant.

17.3.3 Propulsion DC motors shall be of the double-armature (double-commutator) type with each armature winding designed for at least 50 per cent of the rated power of the plant. Each armature winding shall be supplied from its independent converter. Any single failure in one converter shall not result in complete loss of power.

17.3.4 Provision shall be made for braking or locking devices for a propulsion shaft to prevent its free rotation with a switched-off propulsion motor (shaft) at any environmental conditions or during ship towing.

17.3.5 The electric propulsion plant system shall follow the one failure principle, i.e. if any component of the electric propulsion plant fails, a ship shall be underway at least at the partial power.

17.3.6 Provision shall be made for a warning alarm at all active control stations when any failure occurs in the electric propulsion plant system.

17.3.7 For all auxiliary machinery and essential services, provision shall be made for local control stations to which control is transferred if any component of the remote automated control system of the electric propulsion plant fails.

17.4 EXCITATION SYSTEMS

17.4.1 General.

17.4.1.1 Every excitation system shall be supplied by a separate feeder. The obtainable current and voltage of the excitation system, as well as source of power shall fully comply with the requirements for all electric propulsion plant modes including manoeuvring, overcurrent and short circuit, as well as the capsizing moment conditions.

17.4.1.2 Supply circuits of excitation systems shall be protected against short circuits only. The activation of an electromagnetic release at short circuit shall be supplemented with an alarm at control stations.

17.4.1.3 If the built-in short-circuit monitoring device of the excitation system trips, the respective circuit breaker of the generator or propulsion motor shall also trip.

17.4.1.4 If the excitation system is fitted with independent safety devices against underfrequency and over-voltage or U/f-functions, they shall be adjusted in such a way that the system protection reacts first.

17.4.1.5 Excitation circuits shall be provided with means for suppressing voltage rise when an excitation switch is opened (field suppression system).

17.4.1.6 Means (filters, etc.) shall be provided to limit harmonic distortions and reduce a power factor.

17.4.2 Generator excitation.

17.4.2.1 Excitation systems shall be supplied from the generator, the generator shall be self-excited.

The voltage built up shall be done without the aid of external sources of electrical power.

17.4.2.2 External source of electrical power may be used for exciter control circuits, as well as for initial excitation, provided it is redundant.

The external source of power shall be supplied from the main and emergency switchboards and, additionally, from the standby accumulator battery. At least two external sources of power for all electric propulsion plant generators shall be provided.

17.4.3 Electric propulsion motor excitation.

17.4.3.1 The exciter shall be supplied directly from the same main switchboard section supplying the stator winding.

17.4.3.2 Excitation systems and automatic control systems shall be so designed that electric propulsion motors are protected from overspeeding in the event of the propeller breaking down or working clear of water.

17.5 ELECTROMAGNETIC COMPATIBILITY (EMC)

17.5.1 The electric propulsion plant shall operate without malfunctions and failures being exposed to electromagnetic interference, and comply with the requirements of 2.2.

17.5.2 Equipment producing transient voltage, frequency and current variations shall not cause malfunctions and failures of other equipment on board, neither by conduction, induction or radiation.

17.5.3 If a total harmonic distortion value of 10 per cent is exceeded when operating the propulsion plant, the appropriate filtering and interference-free operation of any consumers shall be ensured.

17.6 PRIME MOVERS OF ELECTRIC PROPULSION PLANT GENERATORS

17.6.1 Permissible speed deviations.

17.6.1.1 If electric propulsion plant generators are also used for supplying the ship network, frequency deviations with the relevant load variations shall meet the requirements specified in 2.11.3, Part IX "Machinery".

17.6.1.2 Where the speed control of the propeller requires speed variation of prime movers of the electric propulsion plant generators, the governors shall be provided with means for local control as well as for remote control.

17.6.1.3 The prime movers rated power and overload capacity shall be adequate to supply the power needed during transitional changes in operating conditions of the electrical equipment, as well as the electric propulsion plant load variations due to maneuvering, at sea, including severe weather conditions.

17.6.2 Parallel operation.

In case of parallel operation of generators, the control system used shall ensure stable proportional distribution of loads over the entire output range of the prime movers as specified in 3.2.2.

17.6.3 Reverse power.

17.6.3.1 When maneuvering from full ahead running to full speed astern the prime movers shall be capable of absorbing a proportion of the recuperated work without tripping due to overspeed or reverse power.

17.6.3.2 To absorb a proportion of the recuperated work and to retard the speed of the electric propulsion motor in reverse, braking resistors may be used ensuring the necessary limits on the prime movers and electrical machines speed. The amount of recuperated work shall be limited by the automated control system of the electric propulsion plant.

17.7 ELECTRIC PROPULSION PLANT GENERATORS

17.7.1 General.

17.7.1.1 Generators operating with semiconductor converters shall be designed for the expected harmonics of the system.

A sufficient output reserve shall be provided to compensate the generator temperature rise, compared with the sinusoidal load.

17.7.1.2 Stator windings of generators with rated power output above 500 kVA shall be provided with temperature sensors.

17.7.1.3 Electric propulsion plant generators shall be fitted with cooling air cleaning filters open-circuit and closed-circuit ventilation. Ventilation ducts shall be arranged so as to prevent water ingress into the machine.

17.7.1.4 Electric propulsion plant generators may be used for supplying auxiliary electrical machinery and services provided voltage and frequency are stable under all conditions, including manoeuvring, in compliance with the requirements of 2.1.3.

17.7.1.5 No circuit breakers shall be fitted in excitation circuits of generators except those which remove excitation of machinery at short circuits or damages in the main current circuit.

17.7.1.6 Means of protection of generators shall comply with the requirements specified in 8.2.

17.7.2 Generator bearings and lubrication.

17.7.2.1 Sliding bearing shells shall be easily replaceable. Provision shall be made for checking the bearing lubrication. Adequate lubrication shall be provided even at the maximum potential trim. Provision shall be made for relevant seals to prevent oil ingress inside the generator.

17.7.2.2 In case of bearings with forced lubrication (under pressure), the following alarms, as a minimum, shall be provided at control stations:

.1 failure of lubricating system (failure of lubrication pump, loss of pressure in the lubrication pipe, etc.);

.2 maximum temperature of each bearing.

17.7.2.3 Generators shall be fitted with backup (emergency) devices for bearings lubrication which, in the event of malfunction or failure of the normal lubricating system, provide adequate lubrication until the machine full stop.

17.7.2.4 To avoid damage to bearings, provision shall be made to ensure that no currents can flow between the bearing and the shaft for which purpose one of the bearings shall be galvanically isolated from the machine housing.

17.7.3 Generators cooling.

17.7.3.1 In addition to thermometers, temperature sensors of cooling air shall be provided which shall initiate an alarm with the excess of a permissible temperature.

17.7.3.2 For machines with a closed circuit cooling and heat exchanger, the flow of primary and secondary coolants shall be monitored. An alarm shall be initiated with the flow failure.

17.7.3.3 Leakage-water and condensed moisture shall be kept away from the machine windings. Provision shall be made for an alarm to monitor leakage.

17.8 ELECTRIC PROPULSION PLANT SWITCHBOARDS

17.8.1 Electric propulsion plant switchboards shall meet the requirements of 4.6 and 18.6.

17.8.2 Where a certain sequence of close-open operations is required, a reliable interlock shall be provided to prevent wrong switching.

17.8.3 Switches for routine switching in de-energized circuits of the electric propulsion plant shall be provided with an interlocking device to prevent their tripping under voltage, or false switching.

17.9 ELECTRIC PROPULSION PLANT POWER TRANSFORMERS

17.9.1 General.

17.9.1.1 Transformers and reactors shall meet the requirements of Section 11 and 18.4.

17.9.1.2 Provision shall be made for at least two independent power transformers for the electric propulsion plant. Only transformers with separate windings shall be used.

17.9.1.3 The winding temperatures of transformers used in electric propulsion plants shall be monitored with a sensor and indicator system.

17.9.1.4 For electric propulsion plant transformers, ammeters on the main switchboard on the primary side in each phase shall be provided.

17.9.1.5 Each electric propulsion plant transformer shall have overcurrent and short circuit protection on the primary and secondary side.

For protection on the secondary side, electric propulsion plant semiconductor converter may be used.

17.9.2 Liquid cooled electric propulsion plant transformers.

17.9.2.1 Windings of liquid cooled transformers shall be completely covered by liquid, even for inclinations up to and including 22,5°.

17.9.2.2 Transformers shall be provided with the necessary collecting and accumulating arrangements for coolant leaks.

Fire detectors and fire-fighting equipment shall be installed in the vicinity of the transformer. The fire-fighting equipment may be manually operated.

17.9.2.3 Transformers shall be fitted with protection against gassing of coolant.

17.9.2.4 The coolant temperature shall be monitored with a sensor system. A pre-alarm shall be actuated before the maximum permissible temperature is attained. When the maximum permissible temperature limit is reached, a separate sensor shall activate protection which switches off the transformer.

17.9.2.5 The coolant level shall be monitored by two sensors, one of them shall actuate an alarm and the other set up to the maximum permissible level shall switch off the transformer.

17.9.3 Air cooled electric propulsion plant transformers.

17.9.3.1 The operation of fans for transformers cooling, as well as the cooling air temperature shall be monitored with a sensor system.

An alarm shall be given at the excess of temperature or fan failure.

17.9.3.2 Where a closed circuit cooling air system with an air cooler is used, in addition to the requirements of 17.9.3.1, the following shall be monitored:

.1 the minimum flow of primary and secondary coolants (air and water);

.2 heat exchanger leakage to be alarmed.

The heat exchanger shall be so installed that water leakages and condensed moisture are kept away from the windings.

17.10 ELECTRIC PROPULSION PLANT SEMICONDUCTOR CONVERTERS

17.10.1 General.

17.10.1.1 Converters shall meet the requirements of Section 12.

17.10.1.2 At least two entirely independent separate semiconductor converters shall be provided for the electric propulsion plant.

17.10.1.3 Each converter shall be provided with a separate control system.

17.10.1.4 There shall be provided two galvanically isolated speed sensors for each control system. Common housing of both sensors is permitted.

17.10.1.5 If the converter feeds a permanently excited electric propulsion motor, a switch disconnector shall be fitted in the "motor-converter" line which opens automatically in case of an inverter (rectifier) fault. Devices shall be provided for such faults diagnosis.

17.10.1.6 Semiconductor converters, and also the main current circuit equipment shall carry overcurrents not less than 250 per cent of the rated current within 2 s.

17.10.1.7 Electric propulsion plant converters shall be designed for the nominal torque of the drive (nominal torque at a propeller shaft). Short-term overloads and speed variations (dips) resulting from overloads shall not lead to the activation of converter protection.

17.10.1.8 The cabinets for semiconductor converters shall meet the requirements of 4.6 and Section 18.

17.10.1.9 The cabinets for semiconductor converters shall provide for the quick exchange of power components. This can be achieved by use of modular design for separate thyristors, single phase thyristors or by another way.

17.10.2 Cooling of semiconductor converters.

17.10.2.1 If converters are fitted with a forced-cooling system, means for its monitoring shall be provided. In case of a failure of the cooling system, measures shall be taken to prevent the overheat and failure of the converter.

17.10.2.2 The cooling system shall be provided with an alarm system. The alarm signal can be generated by the failure of a coolant flow or by a high temperature of semiconductors.

17.10.2.3 Single failures in the converter cooling system shall not result in tripping all converters of the ship's electric propulsion plant.

17.10.3 Protection of semiconductor converters.

17.10.3.1 Operational overvoltages in a supply system of converters shall be limited by suitable devices to prevent damage (breakdown) of thyristors.

17.10.3.2 A suitable control system shall ensure that the rated current of semiconductor elements cannot be exceeded under all normal and most severe conditions.

17.10.3.3 Power semiconductors shall not be damaged by direct short circuit at the terminals. Protection by fuses against short-circuit currents is permitted. The relevant feedbacks of the converter shall control (limit) the current in such a way, that no components are damaged when the converter is switched on to a blocked motor.

17.11 HARMONIC FILTERING

17.11.1 Line filters shall be used to ensure the required harmonic distortion on the main switchboard busbars at any step of propulsion.

17.11.2 Each individual filter circuits shall be protected against overcurrents and short-circuit currents. The fuses in filter circuits shall be monitored. Any fuse burnout shall be alarmed.

17.11.3 When designing and using line filters, their layout shall be designed for any conceivable line constellations. In particular, self-resonance shall be excluded under any load conditions and operating generators constellations.

17.11.4 In case of several parallel filter circuits, the current symmetry shall be monitored. An unsymmetrical current distribution in the individual filter circuits and the failure of the filter shall be alarmed.

17.12 ELECTRIC PROPULSION MOTORS

17.12.1 General.

17.12.1.1 Stator windings of AC motors and interpole, mainpole and compensation windings of DC motors of electric machines with a capacity above 500 kVA, shall be provided with temperature sensors.

17.12.1.2 Regarding the design and lubrication of electric propulsion motor bearings, the requirements of 17.7.2 shall be met.

17.12.2 Electric propulsion motors cooling.

17.12.2.1 The cooling system shall ensure sufficient cooling under all load and speed conditions.

17.12.2.2 Electric propulsion motors shall be fitted with built-in temperature sensors which shall give an alarm signal with the excess of a permissible temperature.

17.12.2.3 For machines with a closed circuit cooling system and a heat exchanger, the flow of primary and secondary coolants shall be monitored.

17.12.2.4 Provision shall be made to alarm leakage. The heat exchanger shall be installed so that water leakages and condensed moisture are kept away from the windings.

17.12.2.5 If the cooling system of the propulsion motor fails, the emergency operation mode to ensure ship's manoeuvring under heavy navigating conditions shall be provided. Interventions by an operator for opening of emergency air flaps are permitted.

17.12.2.6 Air-cooled electric propulsion motors shall be fitted with two forced-air fans, each having a capacity sufficient for normal operation of the electric motor. A visual signal indicating fans operation and an alarm on their shutdown shall be provided.

17.12.2.7 A liquid cooling system for multi-armature machines shall be independent for each armature.

17.12.3 Protection of electric propulsion motor.

17.12.3.1 Over-current protection in the main and excitation circuits shall be set sufficiently high so that there is no possibility of its operating due to the over-currents caused by ship's maneuvering, operation in heavy seas or in broken ice.

17.12.3.2 Short-circuit and over-current protection may be provided by the converter. Different electric propulsion motor designs (DC, synchronous, induction and permanent-magnet excitation motors) shall be taken into consideration.

17.12.3.3 Provision shall be made for an independent overspeed (runaway) protection device as required in 2.11, Part IX "Machinery".

The electric propulsion motor shall be capable to withstand overspeed up to the limit reached in accordance with the characteristics of the overspeed protection device at its specified operational setting.

17.12.3.4 The motor shall be capable to withstand a sudden short-circuit currents at its terminals under nominal load without damage.

Steady state short-circuit current of a permanent excited motor shall not cause thermal damages of the motor and the current carrying components (e. g. slip rings, cables, feeders or busducts).

17.13 SPECIAL REQUIREMENTS FOR PODDED DRIVES

17.13.1 General.

17.13.1.1 If the space, where an electrical machine and other equipment are located, is inaccessible during operation and associated with special environmental conditions (high temperature, humidity, etc.), special measures shall be taken like use of highly reliable materials and components, adequate number of sensors, as well as special means for protection of components against flooding and damages.

17.13.1.2 The components, e.g. controls, sensors, slip rings, cable connections and auxiliary drives shall withstand undamaged the strength of vibration, of at least 4 g from 3 Hz to 100 Hz.

17.13.2 Sensors.

Sensors which can only be changed during dry docking shall be constructed as double sensors, i.e. two sensor elements in one housing.

17.13.3 Bearings.

17.13.3.1 Oil filling levels in bearing housings shall be monitored during operation and standstill. Any oil leakage shall activate an alarm.

This applies to circulated lubrication systems as well. These systems shall additionally be equipped with lubricating oil flow monitoring. A flow level monitoring alarm shall be independent from the electric propulsion motor control system.

17.13.3.2 The temperature of shaft bearings shall be monitored by an alarm and protection system. The alarm shall be carried out in two steps: alarm and engine stop. The protection system shall be independent from the temperature indication system for shaft bearings, and the alarm system.

17.13.4 Bilges in a pod housing.

The water level in pod bilges and associated spaces shall be monitored with level sensors. In addition to high level sensors in bilges operating for an alarm system, independent sensors to monitor a high emergency level shall be provided which prevent false operations and automatically stop the propulsion.

17.13.5 Fire detection system.

An effective fire detection system with the adequate number of sensors of the relevant type shall be provided. The general requirements for such systems are specified in 7.5.

17.13.6 Accessible spaces (in a pod housing).

Sufficient illumination and ventilation shall be provided for accessible spaces of the pod housing where regular maintenance work and equipment inspection are carried out.

17.13.7 Protection of the propulsion motor.

17.13.7.1 Motors of more than 1 MW and all permanent excited motors shall be provided with protection against internal faults that also monitors the connections between the semiconductor converter and the motor. The power supply to the defective equipment shall be interrupted with an appropriate time delay and an alarm shall be given.

17.13.7.2 Humidity shall be monitored for motors with closed air cooling systems. The excess of the permissible humidity level shall be alarmed.

17.13.8 Motor supply lines.

17.13.8.1 Cables operated at high temperature limits shall be installed separate from other cables. If required, splitters shall be provided to prevent contacts between cable sheaths.

17.13.8.2 IP protection for all terminals, cable glands and busbar connections shall be equal to motor protection, however, at least IP 44. These requirements also apply to control cables.

17.13.9 Slip rings.

17.13.9.1 Where data from feedback sensors, controlled variable sensors, etc. are transmitted via a data bus of slip rings, the busbar shall be duplicated. Failure of each single busbar shall be alarmed.

17.13.9.2 Slip rings unit fitted with external forced cooling system shall be capable of operation without a cooling system for a certain period of time. The cooling system failure shall be alarmed.

17.13.10 Azimuth drive.

17.13.10.1 Azimuth drive shall meet the requirements for steering gear in accordance with the requirements of 5.5.

17.13.10.2 The single failure localization principle shall be ensured for all electrical and hydraulic components. Safe operation of the ship shall be ensured independently of the rudder angle and ship's speed at any time a failure occurs. The designer shall develop and submit for approval the "Failure Mode Effect Analyses" (FMEA).

17.13.10.3 The position of the azimuth drive shall be mechanically indicated on a scale at the drive location (steering compartment).

17.13.10.4 At least two independent electric drives shall be provided for each azimuthal unit for turn, whereby one drive shall be supplied from the main switchboard and the other, from the emergency switchboard.

17.13.10.5 Azimuth electric drives shall be protected against overcurrent (by converter, if applicable) and short circuit. They shall be able to supply 160 per cent of the torque necessary for the rated speed of movement in accordance with the requirements of 6.2.2, Part IX "Machinery" for 60 s.

Azimuth drives with different design, e. g. hydraulic, shall also be able to fulfill the above requirements.

17.13.10.6 The thrust azimuth angle shall be limited to $\pm 35°$. At low propulsion power rating and thus low ship's speed or crash-stop maneuver these limits may be disabled with the control system.

17.13.10.7 The thrust azimuth angle shall be limited related to the steps of the set ship's speed that the safety of the ship is not endangered (due to excessive thrust while turning). The limitation (interlock) shall be provided redundantly and independently of the control of the azimuth angle (pod turning).

17.13.10.8 Reaching or exceeding the permissible limitations of the azimuth angle shall be alarmed. After triggering the limitation, it shall be possible to move the azimuth drive back to the permitted angles of the drive turn without manual reset.

17.13.10.9 The operation and indication equipment of the azimuth drive shall be arranged in such a way that the set direction of the propeller thrust or the direction of the ship's moving is clearly indicated. It shall be clear to the operator whether the direction of the ship's moving or the direction of the propeller thrust of the electric propulsion plant was chosen.

17.13.10.10 The local control station for azimuthal unit shall be equipped with the following:

.1 ammeters for each supply system of each load component;

.2 azimuth angle (turn angle) indicators for each drive;

.3 power supply system readiness for operation indicators for each drive;

.4 power supply system disturbance indicators for each drive;

and provide for the following:

.5 power limitation (from converter);

.6 control from engine control room;

.7 control from the navigating bridge;

.8 control from local control station;

.9 running indication for the associated propulsion drive.

The local control station can be activated locally at any time and shall have the highest priority.

17.14 ELECTRIC PROPULSION PLANTS CONTROL SYSTEMS

17.14.1 Powerplant control systems.

17.14.1.1 For power supply systems of electric propulsion plants with generators operating in parallel, the automated powerplant control system shall be provided which will ensure adequate power generation being consistent with the needs of specific operational modes of the electric propulsion plant, in transit/maneuver including. Automatic load based disconnection of generators in maneuver mode is not permitted.

17.14.1.2 In case of under-frequency on main switchboard busbars, overcurrent or overload and reverse power, the propulsion power shall be automaticaly limited (to prevent de-energizing of main switchboard busbars).

17.14.1.3 If generators are running in parallel and one of them is tripping by protection system, the automated powerplant control system shall automatically reduce the electric propulsion plant load to protect the remaining generators against unacceptable overloads and ensure their operation at permissible loads. The same requirement applies to the main switchboard busbars tiebreakers.

17.14.1.4 Tripping of the main switchboard busbars tiebreaker shall not lead to any malfunction of the system. It is not necessary that the powerplant control system remains in the automatic mode if the power supply system is split.

Any loss of the control system automatic functions shall be alarmed.

17.14.2 Location of the electric propulsion plant control stations.

17.14.2.1 Electric propulsion plant control stations may be located at any convenient place according to the ship's purpose.

Where control stations are arranged outside the machinery space, i.e. on the bridge or in other locations, control stations in the machinery space or engine control room shall be provided as well.

17.14.2.2 The local control station has a priority and shall be located in the vicinity of the drive or semiconductor converters. Changes of electric propulsion plant modes generated at this station shall be displayed by the system indicating a preset and executed commands.

17.14.2.3 Where several control stations are available, a control stations switch in the control station having a priority shall be provided. Such switch shall provide switching of any, but only one control station (central and wing stations on the navigating bridge are considered as one control station).

17.14.2.4 Each control station shall have an emergency stop device independent of the control system and the active (in "on" condition) control station.

17.14.3 Main and local control stations.

17.14.3.1 At least two mutually independent main and local control stations shall be provided for electric propulsion plant.

17.14.3.2 In case of damage, malfunctioning or loss of power supply of the main station control system, a local control of the electric propulsion plant converters shall be provided.

17.14.3.3 The bridge shall be fitted with control systems such that the steering (azimuth thrust change) control system can operate independently of the speed and electric propulsion plant electric propulsion motor reverse control system.

17.14.3.4 All electric propulsion plant alarms shall be acknowledged at the local control station. Alarms which do not require any further intervention of the personnel can be acknowledged at the main control station (on the navigating bridge) with the mandatory follow-up acknowledgement at the local control station.

17.14.3.5 Restart of the electric propulsion plant shall be possible from both (main and local) control stations, depending on which one has been preselected. After the main switchboard de-energizing it shall be possible to restart the electric propulsion plant at the main control station.

17.14.3.6 If the electric propulsion plant is controlled from a panel or desk with the use of electric, pneumatic or hydraulic drive, the failure of them shall not result in electric propulsion plant tripping, and each control station at the panel or desk shall be immediately ready for manual operation.

17.14.3.7 Mechanically linked control stations installed in the wheelhouse (on the navigating bridge) for their synchronous operation may be permitted.

17.14.3.8 The remote control system of the electric propulsion plant shall be so designed that no time delay is needed for the personnel to move a control handle at a control station to a new position.

17.14.3.9 The electric propulsion plant control system shall be provided with an interlock to prevent the electric propulsion plant activation with a shaft turning gear engaged.

17.14.3.10 Each control station shall have a visual indication on the control system being alive.

17.14.4 Measuring, indicating and monitoring equipment.

17.14.4.1 Failures in measuring, monitoring and indicating equipment shall not result in failure of the electric propulsion plant control system, e. g., failure of the actual value (speed) sensor or of the reference speed value sensor shall not cause an excessive increase of propeller speed.

17.14.4.2 The local (active) control station shall be equipped with the following:

.1 ammeter for each power supply line of each load component (stator current of each winding, etc.), and also in the excitation circuit (for adjustible-excitation systems);

.2 voltmeters for each power supply line of each load component, and also for power supply of the excitation system (for adjustible-excitation systems);

.3 speed indicator for each shaft;

.4 "Powerplant ready for electric propulsion plant operation" indicator;

.5 "Powerplant disturbed" indicator;

.6 "Electric propulsion plant power limited" (from converter) indicator;

.7 "Control from the engine control room" indicator;

.8 "Control from the navigating bridge" indicator;

.9 "Control from the local control station" indicator.

17.14.4.3 The main control station (on navigating bridge) shall be equipped with the following:

.1 revolution indicator for each shaft;

.2 each shaft power meter;

.3 "Powerplant ready for switching on" (additional generators) indicator;

.4 "Power plant ready for electric propulsion plant operation" indicator;

.5 "Power plant disturbed" indicator;

.6 "Electric propulsion plant power limited" indicator;

.7 "Request to reduce power" indicator — if not automatically controlled or "override" button pushed (cancellation of the plant automated control);

.8 "Control from the engine control room" indicator;

.9 "Control from the navigating bridge" indicator;

.10 " Control from the local control station" indicator;

.11 indication of the generators operating at the electric propulsion plant;

.12 indication of power reserve (recommended).

17.14.4.4 When two or more control stations are provided for change of speed and angle of turn of CPP blades, both speed change and angle of turn of CPP blades indicators shall be provided at each control station.

17.14.4.5 The engine control room shall be equipped with the following:

.1 speed indicator for each shaft;

.2 each shaft power meter;

.3 "Powerplant ready for switching on" (additional generators) indicator;

.4 "Power plant ready for electric propulsion plant operation" indicator;

.5 "Power plant disturbed" indicator;

.6 "Electric propulsion plant power limited" indicator;

.7 "Request to reduce power" indicator — if not automatically controlled or "override" button pushed (cancellation of the plant automated control);

.8 "Control from the engine control room" indicator;

.9 "Control from the local control station" indicator;

.10 "Control from the navigating bridge" indicator;

.11 indication of the generators operating at the electric propulsion plant.

The list of parameters controlled by the alarm system is given in Tables 17.14.4.5-1 and 17.14.4.5-2.

17.14.5 Fail-safety of electric propulsion plant control systems.

17.14.5.1 Electric propulsion plant control systems with the use of processors shall comply with the requirements of Section 7, Part XV "Automation".

17.14.5.2 The loss of power or malfunctioning of any other control and monitoring systems shall not result in loss of propulsion and electric propulsion plant control, ship's steering or azimuth drive.

17.14.5.3 Electric propulsion plant, azimuth drives and their control systems shall have self-check system and an alarm system to detect failures quickly.

17.14.5.4 The most probable failures, e. g. loss of power, wire failure or cable and wire short circuits, etc. shall result in the least critical of all possible new conditions of the ship (fail to safety).

17.15 ELECTRIC COUPLINGS

17.15.1 General.

17.15.1.1 Electric couplings shall be designed so that they may be dismantled without the disassembly of a driving motor or reduction gear. The design and location of couplings shall ensure free access for their maintenance, brush replacement and air gap measurements without dismantling the couplings.

17.15.1.2 Enclosures and end shields shall be made of steel or material of equivalent strength (refer also to 10.1.1).

17.15.1.3 The rotating parts of couplings, as well as their windings shall be designed and secured so that they cannot be damaged in the event of a sudden stop. Electric couplings shall not cause axial forces. Balance ratio of electric couplings shall meet the requirements of 4.1.2, Part IX "Machinery".

17.15.1.4 The maximum torque under excitation forcing conditions shall not exceed the twofold rated torque of the coupling.

The requirements of the present Chapter also apply to electric couplings fitted in other systems.

17.15.2 Protection and interlocking.

The design of the coupling connection system or the interlock used shall be such that the coupling

Table 17.14.4.5-1

List of monitored parameters of the electric propulsion plant with AC synchronous, permanent excited and induction electric propulsion motors

Monitored parameter	Limiting value, Max/Min	Local measuring instrument	Alarm, display in the engine control room	Load reduction	Automatic "Stop"	Main control station (bridge), group alarm
Electric propulsion motor:						
Lubrication system	Malfunction	Inspection glass	×	×	×	×
Bearing temperature	Max	Thermometer	×			×
Stator winding temperature	Max		×	×		×
Slip rings (synchronous electric propulsion motor)	Malfunction (electric arc)	Inspection hatch	×			×
Water/air cooling system	Malfunction		×			×
Cooling air temperature at the inlet	Max	Thermometer	×			×
Coolant	Leakage		×			×
Speed	Max		×		×	×
Voltage regulation (synchronous electric propulsion motor)	Failure		×		×	×
Insulation resistance for stator and feeder	Min		×			×
Insulation resistance for excitation system and feeder (synchronous electric propulsion motor)	Min		×			×
Transformers:						
Winding temperature	Max		×	×		×
Coolant	Leakage		×	×		×
Cooling system	Malfunction		×			×
Converters:						
Mains	Malfunction		×		Start	×
Cooling system	Malfunction		×	×		×
Power units temperature	Max		× Max1		× Max2	×
Cooling agent flow	Min		×			×
Coolant	Leakage		×			×
Preliminary alarm						×
Accident, failure			×		×	×
Rotor speed and position sensor (synchronous electric propulsion motor)	Malfunction		×			×
Emergency stop (Converter switched off)			×		×	×
Semiconductor fuse	Malfunction		×		×	×
Semiconductor temperature	Max		×	Reduction		×
Voltage (direct current link)	Max		×		×	×
Current (direct current link)	Max		×		×	×
Current at the converter outlet	Max		×		×	×
Electric propulsion plant main, shipboard electrical system:						
Harmonic trap	Accident, damage		×			×

excitation during the main propulsion engine starting and reversing is prevented.

Where several driving motors operate on a common transmission, in order to prevent the simultaneous start of driving motors rotating in opposite directions, the interlock in the coupling excitation system shall be used.

17.15.3 Electric couplings excitation.

Excitation windings of electric couplings shall be protected against overvoltage.

The excitation circuit of electric couplings shall include:

.1 a two-pole switch;

.2 a magnetic field discharging device;

.3 short-circuit protection.

Table 17.14.4.5-2

List of monitored parameters of the electric propulsion plant with DC electric propulsion motors

Monitored parameter	Limiting value, max/min	Local measuring instrument	Alarm, display in the engine control room	Load reduction	Automatic "Stop"	Main control station (bridge), group alarm
Electric propulsion motor:						
Lubrication system	Malfunction	Inspection glass	×	×	×	×
Bearing temperature	Max	Thermometer	×			×
Main pole temperature	Max		×	×		×
Auxiliary pole/compensating winding temperature	Max		×	×		×
Water/air cooling system	Malfunction		×			×
Cooling air temperature at the inlet	Max	Thermometer	×			×
Coolant	Leakage		×			×
Speed	Max		×		×	×
Commutator/brushes	Malfunction (electric arc)	Inspection hatch	×			×
Armature current	Max		×		×	×
Insulation resistance for armature circuit and feeder	Min (earth fault)		×			×
Transformers:						
Winding temperature	Max		×	×		×
Coolant	Leakage		×			×
Cooling system	Malfunction		×			×
Converters:						
Mains	Malfunction		×		Restart	×
Cooling system	Malfunction		×	×		×
Power units temperature	Max		× Max1		× Max2	×
Cooling agent flow (direct cooling)	Min		×			×
Coolant	Leakage		×			×
Preliminary alarm						×
Accident, failure			×		×	×
Armature speed sensor	Malfunction		×			×
Emergency stop (Converter switched off)			×		×	×
Semiconductor fuse	Malfunction		×		×	×
Electric propulsion plant main, shipboard electrical system:						
Harmonic trap	Accident, damage		×			×

18 ADDITIONAL REQUIREMENTS FOR ELECTRICAL EQUIPMENT DESIGNED FOR A VOLTAGE IN EXCESS OF 1000 V UP TO 15 KV

18.1 GENERAL

18.1.1 Scope of application.

The requirements apply to three-phase a.c. systems with the rated voltage in excess of 1 kV where the rated voltage means the voltage between phases.

Unless otherwise specified in this Section, the requirements for design and installation for low-voltage equipment (up to 1000 V) given in the present Part also apply to high-voltage equipment.

18.1.2 Segregation of high-voltage and low-voltage equipment.

18.1.2.1 Electrical equipment for a voltage over 1000 V shall not be housed in the same casing (enclosure) with low-voltage equipment unless the relevant segregation is provided or appropriate measures ensuring safe access for low-voltage equipment maintenance are taken.

18.1.2.2 Insulating materials used for electrical equipment shall ensure the insulation resistance of 1500 ohms per 1 V rated voltage, but at least 2 megohms during the unit operation.

18.1.2.3 At the entrance to special electrical spaces, a warning notice shall be provided indicating the voltage. Enclosures of electrical equipment installed outside special electrical spaces shall be provided with warning notices indicating the voltage.

18.2 SYSTEM DESIGN

18.2.1 Distribution design.

18.2.1.1 The following power distribution systems may be used for three-phase a.c. current high-voltage plants:

insulated three-wire system;

three-wire system with the neutral earthed to the ship's hull through a high-capacity resistor or reactor;

four-wire system with the deadly earthed neutral.

18.2.1.2 Configuration of network for ensuring uninterruptible power supply.

The main switchboard design shall provide for the possibility of its separation into, as a minimum, two independent parts by means of a circuit breaker or disconnector.

Each part of sections shall be connected to, as a minimum, one generator.

Where two independent main switchboards interconnected by cable jumpers are provided, circuit breakers shall be fitted at its both sides. All the duplicated electrical drives shall be supplied from different main switchboards or its split sections.

18.2.1.3 Systems with earthed neutral.

18.2.1.3.1 Neutral points of generators running in parallel may be connected to a common bus before an earthing resistor or reactor fitted in a switchboard or immediately at the generators.

18.2.1.3.2 In case of an earth fault, the leakage current shall not exceed the rated current of the largest generator or the total rated current of a relevant main switchboard section and shall not be less than the triple minimum current required for earth-fault protection activation.

18.2.1.3.3 When the system is energized, at least one neutral earthing point shall be closed. The electrical equipment in systems with a deadly earthed neutral connected to the hull through a high capacity resistor or reactor shall bear without damage the single plase-to-earth fault current during the time needed for protection device activation.

18.2.1.4 Neutral opening.

In the neutral wire of each generator, provision shall be made for a disconnector, which may cut out the neutral from earthing for insulation resistance measurements and generator maintenance.

18.2.1.5.1 All earthing impedances of neutral points shall be connected to the hull. The connection to the hull shall be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, intercommunication and control equipment circuits.

18.2.1.5.2 It is allowed to connect all resistors or reactors to the common earthing busbar, which shall be connected to the ship's hull at least at two points.

18.2.1.6 Divided systems.

18.2.1.6.1 Neutral connections to the hull shall be provided for each split group of main switchboard sections in divided systems with an earthed neutral.

18.2.2 Degrees of enclosures protection.

18.2.2.1 General requirements.

Each part of electrical equipment shall have shielded enclosures corresponding to its location and effecting environmental conditions. The requirements of IEC Standard 60092-201 may be considered as minimum.

18.2.2.2 Electrical machines.

A degree of protection by enclosure for electrical machines shall be at least IP23. The degree of protection of machines lead boxes shall not be less than IP44.

Motors installed in spaces accessible to unqualified personnel shall have the degree of protection of at least IP4X to prevent touching of live and rotating parts.

18.2.2.3 Transformers.

A degree of protection by enclosure for transformers shall be at least IP23.

Transformers installed in spaces accessible to unqualified personnel shall have the degree of protection of at least IP4X.

The requirements of 18.7.1 apply to transformers having no enclosure.

18.2.2.4 Switchgear, control panels and converters.

A degree of metal enclosures protection for switchgear, control panels, static converter cabinets shall be at least IP32. Panels installed in spaces accessible to unqualified personnel shall have the degree of protection of at least IP4X.

18.2.3 Insulation distances.

18.2.3.1 Air clearances.

Air clearances between live parts with different potentials or between live parts and earthed metal parts or the casing shall not be less than specified in Table 18.2.3.1.

Table 18.2.3.1

Nominal voltage, kV	Minimum air clearance, mm
3 (3,3)	55
6 (6,6)	90
10 (11)	120
15	160

Minimum clearances for intermediate values of working voltages are assumed as for the next larger value of a standard voltage.

Selecting lesser clearance, special high-voltage impulse tests shall be made to confirm admissibility of such an option.

18.2.3.2 Creepage distances.

Creepage distances between live parts with different potentials and between live parts and the hull shall be selected on the basis of national and international standards.

For non-standard equipment parts within the busbar section of a switchgear assembly, the minimum creepage distance shall be at least 25 mm/kV and behind current limiting devices, 16 mm/kV.

18.2.4 Protective devices.

18.2.4.1 Faults on the generator side.

In addition to the types of protection specified in 8.2, generators shall be provided with protection devices against an interphase fault in the cables connecting the generator and main switchboard, and against turn-to-turn faults inside the generator.

When this protection device is activated, the generator shall be shut off from the main switchboard and its excitations shall automatically be removed.

In distribution systems with deadly earthed neutral, the earth fault of a generator phase shall also result in the activation of protection.

18.2.4.2 Faults to earth.

18.2.4.2.1 An audible and visual alarm shall be activated in a system at any earth faults.

18.2.4.2.2 Protection automatically disconnecting a faulted circuit at earth faults shall be activated in low-impedance (deadly-earthed) systems.

18.2.4.2.3 In high-impedance earthed systems (systems with a neutral earthed through a high-resistance resistor), where the feeders outgoing from the main switchboard can not be disconnected at an earth fault, the insulation of electrical equipment supplied from these feeders shall be designed for the line voltage of the system.

Notes. 1. The systems to be classified as effectively earthed (low impedance) if a coefficient of earthing is below 0,8, and ineffectively earthed (high impedance), 0,8 and over.

2. The efficient of earthing means a ratio between a voltage "phase – earth" in a healthy, i.e. intact system, and a line ("phase – phase") voltage.

18.2.4.3 Power transformers.

Power transformers shall be protected against a short circuit and overloading with circuit breakers.

Where the transformers are intended for running in parallel, the activation of protection on the primary side shall cause their automatic disconnection on the secondary side as well.

18.2.4.4 Voltage transformers for control systems and instruments.

Transformers intended for supply of control circuits and instruments shall be protected against overloading and short circuits on the secondary side.

18.2.4.5 Fuses.

Protective fuses shall be used for short-circuit protection.

No fuses for overload protection are allowed.

18.2.4.6 Low-voltage systems.

Low-voltage distribution systems (up to 1000 V) supplied from high-voltage transformers (systems) shall be protected against overvoltages associated with the ingress of a high voltage on the secondary (low voltage) side. This may be achieved by:

earthing of the low voltage system;

appropriate neutral voltage limiters;

earthed screen between the primary and secondary windings of the transformer.

18.2.4.7 Protective earthing.

Metal enclosures of electrical equipment shall be earthed by external flexible copper conductors having a cross-sectional area designed for a single-phase short-circuit current, but not less than 16 mm^2. Earthing wires shall be marked.

Earthing conductors may be connected by welding or by bolts of at least 10 mm in diameter.

18.3 ELECTRICAL MACHINES

18.3.1 Stator windings of generators.

Generator stator windings shall have accessible both phase and neutral ends to ensure the installation of the differential protection.

18.3.2 Temperature detectors.

Electrical machines shall be fitted with built-in temperature detectors in their stator windings to actuate an audible and visual alarm whenever the temperature exceeds the permissible limit.

For built-in temperature detectors, means shall be provided to protect measurement circuits against overvoltage.

18.3.3 Tests.

In addition to the tests required for all electrical machines, high-frequency testing voltage tests, in accordance with IEC Standard 60034-15, of individual phase windings (coils) of the machine shall be provided to demonstrate a satisfactory level of resistance to turn-to-turn faults caused by step-fronted switching surges.

18.3.4 Design.

18.3.4.1 A machine casing, bearing shields, guards of air intakes and outlets shall be made of steel alloys. Aluminium alloys for the above parts are not allowed.

18.3.4.2 A draining arrangement readily accessible for maintenance shall be provided in the lower part of a machine casing for removal of condensate.

Vertically-designed motors shall be fitted on their top with a rigidly secured canopy preventing the ingress of water and foreign objects inside the machine. A lower end shield shall be shaped so as to prevent accumulation of water in way of a bearing.

18.3.4.3 Lead boxes of machines shall be dimensioned so as to ensure:

necessary insulation distances between current-carrying parts and the casing;

a sufficient space for arrangement of connecting cable terminations and windings ends;

an opportunity to change the location of supply cable entries up to four positions at an angle of 90°.

An individual terminal box shall be provided for instrument current transformers, heating anticondensation elements, temperature detectors, etc.

18.3.4.4 The leads of stator winding phases shall enter a separate terminal box, which is different from the ones for lower voltages, through a sealing gasket.

A separate terminal box may be provided for neutral leads.

Terminals for earthing cable cores shall be provided inside terminal boxes. In this case, a reliable electrical connection between a machine casing and box body shall be ensured.

18.3.4.5 Motors having the rated power 1000 kW and over shall be fitted with differential protection devices. For this purpose, a separate lead box shall be provided on a motor casing, located on the opposite side from the main box, in which a sufficient space for three current transformers and leads of neutral winding ends shall be provided.

18.3.4.6 Bearings temperature of motors with power of 1000 kW and over shall be controlled by local indicators (devices). Temperature detectors for remote control shall also be provided for each bearing.

18.3.4.7 In order to prevent the harmful effect of bearing currents, the bearing on the side opposite to a drive shall be electrically isolated from a casing. The possibility of measuring insulation resistance of an isolated bearing without its disassembly shall be provided.

18.3.4.8 The design of plain bearings shall provide:

local indicators of the lube oil level;

separate pump with a local pipeline, tank, cooler, filter and flow-rate indicator when forced circulating lubrication is used;

potential fitting of instruments for vibration control, including pertinent cable lines, as well as of instruments for bearing wear measurements;

potential use of the motor starting interlock when lubrication fails.

18.4 POWER TRANSFORMERS

18.4.1 General.

18.4.1.1 Dry-type transformers shall meet the requirements of IEC Standard 60726.

Dry-transformers in use shall have earthed screens between high and low voltage windings.

Liquid-cooled transformers shall meet the requirements of IEC Standard 60076.

Oil-immersed transformers shall, as a minimum, be provided with the following alarms and protections:

"minimum liquid level" – alarm and automatic trip;

"maximum liquid temperature" – alarm and automatic trip or load reduction;

"high gas pressure in enclosure" – automatic trip.

18.4.1.2 Transformers located in spaces accessible to unqualified personnel shall have a degree of protection provided by enclosure of at least IP4X.

18.4.1.3 Where the low-voltage side of transformer has an insulated neutral point, a spark fuse shall be inserted between the neutral point of each transformer and ship's hull.

The fuse shall be rated for not more than 80 per cent of the minimum test voltage of services fed through the given transformer.

18.4.1.4 The equipment for monitoring the condition of insulation on the lower-voltage side of the unit or for detecting locations of this insulation damages may be connected to the fuse in parallel. This equipment shall not interfere with the reliable operation of the fuse.

18.4.1.5 Effective means (e.g. heating) shall be provided to prevent condensation and moisture accumulation inside the transformers when de-energized.

18.5 CABLES

18.5.1 General.

18.5.1.1 Cables shall be constructed in accordance with the requirements of IEC Standards 60092-353 and 60092-354 or other equivalent standards.

18.5.1.2 For three-phase cable systems, triple-core cables with multiwire cores shall be used. The cross-sectional area of the cable conductor for power circuits shall be at least 10 mm^2.

18.5.1.3 The construction, type and permissible current loads of the cables used are subject to the special consideration by the Register in each case.

18.6 SWITCHGEAR AND CONTROLGEAR ASSEMBLIES

18.6.1 General.

Switchgear and controlgear assemblies shall be constructed according to IEC Standard 60298 and the following additional requirements.

18.6.2 Construction.

18.6.2.1 Mechanical construction.

18.6.2.1.1 Switchgear shall be of the metal-enclosed type in accordance with the requirements of IEC Standard 60298, or of the insulation-enclosed type in accordance with the requirements of IEC Standard 60466, or in accordance with the requirements of national standards.

18.6.2.1.1.1 Switchboards shall be locked with a special key other than for lower-voltage switchboards and switchgear. Opening of doors and withdrawal of separate part shall be possible only after disconnection of the panel or switchboard from the electric network.

18.6.2.1.1.2 Passageways for a switchboard and electrical equipment inspection at least 800 mm wide and 1000 mm wide between the bulkhead and switchboard, and between parallel switchboard sections respectively, shall be provided along the switchboards. Where intended for maintenance, their width shall be increased up to 1000 mm and 1200 mm respectively.

The specified width of these passageways is required irrespective of the applied means of protection against contact, like doors, a net or insulated guardrails.

The doors, continuous bulkheads and net screens shall be at least 1800 mm high.

The perforated bulkheads or net screens shall ensure a degree of protection not below IP2X.

Two insulated guardrails shall be fitted along the switchboard at the heights of 600 mm and 1200 mm.

18.6.2.1.1.3 Live parts of electrical installation shall be located at a distance specified in Table 18.6.2.1.1.3 away from protection guards.

Table 18.6.2.1.1.3

Nominal voltage, kV	Minimum height of passageway, mm	Minimum distances of live electrical parts from various protection guards, mm		
		solid doors and continuous	bulkheads net doors and screens	insulated guardrails
3 (3,3)	2500	100	180	600
6 (6,6)	2500	120	200	600
10 (11)	2500	150	220	700
15	2500	160	240	800

18.6.2.2 Locking facilities.

Withdrawable circuit breakers used in switchboards shall be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and other equipment and fixed disconnectors shall be provided.

Withdrawable circuit breakers shall be located in the service position so that there is no relative motion between fixed and moving portions.

18.6.2.3 Shutters.

The fixed current-carrying contacts of withdrawable circuit breakers shall be automatically covered by insulating shutters when the circuit breaker is drawn out.

18.6.2.4 Earthing and interphase fault devices.

In order to ensure the safe maintenance of high-voltage switchgear, an adequate number of devices for forced busbar fault and earthing for busbars and outgoing feeders shall be provided.

The device shall be designed for a maximum short-circuit current, and may be portable if approved by the Register.

18.6.3 Auxiliary supply system.

18.6.3.1 Source of supply.

Where a separate auxiliary electrical or other source of power is required for operation of circuit breakers and other switches, and also for protection devices, in addition to such a main source, a stand-by one, which an energy supply shall be sufficient for at least two operations of all the components, shall be provided.

However, the circuit breaker releases activated due to overload, short-circuit or undervoltage shall be independent of any electrical sources of power.

The requirements does not preclude using the releases activated by an operating voltage, provided that the control of tripping circuits and their supply system integrity (continuity) will be ensured, i.e. if the integrity of the circuits is broken or their supply system is faulty (fails), an alarm will be activated.

18.6.3.2 Number of supply sources.

At least one independent stand-by source of power supply for split main switchboards (refer to 18.2.1.1) for operation of circuit breakers and other switches, in addition to their own supply sources each fed from its own busbar system, shall be provided. Where necessary, an emergency source of electrical power intended for activation of the machinery installation from fully de-energized or dead ship condition may be used for this purpose.

18.6.4 High-voltage tests.

Every main and other switchboards shall be tested by a high voltage of standard frequency. The test procedure and voltage values shall meet the requirements of an appropriate national standard or IEC Standard 60298.

18.7 INSTALLATION

18.7.1 Electrical equipment.

18.7.1.1 Where high-voltage equipment is not contained but a special room forms the enclosure of the equipment, the access doors shall be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance of the rooms or spaces where high-voltage equipment is installed, caution notes shall be placed, which indicate danger of high-voltage.

18.7.1.2 Electrical equipment shall be in special electrical spaces and shall have a degree of protection at least IP23 (refer also to 18.6).

When justified, the equipment may be installed outside the above spaces provided its degree of protection is the last IP44 and access to current-carrying parts of the equipment will only be possible when the voltage is off and special tools are used.

18.7.1.3 A diagram of connections and a drawing of electrical equipment arrangement shall be available in the special electrical space.

18.7.2 Cables.

18.7.2.1 Cable run laying.

Cables shall not run through accommodation spaces. However, when required due to technological reasons, such laying is allowed in special enclosed transit systems (structures).

18.7.2.2 Segregation.

High-voltage cables shall be segregated from cables for voltage below 1000 V. In particular, they shall not be run in the same cable bunch, nor in the same ducts or pipes, or in the same boxes with cables for a voltage 1000 V and below.

Where high-voltage cables of different voltage ratings are installed on the same cable tray, the insulation distances between the cables shall not be less than those specified for a high-voltage cable as per 18.2.3.1.

18.7.2.3 Installation of cables.

High-voltage cables shall be laid in earthed metallic pipes or metallic ducts, or to be protected by earthed metallic enclosures.

Open installation of cables (on carrying pressed panels) is allowed if they have a continuous metallic armour, which shall be reliable and repeatedly earthed.

18.7.2.4 Cable terminations.

Terminations in all conductors of high-voltage cables shall be effectively covered with a suitable insulating material. In terminal boxes, if conductors are not insulated, phases shall be separated from earth and from each other by other by durable barriers of a suitable insulating material.

High-voltage cables, having a conductive layer between phases to control the electric field within the insulation, shall have terminations, which provide electric stress control.

Terminations shall be of the type compatible with the insulation and jacket material of the cable and to be provided with means for earthing all metallic shielding components (metallic tapes, wires, etc.).

18.7.2.5 Marking.

High-voltage cables shall be readily identifiable by suitable marking.

18.7.2.6 Tests after installation.

Before putting into service of a new high-voltage cable network or after its updating (repair or additional cables installation), each cable and its accessories (terminations, earthing ends, etc.) shall be tested by a high voltage.

Tests shall be carried out after an installation resistance measurement.

When a d.c. voltage withstand test is carried out, the test voltage shall not be less than:

1,6 (2,5 U_0 + 2 kV) for cables of a rated voltage U_0 up to and including 3.6 kV, and

4,2 U_0 for higher-rated voltages,

where U_0 is the rated power frequency voltage between each conductor and earth or a metallic screen, for which the cable is designed.

The test voltage shall be maintained for at least 15 min after completion of the test, the conductors shall be connected to earth for a sufficient time period in order to remove any trapped electric charge.

An insulation resistance measurement is then repeated.

When an a.c. voltage withstand test of high-voltage cable insulation is carried out (according to the manufacturer's recommendations), the test voltage shall not be less than the rated one and it shall not be less than the rated one and it shall be maintained for a minimum of 24 hours.

Note. Test according to the requirements in IEC Standard 60502 are recognized by the Register as equivalent to given above.

19 REQUIREMENTS FOR ELECTRICAL EQUIPMENT PROCEEDING FROM SHIP PURPOSE[1]

19.1 PASSENGER SHIPS

19.1.1 Supply and signalling.

19.1.1.1 Electric drives of sea-water pumps, air compressors and control-and-signalling devices of automatic sprinkler systems shall be supplied directly from the main and the emergency distribution boards through separate feeders. The feeders shall be connected to an automatic switch fitted near the pump of the sprinkler system. Normally, the switch shall be connected to the feeder from the main distribution board, and in case of supply failure it shall automatically switch over to the supply feeder from the emergency distribution board. At the main and the emergency distribution boards, the switches of the feeders shall be clearly marked off and shall be permanently in the "on" position. No other switches shall be fitted to these feeders.

19.1.1.2 Supply cables of sea-water pumps, air compressors and control-and-signalling devices of automatic sprinkler systems shall not run through machinery casings, galleys and other enclosed spaces of high fire hazard, except where the above devices and machinery are installed in the spaces in question.

19.1.1.3 In saloons, in way of stairs, passages and ladders to the boat deck, the lighting fixtures shall be supplied through two independent feeders at least (refer also to 6.2.3).

19.1.1.4 The supply systems of essential ship gear shall be so designed that a fire in one of the main vertical fire zone would not damage the above service supply systems in another main vertical fire zone. This requirements may be considered satisfied where the main and emergency supply feeders of the services running through any such zone are as distant from each other as possible both vertically and horizontally.

19.1.1.5 General alarm system shall consist of two independent groups: one for passengers and the other for the crew.

A special alarm, operated from the navigating bridge or fire control station, shall be fitted to summon the crew. The alarm may be part of the ship's general alarm system the requirements for which are specified in 7.4.

In passenger ships with a low-power electrical plant or with a number of passengers less than 36, one group of general alarms is permitted.

19.1.1.6 The fire detection and alarm system shall additionally meet the following requirements:

.1 in ships not fitted with fire detection and fire alarm system capable of remotely identifying the exact place of fire by each automatic detector, the same section shall not serve spaces on both sides of the ship and on more than one deck and it shall not be located in more than one main vertical zone. The same section may serve spaces on more than one deck if those spaces are located in the fore or aft end of the ship or if the detectors protect common spaces on different decks (e.g. fan rooms, galleys, public spaces, etc.);

.2 in ships fitted with the system capable of remotely identifying the exact place of fire by each automatic detector, a section may serve spaces on both sides of the ship and on several decks, but it shall not be located in more than one main vertical zone.

19.1.2 Supply from emergency sources of electrical power.

19.1.2.1 In passenger ships of unrestricted service and of restricted area of navigation **R1**, the emergency sources of electrical power shall simultaneously supply, during 36 hours, the following services:

.1 emergency lighting for:

muster and embarkation stations for boarding life-saving appliances and spaces overboard where life-saving appliances are launched according to 2.3.4 and 2.7.7, Part II "Life-Saving Appliances" of the Rules for the Equipment of Sea-Going Ships;

indicators of exits to the boat deck and notice-plates at the life-saving appliances;

exits from the spaces where a large number of passengers, special personnel or crew members can gather simultaneously;

[1] The present requirements are additions and amendments to the relevant requirements of Sections 1 to 18 of the present Part.

alleyways, stairways and exits to the open deck in all accommodation and service spaces as well as passenger lift cars;

machinery spaces and generator rooms with their local control stations;

all control stations as well as main and emergency switchboards;

emergency diesel generator space;

wheelhouse;

chartroom and radioroom;

stowage positions for emergency and fireman's outfit and positions where manual fire alarms are fitted;

steering gear compartments;

positions of attendance upon emergency fire and bilge pump, sprinkler pump and starting positions of their motors;

helicopter hangars and landing areas;

gyrocompass space;

medical space.

.2 navigation lanterns, lanterns of "Vessel not under command" signal and other lanterns required by Part III "Signal Means" of the Rules for the Equipment of Sea-Going Ships;

.3 radio equipment and navigational equipment according to the requirements of Parts IV "Radio Equipment" and V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships;

.4 internal communication, announcing and general alarm systems;

.5 fire detection and alarm systems, fire door control devices and indicators showing the position of fire doors specified in 2.2.3.3, Part VI "Fire Protection";

.6 sound signal means (whistle, gong, etc.), daylight signalling lamps, manual summoning signals and other signals as required under emergency conditions;

.7 one of the fire pumps, a pump of the automatic sprinkler system, an electric-driven pump of the pressure water-spraying system referred to in 3.4.7, Part VI "Fire Protection", as well as electrical equipment used to ensure operation of foam generators referred to in 3.7.3.7, Part VI "Fire Protection";

.8 emergency bilge pump and equipment essential for operation of remote-controlled bilge valves;

.9 services listed in 7.3.6 and 7.3.8, Part VI "Fire Protection" for Class **INF2** and **INF3** ships in accordance with classification given in 7.3.2, Part VI "Fire Protection", regardless of area of navigation and tonnage of the ship.

.10 other systems, which operation will be considered by the Register to be vital for ensuring the safety of the ship and persons on board.

The services indicated in 19.1.2.1.3 to 19.1.2.1.6 may be fed from its own accumulator batteries located according to 9.2 and having a capacity sufficient for their supply for a period of 36 hours.

For ships of restricted navigation area **R3**, the period of 36 hours may be reduced to 12 hours.

19.1.2.2 Emergency sources of electrical power shall ensure the supply of steering gear in accordance with 5.5.6.

19.1.2.3 Emergency sources of electrical power shall supply, for a period of 30 min, the following services:

.1 electrical drives of watertight doors together with their indicators and warning signals. Sequential operation of the doors may be permitted providing all doors can be closed in 60 s;

.2 emergency electric drives of passenger lifts. Passenger lifts may be operated sequentially.

19.1.2.4 Where a generator serves as the emergency source of electrical power, it shall be:

.1 driven by an internal combustion engine (refer to 2.2.5, Part IX "Machinery");

.2 automatically started in case of supply failure, and automatically switched over to the busbars of the emergency distribution board; services listed under 19.1.2.7 shall be automatically supplied from the emergency generator. The total time for starting and carrying the board by the generator shall not exceed 45 s;

.3 for an emergency, a transitional source of electrical power shall be provided, which shall be activated immediately upon de-energizing.

19.1.2.5 Where an accumulator battery serves as the emergency source of electrical power, it shall:

.1 operate without recharging and with voltage across its terminals within 12 per cent of rated voltage during the whole discharge period, where voltage variations across the terminals of accumulator battery connected to an electronic voltage converter are determined by the permissible range of voltage variation across the terminals of the converter;

.2 be automatically connected to the busbars of the emergency distribution board in case of supply failure and supply at least the services listed under 19.1.2.7 during the time stipulated by 19.1.2.1.

19.1.2.6 For the emergency transitional source of electrical power required by 19.1.2.4.3, an accumulator battery shall be used, which shall operate without recharging and with voltage across its terminals within 12 per cent of rated voltage during the whole discharge period. Voltage variations across the terminals of accumulator battery connected to an electronic voltage converter are determined by the permissible range of voltage variation across the terminals of the converter.

19.1.2.7 The capacity of the battery serving as transitional source of electrical power shall be sufficient for supplying the services listed below during 30 min:

.1 lighting and necessary navigation lights according to 19.1.2.1.1 and 19.1.2.1.2;

.2 internal communication and announcing systems required in an emergency;

.3 general alarm system, fire detection and alarm systems, control devices of fire doors and indicators showing the position of fire doors specified in 2.2.3.3, Part VI "Fire Protection";

.4 daylight signalling lamps, sound signal means (whistles, gongs, etc.) and other types of signals required under emergency conditions;

.5 arrangements for closing watertight doors, their position indicators and signals warning of their closing.

Sequential closing is permitted.

.6 ship's security alarm system and AIS installation required by Part IV "Radio Equipment" and Part V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships.

Services listed under 19.1.2.7.2 to 19.1.2.7.6 may be supplied from their own accumulator batteries, which shall ensure their supply during the time necessary.

19.1.3 Electrical equipment of watertight doors.

19.1.3.1 As far as practicable, electrical equipment and components for watertight doors shall be situated above the bulkhead deck and outside dangerous areas and spaces.

19.1.3.2 Suitable protection from water penetration shall be provided for the enclosures of the following electrical equipment positioned perforce below the bulkhead deck:

.1 electric motors and control equipment circuits related thereto — IPX7;

.2 door position indicator sensors and circuit elements related thereto — IPX8;

.3 door movement audible alarm elements — IPX6.

19.1.3.3 Electric power, control, indication and alarm circuits shall be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door shall not result in a damage in the electric power and control circuits. Arrangements shall be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

19.1.3.4 A single failure in the power operating or control circuits of a sliding watertight door shall not result in a closed door opening. Availability of the power supply shall be continuously monitored in the immediate vicinity of each of the motors required by 7.12.5.7, Part III "Equipment, Arrangements, and Outfit". Loss of power supply in the power operating and control circuits shall activate an audible and visual alarm in the main control station and at the navigating bridge.

19.1.4 Electrically powered low-location lighting (refer to 8.5.5, Part III "Equipment, Arrangements and Outfit").

19.1.4.1 The low-location lighting system shall be connected to the busbars of the emergency switchboard so as to be powered by the main source of electrical power under normal circumstances and also by the emergency source of electrical power when the latter is in operation.

The low-location lighting system shall function at all times.

19.1.4.2 Where an accumulator battery is the emergency source of electrical power, its capacity shall be sufficient for powering the low-location lighting system for at least 60 min.

19.1.4.3 The additional emergency lighting required by 19.3.3 may be accepted to form partly or wholly the low-location lighting system, provided that such system complies with the requirements of 19.1.4.

19.1.4.4 The electrically powered low-location lighting system shall ensure the following minimum standards of luminance:

.1 for luminous surface of the planar source — 10 cd/m^2, the light band being not less than 15 mm in width;

.2 for the point source — 35 mcd in the directions of approach and viewing, along with that:

the direction of viewing for the sources located on a horizontal plane, i.e. on the deck, shall be within a cone with an angle of 60°, the axis of which is inclined at 30° to the source installation plane (refer to Fig. 19.1.4.4.2-1);

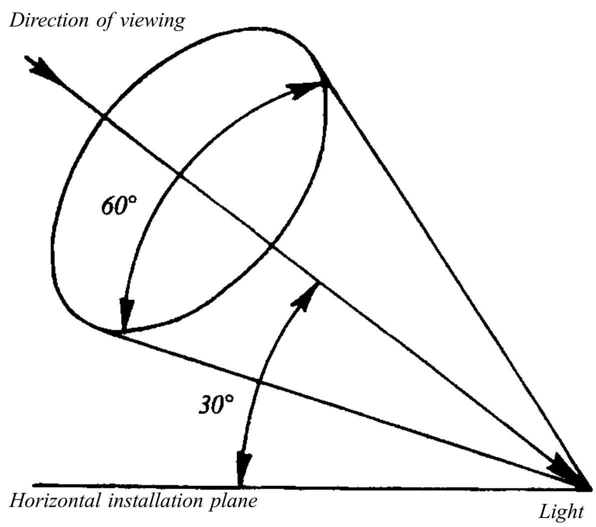


Fig. 19.1.4.4.2-1

the direction of viewing for the sources located on a vertical plane, i.e. on the bulkheads (e.g. for marking of the door handles) shall be within a cone with an angle of 60°, the axis of which is perpendicular to the source installation plane (refer to Fig. 19.1.4.4.2-2);

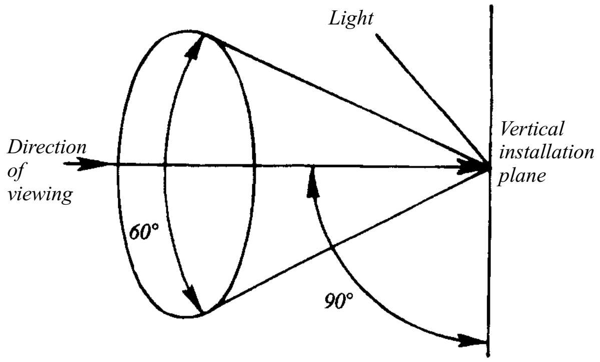


Fig.19.1.4.4.2-2

spacing between sources shall be not more than 300 mm.

19.1.4.5 Power supply of the LLL system shall be such that a failure of any single light or fire in one fire zone or on one deck do not result in lighting and escape route marking in another fire zone being ineffective.

19.1.4.6 Failure or damage, other than short circuit, of any single light, shall not result in loss of visible delineation of the escape route at a length of more than 1 m.

19.1.4.7 The electrical equipment (lights) shall be provided with a minimum degree of ingress protection of IP55.

19.2 OIL TANKERS AND OIL RECOVERY SHIPS

19.2.1 General.

The requirements of the Chapter cover the electrical equipment of oil tankers and oil recovery ships intended for the carriage of petroleum products having a flash point 60 °C and below and petroleum products having a flash point 60 °C and above, which require heating up to a temperature less than 15 °C below the flash point.

The electrical equipment of oil tankers (> 60 °C), oil recovery ships (> 60 °C) and bilge water removing ships (> 60 °C) is covered by the requirements of 19.2.3.2.3.2, 19.2.5, 19.2.6.2 (refer also to 9.6.5, Part VIII "Systems and Piping").

19.2.2 Distribution of electrical power.

For distribution of electrical power on board the ship, only the following systems may be used:

.1 two-wire insulated system for direct current;

.2 two-wire insulated system for single-phase alternating current;

.3 three-wire insulated system for three-phase alternating current (also for voltage above 1000 but not in excess of 11000 V a.c.);

.4 three-wire system with neutral earthed through a high-value resistor for voltages above 1000 but not in excess of 11000 V a.c., provided that any possible resulting current does not flow directly through any dangerous spaces and areas.

19.2.3 Dangerous zones, spaces and areas.

19.2.3.1 Classification of dangerous zones.

Zone 0, in which an explosive gas/air mixture is continuously present or present for long periods.

Zone 1, in which an explosive gas/air mixture is likely to occur in normal operation.

Zone 2, in which an explosive gas/air mixture is not likely to occur, and if it occurs it will only exist for a short time.

19.2.3.2 Division of spaces and areas into zones.

19.2.3.2.1 *Zone 0*:

.1 internal areas of cargo compartments and tanks, cargo piping and transfer systems of recovered oil;

.2 open areas lying at a height up to 1 m from oil-covered water surface (for ships operating in the oil spill).

19.2.3.2.2 *Zone 1*:

.1 cofferdams and segregated ballast tanks adjoining cargo tanks as well as the forepeak, if served by a system connected to ballast tanks installed in the cargo area;

.2 enclosed or semi-enclosed spaces containing cargo pumps or cargo piping, provided the latter is not all-welded;

.3 enclosed and semi-enclosed spaces above the deck of cargo compartments and tanks, which have their bulkheads above or level with the bulkheads of the cargo compartments and tanks;

.4 enclosed and semi-enclosed spaces immediately above cargo pump rooms and also above vertical cofferdams adjoining cargo compartments and tanks unless separated by a gastight deck and provided with mechanical ventilation;

.5 areas and spaces other than cofferdams adjoining cargo compartments and tanks and located below cargo compartment and tank top;

.6 areas and semi-enclosed spaces on the open deck within 3 m of any outlets other than ventilation outlets, cargo tank manholes and hatches, pump rooms and cofferdams adjoining cargo tanks, of cargo valves and cargo piping flanges, as well as areas on open deck within 3 m of the outlets of vent pipes mentioned in 12.4.6, Part VIII "Systems and Piping";

areas in way of pressure/vacuum valve outlets and vent pipe outlets in accordance with 9.7, Part VIII "Systems and Piping";

.7 areas on open deck, or semi-enclosed spaces on open deck in the vicinity of any cargo gas outlet equipped with high-speed devices to ensure the passage of large volumes of gas or vapour mixture at the rate of 30 m/s at least during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the center of the outlet, and within a hemisphere of 6 m radius below the outlet;

.8 areas on open deck, or semi-enclosed spaces on open deck, within 1,5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams or other zone 1 spaces;

.9 areas on open deck within spillage coamings and trays surrounding cargo manifold valves and 3 m beyond these, up to a height of 2,4 m above the deck;

.10 areas on the open deck above cargo compartments and tanks over the full breadth of the ship and 3 m fore and aft of their boundary bulkheads up to a height of 2,4 m above the deck as well as enclosed and semi-enclosed spaces within this area. For ships operating in the oil spill, this area is extended to cover the whole length of the ship;

.11 storage spaces for cargo hoses and equipment for collecting spilt oil (oil collectors);

.12 enclosed and semi-enclosed spaces having direct access or other openings into one of the above areas and spaces;

.13 spaces and areas above cofferdams adjoining cargo compartments and tanks, which are not divided by oil- and gastight bulkheads and decks, not adequately ventilated and entered from an upper deck.

19.2.3.2.3 *Zone 2*:

.1 areas above zone 1 over the full breadth and length of the ship to a height of 6 above the deepest load waterline (for ships operating in the oil spill);

.2 internal areas of cargo compartments and tanks, slop tanks, cargo piping, transfer systems of recovered petroleum products having a flash point > 60 °C and their ventilation systems;

.3 areas on open deck or semi-enclosed spaces 4 m beyond the cylinder and 4 m beyond the sphere with the radius of 6 m defined in 19.2.3.2.2.7;

.4 areas or spaces within 2 m of the areas defined in 19.2.3.2.2.6.

19.2.3.2.4 Spaces and areas not included in zones 0, 1 and 2 are considered safe.

19.2.3.3 Enclosed spaces having direct access to or other openings into areas listed under 19.2.3.2.2.10 are not regarded as dangerous if provision is made for two self-closing gastight doors forming an air lock and, additionally, for mechanical supply ventilation with air suction from locations outside dangerous zones.

19.2.3.4 In the case of ships operating in the oil spill, entrances, ventilation openings (both for suction and discharge) and other openings of safe spaces such as accommodation, service spaces and machinery spaces, control stations and wheelhouse, which have no gastight closures, shall not be located more than 6 m below the deepest waterline and, under all circumstances, shall be outside dangerous zones.

Entrances to safe spaces lying more than 6 m below the deepest waterline or within dangerous zones shall be provided with air locks. In such spaces, openings more than 6 m below the waterline shall bear gastight closures when operating in the oil spill.

19.2.4 Installation of electrical equipment in dangerous spaces and zones.

19.2.4.1 Installation of electrical equipment other than safe-type equipment listed below is not permitted in dangerous spaces and zones:

.1 lighting fixtures and navigation lanterns with pressurized enclosure (*Exp*), with flameproof enclosure (*Exd*) or of increased safety type (*Exe*);

.2 junction boxes of increased safety type (*Exe*) or with flameproof enclosure (*Exd*);

.3 control, monitoring, remote-control and communication equipment of intrinsically safe type (*Exi*);

.4 electric motors of increased safety type (*Exe*), with flameproof enclosure (*Exd*) or with pressurized enclosure (*Exp*).

19.2.4.2 In the internal space of cargo compartments and tanks, cargo piping and recovered oil transfer systems, no electrical equipment or cables may be installed except for those of intrinsically safe type (*Exia*).

19.2.4.3 In open spaces extending up to 1 m above oil-covered water surface (in the case of ships operating in the oil spill) no electrical equipment or cables may be installed except for those of intrinsically safe type (*Exi*).

19.2.4.4 In cofferdams and other spaces adjoining cargo tanks no electrical equipment is permitted, except for the following:

.1 intrinsically safe devices (*Exi*);

.2 echo-sounder transducers and associated cables according to the requirements of Part V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships;

.3 cables of impressed current cathodic protection system for external hull protection installed in steel corrosion-resistant pipes with gastight joints up to the upper deck.

19.2.4.5 In enclosed or semi-enclosed spaces containing cargo pumps or cargo piping, only the following may be installed:

.1 electrical equipment as defined in 19.2.4.4;

.2 lighting fixtures arranged on at least two circuits with fuses and switches in all poles or phases located outside dangerous spaces and zones. The following types of the equipment are permitted:

lighting by means of fixtures arranged outside the dangerous spaces and zones through glazed non-opening ports in gastight bulkheads or decks, provided they do not impair the strength, gastightness of fire integrity of the bulkheads and decks;

lighting fixtures of safe type: with pressurized enclosure (*Exp*) or with flameproof enclosure (*Exd*); cables supplying these fixtures shall be protected with metal casings against mechanical damage;

.3 cable runs for the above services.

The electric motors driving the arrangements located in pump rooms shall be installed in adjacent non-dangerous spaces (refer to 4.2, Part VII "Machinery"). The electric motors shall be provided with remote disconnecting switches fitted outside the spaces where the motors are installed and above the cargo tank deck (refer also to 9.4.4, Part VIII "Systems and Piping").

Lighting in pump rooms shall be interlocked with ventilation of these spaces in such a way that ventilation is put in operation when the lighting is switched on. Failure of the ventilation system shall not cause the lighting to go out. Emergency lighting, if fitted, shall not be interlocked.

19.2.4.6 In enclosed and semi-enclosed spaces above the deck, on which cargo compartments, tanks and areas are located, which bulkheads are higher or level with those of cargo compartments and tanks, in enclosed and semi-enclosed spaces directly above pump rooms and also above vertical cofferdams adjoining cargo compartments and tanks unless separated by a gastight deck and provided with mechanical ventilation, in compartments for cargo hoses and equipment for collecting spilt oil, only equipment listed below may be installed:

.1 intrinsically safe equipment (*Exi*);

.2 safe-type lighting fixtures with pressurized enclosures (*Exp*), with flameproof enclosures (*Exd*) or of increased safety type (*Exe*); the switches of these lighting fixtures shall be located outside the dangerous spaces and zones;

.3 cable runs for the above services.

19.2.4.7 In spaces and areas other than cofferdams adjoining cargo compartments and tanks, but located below their top only the following equipment may be installed:

.1 electrical equipment listed in 19.2.4.4;

.2 safe-type lighting fixtures: with pressurized enclosure (*Exp*) or with flameproof enclosure (*Exd*). The lighting fixtures shall be arranged on at least two independent supply circuits with fuses and switches which shall interrupt all poles and phases and are located outside the dangerous spaces and zones;

.3 cable runs for the above services.

19.2.4.8 In areas and semi-enclosed spaces on the open deck within 3 m of any non-ventilation openings in cargo compartments and tanks, pump rooms and cofferdams adjoining cargo tanks, of cargo valves and cargo piping flanges it is permitted to install only:

.1 electrical equipment listed in 19.2.4.1;

.2 cable runs in conduits or pipes, except for expansion loops.

19.2.4.9 In areas on the open deck above cargo compartments and tanks (including ballast tanks used as cargo tanks) to the full breadth of the ship plus 3 m fore and aft from their end bulkheads up to a height of 2,4 m above the deck (to the full length of ships operating in an oil spill), as well as in enclosed or semi-enclosed spaces having direct access or other openings into one of the above spaces or zones, except as listed under 2.9.8, only the following equipment may be installed:

.1 electrical equipment listed in 19.2.4.1;

.2 cable runs in conduits or pipes.

19.2.4.10 In spaces and areas above cofferdams adjoining cargo compartments and tanks not separated by oil- or gastight bulkheads and decks, which do not have adequate ventilation and may be entered from an upper deck, only the following equipment may be installed:

.1 safe-type lighting fixtures with pressurized enclosures (*Exp*), with flameproof enclosures (*Exd*) or of increased safety type (*Exe*);

.2 other electrical equipment of safe type.

19.2.4.11 The possibility shall be considered of explosive mixtures of gas and air forming during cargo transfer, ballasting and mechanical removal of gases from spaces mentioned in 19.2.3.2.1, 19.2.3.2.2.1 to 19.2.3.2.2.13. The design of electrical equipment operable during the above operations, i.e. of lighting fixtures, winches, electrical equipment installed in wheelhouse wings, etc., shall be such that no arcs or sparks are formed, and the surfaces of equipment do not heat up to dangerous temperatures during normal service.

19.2.4.12 In spaces and areas mentioned in 19.2.3.2.3.2, it is allowed to install electrical equipment listed in 19.2.4.1, special design equipment of protection class "n", as well as equipment, which does not generate arcs or sparks in service and which surface do not reach unacceptable high temperature under normal conditions.

19.2.5 Portable electrical equipment used for collecting spilt oil.

19.2.5.1 Portable equipment for collecting and transfer of oil shall be of safe type.

19.2.5.2 Distribution boards and socket outlets for supplying portable oil-collecting and transfer equipment on deck shall be permanently fitted in such a way that a cable connected to them would not pass through door coamings or other closed openings serving as a boundary of dangerous spaces and zones.

The design of such distribution devices and socket outlets shall provide for an interlock that would rule out the possibility of the portable electrical equipment being connected to them when energized and ensure protection from short-circuit currents and overvoltage in each phase.

19.2.5.3 Flexible cables for connection of portable electrical equipment used for collecting spilt oil shall have a metallic braid (screen) covered by an external proof sheathing of an oil-resistant material.

19.2.6 Installation of cables.

19.2.6.1 On the decks of oil tankers and oil recovery ships, cables shall run on flying bridges in suitable conduits (grooves). Single cables may be laid in pipes. Where the flying bridges are within zone 1, cables complying with the requirements of 2.9.11 shall only be installed.

Cases not covered by this paragraph are subject to special consideration by the Register.

19.2.6.2 When cables are installed in conduits (grooves), the following requirements shall be met:

.1 cables in conduits (grooves) shall be loosely laid in rows on separators of non-metallic materials; in this case, the possibility of lateral displacement of the row (cable) shall be excluded. It is permitted to use methods of fixed pipeless installation of cables (in cable hangers, under clips), which shall be approved by the Register from the viewpoint of the design features; in case of fixed installation cables shall be laid not more than in two rows;

.2 cables shall not be in contact with metal parts of the conduit (groove);

.3 cables shall not be subjected to constant or variable tensions due to deformation of the ship's hull and shall be protected from this deformation, especially in way of detachable or sliding connections between the gangway or platform and superstructures. In way of detachable or sliding connections of the gangway or platform provision shall be made for expansion loops having the inside radius of not less than 10 diameters of the thickest cable;

.4 cables shall be protected from direct exposure to solar radiation, sea waves, oil products carried on board the ship and from mechanical damage;

.5 cables shall be separated from sources of heat by a distance specified in 16.8.4.1;

.6 cables runs on the passageway platform or in pipes inside spaces within zone 1, as well as expansion loops shall not be located below 300 mm from the cargo tank deck;

.7 metal sheaths or armours of cables shall be earthed at both ends. For final subcircuits earthing of the metal sheath may be effected only at the supply end.

19.2.6.3 In systems with voltages specified in 19.2.2.1.4, only cables having copper screens with additional insulation covering may be used. The cross-sectional area of a screen shall be at least the cross-sectional area of a conductor.

The structure of such cables is subject to the special consideration of the Register.

19.2.7 Integrated cargo and ballast systems.

19.2.7.1 These requirements are applicable to integrated cargo and ballast systems on tankers, irrespective of the size or type of the tanker.

Within the scope of these requirements, integrated cargo and ballast system means any integrated hydraulic and/or electric system used to drive both cargo and ballast pumps (including active control and safety systems and excluding passive components, e.g. piping).

19.2.7.2 Measures shall be taken to prevent cargo and ballast pumps becoming inoperative simultaneously due to a single failure in the integrated cargo and ballast system, including its control and safety systems.

19.2.7.3 The emergency stop circuits of the cargo and ballast pumps shall be independent from the circuits for the control systems. A single failure in the control system circuits or the emergency stop circuits shall not render the integrated cargo and/or ballast system inoperative.

19.2.7.4 Manual emergency stops of the cargo pumps shall be arranged in a way that they are not cause the stop of the power pack making ballast pumps inoperable.

19.2.7.5 The control systems shall be provided with a duplicate power supply from the main switchboard. The failure of any power supply shall provide audible and visible alarm activation at each pump control location.

19.2.7.6 In the event of failure of the automatic or remote control systems, a secondary means of control shall be made available for the operation of the integrated cargo and ballast system. This can be achieved by manual overriding and/or redundant arrangements within the control systems.

19.3 SHIPS INTENDED FOR CARRIAGE OF MOTOR VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR PROPULSION

19.3.1 General.

19.3.1.1 The requirements of the present Chapter are applicable to electrical equipment of holds and other spaces and areas intended for the carriage of motor vehicles with fuel in their tanks necessary for their propulsion.

19.3.1.2 The holds and spaces specified in 19.3.1.1 belong to the category of dangerous spaces and zones.

19.3.1.3 Cables shall be protected against mechanical damage. Cables installed horizontally shall be positioned at a distance not less than 450 mm above the continuous deck or platform preventing a free propagation of gases in the downward direction. The sealings where cables penetrate bulkheads and deck shall be gastight.

19.3.1.4 Electrical equipment installed in ventilation ducts shall be of the following safe types: increased safety (*Exe*) or with flameproof enclosure (*Exd*).

19.3.1.5 The lighting system in holds and spaces specified in 19.3.1.1 shall be arranged at least in two groups, each supplied separately from an independent circuit.

19.3.2 Installation of electrical equipment in holds and spaces intended for carriage of motor vehicles with fuel in their tanks in passenger ships and ferries.

19.3.2.1 In holds and compartments, in spaces located at a height of more than 450 mm above the cargo deck or platform preventing free penetration of gases downwards, it is allowed to install electrical equipment:

with the degree of protection at least IP55 provided the ventilation system ensures at least 10 air changes per hour;

specially designed for use in Zone 2.

19.3.2.2 In holds and spaces above the bulkhead deck, in zones less than 450 mm above the deck or platform preventing, a free propagation of gases in the downward direction, electrical equipment installed shall be of the following safe types: intrinsically safe (*Exi*), with pressurized enclosure (*Exp*), with flameproof enclosure (*Exd*) or increased safety (*Exe*).

19.3.2.3 In holds and spaces below the bulkhead deck all the electrical equipment shall be of the following safe types: intrinsically safe (*Exi*), with pressurized enclosure (*Exp*), with flameproof enclosure (*Exd*) or increased safety (*Exe*).

19.3.3 Special requirements for passenger ships having ro-ro cargo spaces.

19.3.3.1 In passenger ships with roll-on/roll-off cargo spaces or special-category spaces as mentioned under 1.5, Part VI "Fire Protection", apart from emergency lighting required by 19.1.2.1.1, additional emergency lighting shall be provided in all public spaces and corridors, that shall serve for 3 hrs at least under any heel of the ship and when all other electrical power sources fail.

This lighting shall make the escape routes clearly visible (or ensure an illumination intensity of 0,5 lx). Any damage to a lighting fixture shall be clearly visible.

19.3.3.2 As electrical power sources for this additional lighting, accumulator batteries shall serve fitted in lighting fixtures, continuously recharged from the emergency distribution board and replaced within the period established by the manufacturer with regard to their service conditions.

19.3.3.3 In each corridor of crew spaces, in crew recreation rooms and in each space where the crew members generally work, a hand lamp (lantern) shall be provided supplied from an accumulator unless additional emergency lighting stipulated by 19.3.3.1 and 19.3.3.2 is installed in the space.

19.3.4 Installation of electrical equipment in holds and spaces intended for carriage of motor vehicles with fuel in their tanks in cargo ships.

19.3.4.1 In holds and compartments, in spaces located at a height of more than 450 mm above the cargo deck or platform preventing free penetration of gases downwards, it is allowed to install electrical equipment:

with the degree of protection at least IP55 provided the ventilation system ensures at least 10 air changes per hour;

specially designed for use in Zone 2.

19.3.4.2 In holds, spaces and zones less than 450 mm above the cargo deck or platform preventing a free propagation of gases in the downward direction, electrical equipment installed shall be of the following safe types: intrinsically safe (*Exi*), with pressurized enclosure (*Exp*), with flameproof enclosure (*Exd*) or increased safety (*Exe*).

19.4 SPECIAL PURPOSE SHIPS

19.4.1 Supply of essential services.

In special purpose ships carrying more than 50 special personnel, the supply circuits of essential services shall comply with 19.1.1.4.

19.4.2 Emergency sources of electrical power.

19.4.2.1 In special purpose ships carrying not more than 50 special personnel, the emergency source of electrical power shall comply with 9.3.

Ships having a length above 50 m shall additionally comply with 19.1.2.3.1.

19.4.2.2 In ships carrying more than 50 special personnel, the emergency source of electrical power shall comply with 19.1.2.

19.4.3 Electrical equipment in storerooms for explosives.

19.4.3.1 Except for lighting fixtures in glass hoods and protection gratings and cables in gastight pipes, no electrical equipment shall be installed in storerooms for explosives specified in 2.1.7, Part VI "Fire Protection".

19.4.3.2 Switches of lighting circuits shall be fitted outside storerooms for explosives and shall be provided with light signals to indicate the presence of voltage in the lighting fixtures.

19.4.3.3 In storerooms for explosives, the devices for connection of portable electrical equipment to the ship's mains shall be provided with nameplates indicating the rated electrical parameters and shall have a protective enclosure not below IP56 type.

19.4.4 Ships used for processing the living resources of the sea and not engaged in their catching.

19.4.4.1 Survey of electrical equipment.

In addition to the requirements of 1.3.2, the electrical equipment of processing machinery (catch processing) is subject to survey on board the ship (refer also to 1.3.2.4.1).

19.4.4.2 Survey during manufacture of electrical equipment.

The electrical equipment of processing machinery specified in 19.4.4.1 is subject to survey during manufacture in addition to that listed in 1.3.3.1.

Use of electrical equipment specified in 19.4.4.1, which does not meet the requirements of Sections 1 to 18 in full measure, is subject to special consideration by the Register.

19.4.4.3 Structural requirements and protection of electrical equipment of processing machinery and refrigerating plants.

19.4.4.3.1 The electrical equipment installed in catch processing spaces shall be resistant to seawater and fish processing products influence or shall be adequately protected against it.

19.4.4.3.2 The electric motors of the processing refrigerating compressors, fans of the refrigerated holds and freezing apparatus and, in well-grounded cases, the electrical equipment of other processing machinery shall be provided with heating arrangements to maintain a temperature which is at least by 3 °C higher than the ambient temperature.

19.4.4.3.3 Distribution gear and start, control and protection devices of electrical equipment specified in 19.4.4.3.1 shall be installed in special electrical spaces.

19.4.4.3.4 Cables installed in spaces subjected to prolonged influence of salt and other products of fish processing shall be provided with sheaths resistant to such influence or be adequately protected.

19.4.4.4 Composition and capacity of main electrical power source.

19.4.4.4.1 Determination of the composition and capacity of the main source of electrical power shall determined with regard to the following operating conditions of the ship:

running conditions;

manoeuvring;

in case of fire, hole in the ship's hull or other conditions affecting the safety of navigation, with the main source of electrical power in operation;

processing.

19.4.4.4.2 The capacity of generators composing the main electrical power source shall be such that if any of them fail, the rest will ensure power supply of electrical equipment under conditions specified in 19.4.4.4.1, as well as minimal habitable conditions to persons on board.

19.4.4.5 Distribution of electrical power.

19.4.4.5.1 Where the main electrical power source incorporates shaft generators not intended for operation in parallel with the independently driven generators, the machinery and systems ensuring propulsion, manoeuv-rability and safety of navigation shall be supplied from the busbars of independently driven generators, while the electrical equipment of processing refrigerating plant and machinery shall be supplied from the busbars of shaft generators.

19.4.4.5.2 The electric drives of processing refrigerating compressors shall be supplied by separate feeders from the busbars of the main switchboard. It is admissible for these drives to be fed from a separate switchboard supplied by two feeders connected to different sections of the main switchboard.

19.4.4.5.3 Electrical circuit for supplying switchboards of the processing machinery (catch processing) shall be separated electrically (galvanically) from the ship's mains.

19.4.4.5.4 If provision is made for electrical power transmission to other ships, a power transmission switchboard separated electrically (galvanically) from the ship's mains shall be installed.

19.4.4.5.5 Where portable tools and movable mechanization facilities not permanently installed are supplied from a circuit of more than 50 V, a safety isolation device in combination with a separating transformer shall be used for each consumer. Such device shall interrupt power supply if the hull leakage current exceeds 30 mA.

19.4.4.6 Lighting.

19.4.4.6.1 Catch processing spaces and refrigerating machinery rooms shall be illuminated by stationary lighting fixtures, which shall be supplied and arranged in accordance with 6.2.3.

19.4.4.6.2 Fish storage holds shall be illuminated with stationary lighting fixtures, which shall be supplied in accordance with 6.2.7.

19.4.4.7 Signalling.

A "Man-in-Hold" signal push-button shall be located inside the refrigerated holds at each exit to actuate signal at the wheelhouse or another permanent attended space.

19.4.4.8 Emergency electrical installations.

19.4.4.8.1 The emergency source of electrical power shall comply with the requirements of 9.3.

19.4.4.8.2 In addition to the requirements of 9.3.1.1, the emergency source of electrical power shall supply the emergency lighting for the catch processing spaces and the exits therefrom as well as for the deck in way of fishing machinery.

19.4.4.8.3 Where a generator is used as the emergency source of electrical power, an emergency transitional source of electrical power (accumulator battery) shall be provided, the capacity of which shall be sufficient to supply the consumers specified in 9.3.7 and 19.4.4.8.2 during 30 min.

19.5 CONTAINER SHIPS

19.5.1 General.

The requirements of the Chapter are applicable to the electrical equipment of ships intended for the carriage of thermal containers.

19.5.2 Supply and distribution of electrical power.

19.5.2.1 As the rated power of electrical equipment of thermal containers their prescribed power shall be taken. The consumed power of the electrical equipment of thermal container shall not exceed 15 kW (18,75 kVA) under rated operating conditions.

The application of correction factors is subject to special consideration by the Register in each case.

19.5.2.2 The overload protective device of sources of electrical power prescribed in 8.2.3 shall ensure disconnection of thermal containers from the main switchboard in the last turn (refer also to 20.2.1).

19.5.2.3 The electrical circuit supplying the equipment of thermal containers shall be separated from the ship's mains by transformers with separate windings, fed from the main switchboard.

19.5.2.4 The electrical installations of thermal containers shall be fed from special distribution gear energized by separate feeders.

19.5.2.5 Socket outlets installed in cargo holds or on open decks in areas of stowage of thermal containers shall be supplied by separate outgoing feeders from the special distribution gear (switchboards) specified in 19.5.2.4 and 19.5.3.3.

19.5.2.6 The electrical circuit of socket outlets intended for supply of the electrical installations of thermal containers shall be rated for 220/380 V voltage at 3-phase alternating current, 50 Hz in frequency, or for 240/440 V voltage at 3-phase alternating current, 60 Hz in frequency.

19.5.3 Distribution gear and transformers.

19.5.3.1 The distribution gear (switchboards) of thermal containers, electrical converters, if any, and transformers with separate windings shall be installed in special electrical spaces.

19.5.3.2 The secondary winding of transformers with separate windings shall have an isolated zero point.

19.5.3.3 Each distribution gear (switchboard) shall be equipped with appliances, which ensure:

.1 visual signalling to indicate the presence of voltage;

.2 connection and disconnection of each outgoing feeder supplying the socket outlets;

.3 short-circuit protection at the outgoing feeders supplying the socket outlets;

.4 measurement of insulation resistance.

19.5.4 Socket outlets.

19.5.4.1 In holds containing thermal containers it is allowed to install socket outlets used only for power supply of containers with the degree of protection not less than IP55 type, and on open decks — IP56 type.

When the electrical systems of remote control over temperature, humidity, ventilation and other characteristics of thermal containers are used, it is permitted to install additional socket outlets for connection of these control devices in holds or on decks.

19.5.4.2 Socket outlets for power supply of the electrical equipment of thermal containers shall, in addition to requirements of 6.6, be fitted with an isolating switch interlocked so that the plug cannot be inserted or withdrawn while the switch is in the "on" position. A nameplate indicating the voltage shall also be fitted.

19.5.4.3 The electrical installation of thermal containers shall be supplied from the ship's mains at the direct sequence of phases *A*(*R*), *B*(*S*), *C*(*T*) according to the scheme given in Fig. 19.5.4.3.

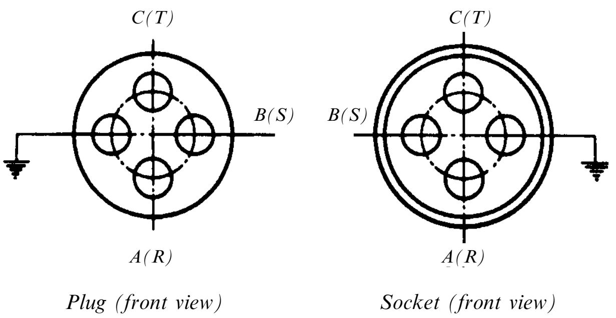


Fig. 19.5.4.3

19.5.4.4 Socket outlets intended for supply of the electrical installations of thermal containers shall be rated at the following currents:

63 A for voltage of 220 V, 50 Hz or 240 V, 60 Hz;

32 A for voltage of 380 V, 50 Hz or 440 V, 60 Hz.

19.5.4.5 Socket outlets shall be designed so as to prevent connection of plugs rated for one voltage to socket outlets rated for another voltage.

19.5.4.6 Design and dimensions of plugs and sockets shall correspond to international standards.

19.5.5 Protection earthing.

The receptacle intended for connection of the earthing conductor in the flexible cable of the thermal container shall be grounded through the earthing conductor in the supply feeder, where the distribution gear (switchboard) is installed for supply of socket outlets of thermal containers.

19.6 CATAMARANS

19.6.1 In each hull of the ship at least one generator being a part of the main source of electrical power shall be provided.

19.6.2 In each hull of the ship, a main distribution board shall be installed. One of the boards may be installed above the bulkhead deck.

19.6.3 The busbars supplying the ship hulls shall be sectioned.

19.6.4 The emergency services of each hull shall be supplied from the emergency source of electrical power through separate feeders.

19.6.5 The disconnecting switches of electrical equipment specified in 5.7.1, 5.7.2, 5.8.1, 5.8.2 and 5.8.3 shall be grouped separately for each hull.

19.7 FLOATING CRANES AND CRANE SHIPS

19.7.1 Where systems similar to those mentioned in Section 17 are used for crane machinery of floating cranes and crane ships, the requirements of this Section being also applicable to the electric drives of crane machinery, such systems fall, so far as practicable, under the relevant requirements of the Section deemed necessary by the Register.

19.7.2 For self-driven floating cranes, the capacity of the main source of electrical power shall be sufficient for the selective operation of the crane both underway and during cargo-handling operations.

19.7.3 Accumulator rooms, accumulator boxes and spaces containing emergency sources of electrical power may be located below the bulkhead deck, provided all the requirements of 9.2 and 13.2 are satisfied.

19.7.4 To produce sound signals during cargo-handling operations, a sound-signal means shall be fitted on the crane, activated from the operator's cabin.

19.8 FLOATING DOCKS

19.8.1 General.

The requirements of the present Chapter cover the electrical equipment of steel floating docks in addition to the relevant requirements set forth in Sections 1 to 18.

19.8.2 Survey of electrical equipment.

19.8.2.1 In addition to requirements of 1.3.2.1, the following kinds of equipment, systems and devices are subject to survey on board the floating dock:

.1 electric drives and their systems of control and monitoring of the mechanisms ensuring submersion and emersion of the dock;

.2 earthing of the docked ship.

19.8.2.2 All kinds of electrical equipment used in steel floating docks and listed under 1.3.3.1 and 19.8.2.1 are subject to survey during manufacture.

In particular cases, on agreement with the Register, for machinery and gear of non-autonomous docks, it is allowed to use the electrical equipment manufactured out of full conformity with Sections 1 to 18 and without the Register survey.

19.8.3 Protective enclosures of electrical equipment.

Protective enclosures of the electrical equipment shall be in compliance with Table 2.4.4.2 considering that dry compartments of the dock wing walls refer to the spaces of increased humidity, and dry compartments of pontoons, tunnels in pontoons and other similar spaces refer to the extra humid category.

19.8.4 Earthing.

19.8.4.1 Each docked ship shall be earthed to the dock hull through at least two special flexible cable connectors having a cross-sectional area not less than 70 mm^2 each, and devices for connection thereof to the dock hull shall be provided at the dock.

19.8.4.2 To connect the dock hull to the shore earthing system, it is necessary to provide at least two flexible copper cables, having a cross-sectional area not less than 70 mm^2 each, and also a device for connection of these cables to the dock hull.

No metal earthing of the dock hull is allowed if a system of cathodic protection from corrosion is applied, and circuits of the dock are electrically separated from the shore circuits.

19.8.4.3 All sections of the dock hull, pontoons, wing walls and similar structures shall be electrically connected by reliable means.

19.8.5 Number and output of sources of electrical power.

19.8.5.1 The systems of supply specified below may be used as main sources of electrical power of docks:

generators;

shore electrical power system.

19.8.5.2 At least two generators and, in addition, a shore electrical power system, if necessary, shall be provided as main sources of electrical power on autonomous docks.

For non-autonomous docks it is allowed to use only a shore electrical power system.

19.8.5.3 The power of main generators of autonomous docks or the power available from a shore electrical power system shall be sufficient to ensure the following operating conditions of the dock:

submersion of the dock;

docking of the ship;

emersion of the dock;

emergency condition;

other conditions in accordance with the dock's purpose.

19.8.5.4 The power of main generators of the autonomous dock shall be such that in case of failure of any generator the rest of the generators ensure safe submersion and emersion of the dock and also docking and undocking of ships.

19.8.6 Distribution of electrical power.

19.8.6.1 The following systems of electrical power distribution are allowed for use in docks in addition to those specified in 4.1.1:

.1 three-phase four-wire alternating current system with earthed neutral wire;

.2 one-wire system, both alternating and direct current, with dock's hull return only for welding circuit (refer also to 19.8.4), and also for devices of monitoring and measurement of insulation resistance.

19.8.6.2 In addition to 4.3.1 the following consumers shall be supplied by separate feeders from the main switchboard busbars energized directly by the generators proper or through the transformer, or by the shore electrical power system:

.1 system of monitoring, signalling and control of the dock submersion and emersion;

.2 switchboards for electric drives of the ballast system sluice valves associated with safe operation of the dock;

.3 switchboards for supply of welding outfit;

.4 switchboards for supply of the docked ship.

N o t e . Supply of essential consumers from the main busbar conduit is subject to special consideration by the Register in each case.

19.8.6.3 Essential consumers and electric drives of machinery situated at the wing wall where no source of electrical power is installed shall be supplied from the switchboard located therein. This switchboard shall be considered as a separate part of the main switchboard and shall be fed from the main switchboard by two feeders. The cross-section of each feeder shall be sufficient for supply of the wing wall essential consumers in case of failure of one feeder. The supply feeders shall run between wing walls in different spaces if it is permitted by the dock design.

In separate cases, installation of both feeders in one space may be allowed.

19.8.6.4 Signal marker lights may be supplied from lighting switchboards.

19.8.6.5 In case of high-voltage electrical power supply of the non-autonomous dock from the shore electrical power system, in addition to the high-voltage feeder a device shall be fitted for connection of the low-voltage supply feeder. This device shall be designed for continuous transmission of electrical energy required at the idle dock when no repairs are carried out. In this case, provision shall be made for continuous supply of at least one electric drive of maximum power for the fully loaded fire pump and also for supply of all electric motors of sluice valve drives and lighting of main spaces.

When high-voltage electrical power is supplied to the non-autonomous dock by two independent feeders, a low-voltage supply feeder need not be provided.

19.8.6.6 When the dock is supplied from the shore low-voltage electrical power system, it is required to provide two feeders and two devices for reception of electrical power, one of them supplying the consumers specified in 19.8.6.2 and the other — at least the consumers referred to in 19.8.6.5.

19.8.6.7 Arrangement and design of devices for connection of cables used for power supply from the shore electrical power system shall be such as to ensure:

.1 installation of cables at an adequate distance from one another to prevent simultaneous damage of high-voltage and low-voltage feeders;

.2 absence of mechanical stresses in cables during submersion and emersion of the dock;

.3 prevention of transmission of mechanical stresses to the terminals intended for connection of cables or wires.

It is recommended that the devices for reception of electrical power from the shore electrical power system shall be located on different wing walls of the dock.

19.8.6.8 A bright and clear warning inscription indicating the voltage shall be made on the hull in a prominent position or on the door of the external supply switchboard.

19.8.6.9 The maximum permissible level of the short-circuit power shall be determined for each dock, which may be supplied from the shore electrical power system. This level shall be marked on the warning inscription of the external supply switchboard.

19.8.6.10 The docked ships shall be fed from the stationary supply switchboards installed in the dock.

19.8.6.11 Each supply switchboard of the docked ship shall be fitted with:

.1 switchgear and protective devices, terminals or plug and socket connectors for flexible cables connected to the docked ship. All the terminals of the switchboard shall bear a mark indicating a phase or pole;

.2 a pilot lamp indicating the presence of voltage across switchboard terminals;

.3 a nameplate indicating the nominal voltage, nature of current, its permissible value and frequency.

19.8.6.12 At the supply switchboard of the docked ship provision shall be made for the device for fastening the ends of the flexible cable feeding the docked ship.

19.8.6.13 Cross-sectional area of the flexible supply cable of the docked ship shall be chosen for rated current of the protection setting fitted in the outgoing feeders of the supply switchboard of the docked ships.

19.8.7 Transformers.

In floating docks one transformer of adequate power may be used for supply of the lighting circuit and circuits of essential consumers. In this case, it is recommended to provide for possible reserve supply of these consumers from the transformer intended for feeding the docked ships.

19.8.8 Lighting.

In addition to provisions of 6.6.1, socket outlets for portable lighting fixtures shall be installed at least:

in dry compartments of wing walls where equipment and outfit for the system of submersion and emersion of the dock is located;

in spaces of safety deck where the equipment for the system of submersion and emersion of the dock is located;

in the space where the main control desk of the dock submersion and emersion is located;

in the area of location of the mooring machinery electric drives.

19.8.9 Service telephone communication.

19.8.9.1 In the absence of other types of voice communication provision shall be made for telephones of the ship's control group, which ensure clear two-way communication between the following spaces:

main control station — warping capstans;

main control station — emergency diesel-generators space;

main control station — main switchboard space;

main control station — main diesel generator space;

main control station — high-voltage transformer space;

main control station — spaces of location of hand drives for sluice valves of the dock submersion and emersion system;

main control station — fire-extinguishing station.

Besides, two-way independent voice communication shall be provided between the main control station and machinery space.

19.8.9.2 In docks provision shall be made for connection of at least one telephone set to the shore telephone system.

19.8.10 General alarm system.

General alarm system shall be actuated from the main control station and from the space intended for the personnel on watch, if such a space is provided.

19.8.11 Installation of cables.

19.8.11.1 If the pontoon deck is illuminated with lighting fixtures of submersible type and if the cables used are not light, they shall run to the lighting fixtures in water- and gastight pipes.

The pipes and their packings shall be selected with regard to operation under pressure not less than the permissible pressure of submersible lighting fixtures.

19.8.11.2 On special agreement with the Register, cables may be installed on tray plates (saddles) welded directly to the dock plating.

19.8.12 Distribution of electrical power and cabling with the use of one-wire system.

19.8.12.1 Relevant terminals of sources and consumers of electrical power shall be reliably connected to the dock hull. This connection shall not be made in pipelines, tanks and cylinders containing compressed gases, petrol and oil.

19.8.12.2 For direct-current circuit the insulated wire shall be connected to the positive poles and terminals of sources and consumers of electrical power.

Instruments, switchgear and protective devices shall be set to the positive pole.

19.8.12.3 Conductors used for connection of terminals of the electrical equipment and the dock hull shall be equal in cross-sectional area to the conductors isolated from the hull.

19.8.12.4 Points of connection of conductors to the steel hull of the dock shall be situated in areas and positions readily accessible for control and maintenance of contacts.

These points shall be located on structures, which are reliably joined by welding to the dock hull.

19.8.12.5 Working earthing conductors shall be joined in such a manner that reliable electrical connection to the hull is ensured.

It is recommended to use high-power busbars, which are connected to the dock hull in several points.

19.8.12.6 Regardless of the system of electrical power distribution used for welding circuit, the welding station in the docked ship shall be supplied by two-wire system from the welding circuit of the dock.

Hull return system of the docked ship is not permitted.

19.8.12.7 When carrying out welding operations on the hull of the docked ship, a cable with a potential opposite to that of the electrode shall be connected to the hull as close to the part being welded as possible.

19.8.13 Busbar conduits.

19.8.13.1 The application of busbar conduits is allowed for floating docks. The degree of protection of busbar conduits depending on the place of installation shall comply with the requirements of 2.4.4.2.

19.8.13.2 Busbar conduits shall be designed for adequate load and shall withstand, along with insulators and holders, mechanical stresses resulting from short-circuit current directly at busbars.

19.8.13.3 At alternating current exceeding 1500 A, provision shall be made for reduction of the current loss in busbar holders, fixtures, insulators and structures which results from the influence of magnetic fields.

19.8.13.4 All protective devices and switchgear connected immediately to the busbar conduit shall be installed in places accessible for inspection and repair.

Cables and busbars connecting the protection devices and the busbar conduit shall not be more than 2 m in length.

19.8.13.5 Busbar conduits with the degree of protection IP20 and below shall be installed at a height not less than 2,5 m above the floor level.

19.8.13.6 Warning inscriptions indicating the voltage shall be made on the protective enclosure of the busbar conduit at 3 to 5 m intervals throughout the whole length.

19.8.14 Emergency electrical installations.

19.8.14.1 Each floating dock shall be provided with an emergency source of electrical power ensuring power supply of all the necessary consumers for not less than 3 hours.

19.8.14.2 Emergency source of electrical power shall ensure supply of consumers as per 9.3.1, which are installed on board the dock, and also supply of the following consumers:

.1 electrical drives essential for sluice valves of the system of the dock submersion and emersion (at least 2 closings and openings of the sluice valves);

.2 indication and control circuits of the system of the dock submersion and emersion;

.3 command service communication.

19.8.14.3 If the emergency source of electrical power is a diesel generator with an automatic starting system, provision shall be made for local starting of the diesel generator.

19.8.14.4 All the emergency consumers shall be supplied from the emergency switchboard.

In well-grounded cases, the emergency diesel generator and emergency switchboard may be installed in different spaces, and also one section of the main switchboard may be used as an emergency switchboard, provided the main switchboard is located above the level of the margin line of the dock.

19.8.15 Electric drives of submersion and emersion system of the dock.

19.8.15.1 Electric drives for sluice valves of the submersion and emersion system shall not hinder manual opening and closing of sluice valves. Interlocking device shall be also provided to prevent the electric drive from operation in case of sluice valve change-over to manual control.

19.8.15.2 Electric drives for sluice valves shall be fitted with local and remote-controlled (in the main control station, etc.) indicators of sluice valve limit positions. For electric drives of sluice valves intended for water distribution in the pontoon compartments it is also recommended to provide for devices indicating the extent to which the sluice valve is open.

19.8.15.3 For sluice valves intended for water distribution in the pontoon compartments it is recommended to provide for separate control of each sluice valve, as well as for group control of port and starboard sluice valves.

19.8.15.4 Control circuit for electric drives of the drain (ballast) pump shall provide for local and remote control from the main control station with indication of the pump operation or control of electric motor load on the ammeter.

19.8.16 Connection of electrical power supply sources.

When generators of the autonomous dock or transformers of the shore power supply are connected directly to the distribution busbar conduit, and the main switchboard is not installed, provision shall be made for a common control desk fitted with control gear for circuit breakers of generators or transformers and with instruments and devices of control, signalling and protective systems.

These instruments and devices are listed in 4.6.

19.8.17 High-voltage electrical installation of the dock.

19.8.17.1 High-voltage electrical installation of the dock shall comply with the requirements of national standards and rules applicable to the shore electrical installations.

19.8.17.2 High-voltage electrical installation of the dock shall be located in separate special electrical spaces.

19.9 BERTH-CONNECTED SHIPS

19.9.1 For berth-connected ships, the following sources may be used as main sources of electrical power:

generators;

shore electrical power system.

19.9.2 On independent berth-connected ships, provision shall be made for at least two generators as main sources of electrical power.

In addition, the ship mains may be supplied from the shore electrical power system.

Berth-connected ships that are not independent may be supplied from the shore electrical-power system only.

19.9.3 On independent berth-connected ships, the power of generators of the main power source or the power supplied by the shore electrical power system shall be sufficient for the operation of services in accordance with the ship purpose, in case of fire, hull leakage or other circumstances adversely affecting the safety of the berth-connected ship while the main source of electrical power is in operation.

19.9.4 The main generator power of an independent berth-connected ship shall be sufficient to ensure operation in accordance with 19.9.3 in the case of failure of any of the generators.

19.9.5 In floating hotels and hostels, power supply and signalling functions of essential systems and gear shall be effected in conformity with 19.1.1.1 to 19.1.1.4.

The side, bow and stern lights may be supplied from lighting switchboards.

19.9.6 Each floating hotel or hostel shall be provided with an independent emergency source of electrical power to ensure the operation of services in accordance with 19.1.2.1 during 12 h, as well as the operation of services in accordance with 19.1.2.3 during 30 min.

For other types of berth-connected ships, provision of an emergency power source is subject to the special consideration by the Register in each case.

19.9.7 As regards the automatic starting of the emergency source of electrical power and provision of an emergency transitional source in floating hotels and hostels, the requirements of 19.1.2.4 to 19.1.2.7 shall be complied with.

19.10 FISHING VESSELS

19.10.1 Survey of vessel's electrical equipment.

19.10.1.1 In addition to the requirements of 1.3.2 the following kinds of equipment, systems and devices are subject to survey on board the ship (refer also to 1.3.2.4.2):

.1 electrical equipment of fishing machinery;

.2 electrical equipment of processing machinery (catch processing).

19.10.2 Survey during manufacture of electrical equipment.

The electrical equipment specified in 19.10.1.1 is subject to survey in addition to that listed in 1.3.3.1. Use of electrical equipment specified in 19.10.1.1.2, which doesn't meet the requirements of Sections 1 to 18 of the present Part of the Rules in full measure, is subject to special consideration by the Register.

19.10.3 Structural requirements and protection of electrical equipment of fishing and processing machinery.

19.10.3.1 The electrical equipment installed in catch processing spaces shall be resistant to sea water and fish processing products influence or shall be adequately protected against it.

19.10.3.2 Electrical equipment distribution gear and start-protection devices specified in 19.10.3.1 shall be installed in special electrical spaces.

19.10.3.3 Cables installed in spaces subjected to prolonged influence of salt and other products of fish processing shall be provided with sheaths resistant to such influence or be adequately protected.

19.10.4 Composition and capacity of main electrical power source.

19.10.4.1 The composition and capacity of the main source of electrical power shall be determined with regard to the following operating conditions of the vessel:

.1 running conditions;

.2 manoeuvring;

.3 in case of fire, hole in the ship's hull or other conditions affecting the safety of navigation, with the main source of electrical power in operation;

.4 fishing.

19.10.4.2 The capacity of generators composing the main electrical power source shall be such that if any of them fail, the rest will ensure power supply of electrical equipment necessary under conditions specified in 19.10.4.1 as well as minimal habitable conditions to persons on board.

In well-grounded cases, in vessels of less than 500 gross tonnage the capacity necessary to ensure fishing operations and/or catch processing may be neglected.

19.10.5 Distribution of electrical power.

19.10.5.1 Where the main electrical power source incorporates shaft generators not intended for parallel operation with the independently driven generators, the machinery and systems ensuring propulsion, manoeuv-rability and safety of navigation shall be supplied from the busbars of independently driven generators, while the electrical equipment of fishing and processing machinery shall be supplied from the busbars of shaft generators.

19.10.5.2 The electric drives of refrigerating compressors shall be supplied by separate feeders from the busbars of the main switchboard. It is admissible for the electric drives of refrigerating compressors to be fed from a separate switchboard supplied by two feeders connected to different sections of the main switchboard.

19.10.5.3 Where portable tools and movable mechanization facilities not permanently installed, are supplied from a circuit of more than 50 V, a safety isolation device in combination with a separating transformer shall be used for each consumer.

Such device shall interrupt power supply if the hull leakage current exceeds 30 mA.

19.10.6 Lighting.

19.10.6.1 Catch processing spaces and refrigerating machinery rooms shall be illuminated by stationary lighting fixtures, which shall be supplied and arranged in compliance with 6.2.3.

19.10.6.2 Fish storage holds shall be illuminated by stationary lighting fixtures, which shall be supplied in accordance with 6.2.7.

19.10.7 Signalling.

A "Man-in-hold" signal push-button shall be located inside the refrigerated holds at each exit to actuate signal at the wheelhouse or another permanently attended space.

19.10.8 Emergency electrical installations.

19.10.8.1 The emergency source of electrical power shall comply with the requirements of 9.3.

19.10.8.2 In addition to the requirements of 9.3.1.1, the emergency source of electrical power shall supply the emergency lighting for the catch processing spaces and the exits therefrom as well as for the deck areas where the fishing machinery is installed.

19.10.8.3 Where a diesel generator is used as the emergency source of electrical power, an emergency transional source of electrical power (accumulator battery) shall be provided, the capacity of which shall be sufficient to supply the consumers specified in 9.3.7 and 19.10.8.2 during 30 min.

19.11 SHIPS CARRYING DANGEROUS GOODS

19.11.1 General.

19.11.1 The requirements of this Chapter, in addition to the requirements of 7.2, Part VI "Fire Protection", apply to the electrical equipment of ships and cargo spaces intended for the carriage of dangerous goods, the classification of which is presented in 1.2, Part VI "Fire Protection".

19.11.2 Dangerous zones, spaces and areas.

19.11.2.1 Classification of dangerous zones.

Zone 1, in which an explosive gas/air mixture is likely to occur in normal operation.

Zone 2, in which an explosive gas/air mixture is not likely to occur, and if it occurs, it will only exist for a short time.

Typical examples of arrangement of the dangerous zones are given in Table 19.11.2.1.

19.11.2.2 For dangerous goods carried in bulk, Class 1, except of subclass 1.4S, the dangerous zones encompass the following spaces and areas classified as *Zone 1*:

.1 enclosed spaces of cargo compartments/holds as well as open or enclosed ro-ro cargo spaces;

.2 integral storerooms for the ship's stock of explosives.

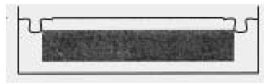
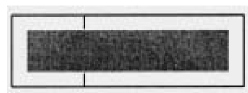
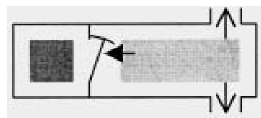
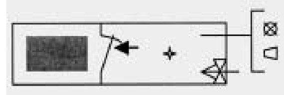
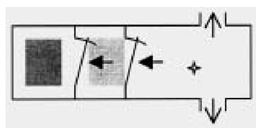
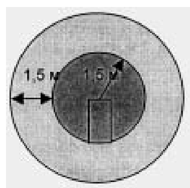
19.11.2.3 For packaged dangerous goods, Class 4.1, 4.2, 9 and MHB (Materials Hazardous in Bulk) capable of producing explosive dust/air mixtures, the dangerous zones encompass the following spaces and areas classified as *Zone 1*:

.1 enclosed spaces of cargo compartments/holds;

.2 air ducts of ventilation systems for spaces of cargo compartments/holds specified in 19.11.2.3.1.

Table 19.11.2.1

Dangerous zones for dangerous goods

Subparagraphs	Typical examples	Comments
19.11.2.2 19.11.2.3.1 19.11.2.4.1.1 19.11.2.5.1.1		—
19.11.2.3.2 19.11.2.4.1.2 19.11.2.5.1.2		—
19.11.2.4.1.4 19.11.2.5.1.4		—
19.11.2.4.2.1 19.11.2.5.2.1		natural ventilation
		space under overpressure, visual and audible alarm in control stations to be actuated when pressure drops
19.11.2.4.2.1 19.11.2.5.2.1 – only for fore room		natural ventilation
19.11.2.4.1.3 19.11.2.5.1.3 19.11.2.4.2.2 19.11.2.5.2.2		

 — gastight self-closing door

 — non-dangerous space

 — dangerous zone 1

 — dangerous zone 2

19.11.2.4 For dangerous goods carried in bulk, Class 4.3, capable of producing explosive gaseous mixture, the dangerous zones encompass the following spaces and areas:

19.11.2.4.1 *Zone 1*:

.1 enclosed spaces of cargo compartments/holds;

.2 air ducts of ventilation systems for spaces of cargo compartments/holds specified in 19.11.2.4.1.1;

.3 areas on open deck or semi-enclosed spaces on open deck within 1,5 m of any ventilation outlets of cargo compartments/holds specified in 19.11.2.4.1.1;

.4 enclosed or semi-enclosed spaces having direct access to or other openings into spaces and areas specified in 19.11.2.4.1.1, 19.11.2.4.1.2, unless ap-prop-riate measure are taken to prevent the explosive mixture from penetration into these spaces;

.5 air ducts of ventilation systems, pipelines of bilge systems, etc. where open ends of this piping directly face dangerous Zone 1.

19.11.2.4.2 *Zone 2*:

.1 enclosed or semi-enclosed spaces with natural ventilation, having direct access to or other openings into spaces and areas specified in 19.11.2.4.1.1, 19.11.2.4.1.2 and separated from these spaces by gastight self-closing doors as well as directly within air lock, if any;

.2 areas within 1,5 m of areas and spaces on open deck specified in 19.11.2.4.1.3;

.3 closed spaces (e.g. pipe tunnels, pump rooms with bilges, etc.) with piping specified in 19.11.2.4.1.5 along with their flanges, valves, pumps, etc. except cases when special methods of pressure buildup approved by the Register are used in those spaces.

19.11.2.5 For packaged dangerous goods, Class 2.1 and also Classes 3.1, 3.2, 6.1 and 8 (liquids with $T_{flash} \leqslant 23$ °C), the dangerous zones encompass the following spaces and areas.

19.11.2.5.1 *Zone 1*:

.1 enclosed spaces of cargo compartments/holds;

.2 air ducts of ventilation systems for spaces of cargo compartments/holds specified in 19.11.2.5.1.1;

.3 areas on open deck or semi-enclosed spaces on open deck within 1,5 m of any ventilation outlets of cargo compartments/tanks specified in 19.11.2.5.1.1;

.4 enclosed or semi-enclosed spaces having direct access to or other openings into one of the above areas specified in 19.11.2.5.1.1 and 19.11.2.5.1.2, unless appropriate measure are taken to prevent the explosive mixture from penetration into these spaces.

19.11.2.5.2 *Zone 2*:

.1 enclosed or semi-enclosed spaces with natural ventilation having direct access to or other openings into spaces specified in 19.11.2.5.1.1, 19.11.2.5.1.2 and separated from these spaces by gastight self-closing doors, as well as directly within air lock, if any;

.2 areas within 1,5 m of areas or spaces on open deck specified in 19.11.2.5.1.3.

19.11.3 Installation of electrical equipment in dangerous spaces and zones.

19.11.3.1 Electrical equipment installed in spaces and areas where only explosive dust is likely to occur due to bulk cargoes, shall comply with the following minimum requirements, unless otherwise specified (refer to Table 19.11.3.3):

.1 protection level IP55 and the maximum surface temperature of 200 °C or,

.2 certified safe type with temperature class T3 and protection level IP55.

19.11.3.2 Electrical equipment installed in areas where only explosive gas atmosphere is likely to occur shall be of certified safe type and comply with the following minimum requirements, unless otherwise specified (refer to Table 19.11.3.3):

.1 temperature class T3;

.2 sub-group of equipment IIB.

The certified safe-type electrical equipment shall be at least with protection suitable for operation in *Zone 1*.

Table 19.11.3.3

Requirements for electrical equipment depending on specific solid bulk cargoes

Dangerous goods	IMO class	Dominant risk[1]	Protection against explosive dust	Protection against explosive gas atmosphere	
				Subgroup A	Temperature class
Aluminium dross	4.3	Hydrogen	—	II	2
Aluminium ferrocilicon powder	4.3	Hydrogen	—	II	2
Aluminium cilicon powder, uncoated	4.3	Hydrogen	—	II	2
Ammonium nitrate fertilizers:		Refer to footnote[2]			
type A	5.1		—	—	—
type B	9		—	—	—
Coal	MHB	Dust, methane	IP55	IIA	T4
Direct-reduced iron	MHB	Hydrogen	—	II	2
Ferrophosphorus (no briquettes)	MHB	Hydrogen	—	II	1
Ferrocilicon	4.3	Hydrogen	—	II	1
Iron oxide, spent. Sponge iron, spent	4.2	Dust	IP55	IIA	2
Seed cake, expelled	4.2	Hexane	—	IIA	3
Silicomanganese	MHB	Hydrogen	—	II	1
Sulfur	4.1	Inherent	IP55	—	4
Zinc slag	4.3	Hydrogen	—	II	2

[1] This column relates to the possible evolution of substances, which may affect the installations of electrical equipment and cables.
[2] Provision shall be made to disconnect all electric circuits terminating within cargo spaces in accordance with the provisions of 2.9.9.

19.11.3.3 Electrical equipment installed in spaces and areas where only solid bulk cargoes and MHB are carried shall comply with the requirements of 19.11.3.1, 19.11.3.2 and the minimum requirements of Table 19.11.3.3.

19.11.3.4 Electrical equipment installed in spaces and areas where explosive gas atmosphere and dust are likely to occur shall comply with the requirements of 19.11.3.1, 19.11.3.2.

19.11.3.5 Electrical equipment installed in spaces and areas where dangerous goods of Class 1, except for Class 1.4S, are likely to be carried, shall comply with the following requirements:

.1 protection level IP65;

.2 the maximum surface temperature — 100 °C.

19.11.3.6 Electrical equipment installed in dangerous zone of category 2 shall be:

.1 of type suitable for use in adjacent spaces in accordance with 19.11.3.1 to 19.11.3.5; or

.2 of special design for protection class “n” and appropriate temperature class, sub-group and protection level in accordance with 19.11.3.1 to 19.11.3.5; or

.3 of such design that does not generate arcs or sparks in service and which surfaces do not reach unacceptable high temperatures under normal conditions.

19.11.3.7 Portable electrical equipment shall, in general, have its own independent source of electrical power (except for intrinsically safe electric circuits) and be of certified safe type with protection suitable for operation in *Zone 1*.

20 REQUIREMENTS FOR ELECTRICAL EQUIPMENT OF REFRIGERATING PLANTS

20.1 GENERAL

20.1.1 The requirements of the Section cover the electrical equipment of classed refrigerating plants.

The requirements of 20.2.3, 20.2.4, 20.3.1 and 20.4 apply to unclassed refrigerating plants as well.

20.2 POWER SUPPLY AND SWITCHING

20.2.1 The electric drives of refrigerating plants shall be powered through separate feeders from the switchboard of the refrigerating plant.

The electric drives of refrigerating compressors may be supplied directly from the main switchboard. The refrigerating fans may be supplied from the switchboard of the refrigerating plant or other switchboard energized directly from the main switchboard.

For each method of power supply it is necessary to provide that in case of generator overload the refrigerating plant electric drives are disconnected in the last turn.

The emergency ventilation system shall be supplied through a separate feeder from the switchboard energized from the main switchboard or directly from the main switchboard.

20.2.2 Power supply of electric drives of thermal containers shall comply with the requirements of 19.5.2.

20.2.3 When using the refrigerants of Group II according to Table 2.2.1, Part XII "Refrigerating Plants", a device shall be provided for emergency remote disconnection of the refrigerating plant switchboard operated from the following locations:

.1 from the permanent control post of the refrigerating plant in the refrigerating machinery room;

.2 from a location outside the space that may be contaminated with the refrigerant of Group II in case of breakdown in the refrigerating machinery room;

.3 outside, near every exit from the refrigerating machinery room.

The apparatus for emergency remote disconnection shall be installed in such a manner that it cannot be actuated inadvertently.

20.2.4 The apparatus for emergency remote disconnection of the switchboard of the refrigerating plant working with Group II refrigerant shall simultaneously switch off the electric drives of refrigerating compressors if they are fed from the main switchboard (refer to 20.2.1), main lighting of the refrigerating machinery compartment and switch on the emergency ventilation, water screens and emergency lighting.

Additionally, near the device for emergency remote disconnection of the refrigerating plant switchboard at locations stated in 20.2.3.1 and 20.2.3.2, devices shall be installed for remote starting in any sequence of emergency ventilation, water screens, and emergency lighting, without disconnection of the refrigerating plant switchboard.

20.2.5 It is recommended that the electrical heating appliances for hatches and doors to refrigerated spaces and freezing chambers shall be supplied at safety voltage.

20.3 VENTILATION

20.3.1 If the refrigerant of Group II is used, the exhaust fan electric motors of the emergency ventilation in the refrigerating machinery rooms, installed in the exhaust ducts, shall be of safe type.

20.3.2 The electric motors of fans located in the stream of air coming from the refrigerated cargo spaces shall have a degree of protection not below IP55.

20.4 LIGHTING

20.4.1 If the refrigerant of Group II is used, safe-type reserve lighting fixtures shall be installed in the refrigerating machinery room in addition to the main lighting fixtures. The reserve lighting fixtures shall be powered separately from the electrical equipment and main lighting fixtures installed in the refrigerating machinery room.

21 SPARE PARTS

21.1 Every ship shall be provided with spare parts in the amount sufficient for repairing when essential services fail at any situation, an accident at sea inclusive, in order to ensure movement, control and safety of a ship and people on board.

21.2 Specifying a required minimum of spare parts, the recommendations of manufacturers of specific kinds of equipment shall be followed.

21.3 Spare parts shall be included in the list of spare parts mentioned in 3.2.11.1.25, Part I "Classification" approved by the Register, and their amount on board shall, at least, comply with this list.

PART XII. REFRIGERATING PLANTS

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to stationary marine refrigerating plants and their equipment in compliance with 4.1, Part I "Classification".

1.1.2 Classed refrigerating plants shall comply with all the requirements of the present Part.

1.1.3 Unclassed refrigerating plants shall comply with the requirements of the present Part, set forth in 1.3.2.1, 1.3.2.2, 1.3.2.5 (only for heat exchangers and vessels subject to a pressure of a refrigerant), 1.3.2.6 (only for refrigerant systems), 1.3.2.7 (only for the protection system), 1.3.4.2 (only for systems working under a pressure of a refrigerant), 1.3.4.3, 1.3.4.5, 1.3.4.7 (only for protection systems), 1.3.4.8, 2.1.2, 2.2.1, 2.2.2, 3.1.1, 3.1.3 to 3.1.7, 3.2.1 to 3.2.5, 3.3.4, 3.3.8, 3.3.10, 3.4.3, 3.5, 4.1.2, 4.1.5, 5.1.1, 5.1.2, 5.1.4, 5.1.5, 5.2.1, 6.1.1, 6.1.2, 6.2.1 (only for refrigerant piping), 6.2.2, 6.2.3, 6.2.5 to 6.2.8, 7.1.2, 7.2.2, 7.2.3, 7.2.4.2, 7.2.4.3, 7.2.7, 8.2.3, 8.2.4, 12.1.2 (only for equipment working under a pressure of a refrigerant), 2.5, 3.3.12, 12.1.3, 12.1.6, 12.2.2, 12.2.4, 12.2.6.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to general terminology of the Rules are given in Part I "Classification".

For the purpose of the present Part the following definitions and explanations have been adopted.

Refrigerating machinery space is a space containing mechanical and other types of equipment intended for cold production.

Refrigerated spaces are cargo spaces provided with equipment capable of maintaining the reduced temperatures and intended for the carriage of refrigerated and frozen cargoes.

Refrigerant is a working medium of the refrigerating cycle.

Secondary refrigerant is a substance for heat removal from refrigerated objects and heat transfer to a refrigerant.

Note. A brine is an example of a secondary refrigerant.

1.3 SCOPE OF SURVEYS AND TECHNICAL DOCUMENTATION

1.3.1 General provisions and procedure of classification, surveys as well as the amount of technical documents for the refrigerating plant, which shall be submitted to the Register for review and approval are specified in the General Regulations for the Classification and Other Activity, as well as in Section 4, Part I "Classification" and in Section 12 of the present Part.

The technical documents for compressors and pumps to the extent, which shall be submitted to the Register for review, are specified in 1.2.3.2, Part IX "Machinery" and for heat exchangers and pressure vessels, as determined in 1.3.4.1, Part X "Boilers, Heat Exchangers and Pressure Vessels".

1.3.2 The following machinery and apparatus shall be surveyed by the Register in the process of manufacture:

.1 refrigerant compressors;

.2 refrigerant pumps;

.3 secondary refrigerant pumps;

.4 cooling water pumps;

.5 heat exchangers and other apparatus and pressure vessels of refrigerant, secondary refrigerant or cooling water;

.6 pipes and fittings intended for work at a pressure of 1,0 MPa and over;

.7 devices of control, indication and protection systems as well as instruments for measuring and recording of temperature in the refrigerated spaces.

1.3.3 The parts of machinery and apparatus mentioned in 1.3.2 are subject to survey by the Register during manufacture to ensure that the provisions of Part XIII "Materials" and Part XIV "Welding" as well as particular requirements of technical documents approved by the Register are complied with. The parts of machinery under 1.3.2.1 to 1.3.2.4 are listed in Table 1.2.4, Part IX "Machinery" and the parts of apparatus indicated in 1.3.2.5 are given in Table 1.3.3, Part X "Boilers, Heat Exchangers and Pressure Vessels".

1.3.4 In the process of ship's construction the following shall be subjected to survey by the Register:

.1 manufacture and testing of the relevant items of the refrigerating plant at the workshop;

.2 mounting of machinery, heat exchangers and pressure vessels;

.3 mounting of refrigerant systems;

.4 mounting of secondary refrigerant, cooled air and cooling water systems;

.5 mounting of the main and emergency ventilation systems;

.6 fitting of insulation of the cooling spaces and freezing chambers, apparatus, pressure vessels and refrigerating pipes;

.7 installation of control, indication, alarm and protection systems of the refrigerating plant;

.8 testing of the refrigerating plant.

2 GENERAL TECHNICAL REQUIREMENTS

2.1 GENERAL

2.1.1 The machinery and other units of the refrigerating plant shall remain operative under the environmental conditions specified in 2.3, Part VII "Machinery Installations".

2.1.2 The machinery and equipment of the refrigerating plant shall be installed and secured on board the ship in accordance with the requirements of 4.4.1, 4.4.4, 4.4.6 to 4.4.8, Part VII "Machinery Installations".

2.2 REFRIGERANTS AND DESIGN PRESSURE

2.2.1 The refrigerants in accordance with Table 2.2.1 are subdivided into two groups as follows:

I — freons;

II — ammonia.

Use of other refrigerants is subject to special consideration by the Register with regard to their toxicity, inflammability and explosion hazard.

Table 2.2.1

Refrigerant group	Symbol	Chemical formula	Design pressure *p*, MPa
I	R22	CHF_2Cl	2,0
	R134A	$CF_3 — CH_2F$	1,2
II	R717	NH_3 (ammonia)	2,0

2.2.2 In strength calculations of the items operating under refrigerant pressure the design pressure shall be taken not less than the excessive pressure of the saturated vapours of the refrigerant at temperature +50 °C in accordance with Table 2.2.1.

For the refrigerant equipment working under the pressure of refrigerants with low critical temperatures (below +50 °C) the design pressure is subject to special consideration by the Register in each case.

The refrigerating plant components working under pressure shall be calculated for compliance with hydraulic test pressure (refer to 12.1.2). The stresses involved shall not exceed 0,9 times the yield stress of material.

2.3 COMPOSITION AND CAPACITY OF THE REFRIGERATING EQUIPMENT

2.3.1 The refrigerating plant shall provide effective maintenance of the temperatures in refrigerated spaces as may be required for the cargo carried, depending upon its type and conditions of navigation area as well as cold treatment of cargo.

2.3.2 The refrigerating plant shall provide maintenance of required temperatures in the refrigerated cargo spaces with the main equipment at work supplying cold to all consumers under the following environmental conditions:

sea water temperature not below + 32 °C;

ambient air temperature not below + 40 °C.

The design environmental conditions of the refrigerating plants of fishing vessels and special purpose ships, which, in addition to the refrigerating plants of the cargo spaces, are equipped with other refrigerating facilities, are subject to special consideration by the Register in each case.

2.3.3 Capacity of main equipment of the refrigerating plant shall be sufficient to maintain the required temperatures in refrigerated spaces when working 24 hours a day and to supply cold to other consumers.

The main equipment shall comprise not less than two similar condensers and, where intermediate secondary refrigerant or cascade and stage cycles are used, two similar evaporators, intercascade heat exchangers and intermediate pressure vessels.

2.3.4 Capacity of the refrigerating plant designed also for cooling of non-precooled cargo with all the machinery at work including the standby unit shall be sufficient to reduce the cargo temperature to the required temperature as quickly as it is necessary for preservation of that cargo.

2.3.5 Standby equipment of compressor refrigerating plant shall comprise one compressor with a drive motor, one condenser, control systems and all fittings necessary for independent operation of all components of this equipment.

Capacity of the standby equipment shall be such as to supply cold to all consumers with one of the main compressors or condensers inoperative.

2.3.6 For fishing vessels and special purpose ships which, in addition to the refrigerating plants of the cargo spaces, are equipped with other refrigerating facilities (e.g. freezing, cooling and ice making), provision of the standby equipment is subject to special consideration by the Register in each case.

2.3.7 Freezing and cooling facilities shall provide freezing (cooling) of cargo during the time period as required by the conditions of its preservation, handling and proper carriage.

2.3.8 Pipelines between apparatus and machinery shall be joined in such a way as to provide operation of the refrigerating units at various combinations of apparatus, machinery and facilities necessary for their independent operation.

The apparatus shall be fitted with the connections for suction and delivery pipes providing the transfer of the refrigerant and its discharge from the apparatus.

2.3.9 When pumping for liquid refrigerant circulation is used, at least two circulating pumps shall be fitted, one of which shall be a standby pump.

If the refrigerant system is so designed that it is capable of properly working without pumps, the standby pump need not be installed, provided the refrigerant system capacity meets the requirements of 2.3.1 and the freezing units capacity is not reduced in excess of 20 per cent.

2.3.10 The secondary refrigerant system serving a single group of cold consumers shall comprise at least two circulating pumps, one of which being standby.

In case of two or more groups of cold consumers with separate secondary refrigerant systems (differing in temperatures), each group shall have at least one circulating pump; a common standby pump may be admitted provided it has adequate capacity and pressure head.

2.3.11 Cooling water supply to the refrigerating plant shall be provided from at least two circulating pumps, one of which shall be used for standby purpose. Any of sea water pumps with adequate capacity and pressure head may be accepted as standby means.

2.3.12 Cooling water shall be supplied from at least two sea connections. Where it is intended to use sea connections of general service, proper structural arrangements shall be provided for adequate supply of cooling water from each sea connection under normal service conditions of the ship.

2.4 MATERIALS

2.4.1 Quality and main characteristics of materials used for the manufacture of parts, assemblies and securing items of the refrigerating equipment subject to the dynamic loads, excessive pressure, variable and low temperatures shall comply with the requirements of Part XIII "Materials".

The choice of materials depends on the working temperature and physical and chemical properties of the refrigerant:

.1 materials used for the manufacture of parts of equipment exposed to the refrigerants, lubricating oils and their combinations, cooling and cooled media shall be inert and resistant to their action;

.2 materials used for the manufacture of parts of equipment working at low temperatures shall not be subject to structural irreversible modifications and shall maintain adequate strength at the temperatures concerned;

.3 materials used for the manufacture of parts and assemblies of the refrigerating equipment working at temperatures not below $-50\,^{\circ}\mathrm{C}$ shall comply with the requirements of 1.2, Part II "Hull" and 3.5, Part XIII "Materials";

.4 materials used for the manufacture of parts of equipment working at temperatures below $-50\,^{\circ}\mathrm{C}$ are subject to special consideration by the Register in each case.

2.4.2 Parts of machinery and apparatus exposed to the action of corrosive agents shall be made of materials with adequate corrosion resistance or be protected by corrosion-resisting coatings.

Assemblies and parts of machinery and apparatus made of materials differing in electrolytic potential shall be protected against contact corrosion.

2.4.3 Steel piping of refrigerant, secondary refrigerant and connecting pieces of these pipes made of steel other than stainless steel shall be galvanized on the outside or treated in some other way ensuring equivalent antirust protection. Surfaces in contact with refrigerant or secondary refrigerant shall not be galvanized.

In manufacturing pipes the requirements of 2.4.1 and 2.4.2 shall be taken into consideration.

2.5 ELECTRICAL EQUIPMENT

2.5.1 Electrical equipment of refrigerating plants and automatic devices as well as the lighting of refrigerating machinery and refrigerated spaces and refrigerant storerooms shall comply with the requirements of Section 20 and other applicable requirements of Part XI "Electrical Equipment".

2.5.2 Driving motors of compressors, pumps and fans shall meet the requirements of Sections 5 and 10, Part XI "Electrical Equipment".

3 SPACES FOR REFRIGERATING PLANTS AND REFRIGERATED CARGO SPACES

3.1 REFRIGERATING MACHINERY SPACES

3.1.1 The refrigerating machinery spaces shall meet the requirements of 4.5.1, 4.5.3 and 4.5.4, Part VII "Machinery Installations" as well as the requirements of the present Chapter.

Refrigerating equipment working with Group II refrigerants shall be arranged in isolated gastight compartments.

Refrigerating machine working with Group II refrigerant may be arranged in common machinery space of a fishing vessel in cases, when the length of the vessel is less than 55 m and the refrigerant charge does not exceed 25 kg. The location where the such refrigerating machine is installed shall be served by a special exhaust hood with exhaust ventilation.

Otherwise the possibility of installation of a refrigerating machine using a Group II refrigerant in the common machinery space of the ship is subject to special consideration by the Register with regard to the formal safety assessment of the ship ammonia refrigerating plants according to the procedure set forth in the Collection of Regulating Documents, Book 14.

Drainage of the refrigerating machinery space with Group II refrigerant shall be provided as required by 7.4.10, Part VIII "Systems and Piping".

3.1.2 The machinery, apparatus and piping shall be so arranged in the refrigerating machinery space as to permit easy access for maintenance and shall enable the parts to be renewed, if necessary, without dismantling the machinery and apparatus from foundations. Care shall be taken that the machinery, apparatus and other equipment be placed not less than 100 mm remote from bulkheads and other vertical surfaces.

3.1.3 The refrigerating machinery space shall have two exits located as far apart as practicable, with the doors opening outwards. Where the refrigerating machinery space is situated above or below the open deck, each escape route shall be fitted with steel ladders as widely separated from each other as possible and leading to the spaces, which give access to the open deck.

A second exit is not required:

.1 for refrigerating machinery spaces, provided the distance between the farthest place where people are likely to be and the exit is 6 m and less;

.2 unattended rooms of automated refrigerating machinery working with Group I refrigerants.

3.1.4 The means of escape from spaces of refrigerating machinery working with Group II refrigerants shall not lead in accommodation, public and service spaces or spaces in communication therewith. One of the means of escape shall lead to the open deck.

Where the escape routes pass through corridors and casings, these shall be fitted with supply and exhaust ventilation, forced air supply being obligatory. The starting arrangements of the ventilation shall be available both inside and outside the refrigerating machinery space, placed in immediate proximity to the exit.

3.1.5 Exits from spaces housing refrigerating machinery working with Group II refrigerants shall be provided with water-screen arrangements. The starting means of water screens shall be available from the outside of the space placed in immediate proximity to the exit.

In the machinery space there shall be one fire hydrant with a hose.

3.1.6 The refrigerating machinery space shall have an independent ventilation system ensuring 10 air changes per hour. Where refrigerating machinery are arranged in other spaces the ventilation system of these spaces is subject to special consideration by the Register in each case.

3.1.7 In addition to the main ventilation system required by 3.1.6, each refrigerating machinery space shall be fitted with emergency ventilation system of a capacity sufficient for:

.1 30 air changes per hour for spaces of refrigerating machinery working with Group II refrigerants;

.2 20 air changes per hour for spaces of refrigerating machinery working with Group I refrigerant.

Depending on density of the refrigerant, exhaust ventilation shall be provided from the uppermost or lowest parts of the space.

When calculating the emergency ventilation system, the capacity of the main ventilators may be included, provided these are operable with the emergency ones, shall the switchboard of the refrigerating units be deenergized.

3.1.8 At least two breathing apparatus suitable for the refrigerant used, access to which will not be cut in case of refrigerant leakage, shall be provided at the exits of the refrigerating machinery space.

At least two sets of gastight protective clothings shall be available at the exits of the spaces of refrigerating machinery working with Group II refrigerants.

3.2 REFRIGERANT STOREROOMS

3.2.1 Refrigerant storerooms shall be separated from other spaces.

The spaces intended for storage of the refrigerant shall be gastight.

In case of storing small amounts of Group I refrigerant the departure is allowed from the above-mentioned requirements on agreement with the Register.

The refrigerant storage cylinders shall comply with the requirements of 6.4.5, Part X "Boilers, Heat Exchangers and Pressure Vessels".

3.2.2 The refrigerant storage cylinders shall be secured in place in such a way that they will not shift in adverse weather conditions.

Non-metallic pads shall be placed between the steel plating and the storage cylinders as well as between storage cylinders proper.

3.2.3 The refrigerant storerooms shall be provided with an independent ventilation system.

3.2.4 Storage cylinders containing compressed gases other than the refrigerant gas are not permitted to be stowed in spaces of refrigerant storage, nor shall combustible materials be used for the outfit of these spaces.

3.2.5 Storage of refrigerant in fixed receivers is permitted on condition that the receivers and spaces they are arranged in comply with the requirements stated in 3.1.5, 3.1.7, 5.1.1, 5.1.2, 5.1.4, 6.2.5 and 6.2.6. Provision shall be made for sucking off Group II refrigerant from the service piping of each receiver after complete filling of the system or periodical replenishing.

Service piping of receivers designed for refrigerant storage is not to pass through accommodation and service spaces.

3.3 REFRIGERATED CARGO SPACES

3.3.1 Cooling apparatus, grids, mechanisms, devices as well as piping and air ducts arranged in the refrigerated cargo spaces shall be efficiently secured and protected from being damaged by cargo.

3.3.2 Where the air cooling system is used, the air coolers may be located either in separate spaces or in the same spaces as the cargo cooled. Being arranged in the refrigerated cargo spaces, the air coolers shall be provided with condensate tray. For the refrigerated spaces with the ambient air temperature being negative, the condensate trays shall be provided with the heating system.

3.3.3 Where the air cooling system is adopted, the air coolers shall be made accessible with the cargo space being entirely loaded with refrigerated cargo. Alternatively, access to the air coolers shall be provided from adjacent non-cooled spaces. The access opening of the air cooler space shall be as large as to permit the fan impeller and electric motor to be carried through, if necessary.

3.3.4 In places where air ducts pass through watertight bulkheads, sluice valves shall be fitted. The sluice valves shall be designed as strong as the bulkhead. The sluice valves shall be operable from positions above the bulkhead deck.

In passenger ships and special purpose ships, the cargo cooling air ducts may pass through more than one watertight bulkhead if the means of closure at such openings are operated by power and are capable of being closed from a central position situated above the bulkhead deck.

3.3.5 Appropriate ventilation system capable of supplying uncontaminated atmospheric air into the spaces of refrigerated cargoes requiring adequate air exchange during carriage shall be provided.

3.3.6 Each air inlet and outlet shall have airtight closure.

3.3.7 Ventilation ducts passing through refrigerated cargo and other spaces shall be airtight and efficiently insulated.

3.3.8 Where cooling arrangements (batteries or air coolers) under a refrigerant pressure are used in cargo spaces, an independent ventilation system shall be provided for these spaces capable to ensure, relative to the volume of the empty space:

.1 two air changes per hour, where a Group I refrigerant is used;

.2 three air changes per hour, where a Group II refrigerant is used.

The above ventilation system may be combined with the system referred to in 3.3.5 and 10.1.8, if any. For spaces where cooling arrangements working under Group II refrigerant pressure are used, the requirement of 3.5.4 as regards two exits shall be met.

3.3.9 The refrigerated spaces shall be fitted with telethermometric arrangements.

3.3.10 Drainage of refrigerated spaces shall conform to the requirements stated in 7.4.10 and 7.8, Part VIII "Systems and Piping".

3.3.11 Piping passing through refrigerated spaces shall comply with 5.4, Part VIII "Systems and Piping".

3.3.12 Each refrigerated space with an indoor temperature of 0 °C and below shall be fitted with a readily identifiable signal push-button located in an accessible position. The "Man-in-Space" signal actuated by this push-button shall be transmitted to the position where continuous watch is kept.

3.4 FREEZING AND COOLING APPARATUS

3.4.1 The arrangement of air coolers and fans in freezing apparatus shall comply with the requirements of 3.3.1.

3.4.2 Provision shall be made in the refrigerating machinery space for the devices for monitoring the operation of freezing and cooling apparatus.

3.5 SPACES CONTAINING PROCESS EQUIPMENT

3.5.1 The arrangement of machinery, apparatus and refrigerant pressure vessels in spaces other than the refrigerating machinery spaces shall be subject to special consideration by the Register in each case.

3.5.2 Spaces containing the process equipment working under pressure of Group II refrigerant shall be provided with a fire hydrant with a hose.

3.5.3 Spaces containing the process equipment working under pressure of a refrigerant shall have an independent ventilation system complying with the requirements of 3.1.6 and 3.1.7.

3.5.4 In spaces containing the process equipment working under pressure of Group II refrigerants there shall be two exits, as it is specified in 3.1.3 and 3.1.4.

When using Group II refrigerants, the exits shall be fitted with arrangements capable of producing water screens. The cut-in device of the screens shall be placed from the outside of the space in immediate proximity to the exit.

4 MACHINERY

4.1 COMPRESSORS

4.1.1 Compressors shall comply with the requirements specified in this Part of the Rules and also with those of 5.1, Part IX "Machinery".

4.1.2 Parts of compressors exposed to the action of dynamic loads and excessive pressure shall be calculated for strength having in view the design pressures in compliance with 2.2.1.

4.1.3 The refrigerant suction and delivery sides of the compressor shall have stop valves apart from the automatic valves.

4.1.4 Cavities in compressors reserved for refrigerant, lubricating oil and cooling water shall have drain arrangements, where necessary.

4.1.5 A pressure relief valve or other safety device shall be fitted in the delivery line of the intermediate and final compression stages of compressor between the delivery cavity and the stop valve, the discharge being led to the suction side of the compressor in case of excessive pressure rise. Discharging capacity of the safety devices shall not be less than the maximum volumetric capacity of the compressor stage protected.

The opening pressure of safety valve shall not exceed 10 per cent of the lifting pressure, with the valve being open.

No shut-off devices are permitted in the refrigerant gas relief line.

4.1.6 Refrigerant compressor safety devices shall comply with the requirements of 7.2.3.

4.2 PUMPS

4.2.1 Pumps shall comply with the requirements set out in 5.2, Part IX "Machinery".

4.3 FANS

4.3.1 Fans shall comply with the requirements set out in 5.3, Part IX "Machinery".

5 HEAT EXCHANGERS, PRESSURE VESSELS AND COOLING ARRANGEMENTS

5.1 HEAT EXCHANGERS AND PRESSURE VESSELS

5.1.1 Heat exchangers and pressure vessels as regards materials, scantlings of components and provision with fittings shall comply with the relevant requirements of Section 6 (except for 6.3.1, 6.3.3, 6.4.1, 6.4.2.3 and 6.4.2.4), Part X "Boilers, Heat Exchangers and Pressure Vessels" and also with the requirements of the present Part.

5.1.2 "Shell and tube" heat exchangers and pressure vessels with the volume of the refrigerant space of 50 dm^3 and over shall be fitted with safety devices having the discharging capacity so designed that the pressure will not rise in excess of 10 per cent of the design pressure, with the valve being completely open.

The designed discharging capacity G, in kg/s, shall not be less than determined by the following formula:

$$G = qS/r \qquad (5.1.2)$$

where q = specific intensity of the heat flow from the space during fire, kW/m^2 (assumed to be 10 kW/m^2 in all cases);
S = area of the outer surface of pressure vessel (heat exchanger), m^2;
r = specific heat of the refrigerant vaporization under opening pressure of the safety valve, kJ/kg.

The safety devices shall consist of two safety valves and a change-over device so constructed that both or one of these valves will, in any case, communicate with the heat exchanger or pressure vessel involved. Each of these valves shall provide the full discharging capacity.

The Register may require that the safety valves are also fitted in other apparatus if this is deemed expedient.

No shut-off valves are permitted between the heat exchanger or pressure vessel and the safety device.

The use of safety devices with one safety valve or safety devices of other types is subject to special consideration by the Register in each case.

5.1.3 Heat exchangers and pressure vessels shall have suitable facilities for removing water, air, lubricating oil and secondary refrigerant.

5.1.4 Pressure vessels with Group II liquid refrigerants shall have suitable facilities for emergency dumping of the latter.

The rated time of refrigerant dumping shall not be more than 2 min with refrigerant in heat exchangers or pressure vessels under constant excessive pressure assumed equal to the design pressure according to 2.2.1.

5.1.5 Cooling facilities of refrigerated cargo spaces, freezing and cooling apparatus arranged outside the space for refrigerating machinery working under the pressure of the refrigerant shall be equipped with shut-off fittings enabling facilities and apparatus to be disconnected remotely from the refrigerant delivery and return lines. The disconnection shall be performed from positions arranged outside the spaces where these facilities and apparatus are placed.

5.2 AIR COOLERS, COOLING GRIDS

5.2.1 Air coolers working under pressure of a refrigerant shall be of welded or soldered construction. Flanged connections between the coil sections and pipes are permitted only when this is proved necessary; all flanged connections shall be arranged in readily accessible places to enable inspection for tightness.

5.2.2 Where only one air cooler is used for cooling cargo spaces, it shall be arranged in not less than two sections, each of which shall be capable of being disconnected, if necessary.

5.2.3 The distribution of cooling grids shall provide the uniform cooling of the space concerned.

Grids shall be combined in not less than two independent sections, with means providing shut-off of each section.

5.2.4 The cooling facilities of refrigerated cargo spaces shall be provided with effective defrosting system or means.

6 FITTINGS AND PIPING

6.1 FITTINGS AND SAFETY VALVES

6.1.1 The refrigerating plants shall be provided with shut-off, regulating and safety devices designed for pressure of not less than $1{,}25p$, where p is the design pressure as given in 2.2.1.

As a rule, valves and fittings shall be made of steel. The use of other types of materials is subject to special consideration by the Register in each case.

The integral shut-off valves and fittings made of grey cast iron, which are intended for the inlet and outlet cavities of the refrigerant compressors, as well as the valves and fittings made of spheroidal graphite cast iron may be permitted when using Group I and Group II refrigerants at ambient temperatures not below -40 °C.

6.1.2 The design of safety valves shall ensure the valve blowing up at a pressure exceeding the design pressure as given in 2.2.1 by not more than 10 per cent.

6.2 PIPING

6.2.1 The piping of refrigerant, secondary refrigerant and cooling water systems as well as air ducts shall comply with the relevant requirements set out in Section 2 and 5.4, Part VIII "Systems and Piping" and also with the requirements of the present Chapter.

In accordance with Table 1.3.2, Part VIII "Systems and Piping", piping conveying Group I refrigerant is Class II piping while piping conveying Group II refrigerant is Class I piping.

6.2.2 The piping of refrigerant and liquid secondary refrigerant shall be made of seamless pipes. The piping of the liquid secondary refrigerant shall be made of steel pipes. The joining of steel pipes carrying the refrigerant shall, as a rule, be made by welding and, where copper pipes are concerned, by welding or brazing. Where pipes are joined with machinery, heat exchangers and pressure vessels, detachable connections may be admitted.

6.2.3 The refrigerant delivery piping of the compressors and refrigerant pumps shall be fitted with non-return valves. These valves need not be used for compressors working with Group I refrigerant and having no discharge facilities.

6.2.4 Refrigerant driers for moisture absorption shall be fitted on the liquid piping carrying the refrigerant slightly soluble in water. They shall be fitted together with gauze filters to the regulators or structurally connected with them.

6.2.5 The pipes from safety devices of Group II shall be led overboard below the waterline corresponding to the minimum draught. These pipes shall be provided with non-return valves fitted in proximity to the ship's side.

Refrigerant leak detectors shall be installed after each safety device (other than those referred to in 4.1.5).

Group I refrigerants may be discharged to the atmosphere at a position safe for people.

6.2.6 The pipes for Group II refrigerant dumping from heat exchangers and pressure vessels in emergency shall terminate into a header (refer to 5.1.4) located outside the refrigerating machinery space, but near the access thereto. Each dumping pipe shall be fitted with shut-off valves located near the header. These valves shall be protected from opening by unauthorized persons and shall be so constructed as to be convenient for sealing when closed. No other shut-off fittings shall be fitted on the emergency drain pipes between pressure vessels or heat exchangers and shut-off valves near the header. The common main of the emergency dumping header shall have a non-return valve fitted in accordance with 4.3.2.10, Part VIII "Systems and Piping" and shall be laid overboard below the waterline corresponding to the minimum draught of the ship. To permit purging of the common main, steam or compressed air connections shall be provided.

The inner diameters of the refrigerant emergency dumping pipes of separate heat exchangers and pressure vessels shall not be less than the diameter of the relief valve determined as required by 5.1.2. The cross-sectional area of the dumping main shall not be less than the total cross-sectional area of three largest dumping pipes communicating with the main.

6.2.7 For pipes laid overboard in a place below the waterline according to 6.2.5 and 6.2.6, the minimum pipe wall thickness in all cases shall not be less than that specified in column 3 of Table 2.3.8, Part VIII "Systems and Piping".

6.2.8 Group II and refrigerant piping shall not pass through accommodation and service spaces. Group I refrigerant piping shall not pass through accommodation spaces.

7 INDICATING AND MEASURING INSTRUMENTS. CONTROL, PROTECTION, REGULATION AND ALARM

7.1 INDICATING AND MEASURING INSTRUMENTS

7.1.1 The compressors and apparatus for the refrigerating plants shall be fitted with suitable devices to permit the working parameters being monitored. Besides, the arrangement shall provide for the possibility of installing additional indicating and measuring instruments required when testing the plant.

7.1.2 Indicating and measuring instruments shall be placed in readily accessible and visible positions. The instruments shall bear clear marks indicating admissible values of the parameters controlled.

Indicating and measuring instruments shall be checked by competent bodies.

7.2 CONTROL, PROTECTION, REGULATION AND ALARM

7.2.1 Protective, regulation and alarm devices shall comply with the applicable requirements of Part XV "Automation".

The requirements for control, regulation and alarm of refrigerating plants of unattended operation are given in 4.8, Part XV "Automation".

7.2.2 Provision shall be made for local control and regulation of operating conditions of the refrigerating plant.

7.2.3 The refrigerant compressors shall be provided with protective devices capable of stopping the compressors in case of:

.1 inadmissible drop of suction pressure;

.2 inadmissible rise of discharge pressure;

.3 inadmissible drop of lubricating oil pressure;

.4 inadmissible rise of refrigerant discharge temperature (intended for the refrigerating plants working with Group II refrigerants as well as for the automated refrigerating plants with unattended operation);

.5 inadmissible axial rotor displacement of centrifugal compressor;

.6 inadmissible temperature rise in sliding bearings of centrifugal compressors.

7.2.4 Liquid separators, intermediate vessels and liquid refrigerant receivers (where pumps are used for refrigerant circulation) as well as free-level type evaporators shall be fitted with regulation and protective devices capable of:

.1 maintaining constant level of refrigerant liquid necessary for proper work of the evaporator, or constant temperature of vapour superheating;

.2 stopping the delivery of liquid refrigerant into evaporators and any type of intermediate vessels, in case of compressor shut-down;

.3 stopping the compressor, shall the level of refrigerant liquid rise inadmissibly.

7.2.5 Plants incorporating "shell and tube" type evaporators shall be fitted with protective devices capable of:

.1 stopping the compressor, shall the circulation of the secondary refrigerant inside the evaporator be impeded, or cutting off this evaporator from the refrigerant system;

.2 stopping the compressor, shall the temperature of secondary refrigerant drop inadmissibly.

7.2.6 The refrigerating plants shall be provided with signal devices, which shall give general warnings at the refrigerating plant control station after operation of protective devices specified in 7.2.3 to 7.2.5.

Provision shall be made at the local control station for decoding of the above signals.

7.2.7 Each space with equipment under refrigerant pressure shall be fitted with gas detection panel and refrigerant leakage alarm that comes into action in the following cases:

for Group I refrigerants (freons):

where the concentration of refrigerant in the working zone air is above the maximum allowable sanitary standard (3000 mg/m^3);

for Group II refrigerants (ammonia):

where the concentration of refrigerant in the working zone air is above the maximum allowable sanitary standards (20 mg/m^3);

where the maximum allowable concentration of refrigerant (60 mg/m^3) in the space protected increases threefold. In this case, provision shall be made for automatic switching on the emergency ventilation, except for the refrigerated spaces;

where the concentration of 500 mg/m^3 is attained. In this case access to the space without individual protection outfit shall be prohibited.

Warning audible and visible alarms shall be mounted in the spaces protected and before entrance to these spaces. Warning signals shall be duplicated at the position where continuous watch is kept.

7.2.8 The system for temperature, humidity and atmosphere control inside the refrigerated spaces shall ensure accuracy in maintaining these parameters within the ranges consistent with the cargo transportation conditions.

8 INSULATION

8.1 INSULATION OF THE REFRIGERATED SPACES

8.1.1 All steelwork of ship's hull inside the refrigerated cargo spaces shall be efficiently insulated. The applied insulating materials shall be of a type approved by the Register and shall also comply with the requirements of the properly authorized Sanitary Inspection Authorities.

8.1.2 The insulating materials adopted for refrigerated cargo spaces shall have adequate resistance to adverse biological factors and shall be of the type that does not give off any odour.

8.1.3 The surfaces of the bulkheads and the inner bottom plating in way of fuel tanks shall be coated with oil-resistant and inodorous material. The coating shall be applied before the insulation of these surfaces is arranged.

8.1.4 Care shall be taken to prevent the insulation from infiltration with water, or, alternatively, suitable means for drying it during service as well as protective measures against damage by rodents shall be provided.

8.1.5 The insulation of refrigerated cargo spaces shall be covered with suitable lining or other protective coating. In places where insulation linings may be crushed by cargo, they shall be suitably protected.

8.1.6 The insulation in freezing apparatus shall comply with the requirements of 8.1.2, 8.1.4, 8.1.5.

8.2 INSULATION OF PIPING

8.2.1 Where pipes are laid through bulkheads and decks, no direct contact with surfaces they pierce is permitted to prevent heat exchange.

8.2.2 Provision shall be made for protecting the insulation of piping from dampness.

8.2.3 The insulating materials used for piping shall be non-combustible in accordance with 1.6.3.1, Part VI "Fire Protection".

This requirement does not apply to insulation of piping arranged within the refrigerated cargo spaces and refrigerated storerooms.

8.2.4 Vapour barriers and adhesives used in conjunction with insulation as well as insulation of pipe fittings need not satisfy the requirements of 8.2.3, provided they are kept to the minimum quantity and their exposed surfaces have low flame spread characteristics in accordance with 1.6.3.5, Part VI "Fire Protection".

9 REFRIGERATING PLANTS DESIGNED FOR COOLING OF CARGO IN THERMAL CONTAINERS

9.1 GENERAL PROVISIONS AND TECHNICAL REQUIREMENTS

9.1.1 The refrigerating plants designed to supply cooled air to the thermal containers and installed permanently on board ship are covered by the applicable requirements of the present Part.

9.1.2 The refrigerating plants shall be capable of supplying cooled air within the required temperature range to the thermal containers with the cargo contained therein.

The degree of air circulation in the containers, devices for measuring and controlling temperature, maintaining required humidity, alarms to indicate maintenance of required parameters shall be consistent with transportation conditions of particular kinds of cargo.

The refrigerating capacity margin of the plant shall not be less than 20 per cent of the specified capacity.

9.1.3 If the purpose of a container is such that for carriage of cargo inside the container atmosphere control is required, its ventilation arrangements, insulation and alarm system shall meet the requirements of Part III "Thermal Containers" of the Rules for the Construction of Containers.

9.1.4 The atmosphere control system inside the thermal containers shall be capable of maintaining the required oxygen concentration in the containers.

9.1.5 The cooled air supplied to the thermal containers shall be sufficiently dry to avoid ice formation in flexible couplings.

9.1.6 The thermal containers carried on board ship shall comply with the requirements of Part III "Thermal Containers" of the Rules for the Construction of Containers and the Rules for Technical Supervision of Containers in Service.

Failure to meet these requirements cannot impede classification of the refrigerating plant.

10 ATMOSPHERE CONTROL SYSTEM

10.1 GENERAL PROVISIONS AND TECHNICAL REQUIREMENTS

10.1.1 To add a character letter **"CA"** (refer to 4.2.2.4, Part I "Classification") to the character of classification of a refrigerating plant at least 50 per cent of the ship's total refrigerated cargo space volume shall meet the requirements for operation with controlled atmosphere.

10.1.2 Equipment, laying of piping shall meet the requirements of 2.1.1, 2.5, 4.1.1, 5.1.1, 6.2.1, 7.2.1.

10.1.3 Each refrigerated space served by the atmosphere control system shall be fitted with a safety device, which pressure set point and pressure relieving capacity shall be such that the pressure in the space shall not exceed 0,5 kPa (50 mm water column) and shall not be less than 0,2 kPa (20 mm water column).

10.1.4 Gas shall be discharged from the safety device through vertical ducts, whice outlets shall be located at least 2 m above the upper deck and within 4 m of the ventilation intakes of accommodation spaces.

10.1.5 Arrangements shall be provided to ensure that the inert gas cannot be delivered to the depressurized refrigerated spaces.

10.1.6 The inert gas used in the system shall not be hostile to the cargo carried, insulating and structural materials of the refrigerated spaces.

10.1.7 Alarm shall be provided to automatically giving audible and visual warning at least 60 s before the inert gas injection takes place.

The alarm shall be interlocked with the inlet valve in such a way that the inlet valve cannot be opened unless the alarm signal has been given.

10.1.8 The refrigerated spaces with the controlled atmosphere shall be provided with an independent ventilation system with a capacity of at least 2 air changes per hour.

10.1.9 All spaces leading to the refrigerated spaces with controlled atmosphere and adjacent to them shall have an independent permanent ventilation system giving at least 6 air changes per hour.

10.1.10 The ventilation system serving the spaces specified in 10.1.8 and 10.1.9 shall be operated from outside the ventilated spaces.

10.1.11 All other spaces adjacent to the refrigerated spaces, other than those specified in 10.1.9 shall be arranged for ventilation by use of at least two portable ventilators provided on board, each of them being capable to give at least 2 air changes per hour.

10.1.12 The refrigerated spaces with controlled atmosphere shall be fitted with permanent devices providing O_2 volume content monitoring in the spaces before they are entered.

In addition, at least two portable O_2 analyzers shall be provided on board ship.

10.1.13 The supply and exhaust ducts of the atmosphere control system shall not pass through the accommodation and service spaces.

11 REFRIGERATING PLANTS DESIGNED FOR COOLING OF LIQUEFIED GAS

11.1 GENERAL

11.1.1 The refrigerating plants shall ensure maintenance of temperatures and pressures as may be required for the carriage of liquefied gas in bulk.

11.1.2 The refrigerating plants shall comply with the requirements of 4.2, Part VI "Systems and Piping" of the Rules for the Classification and Construction of Gas Carriers, as well as the requirements of the present Part.

11.1.3 The minimum temperature the refrigerating plant is capable to maintain in the cargo tank shall be indicated in the Classification Certificate for the refrigerating plant.

12 TESTS

12.1 TESTS AT THE MANUFACTURER'S

12.1.1 Tests of the refrigerating plant components listed in the present Chapter shall be carried out in the presence of a Surveyor to the Register.

12.1.2 Hydraulic tests for strength of the components working under the refrigerant pressure shall be carried out by a test pressure of not less than $1,5p$ in accordance with 2.2.1.

Components working under the pressure of secon-dary refrigerant or water shall be tested by a hydraulic pressure of 1,5 times the working pressure, but not less than 0,4 MPa, whereas box structures shall be tested by a pressure equal to 1,5 times their working pressure.

12.1.3 Pneumatic leak tests of the components working under the refrigerant pressure shall be carried out at a test pressure of not less than the design pressure assumed according to 2.2.1.

12.1.4 Equipment designed for operation under pressure of a refrigerant, which is below the atmospheric pressure, shall be subjected to vacuum-tight tests at a residual pressure of not more than 0,8 kPa.

12.1.5 Fittings in assembly and automatic devices provided with shut-off facilities shall be subjected to a leak test by pneumatic pressure equal to the design pressure in accordance with 2.2.1.

12.1.6 The machinery and equipment specified in 1.3.2 after assembling shall be tested in accordance with the requirements of 1.4, Part IX "Machinery".

12.2 TESTING OF REFRIGERATING PLANT ON BOARD

12.2.1 To verify the fulfilment of the requirements of the present Chapter, the refrigerating plant, after having been completely assembled on board, shall be tested and checked in operation under a programme approved by the Register.

12.2.2 The entire refrigerant system shall be subjected to pneumatic leak tests at a test pressure equal to the design one in accordance with 2.2.1. Pneumatic tests may be carried out using nitrogen, carbon dioxide or dried air. Upon completion of leak test of the Group II refrigerant system, operation of the refrigerant emergency drain system shall be checked.

12.2.3 Upon completion of leak test, the Group I refrigerant system shall be tested for tightness by a vacuum test at a residual pressure of not more than 1 kPa.

12.2.4 After the system has been filled with refrigerant all joints and fittings shall be checked for leak.

12.2.5 All pipes of secondary refrigerant and cooling water systems together with pertaining fittings shall be subjected to leak tests under operational conditions.

12.2.6 The main and emergency ventilation, drainage, water-screen, remote machinery shutdown, safety devices, protective automatic equipment, refrigerant leak gas detection systems shall be checked in operation.

12.2.7 The refrigerating plant equipment shall be checked in operation under all operational conditions and along with that the fulfilment of the requirements of 2.3 and 7.2.8, the work of the regulating automatic equipment and cooling facilities, defrosting efficiency shall be verified.

12.2.8 The refrigerating plant shall be tested at full design cooling load and specified refrigerant boiling and condensing temperatures. Where the tests are carried out at low outdoor temperatures, which differ from the specified ones, the simulation of additional cooling load may be required.

12.2.9 The calculation results of an averaged heat-transfer factor for refrigerated spaces shall be confirmed by insulation quality tests.

12.3 TESTING OF REFRIGERATING PLANTS WITH ATMOSPHERE CONTROL

12.3.1 Air ducts to thermal containers shall be tested for distribution of cooled air by measuring the amount of air supplied to the flexible coupling of the container when the fan is running at full capacity. Air flow (by amount of air) available at each thermal container are not to differ by more than ± 5 per cent from the design one.

12.3.2 After cooled air ducts have been completely fitted onboard before installation of insulation, strength tests shall be carried out by air pressure of not less than 1,5 times the design pressure and also leak tests shall be carried out by a working pressure; the above tests may be combined.

13 SPARE PARTS

13.1 GENERAL

13.1.1 Each refrigerating plant shall be provided with spare parts carried on board to an extent that is not less than required by the present Section.

13.1.2 The spare parts shall be secured in accessible positions marked and protected against corrosion in an effective way.

13.2 REQUIRED MINIMUM OF SPARE PARTS

13.2.1 Compressors, pumps and internal combustion engines driving the compressors shall be supplied with spare parts according to the provisions of Section 10, Part VII "Machinery Installations".

Electric motors of compressors, pumps and fans shall be supplied with spare parts according to the provisions of Section 21, Part XI "Electrical Equipment".

13.2.2 Apart from the requirements of 13.2.1, the refrigerating plants shall be supplied with spare parts in accordance with Table 13.2.2.

Table 13.2.2

Nos	Spare parts	Quantity
1	Compressor piston with connecting rod complete, of each size used	1
2	Shaft seal[1] for compressor of each size used	1
3	Liner of compressor cylinder of each size used	1
4	Blades of rotary compressor of each size used	1 set for 1 compressor
5	Crankshaft bearings of piston compressor or rotor bearings of screw compressor	1 set for each compressor
6	Lubricating oil pump of piston, screw compressor	1
7	Filter elements of each type and size	1
8	Automatic monitoring and protective devices for refrigerating plant of each type	1
9	Fan impeller with shaft for refrigerated spaces and freezing apparatus of each size used	1
10	Control refrigerant expansion valve of each size used	1
11	Assorted cocks, valves and fittings of each size used	1
12	Gaskets and packings of each size used	1
13	Thermometers, pressure gauges and vacuum gauges of each size used	1
14	Safety valve springs of each size used	2
15	Leak detector	1
16	Hydrometer (only where the liquid secondary refrigerant is used)	1

[1] To be provided as spare parts are rapidly wearing parts of seals only if it is permitted by the seal design.

PART XIII. MATERIALS

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to materials and products that are subject, in conformity with the other parts of the Rules, to the survey by the Register during manufacture.

Requirements pertaining to the choice and application of materials and products shall be found in the relevant parts of the Rules.

Requirements to the scope of survey and testing at the initial survey of manufacture of materials and products, as well as at carrying out of the Register technical supervision in course of their manufacture are stipulated in Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

1.1.2 In addition to the requirements of the present Part, materials and products shall meet the requirements of the relevant parts of the Rules.

1.1.3 Materials, being part of a structure or product, on which the requirements not included in the present Part are imposed, due to conditions of their operation, as well as materials not regulated by the present Part, the chemical composition, mechanical and service properties of which were not considered by the Register for a particular application, shall be specially considered by the Register.

Materials being manufactured according to international and national standards or specifications, or other technical documentation may be permitted by the Register for a specific application, provided the requirements of the Rules are followed. In so doing standards, specifications or other technical documentation are recognized by the Register by means of its inclusion in the appropriate Register document and/or by stamping.

The Register may permit the delivery of materials and products only according to the standards, specification or special technical documentation.

Given the distinctions between the above documentation and the Rules, materials testings and their assessment shall be carried out taking into account the most strict requirements.

1.1.4 The materials and products subject to survey by the Register, which are listed below, shall be supplied with the Register certificates and shall be manufactured by the works, for which Recognition Certificates for Manufacturer were issued (refer to 1.1.1):

.1 rolled products of hull structural steel, Z-steel and high strength steel for welded structures;

.2 rolled steel for Class I and Class II boilers and pressure vessels;

.3 steel pipes for boilers, pressure vessels and Class I and Class II piping;

.4 steel forgings and castings;

.5 iron castings;

.6 castings of non-ferrous and light alloys;

.7 semi-finished products of non-ferrous and light alloys;

.8 chain cables and ropes;

.9 chain steel;

.10 slabs, blooms and billets for rolling of shipbuil-ding and boiler, steel, if they are producted at works not constituting a part of a rolling mill.

1.1.5 The materials and products subject to survey by the Register, which are listed below (refer to 1.1.1), may be supplied with the manufacturer's certificates, provided the works have the quality system recognized by an authorized national or international organization or the Register and the Type Approval Certificate for the type of products manufactured:

.1 materials for reinforced plastic structures;

.2 laminated textiles;

.3 retro-reflective materials;

.4 foam plastics;

.5 corrosion-resistant coatings;

.6 pipes and fittings.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to the general terminology of the Rules are given in Part I "Classification".

For the purpose of the present Part the following definitions have been adopted.

Z-steel is steel with guaranteed through-thickness properties, which is intended for welded structures and can withstand considerable stresses perpendicular to the plate surface.

Product — for the purpose of the present Part, semi-finished products, chain cables and accessories, and ropes as well.

Register stamp means a brand, stamp or punch of a certain type specified by the Register applied to finished products, or to products during their manufacture, to confirm the fact of survey by the Register and identify the products with the documents issued for them.

A specimen is a test piece of specified shape and size prepared from a sample and used for the determination of mechanical, technological and other properties of material by testing.

A batch is the limited number of semi-finished products and products, to which the results of statutory tests are extended.

Initial tests mean a particular scope of control tests specified in a special program approved by the Register and performed during the works survey exercised by the Register prior to issue of the Recognition Certificate for Manufacturer to the works.

A semi-finished product is a casting, forging, sheet or tube and etc. intended for machining and technological treatment to acquire the finished state.

Recognized laboratory means a laboratory (center) included into the List of laboratories (centers) having Certificates of Accreditation of Testing Laboratories.

Recognized works mean an enterprise included into the List of recognized (approved) materials and manufacturers.

A sample is a portion of a semi-finished product or product or a specially fabricated blank of which test specimens shall be machined.

Recognition Certificate for Manufacturer means a document confirming the compliance of the manufacturer's products and conditions of their manufacturer with the Register rules and warranting the introduction (entry) of the works into the List of recognized materials and manufacturers.

Acceptance (certification) tests mean a test extent established by the Register rules or documentation agreed upon by the Register for the products delivered under survey by the Register; the test results serve the basis for issue of the Register certificates.

Type Approval Certificate means a document confirming the compliance of the products produced by the works with the Register rules and certifying an entry of the works into the List of approved (recognized) materials and manufacturers.

Manufacturer Certificate means a document of the works certifying the compliance of a particular volume of the specific type of product with the requirements of the order and confirming that the products are manufactured in compliance with production practice adopted at works. The Certificate is issued by the manufacturer and shall be certified by signature of the person representing the Quality Control Department.

Register Certificate means a document certifying the compliance of a particular volume of the specific type of product with the requirements of the Register rules or, if agreed upon specifically, with conditions of the order. The Certificate is issued by the Surveyor to the Register surveying manufacture of the products.

Approval of quality system means an action of the Register, or other organization authorized by the Register, certifying that the necessary degree of certitude is obtained that the properly identified quality management system complies with the Register requirements. The Register-confirmed compliance of the works quality management system with the requirements of ISO 9001 will be considered acceptable.

Lamellar tearing is breaking of welded structure components, made of rolled plates or pipes, due to considerable welding stresses and/or external loads applied in the direction perpendicular to the plate surface.

1.3 SURVEY

1.3.1 General.

1.3.1.1 General provisions, regulating the scope and the procedure of survey shall be found in the General Regulations for the Classification and Other Activity.

1.3.1.2 Prior to commencement of manufacture of the products under the technical supervision the works, as a rule, shall be recognized by the Register. For this purpose the Register carries out survey of the works, which comprises the following:

.1 review and recognition of technical documentation specifying the properties and conditions of production.

Review of technical documentation on materials and products, as a rule, is carried out prior to the testing of materials;

.2 direct survey of production and the quality system of the works, conducting of check testing.

In course of taking the above actions, a compliance of the manufacture parameters and the products with the requirements of the documentation shall be confirmed (refer to 1.3.1.2.1) and the Rules of the Register, as well as the appropriate level of quality stability;

.3 issue of the survey results:

issue of the Recognition Certificate for Manufacturer or Type Approval Certificate, (if the results are satisfactory);

preparation of the conclusion on impossibility of issue of the above mentioned Register documents, (if the results are unsatisfactory).

All the procedures necessary for obtaining the Recognition Certificate for Manufacturer and Type Approval Certificate and the documents, confirming the recognition of the works and its products by the Register shall be executed in accordance with the requirements of Sections 2 and 3, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships based on the application of the works.

1.3.1.3 During production the survey of materials and products in course of the technical supervision includes the following:

.1 tests and inspection;

.2 issue of the documents (refer to 1.4.3) on the basis of the results of tests and inspection.

1.3.2 Testing.

1.3.2.1 Check testing in course of the works recognition is carried out according to the program approved by the Register. The program is compiled on the basis of the respective requirements of the present Part of the Rules, national or international standards and other technical documentation.

Testing under the Register technical supervision during manufacture of products shall be conducted in compliance with the requirements of the chapters of the present Part depending on the materials and products subjected to the tests and/or the standards and specifications recognized by the Register.

1.3.2.2 The site and time of the prescribed tests shall be specified by the manufacturer in advance. Sampling, test procedures, specimen cutout procedures shall be effected in compliance with the applicable requirements of the Rules (according to Section 2). Unless otherwise specified, the Register's representative shall brand the samples and specimens and the tests shall be carried out in his presence.

1.3.2.3 Where the test results are unsatisfactory, unless otherwise specified in the relevant chapters, retesting shall be conducted with the following conditions being observed.

1.3.2.3.1 Tensile test.

From the semi-finished product, which has failed the test, a double number of specimens may be machined from the locality nearest to the area, from which specimens have been originally cut out.

In case the results of tests carried out on this double number of specimens are satisfactory, the semi-finished product submitted to tests, as well as the relevant batch may be accepted.

If at least one specimen (from the additional set) yields unsatisfactory results, the semi-finished product submitted shall be rejected. However, the Register may accept the rest of the batch, provided the test results obtained on two other semi-finished products of the same batch prove satisfactory. If one of two semi-finished products selected additionally yields unsatisfactory results, the whole batch shall be rejected.

1.3.2.3.2 Impact test.

The cases of unsatisfactory test results include:

when the average value of three impact tests (*KV*) fails to meet the prescribed requirements,

or more than one result out of three is below the required average value,

or the result on any one of the specimens is more than by 30 per cent below the required average value.

In any one of the cases listed, re-testing may be carried out on additional number of specimens machined from the same semi-finished product at the locality nearest to the area of preceding cutting-out.

The submitted semi-finished product and the batch may be accepted if the new average value of test results (three initial tests plus three additional tests) exceeds the required average value and not more than two results out of six are below the required average value and not more than one specimen has yielded the result, which is below by 30 per cent the required one.

Where the results of re-testing of the semi-finished product representing a batch are unsatisfactory, this product shall be rejected, but the remaining semi-finished products of the batch may be accepted in case where the results of tests carried out on two additional semi-finished products of this batch are satisfactory. Where the test results of two additional semi-finished products are unsatisfactory, the batch shall be rejected. The mentioned additional semi-finished products shall be the thickest among the products available in the batch.

The test principle proposed here for *KV* may be applicable to U-notched specimen.

1.3.2.3.3 Where the test results are unsatisfactory due to local defects in the specimen material, faulty machining or faulty test equipment or in case of tensile test fracture occurs beyond the design length of the specimen, on agreement with the Register, the test shall be repeated on the same number of specimens.

At the manufacturer's discretion, the semi-finished products from the batch rejected may be submitted to tests item-by-item and where the results are satisfactory, they may be accepted by the Register for supply.

At the manufacturer's discretion, the semi-finished products from the batch rejected may be re-tested after heat treatment, repeated heat treatment, or may be submitted as a category other than that initially declared. Where test results in case of such repeated submission are satisfactory for supply, the Register may accept the material.

Any material that yielded unsatisfactory results during subsequent machining or application shall be rejected irrespective of the availability of records of tests carried out previously or appropriate certificates.

1.3.2.4 If confusion of specimens or test results is detected or the test results do not make it possible to assess the material properties with the required degree of accuracy, the Register may require any tests to be repeated in the presence of its representative.

1.3.2.5 Material produced, the properties of which do not fully agree with the requirements of this Part, the deviations being not essential for the operation of the structure or product, may be used in accordance with the purpose only subject to special review of the deviations by the Register and in case a relevant application from the manufacturer and agreement of the customer is available.

1.4 MARKING AND DOCUMENTATION

1.4.1 Identification.

During manufacture of materials and products at works, the system of monitoring shall be applied, which enable to check the products manufacture at any stage, beginning from the original ladle of metal. Upon the request of the Register representative, the latter shall be given a confirmation of availability of such a system at the works.

1.4.2 Marking.

Prior to submission to the Register representative the materials shall be respectively marked. The marking of the materials, unless specified otherwise, (the peculiarities of marking shall be agreed in advance and shall reflect the particular products properties, for example, refer to 3.2.8), shall be carried out according to the standards taking the following requirements in consi-deration:

.1 in the case of semi-finished products delivered in single pieces each one of them shall be marked. For shipments in bundles two weather-resistant labels containing the marking shall be provided and firmly fastened to the opposite ends of the bundle.

When a great number of semi-finished products is delivered and these are of small size, the marking procedure and the content of the marking shall be agreed with the Register.

Semi-finished products to undergo further machining shall be stamped, as far as possible, in spots shall not be machined.

The stamp shall stand out clearly and be framed with a bright paint resistant to atmosphere;

.2 as a rule, the stamp shall include the following information:

grade or quality of material;

figures or other designation to indicate the origin of the semi-finished product (number of semi-finished product, number of cast and the like);

manufacturer's name or trade mark;

stamp of the quality control service of the manufacturer's;

Register's brand (if required);

.3 if the semi-finished product does not withstand the tests required by the Rules or defects are revealed, which make its use in accordance with the purpose impossible, the Register brand and the material grade designation shall be removed or cancelled.

1.4.3 Documentation.

Every batch of the materials and products, or a separate semi-finished product and a separate item, if the delivery is performed in single pieces, which passed the tests, shall be accompanied by the Register certificate or the manufacturer's document certified by the Register representative.

1.4.3.1 Manufacturer Quality Certificate.

The Register representative simultaneously with the submission of the final material or in advance shall be presented with the Material Quality Certificate. The Certificate shall be attested by the works quality division, witnessed by the authorized person, and, as minimum, shall contain the following data:

name of the works and the order number;

project number, if known;

name, number, dimensions and mass of the semi-finished product with indication of the drawing number or sketch, (if applicable);

mark, (grade) of the material, type of alloy, number of ladle and chemical composition;

identification number;

type and mode of heat treatment (if necessary);

mechanical test results;

non-destructive test results, (satisfactory or unsatisfactory), if applied.

1.4.3.2 The Register Certificate, at least, shall contain the following data:

order number;

building project, if known;

name, number, dimensions and mass of the material;

mark, (grade) of the material and delivery status;

number of Manufacturer Quality Certificate;

number of batch or semi-finished product or identification number, which enables to identify the supplied material;

drawing number, (if applicable).

The obligatory supplement to the Register certificate shall be the Manufacturer Quality Certificates attested by the Register representative. Tests protocols attested by the Register representative may be included to the composition of the supplement to the Register Certificate, if requested by the purchaser.

If the material is supplied only with the manufacturer certificates, attested by the Register representative, its form and contents shall be agreed with the Register and the purchaser.

1.5 LABORATORIES ENGAGED IN TESTING

1.5.1 The present Chapter applies to laboratories engaged in testing of materials subject to the survey by the Register.

1.5.2 Laboratories of metallurgical works and firms engaged in manufacture of materials and testing recognized by the Register are entitled to effect testing for the purpose of determining material properties without being specially recognized by the Register. Reports or statements of those laboratories on the tests conducted are sufficient ground for entering data on chemical composition, mechanical properties, etc. in the certificate for material.

Laboratories of other firms or independent laboratories may determine chemical composition and conduct tests to determine mechanical and other properties of the items of supervision only after being recognized by the Register.

1.5.3 The above mentioned provisions fully apply to the laboratories engaged in testing of items of the Register supervision by non-destructive methods.

1.5.4 Laboratories engaged in non-destructive testing of materials and products shall have a Recognition Certificate issued by the Register and/or any other appropriate document of the authorized national or international organization, which confirms the competence of the laboratory. In the Certificate or the document the scope and conditions of applying testing shall be defined. To be recognized for applying the ultrasonic testing, an application shall be forwarded to the Register supplemented by the following documents confirming that the manufacturer is ready to carry out the ultrasonic testing:

documents in confirmation of availability of qualified personnel together with the name of the body having carried out the certification of the personnel;

technical characteristics of ultrasonic equipment with instructions on the application;

instructions for personnel.

Tests shall be made to confirm reliability of the test results and the possibility of their reproduction.

The test program shall be approved by the Register.

1.5.5 The results of material testing and investigations conducted are recorded in the prescribed way (entered in the test log, report, etc.). The test log (report, etc.) shall contain all the data necessary for the assessment of material quality and subsequent issue of certificate.

A report of testing of products shall include at least the following information: kind of product, material and major dimensions of product, testing method, testing frequency, type of unified reference block, size and position of defects, name of operator and date of testing.

2 PROCEDURES OF TESTING

2.1 GENERAL

2.1.1 The requirements of the present Section cover the types and procedures of testing materials, which are subject to survey by the Register during their manufacture. The need to conduct the tests and evaluation criteria of test results are defined in the relevant sections of the present Part or other parts of the Rules.

2.1.2 The Section gives general requirements for testing conditions, types and dimensions of test specimens, and their preparation.

Alternative testing procedures and types of test specimens may be adopted, subject to approval of the Register and on condition that they provide adequate accuracy, reproducibility and dependability of tests carried out for determination of material properties required by the Rules.

2.1.3 Types and procedures of special tests for the materials intended for specific use and evaluation criteria, if no instructions are contained in the Rules, shall be agreed with the Register.

2.1.4 When tests are carried out, the requirements of the standards or other regulating documents approved by the Register shall be met.

2.1.5 Test samples, from which test specimens are cut shall have undergone the same treatment as the material, from which they have been taken (e.g. heat treatment). Test specimens shall be prepared in such a manner that properties of the material are not affected.

2.1.6 All the tests shall be carried out by competent personnel on testing machines of adequate capacity being maintained in the appropriate operating condition. The measurement accuracy of testing machines shall be within ± 1 per cent. The machines shall be regularly, as a rule at least once per year, checked and calibrated by the duly designated national authorities.

The results of regular checks shall be submitted to the Register.

Charpy machines for impact tests shall be verified in accordance with the requirements of ISO 148-2 or another standard recognized by the Register.

Machines for tensile/compression tests shall be verified in accordance with the requirements of ISO 7500-1 or another standard recognized by the Register.

2.2 TESTING PROCEDURES FOR METALS

2.2.1 Temperature.

The temperature of the ambient air during the tests shall comply with the requirements of the standards unless expressly provided otherwise in the subsequent sections and chapters of the present Part.

2.2.2 Tensile tests.

2.2.2.1 When carrying out tensile tests at the ambient temperature the following tensile properties of metals shall be determined:

.1 yield stress R_e is the value of stress measured at the commencement of plastic deformation at yield or the value of stress measured at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield.

Elastic stress rate shall be within the limits specified in Table 2.2.2.1.1;

Table 2.2.2.1.1

Modulus of elasticity of the material E, N/mm^2	Rate of stressing, N/mm s^{-1}	
	min	max
< 150000	2	20
⩾150000	6	60

.2 when no well defined yield phenomenon exists, the 0,2 per cent proof stress $R_{p0,2}$ shall be determined according to the applicable specification.

For austenitic and duplex stainless steel products the 1 per cent proof stress R_{p1} may be determined in addition to, $R_{p0,2}$.

The rate of loading shall be as stated in 2.2.2.1.1;

.3 tensile strength R_m is the value of stress corresponding to the maximum load directly before the test specimen fractures.

To determine the tensile strength R_m the test specimen is subjected to extension up to the fracture by the continuously rising loading. After reaching the yield or proof load, for ductile material the machine speed during the tensile test shall not exceed that corresponding to a strain rate of 0,008 per second. For brittle materials, such as cast iron, the stress rate shall not exceed 10 N/mm^2 per second.

.4 percentage elongation after fracture A is the ratio of an increment of the gauge length after fracture to the original gauge length, expressed in per cent.

The elongation value is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one third of the original gauge length (L_0). However, the result is valid irrespective of the location of the fracture if the percentage elongation after fracture is equal to or greater than the expected value.

Percentage elongation A_5 is usually determined on the small proportional test specimens when a gauge length is $5{,}65\sqrt{S_0} = 5d$. A_0 is determined on the non-proportional test specimens, for instance, with a gauge length $L = 200$ mm and calculated by the formula

$$A_0 = 2A_5\left(\frac{\sqrt{S_0}}{L_0}\right)^{0{,}40}, \%.$$

Non-proportional test specimens are usually used for ferritic type steels of low and medium strength made without application of cold working;

.5 percentage reduction of area after fracture Z is the ratio of the difference between the original and the minimum cross-sectional areas of the test specimen after fracture to the original cross-sectional area, expressed in per cent. It is determined for test specimens of circular cross-section;

.6 when tensile tests are carried out at an elevated temperature, the test temperature shall be indicated by the inferior figure, for instance $R_{m/350}$, $R_{eL/350}$, $A_{5/350}$, Z_{350} where the number 350 is the test temperature in degrees Celsius.

2.2.2.2 For determination of the test specimen dimensions the following symbols are used, mm:

d = diameter of the parallel test length;
a = thickness of the parallel test length;
b = width of the parallel test length;
L_0 = gauge length;
L_c = parallel test length;
S_0 = cross-section;
R = transition radius;
D = external tube diameter;
t = rolled products thickness.

2.2.2.3 Tensile tests shall be carried out on the test specimens of the following types (refer to Fig. 2.2.2.3):

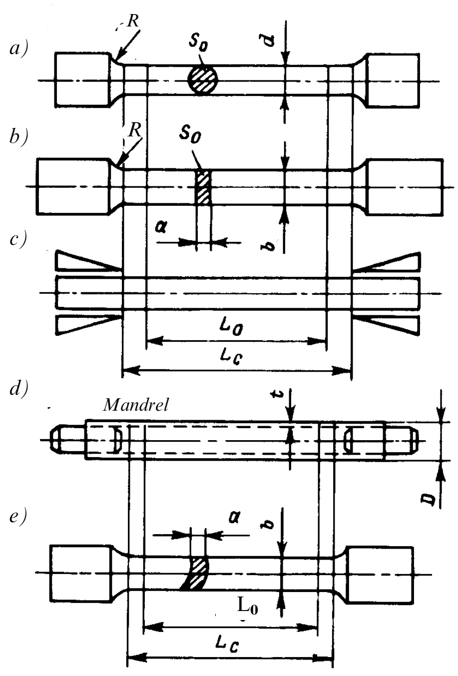


Fig. 2.2.2.3

Test specimens of rectangular cross-section with a gauge length equal to $L_0 = 5{,}65\sqrt{S_0}$ or of circular cross-section with a gauge length $L_0 = 5d_0$ are called proportional test specimens.

Proportional test specimens are preferable for tensile tests. The minimum percentage elongation values given in this Part are specified for these specimens. The gauge length L_0 of the specimen shall preferably be greater than 20 mm.

The value of the specimen gauge length after its measuring may be rounded off to the nearest 5 mm, provided that the difference between this length and L_0 shall be less than 10 per cent of L_0.

Tensile tests for flats up to 40 mm thick shall be carried out with flat specimens of full thickness. It is allowed to reduce the specimen thickness by machining one of the rolled surfaces. The specimen thickness reduction shall be caused by the insufficient capacity of a testing machine.

Tests shall be carried out on the specimens according to Table 2.2.2.3.

Test specimens for a tensile test, as a rule, shall be cut out so that their longitudinal axes were aligned with the metal basic deformation. Test specimens may be cut out transverse if there is the relevant instruction in sections of the present Part, or on agreement with the Register. During the works initial survey the rolled sheet can be tested using both the longitudinal and transverse test specimens.

2.2.2.4 For the determination of tensile strength R_m of nodular cast iron, test specimens of circular cross-section shown in Fig. 2.2.2.4 shall be used.

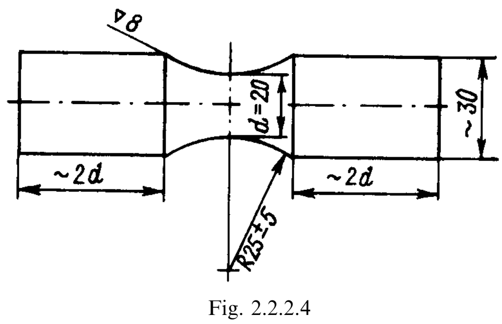


Fig. 2.2.2.4

2.2.2.5 Flat specimens shall be used in tensile tests of semi-finished products of wrought aluminium alloys for thicknesses up to and including 12,5 mm. The tensile test specimens shall be prepared so that both rolled surfaces are maintained. For semi-finished products over 12,5 mm thick, round tensile test specimens are used. Test specimens from semi-finished products up to 40 mm thick are cut out so that their axis is located in the middle of the thickness. Test specimens from semi-finished products over 40 mm thick are cut out so that their axis

Table 2.2.2.3

Semi-finished product	Type of test specimen	Test specimen dimensions
		Round proportional test specimens
Forgings, castings, bars	Fig. 2.2.2.3, *a*	$10 \leqslant d \leqslant 20$, for deposited metal $d = 10$ mm, preferable $L_0 = 5d$ $L_c = L_0 + d$ $R = 10$ mm for materials having $A_5 \leqslant 10\%$, $R \geqslant 1{,}5$ mm for nodular cast iron The axis of the test specimen shall be located at one quarter of the rolled product thickness from the surface.
	Fig. 2.2.2.3, *c*	For rods and products of small dimensions, on agreement with the Register, test specimens of full thickness and with relevant other dimensions may be used $L_c = L_0 + d$
		Flat proportional test specimens
Plates, strips, sections	Fig. 2.2.2.3, *b*	a = rolled product thickness $b = 25$ mm $L_0 = 5{,}65\sqrt{S_0}$ $L_c = 2\sqrt{S_0}$ $R = 25$ mm or:
		Flat non-proportional test specimens
		a = rolled product thickness $b = 25$ mm $L_0 = 200$ mm $L_c = 212{,}5$ mm $R = 25$ mm For materials over 40 mm thick, test specimens shown in Fig. 2.2.2.3, *a* may be used. The axis of the test specimen shall be located at one-quarter of the rolled product thickness from the surface. The use of test specimens of the following dimensions is preferable: $d = 14$ mm $L_0 = 5d$ $L_c \geqslant L_0 + d/2$ If the machine capacity for full thickness test specimens testing is inadequate, flat test specimens, on agreement with the Register, may be planed
Pipes and tubes	Fig. 2.2.2.3, *d* or Fig. 2.2.2.3, *e*	$L_0 = 5{,}65\sqrt{S_0}$ $L_c = L_0 + D/2$, where L_c is the distance between the grips or the mandrels, whichever is lesser. $a = t$ $b \geqslant 12$ mm $L_0 = 5{,}65\sqrt{S_0}$ $L_c = L_0 + 2b$ If possible, the round test specimens (Fig. 2.2.2.3, *a*) with the longitudinal axis located at the mid-wall thickness may also be used

is located at a distance from one of the surfaces equal tone quarter of the thickness.

2.2.2.6 When wire is tested, its specimens of full cross-section shall be of the following dimensions:

$L_0 = 200$ mm,

$L_c = L_0 + 50$ mm.

2.2.2.7 Through thickness tensile tests shall be carried out on test specimens the longitudinal axis of which is perpendicular to the rolling surface (direction Z, refer to Fig. 2.2.2.7-1).

Test procedures and dimensions of the round specimens shall comply with the national and international standards recognized by the Register.

The testing scope is given in 3.14.4.

For plates and wide flats, one test sample shall be taken close to the longitudinal centreline of one end of rolled piece representing the batch as shown in Fig. 2.2.2.7-2.

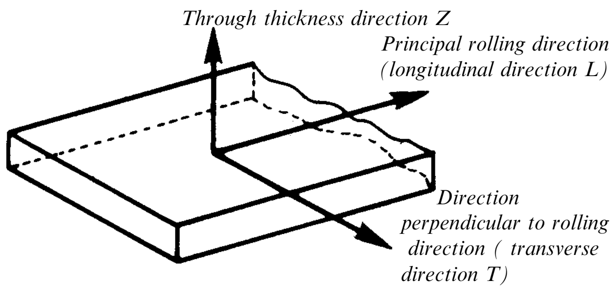


Fig. 2.2.2.7-1

The test sample shall be large enough to accommodate the preparation of 6 specimens. 3 test specimens shall be prepared while the rest of the sample remains for possible retest.

The test is considered invalid and further replacement test is required if the fracture occurs in the weld or heat affected zone.

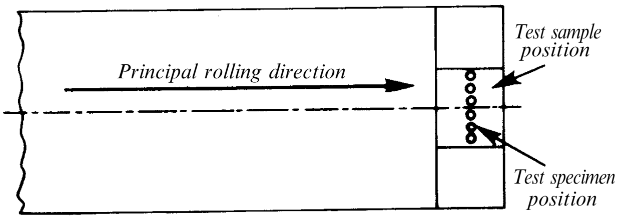


Fig. 2.2.2.7-2

2.2.2.8 In weldability tests (refer to 2.4) tensile test specimens shall have the following dimensions:

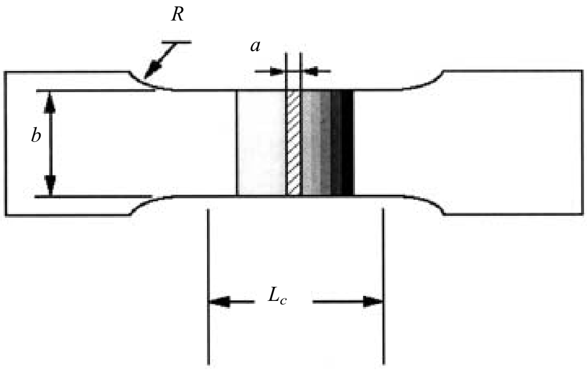


Fig. 2.2.2.8

For deposited metal tensile test:

d = 10 mm;

L_0 = 50 mm;

$L_c \geqslant 55$ mm;

$R \geqslant 10$ mm.

If agreed with the Register, when necessary, the specimens of other dimensions may be used; the geometrical relationship of the above parameters therewith shall be observed;

for butt-weld tensile test (refer to Fig. 2.2.2.8):

$a = t$;

$b = 12$ mm for $t \leqslant 2$ mm;

$b = 25$ mm for $t > 2$ mm;

L_c = width of weld + 60 mm;

$R \geqslant 25$ mm.

The upper and lower surfaces of the flat specimen weld shall be machined flush with the surface of the base metal.

2.2.2.9 The tolerances on specimen dimensions given in 2.2.2 shall be in accordance with ISO 6892-84. If made according to the standards recognized by the Register, the specimen deviations shall comply with these standards.

2.2.3 Impact tests.

2.2.3.1 The impact toughness *KCU* shall be determined on Charpy U-notch type test specimens as in Fig. 2.2.3.1-1 and Table 2.2.3.1-1, the impact energy *KV* and *KU* on Charpy V-notch type test specimens and Charpy U-notch type test specimens as in Figs. 2.2.3.1-2 and 2.2.3.1-3, and Tables 2.2.3.1-2 and 2.2.3.1-3.

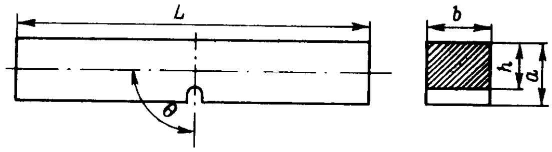


Fig. 2.2.3.1-1

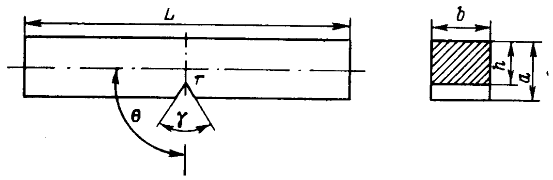


Fig. 2.2.3.1-2

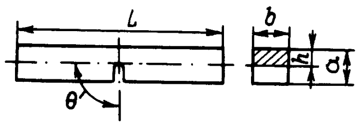


Fig. 2.2.3.1-3

The impact tests shall be carried out on Charpy machines complying with the requirements of ISO 148 or other national or international standard recognized by the Register, and having a striking energy of not less than 150 J. Where the test temperature is other than ambient, the temperature of the text specimen at the moment of breaking shall be the specified temperature within ±2 °C.

Table 2.2.3.1-1

Dimensions	Nominal	Tolerance
Length L, mm	55	±0,60
Width b, mm	10	±0,10
Thickness a, mm	10	±0,10
Depth below notch h, mm	8	±0,10
Root radius r, mm	1	±0,10
Distance of notch from end of test specimen $L/2$, mm	27,5	±0,40
Angle between plane of symmetry of notch and longitudinal axis of test specimen θ, deg	90	±2

Table 2.2.3.1-2

Dimensions	Nominal	Tolerance
Length L, mm	55	±0,60
Width b, mm	10	±0,06
Thickness a, mm	10	±0,11
	7,5	±0,11
	5,0	±0,06
Angle of V-notch γ, deg	45	±2
Depth of notch h, mm	8	±0,06
Root radius r, mm	0,25	±0,025
Distance of notch from end of test specimen $L/2$, mm	27,5	±0,040
Angle between plane of symmetry of notch and longitudinal axis of test specimen θ, deg	90	±2

Table 2.2.3.1-3

Dimensions	Nominal	Tolerance
Length L, mm	55	±0,60
Width b, mm	10	±0,11
Thickness a, mm	10	±0,11
Depth below notch h, mm	5	±0,09
Root radius r, mm	1	±0,07
Distance of notch from end of test specimen $L/2$, mm	27,5	±0,42
Angle between plane of symmetry of notch and longitudinal axis of test specimen θ, deg	90	±2

The impact energy *KV* and *KU* is determined as an average value obtained at testing three specimens. The required mean values of the impact energy depending on the dimensions of the specimens selected for tests (*E* is the required minimum value of impact energy) are given in Table 2.2.3.1-4. The result of tests on one of the specimens therewith may be less than that given in Table 2.2.3.1-4, but its value shall not be less than 70 per cent of the required one.

Table 2.2.3.1-4

Dimensions of test specimen, mm	Average value of impact energy, J
10 × 10 × 55	1E
10 × 7,5 × 55	5/6E
10 × 5 × 55	2/3E

As a rule, for the rolled products having thickness less than 11 mm and 8 mm the specimens selected are dimensioned 7,5 × 10 × 55 mm and 5 × 10 × 55 mm respectively. Tests on the rolled products under 6 mm thick are not usually conducted.

The impact toughness *KCU* is determined as an average value obtained at testing two specimens. In this case, each of impact toughness values obtained shall not be less then required. Impact toughness of material having a thickness less than 10 mm is determined only if required by the Register. The required minimum value of *KCU* shall be subject to agreement with the Register.

2.2.3.2 The dimensions of the test specimens without any notch used for impact tests, in mm, shall be as shown in Fig. 2.2.3.2.

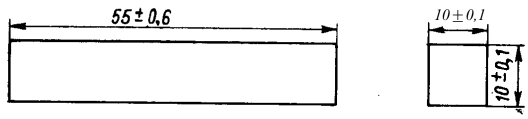


Fig. 2.2.3.2

2.2.3.3 Impact tests shall be carried out on Charpy machines having a striking energy not less than 150 J.

The distance between the supports shall be (40 ± 0,5) mm. The pendulum shall break the test specimen in the plane of symmetry of the notch and from the side opposite to it, the distance between the plane of symmetry of the notch and that of the pendulum being not in excess of 0,5 mm.

In order to provide a specified test temperature during impact testing at low temperatures, the test specimens shall be subjected to supercooling. When the tests are carried at a temperature down to −60 °C, the test specimens shall be supercooled to − 4 °C. Deviations from the required test temperature at the moment of breaking of the test specimen shall not exceed ±2 °C.

2.2.3.4 Strain ageing sensibility tests shall be carried out on specimens made of test samples selected similar to impact test samples. Unless otherwise specified, metal strips from which specimens are cut shall be subjected to extension deformation assuming 5 per cent residual elongation. Impact test specimens made of strips subjected to extension deformation are subject to even heating (artificial ageing) up to 250 °C, with 1 hour exposure at this temperature and subsequent cooling in the air.

Impact tests of these specimens shall be carried out at room temperature (within 18 to 25 °C) and/or at temperature agreed additionally.

Unless otherwise specified, the hull structural steel strain ageing sensibility tests are required at the initial survey of the manufacturer, at procedure alterations and in doubtful or arguable cases related to the rolled products quality on the Surveyor to the Register demand. At the initial survey and at the tests procedure alterations the tests shall be carried out according to the requirements of 1.3.5.3.6. In other cases the steel tests as a rule shall be carried out at room temperature and at the impact tests temperature for the submitted steel grade (e.g. −20 °C for grade D32 steel).

Unless otherwise specified, the hull structural steel strain ageing sensibility tests results shall comply with the Rules requirements for steel during impact tests (e. g. for grade D32 steel the average value of impact tests results shall not be less than 31 J at −20 °C with the steel thickness 50 mm — refer to Table 3.2.3).

When the above tests are carried out at temperatures lower than the prescribed for the submitted steel grade (e.g. for grade D32 steel — lower than −20 °C), the required average value of tests results is set forth by the steel manufacturer on agreement with the Register.

2.2.4 Hardness testing.

Hardness shall be determined according to Brinell (*HB*), Vickers (*HV*), Rockwell (*HRC*) or using any other method approved by the Register.

2.2.5 Technological tests.

2.2.5.1 The test specimens cut as shown in Fig. 2.2.5.1 shall be used for bend test.

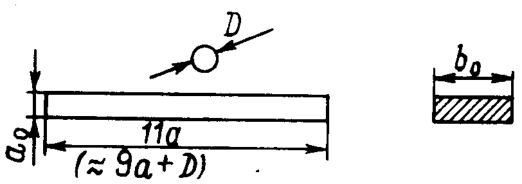


Fig. 2.2.5.1

Edges of the specimens on the tension side may be rounded to a radius of 1 to 2 mm.

The mandrel diameter and the angle of specimen bending is indicated in the relevant chapters of the Part. The bend test of plates and sections, and also the test of welded transverse specimens (both sides) shall be carried out on the test specimens of the following dimensions: $a_0 = t$; $b_0 = 30$ mm, t is the product thickness. Where the thickness of the product exceeds 25 mm, the test specimen may be machined on one side to a thickness of 25 mm. During the test the machined surface shall be on the compression side of the bend test specimen.

The bend tests of forgings, castings and similar semi-finished products shall be carried out on the specimens having the following dimensions: $a_0 = 20$ mm, $b_0 = 25$ mm.

2.2.5.2 Flattening tests are carried out on specimens (pipe lengths) having a length from 10 mm to 100 mm.

The specimen ends shall be plain and smooth with their cuts perpendicular to the tube axis (ISO 8492).

2.2.5.3 Drift expanding tests are carried out on specimens made in accordance with the requirements of ISO 8493 (refer to Fig. 2.2.5.3).

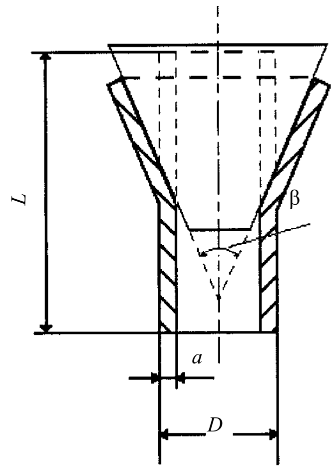


Fig. 2.2.5.3

For metallic tubes, the specimen length (tube length) L is equal to twice the external diameter D of the tube if the angle of the drift β is 30°, and L is equal to 1,5D if the angle of the drift is 45° or 60°. The test piece may be shorter, provided that after testing the remaining cylindrical portion is not less than 0,5D.

The rate of mandrel penetration shall not exceed 50 mm/min.

2.2.5.4 Ring tensile tests are carried out in accordance with the requirements of ISO 8496. The length of specimens (tube lengths) is equal to 15 mm and the rate in tests shall not exceed 5 mm/s.

2.2.5.5 Flanging tests are carried out on specimens (tube lengths) having a length of 1,5D in accordance with the requirements of ISO 8494 (refer to Fig. 2.2.5.5). The test piece may be shorter, provided that after testing the remaining cylindrical portion is not less than 0,5D.

The rate of mandrel penetration shall not exceed 50 mm/min.

2.2.5.6 Ring expanding tests are carried out in accordance with the requirements of ISO 8495 (refer to Fig. 2.2.5.6). The length of specimens (tube lengths) may vary from 10 mm to 16 mm and the rate of mandrel penetration shall not exceed 30 mm/s.

2.2.6 Dropweight tests for determination of nil-ductility temperature.

When required by the Rules, dropweight tests and results evaluation are effected in accordance with

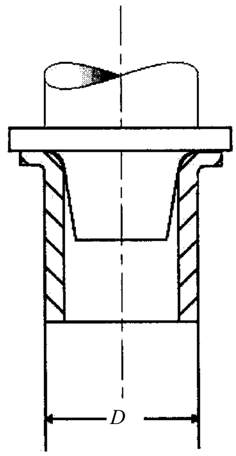


Fig. 2.2.5.5

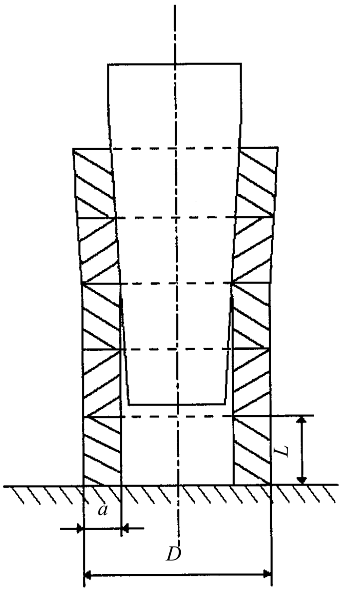


Fig. 2.2.5.6

the ASTM standards and the procedures recognized by the Register. The tests shall be carried out on the specimens of the following types (dimensions in mm):

Type P-1: 25 × 90 × 360;

Type P-2: 19 × 50 × 130;

Type P-3: 16 × 50 × 130.

The dimensions of specimens are chosen so that their thickness approximates that of the material to be tested.

The following shall be noted, unless otherwise specified:

.1 no warming up of specimens is allowed if they are made by machining (if flame cutting is used, the specimen side shall be at least 25 mm from the cut line);

.2 no machining is allowed for the tensiled side of the specimen;

.3 the specimens in the series shall be of the same orientation.

2.2.7 Macro and micro structural analysis.

Where required by this or other Parts of the Rules, macro and micro structural analysis of metals shall be made in compliance with the relevant standards.

2.2.8 Chemical analysis.

The methods for determination of chemical composition of metals and permissible deviations are specified in relevant standards.

2.2.9 Non-destructive testing.

2.2.9.1 When radiography testing is carried out, the results shall be recorded in the form of radiographs with a summary of test evaluations attached.

2.2.9.2 Ultrasonic testing shall be carried out using the pulse-echo methods. For control purposes dual-search units are used.

To provide for more precise examination, single-dual and prismatic search units are used on agreement with the Register. Good condition and accuracy of the test equipment shall be regularly checked.

The method for determination of a defect size is selected in compliance with relevant standards, otherwise it shall be agreed with the Register. The size of permissible defects and criteria for their estimation are subject to agreement with the Register as a part of design documentation for the product.

The surface of the product shall provide a safe and uniform acoustic contact with the search unit. The ultrasonic testing is carried out after heat treatment at the stage of manufacture when the product has the simplest shape.

2.2.9.3 For magnetic particle testing only technique proved satisfactory in practice may be used. The material surface under test shall have appropriate intensity of the field.

A need in demagnetization of the product after completion of the test shall be specified in the technical documentation.

2.2.9.4 On agreement with the Register, testing methods other than those referred to in 2.2.9.1 to 2.2.9.3 may be used. The evaluation criteria test results shall be agreed with the Register.

2.2.9.5 The evaluation of non-destructive testing results shall be made only by the works responsible for the results submitted to the Register. Records of testing shall be appended to the Register certificate in case non-destructive examination is required by the Rules.

2.3 PROCEDURES OF TESTING NON-METALLIC MATERIALS

2.3.1 Testing conditions.

2.3.1.1 Before testing test specimens shall be conditioned at an ambient air temperature (23 ± 2) °C and relative humidity (50 ± 5) per cent. Unless expressly provided otherwise, the duration of conditioning shall be at least 16 h.

Testing shall be carried out immediately after completion of conditioning of the test specimens.

The conditioning may be omitted if it is proved to the Register that testing conditions do not significantly affect the test results and their stability.

2.3.1.2 The test specimens of reinforced materials are cut in the warp or weft direction so that the axis of the test specimen shall be parallel to the fibres of warp or weft, respectively.

2.3.1.3 In well-grounded cases, on agreement with the Register, tests may be carried out on the test specimens, which shape and dimensions differ from those required by the present Chapter.

2.3.1.4 Testing conditions other than those specified in the present Chapter shall comply with the relevant standards.

2.3.2 Tensile tests.

2.3.2.1 Tensile strength of glass-reinforced plastics shall be determined on the test specimens according to Figs. 2.3.2.1-1 and 2.3.2.1-2, and Table 2.3.2.1.

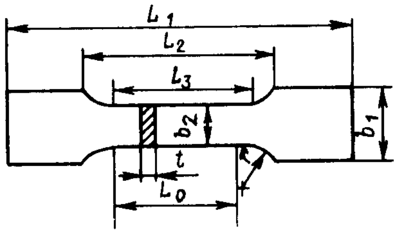


Fig. 2.3.2.1-1

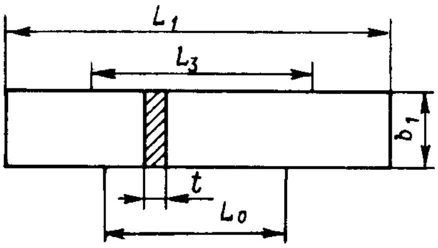


Fig. 2.3.2.1-2

Table 2.3.2.1

Dimensions, mm	Fig. 2.3.2.1-1	Fig. 2.3.2.1-2
L_{1min}	150	250
L_2	115±5	170±5
L_3	60±0,5	—
L_0	50±0,5	50±1
b_1	20±0,5	25±0,5
b_2	10±0,5	—
t	1...10	1...6
r	60	—

2.3.2.2 The tensile strength and elongation at rupture of laminated textiles are determined on test specimens (50 ± 1) mm wide having the original length between the grips of testing machine (200 ± 5) mm.

The pre-load applied is 2N for cloths with a density 200 g/m^3 or less, 5 N for cloths with a density more than 200 and up to 500 g/m^3 and 10 N for cloths with a density above 500 g/m^3.

The moving rate of the testing machine grips is 100 ± 20 mm/min.

Elongation at rupture shall be in accordance with 2.2.2.1.6.

2.3.2.3 The tear propagation strength of laminated textiles is determined on rectangular test specimens measuring (225 ± 5) × (75 ± 5) mm. An incision (80 ± 1) mm long shall be made in the middle of one of the specimen ends parallel to the longitudinal edge. Both the ends of the incised specimen are then fixed in the grips of testing machine so that the area where the tear begins is parallel to the direction, in which the breaking load is applied. The moving rate of the testing machine grips is (100 ± 10) mm/min.

The breaking load is determined as an arithmetic mean of five successive maximum values.

2.3.2.4 The strength of interlayer bonds in a textile is determined on rectangular test specimens measuring (50 ± 5) × (200 ± 5) mm. The specimen coat is carefully cut to the cloth and separated using a knife over a length of 50 mm on the side of the oblique notch as shown in Fig. 2.3.2.4 (the separated area is lined). The ends of layers separated in this manner are clamped in the grips of testing machine.

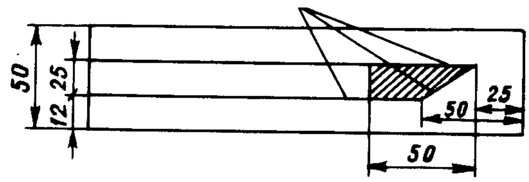


Fig. 2.3.2.4

Delamination is effected on a length of 100 mm, and the forces applied are plotted on a graph. The moving rate of the grips is 100 ± 10 mm/min. The interlayer bond strength is determined as an arithmetic mean of 50 per cent of the lowest peak values to be found in the graph as measured on the central section of the specimen length making up 50 per cent of the total separated length.

2.3.2.5 The tear strength of bond joints of laminated textiles is determined on test specimens prepared in such a manner that the middle of the bond joint coincides with the middle of the specimen length and the joint overlaps the specimen by 25 mm.

The shape and dimensions of test specimens are determined proceeding from 2.3.2.2. The adhesive applied shall agree with the conditions of the products manufacture.

2.3.2.6 The tear strength of retro-reflective materials is determined on specimens 25 ± 1 mm wide having the initial length between the grips of testing machine 100 ± 5 mm.

The moving rate of the testing machine grips is 300 ± 20 mm/min.

Materials with an adhesive layer are tested after removal of protective paper.

2.3.2.7 The strength of the adhesive bondage between the retro-reflective material and the adhesive layer is determined on specimens 25 ± 1 mm wide and 200 ± 5 mm long.

Before testing, protective paper is removed from the adhesive layer of the material on a length of 80 ± 5 mm and placed on the surface being tested which measures (50 ± 5) × (90 ± 5) mm.

The loose end of the specimen is secured in the dead lock of the testing machine. Separation of the specimen is achieved by turning the panel by 180° round the axis passing through the specimen end opposite to the loose one.

2.3.3 Compression test.

2.3.3.1 Compression strength of glass-reinforced plastics shall be determined on the test specimens according to Fig. 2.3.2.1-1 and Table 2.3.3.1.

Table 2.3.3.1

L_1, L_2, mm	L_3, mm	b_1, mm	b_2, mm	r, mm	t, mm
Not regulated	80	20	10 ± 0,5	160	10

2.3.3.2 Compression strength of rigid foamed plastics shall be determined on rectangular test specimens with side dimensions (50,0 ± 0,5) × (50 ± 0,5) mm and a height from (25 ± 1) to (50 ± 1) mm. The load is increased uniformly. The loading rate shall not be in excess of 5 mm/min.

2.3.4 Determination of modulus of elasticity for glass-reinforced plastics.

The modulus of elasticity in tension shall be determined according to 2.3.2.1, and in compression according to 2.3.3.1. The strain increment is determined with initial load P_0 and maximum load P_{max}, which are equal to 2 and 8 — 10 per cent of the breaking load, respectively.

2.3.5 Bend test.

2.3.5.1 The bend test of rigid foamed plastics shall be carried out on the test specimens, the length of which is (120 ± 1,2) mm, width (25 ± 0,25) mm and thickness (20 ± 0,2) mm. The distance between the supports shall be 100 mm, rounding of the supports and the punch (5 ± 0,2) mm. The rate of punch feed is (10 ± 2) mm/min.

2.3.5.2 The bend test of glass-reinforced plastics shall be carried out on test specimens, the length of which equals 20 times their thickness and the breadth is 25 mm. The distance between the supports shall equal 16 times the specimen thickness. The load applied to the midlength of the specimen shall be smoothly increased until the latter breaks.

2.3.5.3 Bend test of laminated textiles.

The test is effected on rectangular specimens measuring (300 ± 5) × (50 ± 1) mm, which are fixed in the testing arrangement as shown in Fig. 2.3.5.3. When the test specimen is fixed the distance between the grips shall be 30 mm.

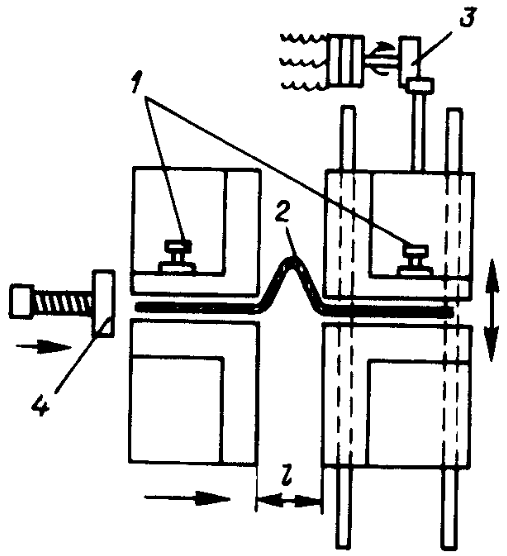


Fig. 2.3.5.3:
1 — grip; *2* — test specimen; *3* — motor; *4* — load

The test specimen being fixed, the grips are brought together until they touch each other. At this time, the load upon the test specimen shall be 10 N.

During the test, the movable grip makes 500 cycles of reciprocating movement with a frequency of 2 Hz and an amplitude of 50 mm.

2.3.6 Determination of relative glass content in glass-reinforced plastic by mass.

In the furnace at a temperature of (625 + 25) °C resin is removed from a specimen having dimensions (10 ± 1,0) × (10 ± 1,0) mm × laminate thickness, the mass of which together with a crucible shall be determined with an accuracy up to 0,01 g. The glass content in the mass, in per cent, is obtained from the following formula:

$$S = (G_2 - G_0)100/(G_1 - G_0)$$

where G_1, G_2 = mass of the crucible together with the specimen before and after roasting, g;
G_0 = mass of the empty roasted crucible, g.

2.3.7 Determination of apparent density of foam plastics.

The apparent density of foam plastics shall be determined on test specimens of regular shape, having a volume not less than 100 cm^3. Before conditioning in accordance with 2.3.1.1 the test specimens shall be dried at a temperature (40 ± 5) °C to its constant mass. The apparent density is determined as the ratio of the mass of the specimen to its volume, in m^3.

2.3.8 Determination of shrinkage of plastics at limiting temperature.

A test specimen with dimensions $(100\pm1)\times\times(100\pm1)\times(15\pm0{,}5)$ mm is conditioned at the appropriate temperature during 48 hours.

Shrinkage is determined as the ratio, in per cent, of linear deformation to the appropriate original size of the specimen.

2.3.9 Water absorption test.

2.3.9.1 Water absorption shall be determined on test specimens having the dimensions $(50\pm1)\times(50\pm1)$ mm and a thickness equal to the thickness of the product, but not more than (50 ± 1) mm.

Before testing the specimens shall be dried to constant mass; drying conditions are specified in the relevant standards. After drying and weighing the specimens are immersed into distilled water and kept at a temperature (23 ± 2) °C for 24 h. Then they are weighed again. Water shall be removed from the specimen surface.

Water absorption is obtained as a fraction of total mass of absorbed water related to the mass of the dry specimen.

Water absorption of foamed plastics is determined as mass of absorbed water related to the surface area of the specimen.

2.3.9.2 A sample, the size of which is determined proceeding from the required number and size of specimens, is immersed in fresh water, the temperature of which is 23 ± 2 °C, to a depth of 1,25 m and soaked for 7 days.

Before testing, as well as a day and seven days after immersion, the sample is weighed.

After soaking, test specimens are prepared from the sample.

2.3.10 Ageing test.

2.3.10.1 A sample, which dimensions are determined depending on the required number and dimensions of test specimens is conditioned in semi-immersed condition in the artificial sea water with a temperature (23 ± 2) °C for 30 days. In the process of conditioning the sample shall be subjected every day to two-hour ultra-violet irradiation with 500 W lamp placed at a distance of 50 cm from it. After conditioning test specimens are prepared from the sample for carrying out the required tests.

2.3.10.2 Two samples, the size of which is determined proceeding from the number and size of specimens required are kept suspended during seven days at ambient temperature 70 ± 1 °C, one of the samples being suspended in a closed volume above water. After that, the same number of test specimens is prepared out of each sample.

2.3.10.3 The test for creasing and stability of shape after ageing is effected on square specimens with a side measuring 100 ± 5 mm, which are folded in two directions, parallel to the edges and at right angles to each other, unfolded and then folded once more along the same folds, but in the opposite direction. After each folding, the edges are smoothed down with the fingers.

2.3.10.4 A sample, which size is determined proceeding from the number and size of specimens required, is subjected to the ultra-violet irradiation by means of a lamp having a power of 500 W from a distance of 50 cm during 30 h for type 1 retro-reflective material and during 60 h for type 2 material.

2.3.11 Petroleum-product resistance test.

2.3.11.1 A disc-shaped specimen is inserted in the testing arrangement as shown in Fig. 2.3.11.1.

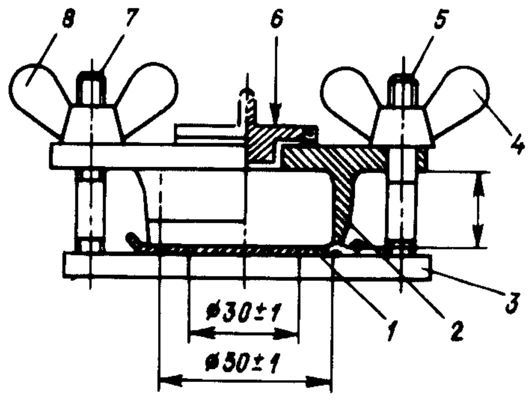


Fig. 2.3.11.1:
1 — test specimen; *2* — cylindrical chamber; *3* — base plate with a hole of 30 mm diameter; *4*, *8* — wing nuts; *5*, *7* — bolts; *6* — plug

The arrangement is filled up to the level of 20 mm with a mixture of oils in the following proportion:

30 per cent of 2, 2, 4 — trimethylethane,

50 per cent of toluene,

15 per cent of diisobutylene,

5 per cent of ethanol.

On agreement with the Register, other oil products may be used such as diesel fuel, petrol, etc.

The test specimen is conditioned in oils during 22 h at a temperature (20 ± 2) °C.

When the test specimen is extracted, it shall be dried a little bit, the wet surface folded in two and the halves pressed to each other.

The wet surfaces shall not stick to each other, nor shall the fingers be stained when the surfaces shalluched.

2.3.11.2 A sample, which size is determined proceeding from the number and size of specimens required, is immersed in diesel oil having a temperature of 23 ± 2 °C and conditioned there for 30 days.

After conditioning, test specimens are prepared from the sample.

2.3.11.3 A sample, which size is determined proceeding from the number and size of specimens required, is immersed in diesel oil or high octane petrol having a temperature of 23 ± 2 °C to a depth of 100 mm and conditioned there during 24 h.

2.3.11.4 Samples, which size is determined proceeding from the number and size of specimens required, are immersed in crude oil, fuel oil, diesel fuel, high octane petrol and kerosene having a temperature of 23 ± 2 °C to a depth of 100 mm and conditioned there for 14 days.

After conditioning, test specimens are prepared from the samples.

2.3.12 Water resistance test.

2.3.12.1 A sample, which dimensions are determined depending on the required number and size of test specimens, is immersed in artificial sea water with a temperature of (23 ± 2) °C and conditioned during 5 months.

After conditioning, test specimens are prepared from the sample.

2.3.12.2 In the case of laminated textiles, a sample measuring 300 × 200 mm glued along the perimeter shall be conditioned in salty water with salt concentration 3,3 — 3,8 per cent during 4 h at a temperature of (40 ± 1) °C and at a depth of 500 mm.

2.3.12.3 Specimens of retro-reflective material measuring (70 ± 5) × (150 ± 5) mm, which are secured on an aluminium panel and have an X-shaped diagonal cut in them, are conditioned in artificial sea water at a temperature of 23 ± 2 °C in semi-submersed condition during 16 h in enclosed volume.

After conditioning, the salt residues on the specimen surface shall be washed off.

2.3.12.4 Specimens of retro-reflective material measuring (70 ± 5) × (150 ± 5) mm, which are secured on an aluminium panel, are sprayed with 5 per cent salt solution at a temperature of 35 ± 2 °C for 5 days.

During that time, the specimens are dried for 2 h every 22 h.

2.3.12.5 Specimens of retro-reflective material manufactured and mounted in conformity with 2.3.2.7 are soaked in distilled and artificial sea water during 16 h in enclosed volume.

2.3.13 Air permeability test.

A disc-shaped specimen having a diameter of 350 mm is covered with wax in such a way that its centre, 290 mm in diameter, is left open, and then clamped between the flanges of the testing apparatus as shown in Fig. 2.3.13.

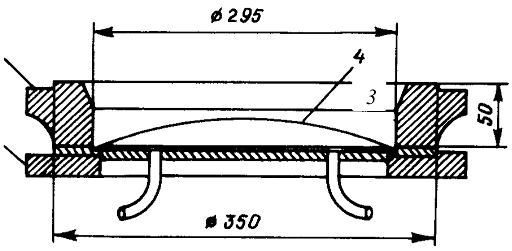


Fig. 2.3.13:
1 — base plate; *2* — clamping ring; *3* — specimen

From below, a positive air pressure of 27,5 kPa acts upon the test specimen. In 10 to 15 min, the specimen is so immersed in water that its uppermost point is 13 mm below the surface. 1 min later no air bubbles shall remain on the specimen surface. Within the following 5 min no bubbles shall rise to the surface.

2.3.14 Cold resistance test.

The cold resistance test of laminated textiles is effected on rectangular specimens measuring (100 ± 5) × (50 ± 5) mm. After being conditioned at a temperature of −30... −5 °C during 1 h and at −80... −5 °C during 10 min, the specimens are bent through an angle of 90 °C.

A sketch of testing apparatus is shown in Fig. 2.3.14.

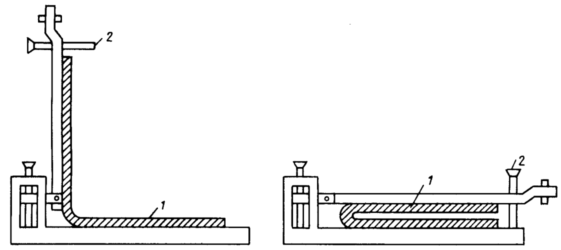


Fig. 2.3.14 Sketch of testing machine
1 — specimen; *2* — regulating screw

By the end of the test the distance between the parallel parts of the test specimen shall equal four times its thickness.

2.3.15 Ozone resistance test.

A test specimen is bent through 180° round a mandrel equalling six times the specimen thickness in diameter and subjected during 1h to the influence of air with ozone concentration of 50 pphm at a temperature of 30 ± 2 °C and the relative humidity of 26 per cent.

2.3.16 A sample, the size of which is determined proceeding from the number and size of specimens required, is successively exposed to ambient air at a temperature of −40 and +70 °C at 8 hour intervals for foam plastics and at 24 hour intervals for retro-reflective materials.

2.3.17 Vibration load test.

A test specimen, the type and size of which are determined proceeding from the expected service of the product, is mounted on a vibration-testing machine and subjected to vibration loads having the following parameters:

oscillation amplitude — 2,5 mm;

frequency range — 5 to 500 Hz with a difference of frequency of 32 Hz and an amplitude of vibration acceleration of 10 g.

2.3.18 Determining the retro-reflection factor of a material.

2.3.18.1 The retro-reflection factor is determined on square specimens measuring 150 ± 5 mm. The entrance and observation angles are adopted in accordance with Table 6.7.2.2.

Measurements are taken at the turning angles of reference plane between 0 and 180° with the spacing not exceeding 30°.

2.3.18.2 The retro-reflection factor for a material staying under a film of water is determined on specimens measuring (150 ± 5) × (75 ± 5) mm secured on a vertical plane in the transverse direction.

During testing, the specimen stays under a continuously moving film of water. A sketch of the testing machine shall be found in Fig. 2.3.18.2. Measurements are taken at the observation angle of 0,2° and entrance angle of 5°.

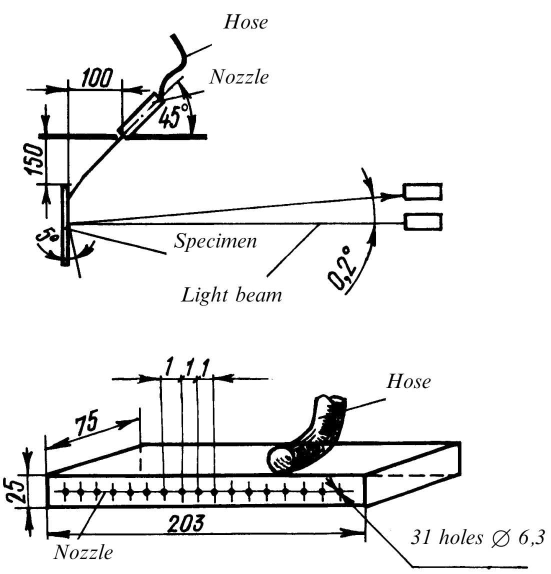


Fig. 2.3.18.2

2.3.19 The bend test of retro-reflective materials is made on specimens measuring (25 ± 5) × (150 ± 5) mm after they have been conditioned, together with a metallic mandrel 3,2 mm in diameter, in a heating chamber at a temperature of 30 °C. The specimens shall be wrapped on the mandrel by a slight touch of the finger.

Retro-reflective materials with an adhesive layer are tested after the removal of protective paper.

2.3.20 The adhesion test of retro-reflective materials is made on square specimens measuring 100 ± 5 mm.

Two specimens are fitted between glass plates 3 mm thick, with their retro-reflective surfaces facing each other and under a load, the mass of which is 18 kg, and conditioned in the heating chamber at a temperature of 65 ± 2 °C during 8 h.

After being conditioned, the specimens are cooled at a temperature of 23 ± 2 °C during 5 min.

2.3.21 Retro-reflective materials are tested for fungus resistance using square specimens measuring 75 ± 2 mm, which are secured on an aluminium panel.

The specimens are conditioned in the soil during two weeks.

After being conditioned, the specimens are wiped clean with a soft cloth wetted in the 70 per cent solution of ethanol alcohol and then conditioned in accordance with 2.3.1.1 during 48 h.

The microbiological activity of the soil is determined on untreated cotton cloth. After being soil-conditioned for 5 days, the ultimate strength of the cloth with a density of 400 to 475 g/m^2 shall not be less than 50 per cent of the initial value.

2.3.22 The abrasion-resistance test of retro-reflective material is made on specimens measuring (150 ± 5) × (425 ± 5) mm, which are secured on an aluminium panel.

The panel, which is fixed in the testing machine, is subjected to 1000 cycles of the reciprocating action of bristles at a frequency of 37 ± 2 cycles per minute.

For testing, trimmed black bristles of a pig are used arranged in clusters in 60 openings 4 mm in diameter on a block measuring (90 ± 5) × (40 ± 5) × (12,5 ± 5) mm and having a total weight of 450 ± 15 g. The bristles shall project above the block surface by not more than 20 mm.

2.3.23 The contaminant-resistance test of retro-reflective material is made on square specimens measuring 150 ± 5 mm, which are secured on an aluminium panel.

The specimens are covered with a contaminant layer 0,75 mm thick, a laboratory glass is placed above, and so they remain for 24 h.

After conditioning, the specimens are wiped clean of the contaminant with a soft cloth wetted in white spirit, washed with 1 per cent solution of a detergent and rinsed in water.

The contaminant used for testing shall have the following composition by weight: 8 parts of soot, 60 parts of mineral oil and 32 parts of white spirit.

2.4 WELDABILITY TEST

2.4.1 The Chapter contains general requirements for the weldability testing procedure of materials being approved.

The Register reserves the right to increase or reduce the number of such tests.

Among the products tested for weldability there are rolled steel, steel castings, steel forgings and aluminium alloys applied in welded ship structures. The test is carried out under the supervision of the Register or in a laboratory recognized by that body.

2.4.2 The weldability of a material shall be examined in the course of approval tests by using the same welding methods that would be applied when producing structures subject to survey by the Register. The welding methods are indicated in the approval documentation for the material.

2.4.3 During the weldability test the following shall be determined:

.1 chemical composition and mechanical properties of the base metal;

.2 cold cracking resistance;

.3 susceptibility to ageing according to 2.2.3.4;

.4 welded joint properties according to Section 4, Part XIV "Welding".

2.4.4 The tests mentioned under 2.4.3 shall be made on plates or other products of maximum thickness taken from at least three different casts.

2.4.5 For metallic materials other than steel the weldability in each particular case is determined proceeding from the results of tests made in conformity with the Register approved program or according to the standards approved by the Register.

3 STEEL AND CAST IRON

3.1 GENERAL

3.1.1 The present requirements are valid for hull structural steel, steel for boilers and pressure vessels, steel pipes and tubes, steel for structures operating at low temperatures, chains, steel forgings and castings, cast iron and steel wire ropes.

In accordance with 1.1.4 all the materials, semi-finished products and items mentioned in the present Section shall be manufactured by recognized works (refer to 1.3.1.2).

3.1.2 It is permitted to use semi-finished products manufactured according to standards or other specifications, if it is proved that requirements contained therein are equivalent to those stipulated by the Rules.

3.1.3 Steel shall be melted in an oxygen steel-making converter, electric or open hearth furnaces, and cast iron in cupolas or electric furnaces. The deoxidation of steel is conducted in accordance with the requirements of Tables 3.2.2-1 and 3.2.2-2. The condition of steel supply shall meet the requirements of Tables 3.2.4-1 and 3.2.4-2.

Use of other methods of steel and cast iron making shall be agreed with the Register.

When steel is not produced at the works where it is rolled, forged or drawn, a certificate shall be supplied to the Surveyor at the mill engaged in further processing of the steel stating the steelworks, process of manufacture, number of cast and chemical composition of steel.

The Surveyor shall have access to steel-making and steel-rolling works.

3.2 HULL STRUCTURAL STEEL

3.2.1 General.

3.2.1.1 The requirements of the Chapter apply to the weldable hot-rolled steel of a normal and higher strength used for plates, strips, sections and bars and intended for hull structures and components being subject to the Register survey during their manufacture.

Hull structural steel conventionally falls into normal strength steel (a minimum yield stress 235 MPa) and higher strength steel (of three strength levels with a minimum yield stress of 315, 355 and 390 MPa, respectively). The requirements for higher strength steel (a minimum yield stress 420 MPa and over) are given in 3.13.

The steel is subdivided into grades as shown in Tables 3.2.2-1 (for normal strength steel), 3.2.2-2, 3.2.3 and 3.5.2.3 (for higher strength steel) depending on the values and conditions required for the performance of impact testing. The relevant data for higher strength steel are given in Table 3.13.3-1.

The requirements of the Chapter depending on the rolled products thickness apply to the steel of the following types:

steel plates and strips of all grades having thickness 100 mm and less;

steel sections and bars of all grades having thickness 50 mm or less.

The requirements for steel rolled products of a larger thickness than specified above may be different from the stated ones, but shall be considered in each particular case and agreed with the Register.

Steel, which does not fully meet the requirements stated in the present Chapter, differs in chemical composition, deoxidation practice and alloying as well as in mechanical properties (e.g. intermediate upper yield stress level, as compared to that required in 3.2.3, and other respective characteristics) may be accepted by the Register upon special consideration. Such steel shall be given a special designation, the letter S may be added to the grade symbol.

3.2.1.2 The recognition of steel rolled products manufacturers by the Register shall be carried out in accordance with 1.3 for each steel grade stated by the manufacturer, for the semi-finished product type and condition of supply. Where different steel production technologies are used at the works, materials approval is carried out individually for each of them.

The weldability of each steel grade and its suitability for bending shall be confirmed by the manufacturer during the initial recognition of steel rolled products by the Register. The survey and tests at the manufacturer's during its recognition by the Register are conducted in accordance with the program (chart) agreed with the Register.

Where the steel is intended for welding with a heat input above 50 kJ/cm, recognition is effected according to the chart given in 2.2.2 of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

3.2.1.3 A manufacturer bears responsibility and assures the use of necessary technological production processes, systems and monitoring methods for the fulfilment of the Register requirements. In case of the deviation of production technology or monitoring and/or of the product quality level degradation, the manufacturer shall identify the cause and take all measures to prevent its recurence. The report on the investigations and analysis conducted on the deviations that took place shall be submitted to the representative of the Register. The Register can demand the increase of tests scope and frequency of tests until the stability of product test results and the confidence in quality level has been recovered.

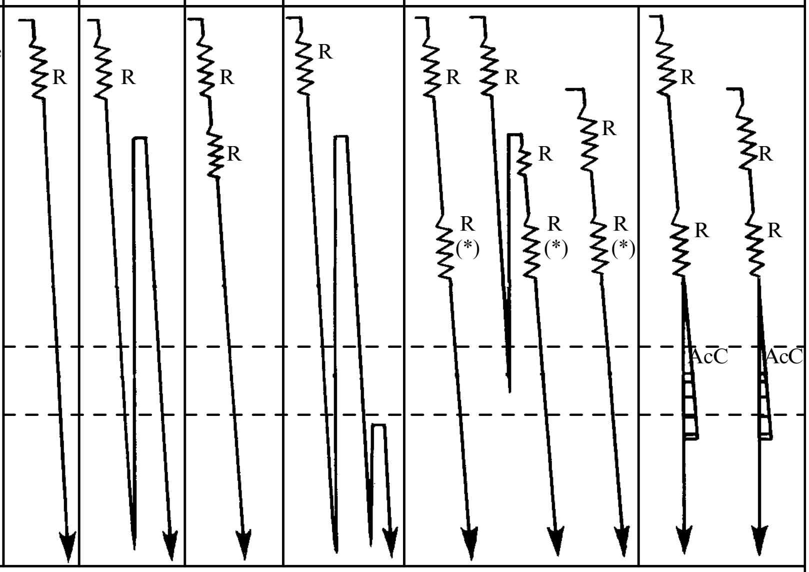
3.2.1.4 The rolling procedures for normal and higher strength steels used by a manufacturer shall comply with the condition of supply given in 3.2.4, and for a higher strength Grade F steel with that given in 3.5.2.4 and higher strength steel with that given in 3.13.4.

The applicable rolling procedures are presented in Table 3.2.1.4 in the form of diagrams, and their definitions are given below.

Table 3.2.1.4

Diagrams of steel processing procedures

Structure	Temperature	Type of processing				
		Conventional processes				Thermo-mechanical processes
		AR	N	CR (NR)	QT	TM
Recrystallized austenite	Slab temperature Normalizing temperature Recrystallization temperature					
Non-recrystallized austenite	A_{r3} or A_{C3}					
Austenite + Ferrite	A_{r1} or A_{C1}					
Austenite + Perlite or Ferrite + Bainite						



Symbols:
AR - as rolling procedure corresponding hot-rolled steel making;
N - normalizing;
CR (NR) - controlled rolling (normalizing rolling);
QT - quenching and tempering;
TM - thermo-mechanical rolling (thermo-mechanical controlled processing);
R - reduction;
(*) - temperature of the dual phase region of austenite and ferrite;
AcC - accelerated cooling.

(AR) as rolled, is the procedure, which involves the rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallization region and above the normalising temperature.

The strength and toughness properties of steel produced by the process are generally less than steel heat treated after rolling or than steel produced by advances processes.

(N) normalising, is the procedure, which involves heating rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallization region followed by air cooling. The process improves the mechanical properties of as rolled steel by refining the grain size.

(CR) controlled rolling, normalizing rolling (NR) is the rolling procedure, in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(TM) thermo-mechanical rolling (thermo-mechanical controlled processing (TMCP) is a procedure, which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region.

Unlike controlled rolled (normalised rolling) the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment.

The use of accelerated cooling on completion of TM-rolling may also be accepted subject to the special approval of the Society. The same applies for the use of tempering after completion of the TM-rolling.

(AcC) accelerated cooling is a process, which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM-rolling operation. Direct quenching is excluded from accelerated cooling.

The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other heat treatment.

(QT) quenching and tempering.

Quenching involves a heat treatment process, in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure. Tempering subsequent to quenching is a process, in which the steel is reheated to an appropriate temperature not higher than the A_{c1} to restore toughness properties (*KV*) by improving the microstructure.

3.2.1.5 When the works are surveyed, the documentation, which describes and specifies the fulfilment of CR, TM, schedules or TM with AcC, normalising, quenching with tempering, etc., shall be submitted to the Register representative on his demand. As specified in 3.2.1.3, a manufacturer is responsible for the observance of all mentioned rolling schedules and heat treatment procedures in the process of steel manufacture. The appropriate records shall be verified by the manufacturer and submitted to the Register repressutative when performing his duties.

Where deviations from the programmed rolling schedules or heat treatment procedures exist, the products may be accepted for use on conditions set forth in 3.2.1.3.

3.2.2 Chemical composition.

The chemical composition of steel shall be determined by the manufacturer from the results of analysis of the samples taken from each ladle of each cast. The manufacturer's analysis will be accepted subject to periodical checks if required by the Register.

The chemical composition of normal strength steel shall comply with the requirements of Table 3.2.2-1 and that of higher strength steel — with the requirements of Table 3.2.2-2.

In Tables 3.2.2-1 and 3.2.2-2 the content of acid soluble aluminium is included. The total aluminium content shall be at least 0,020 per cent.

The Register may also require the content of elements to be determined which are not given in Tables 3.2.2-1 and 3.2.2-2; chromium, nickel and copper content in normal strength steel shall not exceed 0,30 per cent each.

For normal strength carbon steel the total carbon content plus 1/6 of the manganese content shall not exceed 0,40 per cent. The carbon equivalent, in per cent, for higher strength steels is calculated for guidance at approval tests from the ladle analysis using the formula

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}.$$

The arsenic content in steels of all the grades shall not exceed 0,08 per cent.

The steel may contain separately or in combinations aluminium, vanadium, niobium or other grain refining elements. Where the above elements are introduced separately, their content shall be in accordance with Tables 3.2.2-1 and 3.2.2-2. Where the elements are used in combinations, their minimum content in steel is not specified.

Where the content of aluminium or another grain refining element proves to be lower than required, the Register may require the austenite grain size to be determined, which shall not be greater than grain size No. 5.

Table 3.2.2-1

Chemical composition and mechanical properties of normal strength steel

Grade		A	B	D	E
Deoxidation		Killed or semi-killed	Killed or semi-killed	Killed	Killed, fine-grained, aluminium treated
Condition of supply		According to Table 3.2.4-1			
Chemical composition (ladle analysis), %	C (max)	0,21	0,21	0,21	0,18
	Mn (min)	$2{,}5 \times C$	0,80	0,60	0,70
	Si (max)	0,50	0,35	0,35	0,35
	P (max)	0,035	0,035	0,035	0,035
	S (max)	0,035	0,035	0,035	0,035
	Al (min)	—	—	0,015	0,015
Tensile properties	Tensile strength R_m, MPa	400 — 520			
	Yield stress R_{eH}, MPa, min	235			
	Elongation A_5, %, min	22			

Impact testing	Test temperature, °C	+20			0			–20			–40		
	Plate thickness, t, mm	⩽50	>50 ⩽70	>70 ⩽100	⩽50	>50 ⩽70	>70 ⩽100	⩽50	>50 ⩽70	>70 ⩽100	⩽50	>50 ⩽70	>70 ⩽100
	Impact energy, J, min, longitudinal specimens, KV_L	—	34	41	27	34	41	27	34	41	27	34	41
	Impact energy, J, min, transverse specimens, KV_T	—	24	27	20	24	27	20	24	27	20	24	27

Notes:
1. Grade A sections up to a thickness of 12,5 mm may be accepted in rimmed steel.
2. For section steel of Grade A, the carbon content up to 0,23 per cent is permitted.
3. For section steel of Grade A irrespective of thickness, the upper tensile strength may be increased on agreement with the Register.
4. At 20 °C, Grade A steel is expected to withstand the impact energy (*KV*) of 27 J.
5. On agreement with the Register, the manganese content in Grade B steel being impact tested may be reduced to 0,60 per cent.
6. Grade D steel exceeding 25 mm in thickness shall be killed, fine-grained and shall contain $Al \geqslant 0{,}015$ per cent.
7. When the tensile properties of standard full thickness non-proportional specimens with L_0 = 200 mm are determined the minimum elongation shall be as follows:

Thickness t, mm	$t \leqslant 5$	$5 < t \leqslant 10$	$10 < t \leqslant 15$	$15 < t \leqslant 20$	$20 < t \leqslant 25$	$25 < t \leqslant 30$	$30 < t \leqslant 40$	$40 < t \leqslant 50$
Elongation, %	14	16	17	18	19	20	21	22

For higher strength steel subjected to the thermo-mechanical controlled processing (TMCP), the carbon equivalent shall be in compliance with the requirements of Table 3.2.2-3.

Instead of the carbon equivalent the factor estimating the steel susceptibility to cold cracking may be determined according to the formula

$$P_{CM} = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B.$$

The maximum values of the carbon equivalent or P_{CM} are subject to an agreement with the Register and shall be shown in the steel technical documentation being approved.

The actual values of C_{eq} or P_{CM} may be also shown in certificates for steel being delivered.

3.2.3 Mechanical properties.

The mechanical properties of normal strength steel shall comply with the requirements given in Table 3.2.2-1 while the mechanical properties of higher strength steel shall comply with Table 3.2.2-2. Labeling higher strength steel grades the letter H may be added to the grade symbol, for instance DH36.

On agreement with the Register, the impact energy at impact testing may be determined either on longitudinal (KV_L) or transverse (KV_T) specimens.

The testing shall be performed in compliance with the requirements given in Section 2. Values for standard specimens (10 x 10 mm) are given in tables on impact test. When rolled steel products with a thickness under 10 mm are presented, one shall be guided by the provisions set forth in 2.2.3.1. In general, the impact tests of delivered steel shall be performed on longitudinal specimens only (test results on transverse specimens shall be guaranteed by the manufacturer), with the exception of cases stipulated by the Customer or the Register.

Where the test results are unsatisfactory, retesting shall be conducted in compliance with 1.3.4.2.

3.2.4 Condition of supply.

The condition of steel supply shall meet the requirements of Tables 3.2.4-1 and 3.2.4-2 and shall

Table 3.2.2-2

Chemical composition and mechanical properties of higher strength steel

Grade		A32	D32	E32	A36	D36	E36	A40	D40	E40
Deoxidation					Killed					
Condition of supply					According to Table 3.2.4-2					
Chemical composition (ladle analysis), %	C (max)				0,18					
	Mn				0,9 — 1,6					
	Si (max)				0,5					
	P (max)				0,035					
	S (max)				0,035					
	Cu (max)				0,35					
	Cr (max)				0,2					
	Ni (max)				0,4					
	Mo (max)				0,08					
	Al (min)				0,015					
	Nb				0,02 — 0,05 (Nb + V + Ti $\leqslant$ 0,12)					
	V				0,05 — 0,1					
	Ti (max)				0,02					
Tensile properties	Tensile strength, R_m, MPa	440...570			490...630			510...660		
	Yield stress R_{eH}, MPa	315			355			390		
	Elongation A_5, min, %	22			21			20		

N o t e s : 1. Up to a thickness of 12,5 mm the minimum manganese content may be reduced to 0,70 per cent.

2. When steel is supplied in the thermo-mechanical controlled processed condition variations in the specified chemical composition may be allowed or required by the Register.

3. When carrying out tensile tests on standard full thickness non-proportional specimens L_0 = 200 mm the minimum elongation shall comply with the following requirements (in per cent):

Grade of steel	Thickness t, mm							
	$t \leqslant 5$	$5 < t \leqslant 10$	$10 < t \leqslant 15$	$15 < t \leqslant 20$	$20 < t \leqslant 25$	$25 < t \leqslant 30$	$30 < t \leqslant 40$	$40 < t \leqslant 50$
A32 D32 E32	14	16	17	18	19	20	21	22
A36 D36 E36	13	15	16	17	18	19	20	21
A40 D40 E40	12	14	15	16	17	18	19	20

Table 3.2.2-3

Steel grades	Carbon equivalent, %, max	
	$t \leqslant 50$	$50 < t \leqslant 100$
A32, D32, E32, F32	0,36	0,38
A36, D36, E36, F36	0,38	0,40
A40, D40, E40, F40	0,40	0,42

N o t e . The value of the carbon equivalent shall be agreed upon between the Manufacturer and shipyard in each case.

be specified in a certificate and/or manufacturer's document on product quality.

Table 3.2.3

Steel grade	Temperature, °C	Average impact energy, KV, J, min					
		$t \leqslant 50$ mm		50 mm $< t \leqslant 70$ mm		70 mm $< t \leqslant 100$ mm	
		KV_L	KV_T	KV_L	KV_T	KV_L	KV_T
A32	0	31	22	38	26	46	31
D32	–20	31	22	38	26	46	31
E32	–40	31	22	38	26	46	31
A36	0	34	24	41	27	50	34
D36	–20	34	24	41	27	50	34
E36	–40	34	24	41	27	50	34
A40	0	41	27	46	31	55	37
D40	–20	41	27	46	31	55	37
E40	–40	41	27	46	31	55	37

Table 3.2.4-1

Condition of supply for normal strength steel[1]

Grade	Thickness, mm	Condition of supply
A	$t \leqslant 50$ $50 < t \leqslant 100$	Any Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)
B	$t \leqslant 50$ $50 < t \leqslant 100$	Any Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)
D	$t \leqslant 35$ $35 < t \leqslant 100$	Any Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)[2]
E	$t \leqslant 100$	Normalized (N) or thermo-mechanically rolled (TM)[2]

[1] The number of impact tests is determined according to 3.2.6.4-1.

[2] Subject to the special approval by the Register, the sections of Grade D steel may be supplied in as rolled condition provided the results of impact tests are satisfactory. Similarly, the sections of Grade E steel may be supplied in as rolled condition or after controlled rolling.

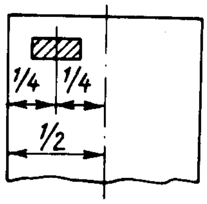


Fig. 3.2.5-1 Plate and flat

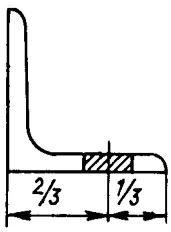


Fig. 3.2.5-2 Angle

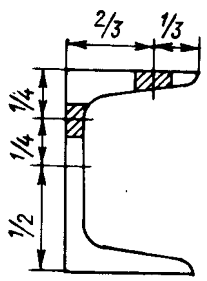


Fig. 3.2.5-3 Channel and beam

3.2.5 Sampling.

Unless otherwise specified, the test samples shall be taken as follows.

The test samples of plates and flats wider than 600 mm shall be taken from one end so that the sample axis is located midway between the longitudinal axis and the edge of the plate or flat (Fig. 3.2.5-1).

The samples of flats 600 mm wide and less and of sections are taken from one end so that the sample axis lies 1/3 from the flat edge or from the outer edge of the section flange or, in the case of small sections, as near as possible to this position (Figs. 3.2.5-2, 3.2.5-3 and 3.2.5-4).

Table 3.2.4-2

Condition of supply for higher strength steel

Grade	Grain refining elements	Thickness, mm	Condition of supply
A32, A36	Nb and/or V	$t \leqslant 12{,}5$ $12{,}5 < t \leqslant 100$	Any Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)
A32, A36	Al or Al and Ti	$t \leqslant 20$ $20 < t \leqslant 35$ $35 < t \leqslant 100$	Any Any, subject to special approval if as rolled (AR) Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)
A40	Any	$t \leqslant 12{,}5$ $12{,}5 < t \leqslant 50$	Any Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)
D32, D36	Nb and/or V	$t \leqslant 12{,}5$ $12{,}5 < t \leqslant 100$	Any Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)
D32, D36	Al or Al and Ti	$t \leqslant 20$ $20 < t \leqslant 25$ $25 < t \leqslant 100$	Any Any, subject to special approval if as rolled (AR) Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)
D40	Any	$t \leqslant 50$	Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM)
E32, E36	Any	$t \leqslant 50$ $50 < t \leqslant 100$	Normalized (N), controlled rolled (CR) or thermo-mechanically rolled (TM) Normalized (N), thermo-mechanically rolled (TM)
E40	Any	$t \leqslant 50$	Normalized (N), thermo-mechanically rolled (TM) or quenched and tempered (QT)

Note. Subject to the approval by the Register sections in Grades A32, A36 and D36 steels may be supplied in as rolled condition, provided the results of impact tests are satisfactory. Similarly, sections in Grades E32 and E36 steels may be supplied in as rolled condition or after controlled rolling. The number of impact fests is determined according to 3.2.6.4-2.

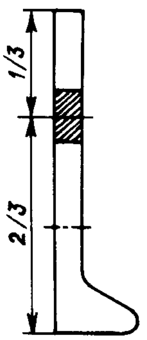


Fig. 3.2.5-4 Bulb bar

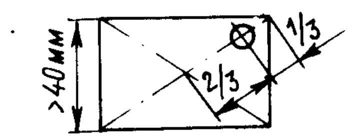


Fig. 3.2.5-5 Rectangular bar

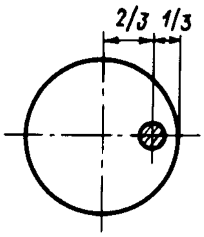


Fig. 3.2.5-6 Cylindrical bar

In the case of channels, beams the test samples may be alternatively taken from the position 1/4 from the web centre line (Fig. 3.2.5-3).

The test samples of bars and similar semi-finished products are taken from one end so that the sample axis is parallel to the direction of rolling.

From rolled bars 50 to 100 m thick, samples are taken 1/4 of the thickness dimension from the surface.

Pieces of smaller cross-section may be tensile tested without prior machining. In other cases, the test samples shall be taken so that their axes lie:

for non-cylindrical semi-finished products, 1/3 of the half-diagonal from the outside (Fig. 3.2.5-5);

for cylindrical semi-finished products, 1/3 of the radius from the outside (Fig. 3.2.5-6).

Pieces selected for the preparation of tensile and impact test specimens shall be the thickest (greatest in diameter) in each batch with their longitudinal axes transverse to the final direction of rolling, except in the case of sections, bars and flats of 600 mm or less in width.

Specimens, on which impact energy *KV* shall be determined, shall be prepared with their longitudinal axes either parallel or transverse to the final direction of rolling of the material unless required in special cases that the test samples are taken with their longitudinal axes transverse to the final direction of rolling.

The notch shall be cut perpendicular to the rolled surface and not closer than 25 mm to the flame cut or sheared edge.

The impact test specimens shall be taken within 2 mm below the rolled surface and where the thickness of the rolled material exceeds 40 mm — within 1/4 of the thickness (the axis of the specimens shall be in a plane located at 1/4 of the thickness and parallel to the surface).

3.2.6 Number of tests.

3.2.6.1 Rolled material is presented for tests in batches. A batch shall comprise rolled products of the same type, from the same cast and in the same condition of supply. Unless otherwise specified, one tensile test piece and one set of impact test pieces shall be tested from each batch presented with the mass not exceeding 50 t (except Grade E, E32, E36 and E40 steel).

Where the batch mass is in excess of 50 t, one extra tensile and impact test shall be made for each 50 t or fraction thereof.

An additional test shall be made for every variation of more than 10 mm in the thickness of plates or for every variation of more than 10 mm in the thickness or diameter of sections and bars comprising the batch.

Samples for testing rolled material batches shall be taken from the thickest semi-finished product belonging to the batch concerned.

3.2.6.2 When, subject to the special approval of the Register, material is supplied in the as-rolled condition, one set of impact test specimens shall be tested from each batch of 25 t or fraction thereof.

3.2.6.3 The number of impact tests for Grade E, E32, E36 and E40 steel shall be as follows:

for plates and wide flats each piece shall be tested;

for sections and bars one set shall be tested from each batch of 25 t or fraction thereof.

When, subject to the special approval of the Register, sections are supplied in the as-rolled or controlled rolled condition, one set of specimens shall be tested from each batch of 15 t or fraction thereof.

Impact tests of the rolled materials after quenching and tempering (QT) shall be carried out on each length undergone such operation .

The number of impact tests of the rolled materials, which on agreement with the Register may be accepted for supply in hot-rolled condition, may be increased. The maximum size of the batch, from which a set of specimens is taken, shall be 25 t.

3.2.6.4 In general, the number impact tests is given in Tables 3.2.6.4-1 and 3.2.6.4-2.

Table 3.2.6.4-1

Grade	Deoxidation	Type of rolled products	Condition of supply (batch size for tests, *KV*) Thickness, mm 10 12,5 20 25 30 35 40 50 100				
A	Killed or semi-killed	Section	A(-)	Not applicable			
	< 50 killed or semi-killed > 50 killed	Plate	A(-)				N(-) TM(-) CR(50), AR*(50)
		Section	A(-)				Not applicable
B	< 50 killed or semi-killed ⩾ 50 killed	Plate	A(50)				N(50) TM(50) CR(25) AR*(25)
		Section	A(-)		A(50)		Not applicable
D	Killed	Plate Section	A(50)		Not applicable		
	Killed and fine-grained	Plate	A(50)			N(50) CR(50) TM(50)	N(50) TM(50) CR(25)
		Section	A(50)			N(50) CR(50) TM(50) AR*(25)	Not applicable
E	Killed and fine-grained	Plate	N (each piece) TM (each piece)				
		Section	N(25)TM(25) AR*(15), CR*(15)				Not applicable

Symbols: A – any; N – normalizing; CR – controlled rolling; QT – quenching and tempering.
Note. AR* as rolled steel and CR* controlled rolling specified in the present and in Table 3.2.6.4-2 may be applied only on agreement with the Register.

Table 3.2.6.4-2

Steel grade	Deoxidation	Grain refining elements	Type of rolled products	Condition of supply (batch size for tests, *KV*) Thickness, mm 10 12,5 20 25 30 35 40 50 100				
A32, A36	Killed and fine-grained	Nb and/or V	Plate	A(50)	N(50) CR(50), TM(50)			N(50), CR(25), TM(50)
			Section	A(50)	N(50) CR(50), TM(50) AR*(25)			Not applicable
		Al or Al + Ti	Plate	A(50)		AR*(25)	Not applicable	
						N(50), CR(50) TM(50)		N(50), CR(25), TM(50)
			Section	A(50)	N(50) CR(50) TM(50) AR*(50)			Not applicable
A40	Killed and fine-grained	Any	Plate	A(50)	N(50) CR(50) TM(50)			N(50) TM(50) QT(each piece)
			Section	A(50)	N(50) CR(50) TM(50)			Not applicable

Table 3.2.6.4-2 — continued

Steel grade	Deoxidation	Grain refining elements	Type of rolled products	Condition of supply (batch size for tests, *KV*) Thickness, mm: 10–12,5	12,5–20	20–35	35–50	50–100
D32, D36	Killed and fine-grained	Nb or V	Plate	A(50)	N(50) CR(50) TM(50)			N(50), CR(25), TM(50)
			Section	A(50)	N(50) CR(50), TM(50) AR*(25)			Not applicable
		Al or Al+Ti	Plate	A(50)		AR*(25)	Not applicable	
						N(50), CR(50), TM(50)		N(50), CR(25), TM(50)
			Section	A(50)	N(50) CR(50), TM(50) AR*(25)			Not applicable
D40	Killed and fine-grained	Any	Plate	N(50) CR(50) TM(50)				N(50) TM(50) QT (each piece)
			Section	N(50) CR(50) TM(50)				Not applicable
E32, E36	Killed and fine-grained	Any	Plate	N (each piece) TM (each piece)				
			Section	N(25) TM(25) AR*(15), CR*(15)				Not applicable
E40	Killed and fine-grained	Any	Plate	N (each piece) TM (each piece) QT (each piece)				N (each piece) TM (each piece) QT (each piece)
			Section	N(25) TM(25) QT(25)				Not applicable
F32, F36	Killed and fine-grained	Any	Plate	N (each piece) TM (each piece) QT (each piece)				N (each piece) TM(each piece) QT (each piece)
			Section	N(25) TM(25) QT(25) CR*(15)				Not applicable
F40	Killed and fine-grained	Any	Plate	N (each piece) TM (each piece) QT (each piece)				N (each piece) TM (each piece) QT (each piece)
			Section	N(25) TM(25) QT(25)				Not applicable

3.2.7 Inspection.

Allowable under-thickness tolerances of shell plates and wide flats for hull structures shall not exceed −0,3 mm. For steel less than 5 mm thick, the under-thickness tolerances shall be in compliance with Register-approved documentation.

Allowable under-thickness tolerances of shell plates and wide flats for ships machinery and other items subject to the Register supervision shall be in accordance with Table 3.2.7.

The steel shall be reasonably free from segregations and non-metallic inclusions. The semi-finished

Table 3.2.7

Thickness t, mm	Maximum permissible tolerances, mm
$5 \leqslant t < 8$	$-0,4$
$8 \leqslant t < 15$	$-0,5$
$15 \leqslant t < 25$	$-0,6$
$25 \leqslant t < 40$	$-0,8$
$40 \leqslant t$	$-1,0$
Notes: 1. The maximum permissible minus tolerances for the case of the thickness being less than 5 mm shall be in accordance with standards. 2. The thickness measurements shall be taken not less than 10 mm from the plate edge.	

products shall be free from cracks, slag inclusions and other defects prejudicial to the use of the material for its intended application. The semi-finished products shall also have workmanlike surface and shall not have been hammer dressed.

The manufacturer shall guarantee complete elimination of piping, which shall be verified by check tests. The methods of testing shall be agreed with the Register.

Surface defects may be removed by local grinding, provided the nominal thickness is in no place reduced by more than 7 per cent, but in no case by more than 3 mm. The total area rectified by grinding shall not exceed 2 per cent of the product surface.

Surface defects, which cannot be removed by local grinding, may be repaired by chipping or grinding followed by welding, subject to the Register consent and under its technical supervision, provided that:

after removal of the defects before welding the thickness of the product is in no place reduced by more than 20 per cent;

welding is carried out in accordance with an approved procedure by qualified welders with approved electrodes;

the welded area is ground smooth to the correct nominal thickness;

the area of a single welding shall not exceed 25 cm^2;

the total welded area shall not be greater than 1 per cent of the product surface;

after welding surface defects the advisability and type of heat treatment, if required, are agreed with a Surveyor to the Register.

3.2.8 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 1.4.

Every semi-finished product shall have clearly visible stamp or brand of the Register marked by the specified method and in specified location.

Besides the mentioned above, the marking shall include the unified indication mark for grade of steel and strength level (e.g., A, B36, E450).

When required by the Register, material supplied in the thermo-mechanically controlled processed condition shall have index "TMCP" added after the identification mark, (e.g., E36TMCP).

Besides, the steel, supplied under the Register technical supervision may have index "PC" before the unified identification mark for grade of steel and strength level (e.g., PCE36TMCP).

In case of the Register approved supply of steel, which does not fully comply with the requirements of the Rules (refer to 3.2.1.1), index "S" may be added after the identification mark for grade of steel and strength level (e.g., PCE368TMCP or PCB368).

Branding of rolled and section rolled steel products may be performed on a label. At that the manufacturer shall confirm the identification system of every rolled product in a bundle.

3.3 STEEL FOR BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

3.3.1 General.

3.3.1.1 The present requirements are applicable to rolled steel for marine boilers, heat exchangers and pressure vessels manufactured under the survey by the Register.

3.3.1.2 The steel shall be manufactured at works recognized according to 1.3.1.2 in accordance with standards or specifications agreed with the Register.

3.3.1.3 Rolled steel which is manufactured and tested in accordance with these requirements is intended for operation at room or elevated temperatures.

3.3.2 Chemical composition.

3.3.2.1 The chemical composition of steel shall be in accordance with standards proceeding from the required mechanical properties at room or elevated design temperatures and the content of base elements in per cent shall not exceed:

for carbon and carbon-manganese steels (ladle analysis), %:

carbon — 0,20, phosphorus and sulphur — 0,04, silicon — 0,50, manganese — 1,60, chromium, nickel, copper — 0,30.

The use of steel with carbon content more than 0,20 per cent for welded structures shall be agreed with the Register on condition sufficient weldability is ensured;

for low-alloy steel (ladle analysis), %:

carbon — 0,18, phosphorus — 0,04, silicon — 0,50, chromium — 2,50, manganese — 0,80, molybdenum — 1,10, sulphur — 0,04, vanadium — 0,35.

3.3.2.2 The steel shall be killed. Using of rimming steel is not permitted, and semi-killed steel is permitted on agreement with the Register. On agreement with the Register, the steel may be treated with grain-refining elements.

Carbon and carbon-manganese steel intended to operate at temperatures over 400 °C shall not contain aluminium.

3.3.2.3 On agreement with the Register, the use of steel, the base element content of which exceeds the limits specified above, as well as steel of other compositions, may be accepted.

3.3.3 Mechanical properties.

The mechanical properties of steel at room and elevated temperature shall be in accordance with standards.

The properties of steel shall be confirmed by the following tests:

tensile test (tensile strength, yield stress and percentage elongation are determined);

bend test;

impact test (*KCU* or *KV*).

The tensile test at elevated temperature and the ageing test shall be carried out if required by the relevant parts of the Rules or by standards.

At the request of the Register the test results obtained at determining the average stress to produce rupture at elevated temperature shall be submitted.

3.3.4 Heat treatment.

The steel shall be manufactured as normalized, normalized and tempered or quenched and tempered. The method of heat treatment shall be as stipulated by standards.

On agreement with the Register, the steel may be manufactured without heat treatment, provided the required properties are guaranteed, and controlled rolling may be accepted as a substitute for normalizing.

3.3.5 Sampling.

Unless stated otherwise, sampling shall be carried out in accordance with 3.2.5.

Tensile test specimens and those for determining the impact toughness *KCU* shall be cut out transverse to, and those for determining the impact energy *KV* — parallel to the direction of the last rolling.

3.3.6 Number of tests.

Each rolled steel plate shall be submitted for testing. In the case of rolled plates of carbon steel up to 12 mm thick, as well as rolled sections, it is permitted to take 10 per cent of the total number of the plates (rolled pieces) or sections for testing purposes, but not less than two and of the same thickness (diameter or shape), one and the same cast and identical heat treatment.

Unless stated otherwise, not less than one specimen for tensile and bend testing and not less than one set of specimens for impact testing shall be taken from the rolled piece intended for testing purposes.

The number of specimens for tensile testing and for the determining of long-term strength at elevated temperature shall be established on agreement with the Register.

From plates (rolled pieces) with a mass of more than 6 t or a length of more than 15 m the samples for test specimens shall be cut out on both ends.

3.3.7 Inspection.

The rolled steel shall be free from defects prejudicial to the use of the material for the intended application. Freedom from non-allowable defects shall be guaranteed by the manufacturer and may be confirmed by the results of non-destructive testing.

Surface defects involved by the manufacturing process are permitted in case their depth is not greater than the allowable under-thickness tolerances, considering from the nominal thickness.

Repair of surface defects by welding followed by post-weld heat treatment is permitted on agreement with the Register only.

3.3.8 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 1.4.

Every semi-finished product shall have clearly visible stamp or brand of the Register marked by the specified method and in specified location.

Branding of rolled and section rolled steel products may be performed on a label. At that the manufacturer shall confirm the identification system of every rolled product in a bundle.

3.4 STEEL TUBES AND PIPES

3.4.1 General.

3.4.1.1 The present requirements apply to hot- and cold-formed steel pipes and tubes intended for boilers, heat exchangers, pressure vessels, ship systems and piping and subject to survey by of the Register during manufacture.

3.4.1.2 The steel pipes and tubes shall be manufactured at works recognized according to 1.3.1.2 in accordance with standards or technical requirements agreed with the Register.

3.4.1.3 The welded pipes and tubes may be manufactured by means of electric induction welding, pressure contact welding or fusion welding.

3.4.2 Chemical composition.

3.4.2.1 The chemical composition of the steel for pipes and tubes shall be chosen on the basis of standards proceeding from the required mechanical properties at room of elevated design temperature; the content of base elements in per cent shall not exceed the values stated below:

for carbon and carbon-manganese steel (ladle analysis), %:

sulphur and phosphorus — 0,04, manganese — 1,50, chromium, nickel, silicon — 0,50, copper — 0,30, carbon — 0,23;

For low-alloy steel (ladle analysis), %:

sulphur and phosphorus — 0,035, manganese — 1,00, chromium — 2,50, silicon — 0,50, molybdenum — 1,20, carbon — 0,20, vanadium — 0,35.

3.4.2.2 The steel shall be killed. Rimming steel is not permitted for manufacturing pipes and tubes and semi-killed steel is permitted on agreement with the Register. The treatment of steel with grain-refining elements is also permitted on agreement with the Register. Carbon and carbon-manganese steel intended for working temperatures above 400 °C shall not contain aluminium.

3.4.2.3 The use of steel, in which the base elements content exceeds the above limits as well as steel containing other base alloying elements than those stated above, may be permitted on agreement with the Register.

3.4.2.4 The chemical composition shall be determined from the heat analysis (ladle analysis); determination of chemical composition on a tubular billet is permitted.

3.4.3 Mechanical and technological properties.

3.4.3.1 At room and elevated design temperature the mechanical and technological properties of steel intended for pipes and tubes shall be in accordance with standards for pipes and tubes.

3.4.3.2 In the process of manufacture the pipes and tubes shall undergo the following tests:

tensile test (tensile strength, yield stress and elongation being determined) according to 2.2.2;

tensile test at elevated temperature (proof stress being determined);

flattening test according to 2.2.5.2, or tensile test of rings according to 2.2.5.4;

expanding test according to 2.2.5.3.

Tensile test at elevated temperature, flattening test, tensile test of rings and expanding test shall be carried out when required by standards for pipes or by technical documentation approved by the Register on the basis of which the test results are estimated. When required by the Register or provided for by the relevant parts of the Rules or by standards, the results of testing the steel intended for pipes and tubes for determining the average stress to produce rupture at elevated temperature shall be submitted.

3.4.4 Heat treatment.

The pipes and tubes shall be heat treated, when stipulated by the relevant parts of the Rules, by standards or technical design documentation approved by the Register. The cold-formed and electrically welded pipes and tubes shall in any case be heat treated, normalized, normalized and tempered or quenched and tempered. The method and conditions of heat treatment shall be chosen by the manufacturer, reported to the Register and stated in the certificate.

3.4.5 Sampling.

Unless stated otherwise, sampling for specimens shall be made from one end of not less than two pipes or tubes of the batch.

3.4.6 Scope of testing.

The pipes and tubes shall be tested by batches. A batch shall consist of pipes and tubes of the same size manufactured from steel of the same heat and heat treated under similar conditions.

The number of pipes or tubes in a batch shall not exceed:

400 in the case of pipes or tubes with an outer diameter of 76 mm or less;

200 in the case of pipes or tubes with an outer diameter over 76 mm.

A rest of pipes or tubes, which is less than half the number stated, shall be included in a relevant batch and one which is half and over, — shall be considered a separate batch.

For testing purposes, out of each sample one specimen for the tensile test, one specimen for the flattening test or the tensile test of rings (when welded pipes and tubes are tested — 2 specimens, during the testing of one of the specimens the welded joint shall be in the tension zone), one specimen for the expanding test shall be cut. All the pipes and tubes shall be tested by hydraulic pressure. The test pressure shall be in accordance with standards for pipes and tubes or with documentation agreed with the Register, but in any case it shall not be less than that stated in 21.2, Part VIII "Systems and Piping" and in 1.7, Part X "Boilers, Heat Exchangers and Pressure Vessels".

On agreement with the Register, hydraulic tests may be omitted if all the pipes and tubes undergo ultrasonic or other equivalent testing.

All the welds in welded pipes and tubes shall undergo the ultrasonic testing.

3.4.7 Inspection.

All the pipes and tubes shall undergo visual examination.

The surface of the pipes and tubes shall be free from cracks, skins, fissures and laps.

A certain number of minor nicks and dents, marks, thin layers of scale, traces of defects grinding and small skins are permitted if due to them the wall thickness would not exceed the allowable underthickness tolerances.

3.4.8 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 1.4.

Branding of rolled and section rolled steel products may be performed on a label. At that the manufacturer shall confirm the identification system of every rolled product in a bundle.

3.5 STEEL FOR STRUCTURES INTENDED FOR LOW TEMPERATURE SERVICE

3.5.1 General.

3.5.1.1 The present requirements apply to steel plates, flats, sections and bars of Grade F having thickness up to 100 mm, as well as to forgings and castings intended for hull structures, ship equipment and machinery cooling up when exposed to low climatic temperatures.

Application of requirements for forgings and castings intended for operation at temperatures below −50 °C is subject to special consideration by the Register in each case.

With no special requirements for the manufacture, inspection, identification, marking and documentation, the relevant requirements of 3.2, 3.7 and 3.8 shall be fulfilled.

The rolled products, forgings and castings shall be manufactured by the manufacturers recognized by the Register in accordance with 1.3.1.2.

3.5.1.2 Steel having its chemical composition, mechanical properties and conditions of supply different from those required may be approved for use after special consideration of the Register with due account of appropriate additional requirements set forth in Part XIII "Materials" of the Rules for the Classification, Construction and Equipment of Mobile Offshore Drilling Units and Fixed Offshore Platforms.

3.5.1.3 Where provision for welding is made during the manufacture of forged or cast items or where such items are meant for welding inside the ship hull, the chemical composition of steel and the welding procedure shall ensure the welded joint resistance to cracking.

For weld metal, the mechanical properties and impact energy obtained at impact test at prescribed temperature shall not be lower than those required for the base metal.

3.5.1.4 Tests of steel shall be carried out in accordance with the requirements of Section 2.

The tests shall be carried out at the temperatures indicated in standards recognized by the Register and/or in the agreed specifications. Unless otherwise specified, the temperature of impact test shall be not less than 5 °C lower than the design temperature.

After impact testing of the specimens, the percentage of fibre in the fracture is determined on the basis of standards or by procedures agreed with the Register.

3.5.2 Hull structural steel.

3.5.2.1 Manufacture.

The steel shall be manufactured in basic oxygen furnaces or converters. Other manufacturing processes may be used subject to an agreement with the Register.

3.5.2.2 Chemical composition.

The chemical composition of a particular steel grade is set down by standards and technical requirements and shall not exceed the ultimate values of Table 3.5.2.2. The steel shall be fully killed and treated with grain-refining elements.

3.5.2.3 Mechanical properties.

The mechanical properties of steel when tensile-tested, as well as impact test results, shall comply with Table 3.5.2.3.

The mechanical properties of steel more than 50 mm thick shall be agreed with the Register. In any case, the impact energy of such a steel shall comply with Table 3.5.2.3 for the respective grade.

3.5.2.4 Condition of supply — in accordance with Table 3.2.4-2.

3.5.2.5 Unless ofherwise specified, scope of tests shall meet the requirements of Table 3.2.6.4.

Table 3.5.2.2

Chemical composition of hull structural steel

Steel grade	Content of elements, %													
	C	Mn	Si	P	S	Al (acid-soluble), min	Nb	V	Ti	Cu	Cr	Ni	Mo	N
	maximum		maximum						maximum					
F32	0,16	0,90-1,60	0,50	0,025	0,025	0,015	0,02-0,05	0,05-0,10	0,02	0,35	0,20	0,80	0,08	0,009 (0,012 if Al is present)
F36	0,16	0,90-1,60	0,50	0,025	0,025	0,015	0,02-0,05	0,05-0,10	0,02	0,35	0,20	0,80	0,08	
F40	0,16	0,90-1,60	0,50	0,025	0,025	0,015	0,02-0,05	0,05-0,10	0,02	0,35	0,20	0,80	0,08	
							Total content 0,12 max							

Notes: 1. Instead of acid-soluble aluminium content, the total content of aluminium may be determined. In this case, the total aluminium content must not be less than 0,020 per cent.

2. Steel may be treated with aluminium, niobium, vanadium or other suitable grain-refining elements either separately or in any combination. If treated with one element, its content shall be in accordance with the Table; if treated with a combination of elements, the content of at least one of them shall be in accordance with the Table.

Table 3.5.2.3

Mechanical properties of hull structural steel

Grade	Yield stress, R_{eH}, MPa	Tensile strength, R_m, MPa	Elonga-tion A_5, %, min	Impact test						
				Test tempe-rature, °C	Average impact energy value, KV, J, min					
					$t \leqslant 50$ mm		$50 < t \leqslant 70$ mm		$70 < t \leqslant 100$ mm	
					KV_L	KV_T	KV_L	KV_T	KV_L	KV_T
F32	315	440-590	22	−60	31	22	38	26	46	31
F36	355	490-620	21	−60	34	24	41	27	50	34
F40	390	510-650	20	−60	39	26	46	31	55	37

3.5.3 Steel forgings.

3.5.3.1 Chemical composition.

The chemical composition of steel for forgings shall be chosen on the basis of standards agreed with the Register proceeding from the required properties at room temperature and low temperatures and shall conform to 3.7.2. The content of sulphur and phosphorus in carbon and carbon-manganese steel shall not exceed 0,025 per cent and 0,030 per cent, accordingly, and in alloy steel — 0,025 per cent of each element.

3.5.3.2 Mechanical properties.

The mechanical properties of forged steel and the results of impact testing at room temperature shall be in accordance with 3.7.3.

Besides, the steel forgings shall be impact tested at the temperature determined proceeding from 3.5.1.4. The required impact energy value shall be chosen on the basis of standards or technical requirements, but in any case it shall not be less than 27 J and the Register may require the percentage of fibre in the fracture of the specimen to be determined after impact test, which shall not be less than 50 per cent.

For the approval of steel to be used for important forgings, which shall operate at −30 °C and below, the Register may require resistance to brittle fracture to be confirmed either by impact testing of specimens with larger cross-sections, drop-weight testing in accordance with 2.2.6, or by other procedures of cranking resistance testing agreed with the Register.

3.5.4 Steel castings.

3.5.4.1 Chemical composition.

The chemical composition of steel for castings shall be chosen on the basis of standards agreed with the Register proceeding from the required properties at room temperature and low temperatures and shall conform to 3.8.2. The content of sulphur and phosphorus shall not exceed 0,025 per cent and 0,030 per cent, accordingly.

3.5.4.2 Mechanical properties.

The mechanical properties of steel castings and the results of impact testing at room temperature shall be in accordance with 3.8.3.

Besides, the steel shall be impact tested at the temperature determined proceeding from 3.5.1.4. The required impact energy value shall be chosen on the basis of standards or technical requirements, but in any case it shall not be less than 27 J, and the Register may require the percentage of fibre in the fracture of the specimen to be determined after impact test, which shall not be less than 50 per cent.

For the approval of steel to be used for important castings, which shall operate at −30 °C and below, the Register may require resistance to brittle fracture to be confirmed either by impact testing of specimens with larger cross-sections, drop-weight testing in accordance with 2.2.6, or by other procedures of cracking resistance testing agreed with the Register.

3.6 STEEL FOR CHAIN CABLES AND ACCESSORIES

3.6.1 General.

3.6.1.1 The present requirements apply to steel rolled products, forgings and castings used for manufacture of chain cables and accessories.

Steel forgings shall generally meet the requirements of 3.7 and steel castings — the requirements of 3.8, unless otherwise stated.

3.6.1.2 All materials used for the manufacture of chain cables and accessories shall be supplied by the manufacturers recognized in accordance with 1.3.1.2. Grade 1 rolled products may be used for the manufacture of chain cables with the manufacturer's certificates.

3.6.1.3 The manufacturer shall submit the specification for material to the Register for approval.

Stated in the specification shall be the melting and deoxidation procedure, specified chemical composition and mechanical properties, and terms of rolled products' acceptance and delivery as well.

Melting and deoxidation procedure, chemical composition and condition of rolled products' delivery, which do not fully comply with the requirements of the Chapter, are subject to the special approval by the Register.

3.6.2 Chemical composition.

3.6.2.1 The chemical composition of steel is determined by ladle analisis. The chemical composition of rolled steel bars, based on ladle analysis for grades 1 and 2 chain cables shall comply with Table 3.6.2.1.

Table 3.6.2.1

Chemical composition of rolled steel bars

Chain cable grade	Content of elements, %					
	C max	Si	Mn	P max	S max	Al total[1], min
1	0,20	0,15 0,35	0,40 min	0,040	0,040	—
2[2]	0,24	0,15 0,55	1,60 max	0,035	0,035	0,020

[1] Aluminium may be replaced partly by other fine graining elements.
[2] If the Register agrees, additional alloying elements may be added.

3.6.2.2 For chain cables of grades 3, R3, R3S and R4 the chemical composition of steel shall comply with the specification agreed with the manufacturer of a chain cable and approved by the Register. In addition the steel for chain cables of grade R4 shall contain not less than 0,2 per cent of molybdenum.

3.6.2.3 The rolled bars shall be made of killed steel, and the steel for chain cables of grades 2, 3, R3, R3S and R4 shall be deoxidized and fine grain treated.

3.6.2.4 The chemical composition of forgings and castings shall be in accordance with the specification approved by the Register and be specified by the manufacturer for each heat.

3.6.3 Mechanical properties.

The mechanical properties of steel for chain cables and accessories shall ensure the properties according to the requirements of Table 3.6.3.

Table 3.6.3

Chain cable grade	Yield stress R_{eH} [3], MPa, min	Tensile strength R_m [3], MPa	Percentage elongation A_5, %	Percentage reduction of area Z[4], %	Impact test [1,2]		
			min		Test temperature, °C	Base material	Weld joint
						Impact energy KV, J, min	
1	—	370 - 490	25	—	—	—	—
2	295	490 - 690	22	—	0	27	—
3	410	690 min	17	40	0(-20)	60(35)	50(27)
R3	410	690 min	17	50	0(-20)	60(40)	50(30)
R3S	490	770 min	15	50	0(-20)	65(45)	53(33)
R4	580	860 min	12	50	-20	50	36

[1] Impact tests of material for grade 2 chain cables may be waived if the chain cable is supplied in a heat treated condition.
[2] On agreement with the Register, impact tests for chain cables of grades 3, R3, R3S and R4 may be carried out at the temperature -20 °C. In this case the impact energy minimum value required is shown in brackets.
[3] For chain cables of grades R3, R3S and R4, $R_{eH}/R_m \leqslant 0{,}92$.
[4] For cast steel of grades R3 and R3S, $Z \leqslant 40$ %, for steel of grade R4 — $Z \leqslant 35$ %. When the material susceptibility to hydrogen embrittlement for chain cables of grades R3, R3S and R4 is determined, $Z/Z_1 \geqslant 0{,}85$, where Z and Z_1 are the sample percentage reduction of area under tension before and after heating, respectively.

3.6.4 Condition of supply.

3.6.4.1 Rolled bars and round section forgings, unless otherwise stated, are supplied in as-rolled condition. The finished forgings and castings may be supplied after heat treatment appropriate to each chain cable grade as specified in Table 7.1.3.4. Forgings and castings may be subjected to normalizing, normalizing and tempering, hardening and tempering. The type of heat treatment shall conform to the specification approved by the Register.

3.6.4.2 When the rolled products manufacturer is recognized, the chain cables of grades 3, R3, R3S and R4 shall be subjected to control testing of material after heat treatment similar to the one of the chain cable manufacturer. For chain cables of grades 1 and 2 it may be demanded by the Register.

3.6.5 Mechanical tests.

3.6.5.1 The rolled bars are submitted for testing in batches. A batch not more than 50 t in mass shall comprise bars of the same cast and supply condition with a tolerance of diameter within 4 mm.

3.6.5.2 From each batch of rolled bars, a sample is taken, out of which a tensile test specimen and a set of test specimens for impact testing (KV) for chain cables of grades 2, 3, R3, R3S and R4 are machined.

Test specimens shall be taken from the test sample in the longitudinal direction according to Fig. 3.6.5.2.

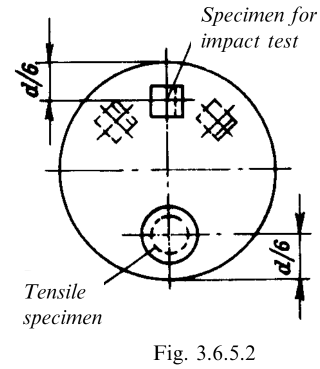


Fig. 3.6.5.2

The tests shall be carried out in accordance with the requirements of 2.2. Prior to the tests, the samples shall be heat-treated following the procedures corresponding to the heat treatment of finished chain cables in accordance with 7.1.3.4. The method and regime of the heat treatment shall be indicated by the chain cable manufacturer.

3.6.5.3 For chain cables of grades R3S and R4, tests of steel susceptibility to hydrogen embrittlement (reduction of ductility margin) shall be performed. For this purpose, two test samples are taken from each cast:

in the case of continuous casting — from metal corresponding to the beginning and the end of the cast section;

in the case of ingot making — from metal corresponding to any two ingots.

Tensile test specimens shall be cut from each sample representing the central part of rolled product (the rolled steel products shall be heat treated in the same conditions and shall preferably belong to the same furnace charge). Two tensile test specimens taken from a heat of steel shall be 20 mm in diameter (on agreement with the Register it is permitted to use specimens 14 mm in diameter). One of the two specimens shall be tested not less than 3 hours after production (for a specimen with a diameter of 14 mm, the time is 1,5 h). The other specimen shall be tested after being soaked for 4 hours at 250 °C (for a specimen with a diameter of 14 mm, the time is 2 h). Throughout the test up to the fracture of the specimen, the strain rate (change of percentage elongation in fractions of gage length of the specimen) shall be less than 0,0003 s^{-1} (which amounts to approximately 10 min for a specimen of 20 mm in diameter). Testing is carried out to determine the breaking stress, percentage elongation and percentage reduction. Test results shall comply with Table 3.6.3 (refer to Note 4 at the bottom of the Table). When the obtained value $Z/Z_1 < 0,85$, the metal presented for testing may be degassed on agreement with the Register, after which all the above testing shall be performed.

3.6.5.4 Mechanical tests results shall meet the requirements of Table 3.6.3.

Where the rest results are unsatisfactory, retests in accordance with 1.3.4.2 shall be carried out. In this case, the reheat treatment is allowed and the new tests may be performed on the metal taken from the material initially submitted for testing. If the retest results are positive, those previously obtained may be disregarded.

3.6.5.5 Recognizing the manufacturer of steel for chain cables of grades R3, R3S and R4 the steel resistance to strain ageing, temper brittleness and hydrogen embrittlement shall be confirmed by following procedures approved by the Register.

3.6.6 Inspection.

3.6.6.1 The tolerances for rolled bars shall be within the limits specified in Table 3.6.6.1.

3.6.6.2 Rolled bars shall be free from shrinkage holes, cracks, flakes (hairlines), folds, laps and scale and also other internal and surface defects that might impair proper workability and use.

The longitudinal noncontinuities, not more than 1 per cent of rolled bars diameter in depth, may be repaired by grinding with smooth transition to the surface.

Table 3.6.6.1

Nominal diameter, mm	Tolerance on diameter, mm	Tolerance on roundness, ($d_{max} - d_{min}$), mm
< 25	−0 +1,0	0,6
25—35	−0 +1,2	0,8
36—50	−0 +1,6	1,1
51—80	−0 +2,0	1,5
81—100	−0 +2,6	1,95
101—120	−0 +3,0	2,25
121—160	−0 +4,0	3,00

3.6.7 Non-destructive testing.

Rolled bars for chain cables of grades R3, R3S and R4 shall be subjected to 100 per cent ultrasonic testing and also to magnetic particle or eddy-current test according to standards approved by the Register.

On agreement with the Register, the scope of non-destructive testing may be reduced if the quality stability of rolled bars manufacturing is confirmed.

3.6.8 Marking and documentation.

Generally, the marking shall be made in accordance with the requirements of 1.4.

The marking content shall allow the identification of the supplied product and may be prescribed by the manufacturer. In this case, as a minimum, the marking shall indicate the grade and heat the rolled products belong to.

Round bars up to and including 40 mm in diameter may be supplied in bundles with the marking allowed to be made on labels (refer to 1.4).

Each batch of steel for Grade 2 and 3 chain cables shall be accompanied by the Register certificate. In individual cases pre-agreed with the Register, the supply of products with manufacturer's certificates witnessed by the Register representative may be allowed.

The manufacturer's certificate shall contain the following data:

certificate number;

order number;

hull number of ship or floating facility;

rolled products quantity and dimensions, batch weight;

specification for steel, and chain cable grade;

heat number;

manufacturing methods;

chemical composition;

procedure for sample heat treatment.

If needed, the protocols of tests performed may be attached to the certificate.

3.7 STEEL FORGINGS

3.7.1 General.

3.7.1.1 The present requirements are applicable to steel forgings intended for hull and machinery applications such as rudder stocks, pintles, propeller shafts, crankshafts, camshafts, connecting rods, piston rods, and other parts of machinery and gearing set forth in other parts of the Rules and having respective references to the present Chapter. Where relevant, these requirements are also applicable to material for forging stock and to rolled bars intended to be machined into components of simple shape.

3.7.1.2 The requirements of the present Chapter are applicable only to steel forgings (or rolled steel when used instead of steel forgings as specified in 3.7.1.1) where the designation is determined proceeding from the properties at ambient temperature. Additional requirements for the forgings intended for service at low or elevated temperatures shall be specially determined in each case.

3.7.1.3 Alternatively to the manufacturing of steel forgings (or rolled steel when used instead of steel forgings as specified in 3.7.1.1), forgings, which comply with national or proprietary specifications, may be accepted by the Register. In this case, according to the procedure specified in 1.3.1.2, the equivalence of these alternative requirements or their justification for the given manufacture and/or application shall be confirmed to the Register.

3.7.1.4 Steel forgings (or rolled steel when used instead of steel forgings as specified in 3.7.1.1) shall be made by the manufacturer recognized by the Register in compliance with 1.3.1.2. The steel used in the manufacture of the forgings shall be made by the process approved by the Register. Adequate top and bottom discards (of a rolled blank) shall be made to ensure freedom from piping and harmful segregations in the finished forgings.

3.7.1.5 The plastic deformation (reduction ratio) shall be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio shall be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, the plastic deformation reached during this operation may be considered.

Unless otherwise stipulated or agreed the total reduction ratio shall be at least:

for forgings made from ingot or from forged bloom or billet, using continuous casting plant — 3:1 where $L > D$ and 1,5:1 where $L \leqslant D$;

for forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \leqslant D$;

for forgings made by upsetting, the length after upsetting shall be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1,5:1, not more than one-half of the length before upsetting;

for rolled bars, 6:1,

where L and D are the length and diameter respectively of the part of the forging or its part.

3.7.1.6 For crankshafts, where grain flow is required in the most favourable direction having regard to the mode of stressing in service, the proposed method of manufacture is subject to agreement by the Register. In such cases, the Register may require to perform structure and grain flow tests.

3.7.1.7 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging shall be carried out before the final heat treatment. Preheating shall be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required.

3.7.1.8 When two or more forgings are joined by welding to form a composite component, the chemical composition and welding procedure shall be agreed by the Register; welding joints' procedure qualification tests may be required by the Register.

3.7.2 Chemical composition.

3.7.2.1 The chemical composition of steel for forgings shall be appropriate for the type of steel and the required mechanical and special properties of the forgings being manufactured.

The forgings shall be made from killed steel.

3.7.2.2 The chemical composition of each heat shall be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

3.7.2.3 The chemical composition shall comply with the requirements of Table 3.7.2.3-1 (for hull steel forgings) and Table 3.7.2.3-2 (for machinery steel forgings) or with the requirements of the specification agreed by the Register.

3.7.2.4 If not otherwise stated, grain refining elements such as aluminium, niobium or vanadium may be added at the discretion of the manufacturer. The content of such elements shall be reported in the results of the chemical analysis.

3.7.2.5 Elements designated, on the agreement with the Register, as residual elements shall not be contained in steel in great quantity. The content of such elements shall be reported in the results of the chemical analysis.

3.7.3 Mechanical properties.

3.7.3.1 Tables 3.7.3.1-1 and 3.7.3.1-2 give the minimum requirements of the Register for yield stress, elongation, reduction of area and impact test energy values corresponding to the different strength levels.

Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values required by the Register for the other properties specified in the above tables may be obtained by interpolation.

Forgings may be used where their properties are those established in the relevant standards recognized by the Register.

Table 3.7.2.3-1[1]

Steel type	C	Si	Mn	P	S	Cr	Mo	Ni	Cu[4]	Total residuals
Carbon, carbon-manganese	0,23[2, 3]	0,45	0,3 — 15	0,035	0,035	0,30[4]	0,15[4]	0,40[4]	0,30	0,85
Alloy[5]	—	0,45	—	0,035	0,035	—	—	—	0,30	—

[1] Composition in percentage mass by mass maximum unless shown as a range.
[2] The carbon content may be increased above this level, provided that the carbon equivalent (C_{eq}) is not more than 0,41 per cent, calculated using the following formula: C_{eq} (%) = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + V)/15.
[3] The carbon content of carbon and carbon-manganese steel forgings not intended for welded construction may be 0,65 per cent maximum.
[4] Element is considered as residual element.
[5] The content of C, Mn, Cr, Mo, Ni and the total content of residual elements shall be indicated in the specification to be submitted for agreement.

Note. Shaft and rudder stocks forgings shall be of weldable quality.

Table 3.7.2.3-2[1]

Steel type	C	Si	Mn	P	S	Cr	Mo	Ni	Cu[4]	Total residuals
Carbon, carbon-manganese	0,65[2]	0,45	0,3—1,5	0,035	0,035	0,30[3]	0,15[3]	0,40[3]	0,30	0,85
Alloy[4]	0,45	0,45	0,3—1,0	0,035	0,035	Min 0,40[5]	Min 0,15[5]	Min 0,40[5]	0,30	—

[1] Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
[2] The carbon content of carbon and carbon-manganese steel forgings intended for welded construction shall be 0,23 maximum. The carbon content may be increased above this level, provided that the carbon equivalent (C_{eq}) is not more than 0,41 per cent, calculated using the following formula: C_{eq} (%) = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + V)/15.
[3] Element is considered as residual element.
[4] Where alloy steel forgings are intended for welded constructions, the proposed chemical composition shall be indicated in the specification to be submitted for agreement.
[5] The content of one or more of the specified elements shall comply with the minimum content.

Table 3.7.3.1-1

Mechanical properties for hull steel forgings

Steel type	Tensile strength R_m, min, MPa	Yield stress R_e, min, MPa	Elongation A_5, min, %		Reduction of area Z, min, %	
			Longitudinal	Tangential	Longitudinal	Tangential
Carbon, carbon-manganese	400	200	26	19	50	35
	440	220	24	18	50	35
	480	240	22	16	45	30
	520	260	21	15	45	30
	560	280	20	14	40	27
	600	300	18	13	40	27
Alloy[5]	550	350	20	14	50	35
	600	400	18	13	50	35
	650	450	17	12	50	35

Note. The tensile strength values obtained at tensile testing shall not exceed the following:
120 MPa for the specified R_m < 600 MPa;
150 MPa for the specified $R_m \geqslant$ 600 MPa.

3.7.3.2 Hardness tests may be required by the Register on the following:

.1 gear forgings after completion of heat treatment and prior to machining the gear teeth.

The hardness shall be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2,5 m, the above number of test positions shall be increased to eight. Where the width of a gear wheel rim forging exceeds 1,25 m, the hardness shall be determined at eight positions at each end of the forging;

.2 small crankshaft and gear forgings, which have been batch tested.

In such cases at least one hardness test shall be carried out on each forging.

The results of hardness tests shall be reported to the representative of the Register. Corresponding Brinell hardness values are given in Table 3.7.3.1-2 for information purposes.

Table 3.7.3.1-2

Mechanical properties for machinery steel forgings[1]

Steel type	Tensile strength[2] R_m, min, MPa	Yield stress R_e, min, MPa	Elongation A_5, min, %		Reduction of area Z, min, %		Brinell hardness[3]
			Longitudinal	Tangential	Longitudinal	Tangential	
Carbon, carbon-manganese	400	200	26	19	50	35	110 — 150
	440	220	24	18	50	35	125 — 160
	480	240	22	16	45	30	135 — 175
	520	260	21	15	45	30	150 — 185
	560	280	20	14	40	27	160 — 200
	600	300	18	13	40	27	175 — 215
	640	320	17	12	40	27	185 — 230
	680	340	16	12	35	24	200 — 240
	720	360	15	11	35	24	210 — 250
	760	380	14	10	35	24	225 — 265
Alloy	600	360	18	14	50	35	175 — 215
	700	420	16	12	45	30	205 — 245
	800	480	14	10	40	27	235 — 275
	900	630	13	9	40	27	260 — 320
	1000	700	12	8	35	24	290 — 365
	1100	770	11	7	35	24	320 — 385

[1] For propeller shaft forgings except ships with categories **Ice1** and **Ice2** ice strengthening, impact testing shall be carried out for all steel types at −10 °C and the average energy value shall be minimum 27 J (*KV*) (longitudinal test). Not more than one specimen out of three may have value, which is 30 per cent below the required average value.
[2] The following ranges for tensile strength may be additionally specified:
the tensile strength values obtained at tensile testing shall not exceed the following:
150 MPa for the specified $R_m < 900$ MPa;
200 MPa for the specified $R_m \geqslant 900$ MPa.
[3] The hardness values are given for information purposes only.

Hardness tests may also be required on forgings, which have been induction hardened, nitrided or carburized. For gear forgings these tests shall be carried out on the teeth after, where applicable, they have been ground to the finished profile. The results of such tests shall comply with the documentation agreed and recognized by the Register (refer to 3.7.4.6).

3.7.3.3 Where the test results are unsatisfactory re-testing shall be conducted in accordance with 1.3.4.2.

3.7.4 Heat treatment (including surface hardening and straightening).

3.7.4.1 All the forgings shall be suitably heat treated to obtain the required mechanical properties and metal structure, and to refine the grain structure. The procedure of heat treatment shall be chosen by the manufacturer proceeding from the chemical composition of steel, the purpose and dimensions of the forging.

3.7.4.2 Except as provided in 3.7.5.7 and 3.7.5.8 forgings shall be supplied in one of the following conditions:

.1 carbon and carbon-manganese steels:
fully annealed,
normalized,
normalized and tempered,
quenched and tempered;

.2 alloy steels:
quenched and tempered.

The tempering temperature shall not be less than 550 °C. Where forgings for gearing are not intended for surface hardening, lower tempering temperature may be allowed.

3.7.4.3 Alloy steel forgings may be supplied in the normalized and tempered condition. In each case the specifications for forgings shall be agreed by the Register and confirmed by the results of control tests when necessary.

3.7.4.4 Heat treatment shall be carried out in properly equipped furnaces, which have adequate means for temperature recording. The furnace shall provide the required quality of operation and proper level of control over the process regardless of forging dimensions. In the case of very large forgings, or lack of the required equipment methods of heat treatment will be specially considered by the Register on a separate request.

3.7.4.5 If for any reasons a forging is subsequently heated for further hot working, the forging shall be reheat treated.

3.7.4.6 Where it is intended to surface harden forgings, the proposed procedure and specification shall be agreed by the Register. For this purpose the Register may require to carry out check tests to verify the uniformity and depth of surface layer (the verification of the required hardness and depth in the absence of soundness and change in the properties of the steel).

3.7.4.7 Where induction hardening or nitriding shall be carried out, forgings shall be heat treated at an appropriate stage and condition suitable for this subsequent surface hardening.

3.7.4.8 Where carburizing shall be carried out, forgings shall be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) and condition providing the required level of mechanical properties and hardening.

3.7.4.9 If a forging is locally reheated or any straightening operation is performed after the final heat treatment, it shall be heat treated to relive the subsequent stress.

3.7.4.10 The forge shall maintain records of heat treatment identifying conditions, the furnace used, furnace charge, time of charging, temperature and time at temperature. The records shall be presented to the Register on request.

3.7.5 Sampling.

3.7.5.1 The sample, sufficient for the required tests and for possible retest purposes, shall be provided with a cross-sectional area of not less than that part of the forging, which it represents. This sample shall be integral with each forging except as provided in 3.7.6.1.10 and 3.7.6.1.13. Where batch testing is permitted according to 3.7.6.1.13, the sample may alternatively be a production part or separately forged. Separately forged sample shall have dimensions not less than those of the forgings represented.

3.7.5.2 Generally, a tensile test specimen and, when required, a set of impact tests specimens shall be cut from a sample.

3.7.5.3 Test specimens shall normally be cut with their axes either mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

Unless otherwise agreed, longitudinal test specimens shall be cut the following way:

.1 for thickness or diameter up to maximum 50 mm, the axis shall be at the mid-thickness

or the center of the cross section;

.2 for thickness or diameter greater than 50 mm, the axis shall be at one-quarter thickness (1/4 of the diameter) or 80 mm, whichever is less, below any heat-treated surface.

3.7.6 Scope of testing.

3.7.6.1 Forgings shall be submitted for testing individually or in batches. Except as provided in 3.7.6.13 the number and direction of tests shall correspond to the listed below:

.1 hull forgings (such as rudder stocks, pintles, etc) and general machinery components (such as shafting, connecting rods, etc.):

one sample shall be taken from the end of each forging in a longitudinal direction except that, at the discretion of the manufacturer, the alternative directions or positions as shown in Fig. 3.7.6.1.1-1, 3.7.6.1.1-2 and 3.7.6.1.1-3 may be used.

where a forging exceeds both 4 tonnes in mass and 3 m in length, one set of tests shall be taken from each end. These limits refer to the "as forged" mass and length but excluding the sample material.

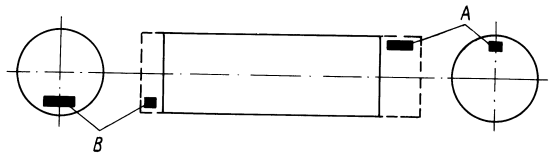


Fig. 3.7.6.1.1-1

B (through bolt hole)

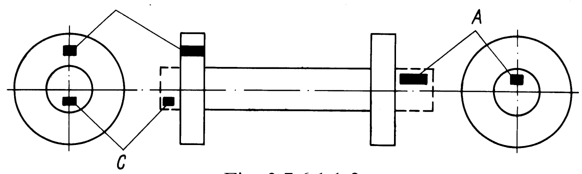


Fig. 3.7.6.1.1-2

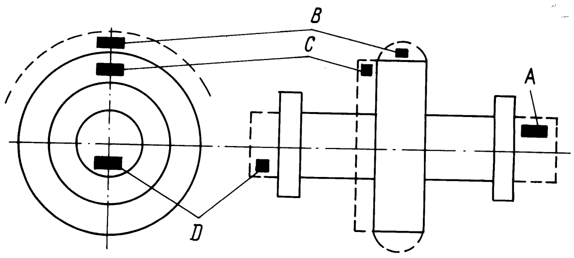


Fig. 3.7.6.1.1-3

.2 pinion forgings:

where the finished machined diameter of the toothed portion exceeds 200 mm, one sample shall be taken from each forging in a tangential direction adjacent to the toothed portion according to Fig. 3.7.6.1.2 (position B). Where the dimensions preclude sampling from position B, sample in a tangential direction shall be taken according to Fig. 3.7.6.1.2 (position C);

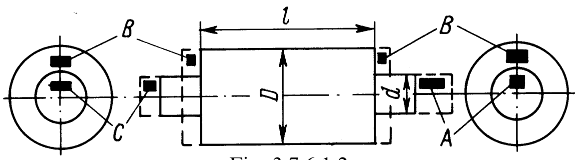


Fig. 3.7.6.1.2

if however, the journal diameter is 200 mm or less, the sample shall be taken in a longitudinal direction according to Fig. 3.7.6.1.2 (position A);

where the finished length of the toothed portion exceeds 1,25m, one sample shall be taken from each end;

.3 small pinion forgings:

where the diameter of the toothed portion is 200 mm or less, one sample shall be taken in a longitudinal direction according to Fig. 3.7.6.1.2 (position A);

.4 gear wheel forgings:

one sample shall be taken from each forging in a tangential direction according to Fig. 3.7.6.1.4 (position A or B);

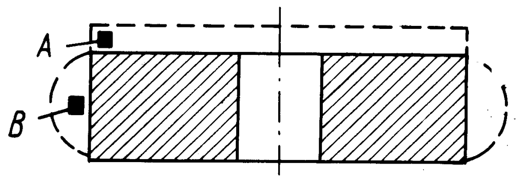


Fig. 3.7.6.1.4

.5 gear wheel rim forgings (made by expanding):

one sample shall be taken from each forging in a tangential direction according to Fig. 3.7.6.1.5 (position A or B);

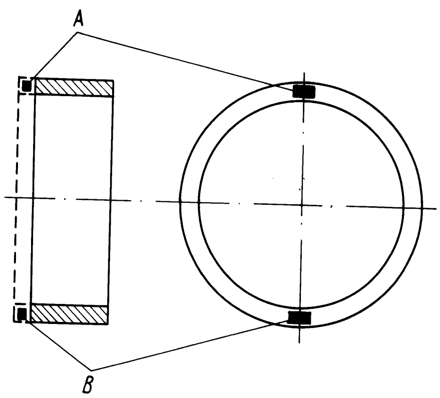


Fig. 3.7.6.1.5

where the finished diameter exceeds 2,5 m or the mass (as heat treated excluding test material) exceeds 3 tonnes, two samples shall be taken from diametrically opposite positions according to Fig. 3.7.6.1.5 (positions A and B).

The mechanical properties may as well be determined on longitudinal test specimens;

.6 pinion sleeve forgings:

one sample shall be taken from each forging in a tangential direction according to Fig. 3.7.6.1.6 (position A or B);

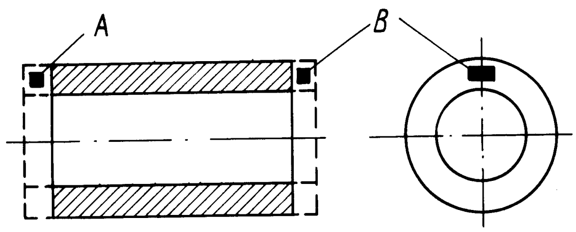


Fig. 3.7.6.1.6

where the finished length exceeds 1,25 m, one sample shall be taken from each end;

.7 crankweb forgings:

one sample shall be taken from each forging in a tangential direction;

.8 solid-forged crankshafts:

one sample shall be taken in a longitudinal direction from the driving shaft end (from coupling) of each forging according to Fig. 3.7.6.1.8 (position A);

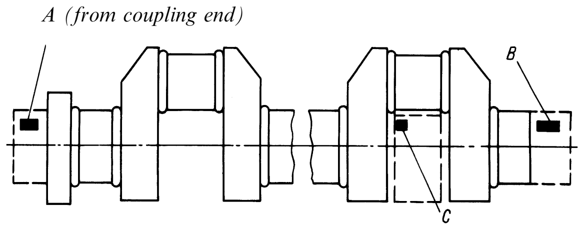


Fig. 3.7.6.1.8

where the mass (as heat treated but excluding test material) exceeds 3 tonnes, one sample in a longitudinal direction shall be taken from each end according to Fig. 3.7.6.1.8 (positions A and B);

where, however, the crankthrows are formed by machining or flame cutting, the second sample shall be taken in a tangential direction from material removed from the crankthrow at the end opposite the driving shaft end (from coupling) according to position C;

.9 forgings with grain flow in the most favorable direction where the method of manufacture is subject to special approval by the Register in accordance with 3.7.1.6:

the number and position of samples shall be agreed in the course of approval of respective procedure and recognition of the manufacturer;

.10 when a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required shall be related to the total length and mass of the original multiple forging;

.11 except for components, which shall be carburized, or for hollow forgings test material shall not be cut from a forging until all heat treatment has been completed;

.12 when forgings shall be carburized, sufficient test material shall be provided for both preliminary tests (after the forge) and for final tests after completion of carburizing. For this purpose duplicate sample shall be taken from positions as detailed in 3.7.6.1, except that irrespective of the dimensions or mass of the forging, tests are required from one position only and, in the case of forgings with integral journals, shall be cut in the longitudinal direction.

This test material shall be machined to a diameter of D/4 or 60 mm, whichever is less, where D is the finished diameter of the toothed portion.

For preliminary tests (after the forge) the samples shall be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging. For final acceptance tests, the rest of samples shall be blank-carburized and heat-treated along with the forgings, which they represent. At the discretion of the forge or gear manufacturer, test samples of larger cross section may either be carburized or blank-carburized, but these shall be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing the forgings to be carburized are subject to special consideration by the Register;

.13 normalized forgings with a mass up to 1000 kg each and quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch shall consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalized forgings and 3 tonnes for quenched and tempered forgings, respectively;

.14 a batch testing procedure may also be used for hot rolled bars. Batch quantity is determined proceeding from the following:

.14.1 material from the same rolled ingot or bloom provided that these are all heat treated in the same furnace charge;

.14.2 bars of the same diameter and heat, heat-treated in the same furnace charge and with a total mass not exceeding 2,5 tonnes;

.15 the preparation of test specimens and testing procedures shall comply with the relevant requirements of Section 2.

Unless otherwise agreed, all tests shall be carried out in the presence of the Register representative.

3.7.7 Inspection.

3.7.7.1 All forgings shall be presented to the Register representative for visual examination including, where necessary, the examination of internal surfaces and bores. Unless otherwise agreed, the verification of dimensions is the responsibility of the Manufacturer.

The forgings shall be free from defects, which would be prejudicial to their proper application.

3.7.7.2 When required by the relevant parts of the Rules or by the Register approved technical documentation, the forgings, including forged composite components, which shall be welded (refer to 3.7.1.8), appropriate non-destructive testing shall also be carried out. The results shall be reported to the Register representative and included in a relevant quality document of the manufacturer on a forging or batch.

The scope of testing and acceptance criteria shall be agreed with the Register.

3.7.7.3 When surface hardening of forgings is required (refer to 3.7.4.6), additional test samples may be selected at the time of inspection. These test samples shall be subsequently sectioned in order to determine the hardness, shape, area and depth of the locally hardened zone and which shall comply with the requirements of the Register approved documentation.

3.7.7.4 In the event of any forging proving defective in accordance with the Rules or Register approved documentation during subsequent machining or testing, it shall be rejected notwithstanding any available covering documents and certificates.

3.7.7.5 It is permitted to remove surface defects by grinding or chipping and grinding within mechanical allowances. The resulting grooves shall have a bottom radius of approximately three times the groove depth. Sharp contours are not permitted. Complete elimination of defective material shall be verified by magnetic particle or liquid penetrant testing.

3.7.7.6 Repair welding of forgings except crankshaft forgings is in each case subject to consideration by the Register. In such cases, procedure and location of the repair, subsequent heat treatment and inspection methods and criteria shall be approved by the Register.

3.7.7.7 The forging manufacturer shall maintain records of repairs and subsequent inspections, which results shall be shown in a drawing or sketch of the forging. Respective information shall be submitted to the Register representative at the latter's request.

3.7.8 Identification and marking.

3.7.8.1 The manufacturer of forgings shall adopt a system of identification, which will enable all finished forgings, at the stage of being submitted to the Register, to be traced to the original cast, and the data pertinent to the process of a particular forging (batch) manufacture, which shall be recorded during the above process, including heat treatment and repair, shall be presented to the Register representative on request.

3.7.8.2 All forgings shall be clearly marked in a specified place and in a specified manner with the Register stamp or brand to include at least the following particulars:

manufacturer's name or trade mark;

identification number or other marking, which will enable the full history of the forging to be traced;

steel grade.

3.7.8.3 Where small forgings are manufactured in large numbers, modified arrangements for identification may be specially agreed by the Register.

3.7.8.4 The manufacturer certificate to be submitted to the Register representative shall include the following particulars:

purchaser's name and order number;

steel grade and description of forgings;

identification number;

steelmaking process, cast number and chemical analysis of ladle sample;

results of mechanical tests;

results of non-destructive tests, where applicable;

details of heat treatment, including temperature and holding time.

3.8 STEEL CASTINGS

3.8.1 General.

3.8.1.1 Steel castings subject to survey by the Register, when produced in conformity with the relevant parts of the Rules, shall be manufactured and tested in accordance with the requirements stated below.

3.8.1.2 These requirements are applicable to carbon and carbon-manganese steel castings used in hull and ship machinery construction, the purpose of which shall be established proceeding from their properties determined at room temperature.

3.8.1.3 The requirements for castings to be used at low or high temperature, as well as for alloy steel castings with special properties (corrosion resistance, heat resistance, high temperature oxidation resistance, etc.) will be specially considered by the Register in each case. The documents submitted to the Register for approval shall contain detailed information on the chemical composition, mechanical and special properties, heat treatment procedures and scope of testing the castings.

3.8.1.4 When two or more castings are joined by welding to form a composite item, the chemical composition of steel and the welding procedure are subject to approval by the Register. The Register may require technological tests of the welded joints to be carried out.

3.8.1.5 The castings shall be manufactured at works recognized according to 1.3.1.2 in conformity with the procedure approved by the Register. Use of surface hardening in the production process shall be also agreed with the Register.

3.8.2 Chemical composition.

3.8.2.1 The chemical composition of a particular type of steel will be established proceeding from the mechanical and special properties required. The castings shall be made from killed steel.

3.8.2.2 For carbon and carbon-manganese steel castings the chemical composition of ladle samples shall comply with the requirements of Table 3.8.2.2 and/or of the documents (specifications, standards, etc.) agreed with the Register.

3.8.2.3 Unless otherwise required, suitable grain-refining elements may be used at the discretion of the manufacturer. The content of such elements shall be reported in the ladle analysis.

3.8.3 Mechanical properties.

3.8.3.1 The mechanical propertied of steel castings shall meet the requirements of Table 3.8.3.1 and/or of documentation approved by the Register. Table 3.8.3.1 give minimum values of yield stress, elongation and reduction of area established depending on the required level of the tensile strength values for the steel castings.

3.8.3.1

Tensile strength R_m, MPa, min	Yield stress R_{eH} or $R_{p0,2}$, MPa	Elongation A_5, %	Reduction of area Z, %
400	200	25	40
440	220	22	30
480	240	20	27
520	260	18	25
560	300	15	20
600	320	13	20

Notes: 1. Minimum yield stress value 250 MPa is allowed.
2. For intermediate tensile strength values, the minimum values of yield stress, elongation and reduction of area may be

3.8.3.2 Where tensile test results are unsatisfactory, retesting shall be conducted in compliance with the requirements of 1.3.4.2.

3.8.4 Heat treatment.

3.8.4.1 To ensure the required structure and mechanical properties the castings shall undergo heat treatment. The procedure of heat treatment shall be chosen by the manufacturer proceeding from the chemical composition of steel, the purpose and shape of the castings. The following conditions shall be observed:

the tempering temperature shall not be less than 500 °C;

the stress relief heat treatment of castings for components such as crankshafts and engine bedplates where dimensional stability and freedom from internal stresses are important, shall be carried out at a temperature of not less than 550 °C followed by furnace cooling to 300 °C or lower;

if a casting is reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required by the Register.

3.8.4.2 As a rule, the steel castings shall be supplied in the following condition:

completely annealed,

after normalizing.

after normalizing and tempering,

after quenching and tempering.

All necessary data on the heat treatment process including procedures and appropriate instrument readings shall be submitted to the Register representative on his demand.

3.8.2.2

Steel grade	Application	C, max	Si, max	Mn, max	S, max	P, max	Residual elements, max				Total number of residual elements
							Cu	Cr	Ni	Mo	
Carbon, carbon-manganese	Non-welded structures	0,40	0,60	0,50 — 1,60	0,040	0,040	0,30	0,30	0,40	0,15	0,80
	Welded structures	0,23	0,60	1,60	0,040	0,040	0,30	0,30	0,40	0,15	0,80

3.8.4.3 In case where steel casting after final heat treatment is subjected to local heating or to operations producing additional strain, heat treatment may be required to relieve residual stress.

3.8.5 Sampling.

3.8.5.1 Sampling may be effected directly from the casting or the test samples may be cast to it. They shall have a thickness not less than 30 mm.

The use of separately cast samples is permitted, in which case the dimensions of the sample shall correspond to the casting dimensions.

3.8.5.2 Where two or more test samples shall be provided for a casting they shall be cast at locations as widely separated as possible.

3.8.5.3 The samples shall be heat treated together with the castings, which they represent.

3.8.5.4 The size of samples shall be such as to ensure the performance of tests including re-tests, if required. All samples shall be identified.

3.8.6 Scope of testing.

3.8.6.1 At least one test sample shall be provided for each casting. Where one casting is made from several casts (without mixing) the number of samples shall be equal to the number of casts involved. The condition of 3.8.5.2 shall be met in this case.

Where the casting is of complex design or where the finished mass exceeds 10 t, at least two test samples shall be provided.

3.8.6.2 A batch testing procedure may be adopted for castings. A batch shall consist of castings of approximately the same size and shape made from one cast and heat treated in the same furnace charge and having the total mass equal to or less than 1000 kg.

Such batch may be represented by one of the castings considered as a test sample or by a separately cast sample, the dimensions of which shall correspond to the castings comprising the batch.

3.8.6.3 Unless otherwise specified, at least one tensile test specimen shall be taken from each test sample.

Test specimens shall be prepared and the tests conducted in conformity with the requirements of Section 2. Unless otherwise stated, tests shall be conducted in presence of the Register representative.

3.8.6.4 Where the tensile tests yield unsatisfactory results the tests shall be repeated on two additional specimens preferably cut out from the same sample. On agreement with the Register, specimens may be cut out from other sample or casting.

Where the tests carried out on two additional specimens yield satisfactory results, the casting and the batch if represented by the casting shall be accepted.

Where the test result on at least one of two additional specimens is unsatisfactory, the casting submitted shall be rejected. However, the remaining semi-finished products of the batch may be accepted by the Register, provided that satisfactory test results are obtained on two more castings comprising the batch involved. Where unsatisfactory test results are obtained on one of two additionally selected castings, the entire batch shall be rejected.

At the manufacturer's discretion, the batch or casting rejected may be submitted to re-tests on the same conditions after repeated heat treatment.

3.8.6.5 Where relevant requirements shall be found in other parts of the Rules, the castings shall be subjected to additional tests, such as pressure tests.

Where upon completion of all tests, owing to machining of the castings or as a result of any structural tests a defect is found, which interferes with the use of casting for its designated purpose, the batch shall be rejected irrespective of the availability of the relevant certificates.

3.8.7 Inspection.

3.8.7.1 The castings submitted for inspection and control testing shall be cleaned, de-gated, free of risers and burrs, etc.

The castings shall be free from defects, which would be prejudicial to their proper application in service.

Unless otherwise specified, the responsibility for fulfilment of the requirements for dimensions of the castings shall be imposed on the manufacturer of the castings.

3.8.7.2 Where relevant requirements shall be found in other parts of the Rules or following the instructions of a Surveyor the castings shall undergo non-destructive testing. The testing procedure and the allowances for defects shall be in conformity with documentation approved by the Register.

3.8.7.3 Surface defects lying within machining allowances may be removed by machining.

3.8.7.4 Defects may be repaired by welding in accordance with 2.6.3, Part XIV "Welding". Prior to carrying out weld repairs of large-sized defects, alloy steel castings, castings for crankshafts and for other main components shall be pre-heated in accordance with 3.8.4; if required by the Surveyor, the welded spots shall be subjected to non-destructive testing.

3.8.7.5 The size, number of defects accepted uncorrected as well as of defects to be corrected shall be established on agreement with the Register.

The procedure of repair and subsequent inspection including, if necessary, welding is subject to agreement with the Register. All work shall be performed by the qualified personnel.

Repair welding shall be performed with the use of welding consumables recognized by the Register, which ensure properties of the deposited metal not inferior than those of the casting metal.

On completion of the repair welding, the castings shall be subjected to heat treatment to relieve residual stress at temperature not lower than 550 °C. The type and procedure of heat treatment depends on the type and nature of repair work performed previously as well as on the material and size of the castings. Refusal to carry out the above postweld heat treatment is generally acceptable for small scopes of repair and is subject to special consideration of the Register in each case.

3.8.7.6 Upon completion of the repair welding of the castings, the magnetic powder or dye penetrant inspection shall be carried out. Additional ultrasonic or radiographic examination may be required depending on the nature and size of surface defects detected.

Inspection and examination criteria are also subject to agreement with the Register.

3.8.7.7 All repair works and their results shall be documented and available for the Register representative.

3.8.8 Marking and documentation.

3.8.8.1 The manufacturer of the castings shall have an identification system, which enables to identify the casting with the ladle at a stage of submission to the Register, while upon the request of the Register representative, the manufacturer shall present the data, recorded in course of manufacture referred to the production process of a particular casting, or a batch, including thermal treatment and repair.

3.8.8.2 Every casting shall have clearly visible stamp or brand of the Register marked by the specified method and in specified location, and, at least, shall contain the following data:

name or designation of the manufacturer;

number or other marking, which enables to identify the presented material and the process of its production;

grade or mark of steel.

3.8.8.3 Where small castings are manufactured in large numbers the castings identification system may be agreed with the Register separately.

3.8.8.4 Manufacturer certificate, submitted to the Register representative, shall contain the following data:

name of purchaser and number of purchase order;

grade, (mark) of steel, type of casting;

identification number;

steel melting process, heat number and chemical composition per the ladle test;

mechanical test results;

non-destructive test results, if necessary;

heat treatment type, including temperature and time at temperature.

3.9 SPHEROIDAL OR NODULAR GRAPHITE IRON CASTINGS

3.9.1 General.

3.9.1.1 As defined in the relevant parts of the Rules, all spheroidal or nodular graphite iron castings subject to survey by the Register during their manufacture shall be manufactured and tested in accordance with the requirements of the following paragraphs. If agreed with the Register and 3.1.2 is followed, castings may be manufactured according to national standards or works specifications.

3.9.1.2 These requirements are applicable to sphe-roidal or nodular graphite iron castings used in hull and ship machinery construction. The purpose of the castings shall be established proceeding from their properties at room temperature.

3.9.1.3 The requirements for castings intended for service at low or elevated temperatures will be specially considered by the Register in each case. In this case, detailed information on the chemical composition, mechanical and special properties, heat treatment, methods and scope of testing the castings shall be submitted to the Register.

3.9.1.4 Where castings of the same type are regularly produced in quantity, alternative procedures for testing and scope of testing may be adopted subject to approval of the Register, provided that the manufacturer verifies the continued efficiency of the manufacturing technique and the quality of castings.

3.9.1.5 Castings subject to survey by the Register shall be manufactured at works recognized by the Register as mentioned in 1.3.1.2.

3.9.1.6 For removal of risers and for castings grinding the relevant metal machining methods may be used. The methods exerting a thermal effect on casting quality are not allowed with the exception of their use as preliminary before machining.

3.9.1.7 When finished, castings shall be free of defects unfavourably effecting their use and shall be in full compliance with the approved documentation for delivery.

3.9.2 Chemical composition.

3.9.2.1 The chemical composition is left to the discretion of the manufacturer who shall ensure that it is suitable for obtaining the mechanical properties specified for the castings.

When required by the Register, the chemical composition of ladle samples shall be reported.

3.9.3 Mechanical properties.

3.9.3.1 The mechanical properties of the castings shall conform to Table 3.9.3.1.

While effecting the tensile test of the casting material the tensile strength and elongation shall be determined.

Table 3.9.3.1

Mechanical properties and structure of nodular graphite iron

Tensile strength[1] R_m, MPa, min		Upper yield stress $R_{p0,2}$, MPa, min	Percentage elongation A_5, %, min	Brinell hardness	Impact energy		Structure[4]
					Test temperature, °C	KV[2], J, min	
Normal quality	370	230	17	120 — 180	—	—	
	400	250	15	140 — 200	—	—	Ferrite
	500	320	7	170 — 240	—	—	Ferrite/ Perlite
	600	370	3	190 — 270	—	—	Ferrite/ Perlite
	700	420	2	230 — 300	—	—	Perlite
	800	480	2	250 — 350	—	—	Perlite structure or structure after tempering
Special quality	350	220	22 [3]	110 — 170	+20	17 (14)	Ferrite
	400	250	18 [3]	140 — 200	+20	14 (11)	Ferrite

[1] For intermediate tensile strength values the minimum values of elongation and upper yield stress may be determined by linear interpolation.
[2] When tests are carried out on three Charpy V-notch type test specimens, the impact energy mean value is given. It is allowed to lower the impact energy value for one of the three test specimens in comparison with data in Table, but not less than given in brackets.
[3] When tensile tests are carried out on test specimens out of cast-on samples, the ultimate values of elongation may be lowered by 2 per cent of the given value.
[4] Data for consideration.

The minimum required tensile strength shall be stated in the agreed technical documentation for the casting, but in no case shall it exceed the limits detailed in Table 3.9.3.1. Additional requirements of the relevant parts of the Rules are also to be complied with.

Where mechanical test results are unsatisfactory, retesting shall be conducted in compliance with the requirements of 1.3.4.2.

3.9.3.2 Where impact testing is required, the standards and type of specimen shall be approved by the Register.

3.9.3.3 The microstructure of the castings shall include not less than 90 per cent of spheroidal or nodular graphite. No flaked graphite is permitted.

3.9.4 Heat treatment.

3.9.4.1 The castings shall be supplied in either as the cast or heat treated condition.

The necessity of heat treatment and the relevant procedure shall be determined by the manufacturer on the basis of chemical composition, purpose and shape of the castings.

For the purpose of structure refining or stress relieving, obligatory heat treatment may be required by the Register. The heat treatment for stress relieving shall follow the heat treatment for structure refining and to procede the machining. Special quality castings having the tensile strength 350 and 400 MPa and the relevant necessary impact energy value shall undergo ferritizing.

3.9.4.2 Where it is proposed to locally harden the surfaces of a casting, full details of the proposed procedure and specification shall be submitted to the Register for consideration.

3.9.5 Sampling.

3.9.5.1 The test samples may be either gated to the casting or separately cast. The dimensions of the samples, when cast separately, shall be in accordance with Figs. 3.9.5.1-1, 3.9.5.1-2 and 3.9.5.1-3 (dimensions are given in mm); the sample length *z* shall be chosen proceeding from the type of the machine for tensile testing.

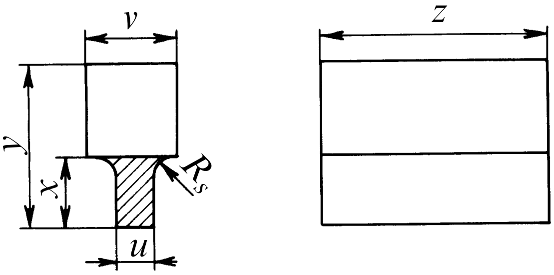


Fig. 3.9.5.1-1 Standard specimen and alternative specimens with dimensions:

Dimensions	Standard specimen	Alternative specimens		
u	25	12	50	75
v	55	40	90	125
x	40	30	60	65
y	100	80	150	165
z	to suit testing machine (for all specimens)			

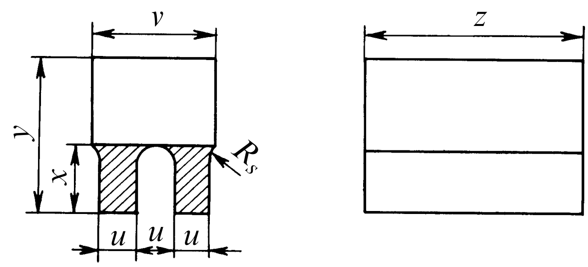


Fig. 3.9.5.1-2 Standard specimen with dimensions: *u* — 25; *v* — 90; *x* — 40; *y* — 100; *z* — to suit testing machine

Subject to agreement with the Register, the samples may have alternative dimensions or they may be taken directly from one of the castings forming the batch.

Thickness of the mould surrounding a standard specimen shall not be less than 40 mm, and for

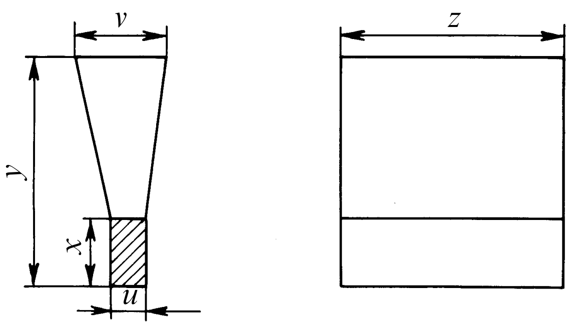


Fig. 3.9.5.1-3 Standard specimen and alternative specimens with dimensions:

Dimensions	Standard specimen	Alternative specimens		
u	25	12	50	75
v	55	40	90	125
x	40	30	50	65
y	140	135	150	175
z	to suit testing machine (for all specimens)			

alternative samples, not less than 40, 60 and 80 mm respectively.

Where separately cast test samples are used, they shall be cast in moulds made from the same type of material as used for the castings and shall not be stripped from the moulds until the metal temperature is below 500 °C.

3.9.5.2 When castings are supplied in the heat treated condition, the test samples shall be heat treated together with the castings, which they represent.

3.9.5.3 Samples for metallographic examination may conveniently be taken from the tensile test specimens, but separately cast samples may be prepared, provided that they are taken from the ladle towards the end of the casting period.

3.9.6 Scope of testing.

3.9.6.1 At least one sample shall be taken from each casting. If metal from several ladles is used for a casting, one sample shall be taken from each ladle.

3.9.6.2 A batch testing procedure may be adopted for castings with the fettled mass of 1 t or less. All castings in a batch shall be of similar type and dimensions, cast from the same ladle of treated metal. One separately cast test sample shall be provided for each multiple of 2 t of fettled castings in the batch.

3.9.6.3 At least one tensile test specimen, shall be prepared from each test sample according to 2.2.2.3 and, where required, a set of Charpy V-notch type test specimens for impact tests according to 2.2.3.1.

3.9.6.4 Where the castings are subject to pressure testing for tightness, both the working and test pressure shall be stated in the technical documentation.

3.9.7 Inspection.

The castings shall be submitted for inspection and control testing in cleaned and de-gated condition, free from risers, etc.

The castings shall be free from defects, which would be prejudicial to their application in service. In general, repairing of defects by welding is not permitted. Subject to approval by the Surveyor, surface imperfections may be removed by grinding. Where there is reason to suspect the soundness of the casting, examination by suitable non-destructive testing procedure may be required. Crankshafts shall undergo magnetic particle testing and metallographic examination.

3.9.8 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 3.8.8.

3.10 GREY IRON CASTINGS

3.10.1 General.

3.10.1.1 All grey iron castings subject to survey by the Register, as defined in the relevant parts of the Rules, shall be manufactured and tested in accordance with the requirements of the following paragraphs.

3.10.1.2 The present requirements apply to grey iron castings used in hull and ship machinery construction.

3.10.1.3 Where castings of the same type are regularly produced in quantity, the manufacturer may adopt alternative procedures for, and scope of, testing subject to approval of the Register and provided that the continued efficiency of the manufacturing technique and the quality of castings is verified.

3.10.1.4 If agreed with the Register and on condition that 3.1.2 is followed, castings may be manufactured in compliance with national standards and works specifications.

3.10.1.5 Castings subject to the Register survey shall be manufactured at works recognized by the Register, as stated in 1.3.1.2.

3.10.2 Chemical composition.

The chemical composition is left to the discretion of the manufacturer, who shall ensure that it is suitable for obtaining the mechanical properties specified for the castings.

When required by the Register, the chemical composition of ladle sample shall be reported.

3.10.3 Mechanical properties.

When carrying out the tensile test of the casting material (according to 2.2.2.4) the tensile strength shall be determined. The specified minimum tensile strength shall be stated in the technical documentation for the casting, but in no case it shall be less than 200 MPa. Any additional requirements of the relevant parts of the Rules shall also be complied with.

Where tensile test results are unsatisfactory, retesting shall be conducted in compliance with the requirements of 1.3.4.2.

3.10.4 Heat treatment.

Castings may be supplied in either as the cast or heat treated condition.

The necessity of heat treatment and the relevant procedure shall be determined by the manufacturer on the basis of chemical composition, purpose and shape of the castings.

For the purpose of structure refining or stress relieving, obligatory heat treatment may be required by the Register. The heat treatment for stress relieving shall follow the heat treatment for structure refining and to precede the machining.

3.10.5 Sampling.

3.10.5.1 Unless otherwise agreed between the manufacturer and the Customer, cast samples shall have the form of cylindrical bars 30 mm in diameter and of a suitable lenght. They shall be cast from the same ladle as the castings in moulds of the same type of material as the moulds for the castings and shall not be stripped from the moulds until the metal temperature is below 500 °C.

If two or more test samples are cast in one mould at the same time, the rod diameter shall not be less than 50 mm and they shall be located as specified in Fig. 3.10.5.1 (dimensions are given in mm).

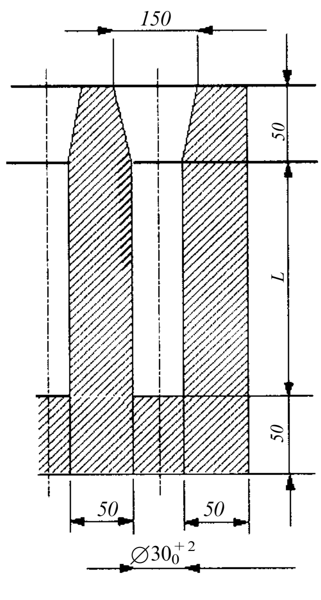


Fig. 3.10.5.1

Subject to approval by the Register, the samples of alternative dimensions may be used, they may be gated to or taken directly from the castings.

As a rule, cast-on samples may be used if the casting wall thickness is over 20 mm and its mass exceeds 200 kg. In addition, the sample type and location shall ensure roughly the same cooling conditions similar to the base casting cooling and are subject to the manufacturer's agreement with a customer.

3.10.5.2 Where castings are supplied in the heat treated condition, the test samples shall be heat treated together with the castings, which they represent.

3.10.5.3 One tensile test specimen shall be prepared from each sample.

3.10.6 Scope of testing.

3.10.6.1 From each casting at least one sample shall be taken. Where metal from several ladles is used for a casting, one sample shall be taken from each ladle.

3.10.6.2 All castings in the batch shall be of similar type and dimensions, and cast from the same ladle of metal. As rule, the batch mass shall not exceed 2 t of fettled castings; separate castings with a mass equal to or over 2 t also form a batch.

At continuous casting of iron of the very same grade and in large quantities, the batch mass may be limited by the metal cast within two hours.

The batch volume and number of samples taken are subject to an agreement with the Register.

3.10.6.3 Where the castings are subject to pressure testing for tightness, both the working and test pressure shall be stated in the technical documentation.

3.10.7 Inspection.

The castings shall be submitted for inspection and control testing in cleaned and de-gated condition, free from risers, etc.

The castings shall be free from defects, which would be prejudicial to their proper application in service. In general, repairing of defects by welding is not permitted. At the discretion of the Surveyor, small surface blemishes may be removed by local grinding. Where these is reason to suspect the soundness of the casting, examination by suitable non-destructive testing procedures may be required.

3.10.8 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 3.8.8.

3.11 MALLEABLE CAST IRON

3.11.1 General.

Malleable cast iron may be used for the manufacture of parts for hull and ship machinery construction that are subject to survey by the Register and are intended to operate at a temperature not exceeding 300 °C and the working pressure not exceeding 2 MPa.

3.11.2 Chemical composition and mechanical properties.

The chemical composition, mechanical properties and scope of testing of items made of malleable cast iron shall be agreed with the Register in each case.

3.11.3 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 1.4.

3.12 STEEL CASTINGS FOR PROPELLERS

3.12.1 General.

3.12.1.1 The requirements of the present Chapter apply to steel castings for cast propellers, blades and bosses during their manufacture. Subject to the special consideration by the Register, these requirements may also be applied in the repair of propellers damaged in service.

The use for propellers of steel according to national standards or other technical requirements, which is different in chemical composition, mechanical properties or heat treatment from, specified here is subject to the special consideration by the Register. In such cases, national standards shall be approved by the Register.

3.12.1.2 Propeller castings shall be manufactured by the works recognized by the Register in accordance with 1.1.4 and 1.3.2. Specifications for material, the description of a technological process, repair and inspection shall be attached to a request for material.

3.12.1.3 Recognizing the works, tests are conducted in accordance with 1.3.1.2 on the basis of the survey and tests program approved by the Register. The tests shall confirm the compliance of castings material and their quality with these requirements.

3.12.1.4 A foundry shall have available a properly equipped laboratory manned with experienced qualified personnel. The laboratory shall have at its disposal everything necessary for the performance of non-destructive testing. However, if the laboratory is unable to conduct tests and inspection, the data on an independent laboratory shall be submitted to the Register. The laboratory shall be recognized by the competent national body and/or Register.

3.12.2 Chemical composition.

The chemical composition of the steel for propellers shall meet the requirements of Table 3.12.2. The alloys in Table are subdivided into four main groups.

Table 3.12.2

Chemical composition of steel for propeller castings[1]

Steel grade and type	C, %, max	Mn, %, max	Cr, %	Mo, %, max	Ni, %
Martensitic (12Cr1Ni)	0,15	2,0	11,5 — 17,0	0,5	Max 2,0
Martensitic (13Cr4Ni)	0,06	2,0	11,5 — 17,0	1,0	3,5 — 5,0
Martensitic (16Cr5Ni)	0,06	2,0	15,0 — 17,5	1,5	3,5 — 6,0
Austenitic (19Cr11Ni)	0,12	1,6	16,0 — 21,0	4,0	8,0 — 13,0

[1] The minimum elements content not specified in Table shall meet the requirements of recognized national or international standards.

3.12.3 Mechanical properties and heat treatment.

3.12.3.1 The mechanical properties of steel during the testing of specimens machined from integrally cast test bars attached to the hub or blade shall meet the requirements of Table 3.12.3.1.

Table 3.12.3.1

Mechanical properties of steel castings for propellers

Steel grade and type	Proof stress $R_{p0,2}$, MPa, min	Tensile strength R_m, MPa, min	Percentage elongation A_5, %, min	Percentage reduction of area Z, %, min	Impact test[1], KV, J, min
Martensitic (12Cr1Ni)	440	590	15	30	20
Martensitic (13Cr4Ni)	550	750	15	35	30
Martensitic (16Cr5Ni)	540	760	15	35	30
Austenitic (19Cr5Ni)	180 ($R_{p1,0}$ 205)	440	30	40	—

[1] The impact test is not required for the ships of **Ice1**, **Ice2** and **Ice3**; ice categories; for all other ships with ice strengthening and for icebreakers, steel castings shall be impact-tested at −10 °C.

3.12.3.2 The level of mechanical properties of the separately cast samples metal is subject to the special approval by the Register.

3.12.3.3 Heat treatment.

Castings of martensitic class steel shall be subjected to austenization and tempering. Austenitic class steels shall be subjected to solution treatment.

3.12.4 Sampling.

3.12.4.1 Samples may be taken immediately from a casting or gated to it. Test specimens, where possible, are taken from the cast-on sample in the area within 0,5R to 0,6R (where R is a propeller radius). The use of separately cast samples to machine specimens is subject to approval by the Register.

3.12.4.2 Separately cast samples shall be taken from the same ladle as the casting as the metal presented and heat treated in the same furnace charge.

In the initial survey of a works in accordance with 3.12.1.2, tests may be conducted in the metal of both separately cast samples and gated to or taken directly from a casting body.

3.12.4.3 Samples shall not be taken from a casting prior to a final heat treatment. Samples are machined in accordance with the standards recognized by the Register.

3.12.4.4 Thermal methods shall not be used for sampling.

3.12.5 Number of tests.

3.12.5.1 At least one tensile test specimen (refer to Table 2.2.2.3) and one set of impact test specimens (refer to 2.2.3) shall be taken from each cast presented. In tensile tests, the tensile strength, proof stress, percentage elongation and reduction of area are determined. Test are conducted in compliance with the requirements of 2.2.

3.12.5.2 Test specimens shall generally be cut out from cast-on samples. If castings are roughly of the same size, less than 1 m in diameter made from metal of one cast and heat treated in one furnace charge, one set of specimens for each 5 castings may be taken from separately cast samples of the relevant dimensions.

3.12.6 Severity zones (repair zones).

3.12.6.1 In order to define the criteria of assessment for propeller defects, the blade surface is divided into three zones designated *A*, *B* and *C* (refer to Figs. 4.2.6.2.1 and 4.2.6.3). The definitions of repair zones are given in 4.2.6.2 and 4.2.6.3.

3.12.6.2 The definition of a skew angle — refer to 4.2.6.1 (Note) and Fig. 4.2.6.1.

3.12.7 Inspection.

3.12.7.1 Propeller castings shall be visually inspected at all the stages of their manufacture. The castings shall be subjected to a thorough 100 per cent visual inspection in the finished condition (the inspection is conducted by the Register representative). A surface shall be free from the defects, which may result in propeller damages during operation. The Register representative can demand the performance of investigation of questionable surface sections including metal etching, particularly prior to repair welding.

3.12.7.2 Dimensions, dimensional and geometrical tolerances shall meet the requirements of the drawings approved by the Register and of order documentation. The above documents and the results of measurements and inspection drawn up in the form of a report or statement are produced to the Register representative during tests. The responsibility for the performance of measurements with an appropriate accuracy for their compliance with the requirements of the drawing and/or order rests with a manufacturer. The Register representative has a right to demand checking measurements.

In accordance with the requirements of the Register-approved documentation, all propellers shall be subjected to static balancing. Dynamic balancing is required for propellers running with a rotational speed of over 500 rpm.

3.12.7.3 Non-destructive testing.

3.12.7.3.1 All the castings of propellers shall be subjected to non-destructive testing. A manufacturer shall have available an appropriate system to record all the non-destructive inspection results for each casting. The Register representative shall be familiarized with that system and the results of the testing carried out. The manufacturer duty shall confirm in the documentary form the true performance and the positive results of non-destructive testing methods.

3.12.7.3.2 Dye-penetrant testing.

Dye-penetrant testing shall be conducted in accordance with the standards or specification approved by the Register. The following definitions therewith are recommended to use:

Reference area is an area of 100 cm^2, which may have square or rectangular shape with the major dimension not exceeding 250 mm. In evaluation of surface quality by a dye-penetrant inspection method, the entire controlled surface is conventionally divided in reference areas of 100 cm^2 each. Segmentation shall be the most unfavourable in relation to indications, i.e. the shape and dimensions of each reference area shall be chosen so that it covers the maximum number of defects without their distribution among adjacent reference areas.

The indications detected in any of such areas with respect to their shape, dimensions and number shall meet the requirements of Table 3.12.7.3.2.

Table 3.12.7.3.2

Allowable number and size of indications depending on severity zone

Severity zone	Total number of indications, max	Indication type	Number of indications of each type, max	Indication size, mm, max
A	7	non-linear	5	4
		linear	2	3
		aligned	2	3
B	14	non-linear	10	6
		linear	4	6
		aligned	4	6
C	20	non-linear	14	8
		linear	6	6
		aligned	6	6

Notes: 1. Singular non-linear indications less than 2 mm in zone *A* and less than 3 mm in other zones may be disregarded.
2. The total number of non-linear indications may be increased to the total allowable number of all type indications, represented by the absence of linear or aligned indications. The total number of non-linear indications may also be increased due to the partial lack of linear or aligned indications retaining the total allowable number of indications.

Indication is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied.

Nonlinear indication is the indication of a circular or elliptical shape with a length less than three times the width (refer to Fig. 4.2.7.3.1(1)).

Linear indication is the indication, in which the length is at least three times the width (refer to Fig. 4.2.7.3.1(2)).

Threshold sensitivity is the opening of a discontinuity like the isolated crack of a certain length detected with the given probability according to the given geometrical and optical parameters of an indication. The indication, any dimension of which is over 1,5 mm, may be considered as the isolated indication taken into account.

Aligned indication is three or more indications in a line separated by 2 mm or less edge-to-edge — (refer to Fig. 4.2.7.3.1(3)).

3.12.7.3.3 Radiographic and ultrasonic inspection.

Where serious doubts exist that castings are not free from internal defects, further radiographic and/or ultrasonic inspections shall be carried out upon request of the Register representative. The evaluation and acceptance criteria shall be agreed between a manufacturer and the Register in accordance with the standards approved by the Register.

3.12.8 Repair of defects.

3.12.8.1 Surface discontinuities, which impair propellers performance, shall be repaired by mechanical methods, e.g. by grinding, chipping and milling. The use of welding to repair defects is allowed only in justified cases to be agreed with the Register representative.

The repair of defects shall be carried out after producing the documentation with the full description of works to be conducted, to the Register representative. The relevant repair zones, dimensions and location of defects, methods of their repair and inspection shall be specified.

After milling or chipping, grinding shall be applied for such defects, which shall not be welded. The grinding shall be carried out in such a manner that the contour of the ground depression is as smooth as possible to avoid stress concentration and/or minimize cavitation corrosion. The metal for welding shall be properly selected and shall have the shape and dimensions needed for welding. The welding of areas less than 5 cm^2 shall be avoided.

3.12.8.2 Repair of defects in zone *A*.

In zone *A*, repair welding is not allowed.

Grinding in zone *A* may be carried out to the extent, which maintains the blade thickness of the drawing approved by the Register. The possible repair of defects by methods not specified here shall be specially considered by the Register.

3.12.8.3 Repair of defects in zone *B*.

The defects that are not deeper than dB = $t/40$ (t = minimum local thickness) or 2 mm (whichever is greater) may be removed by grinding. The defects, which are deeper than allowable for removal by grinding, may be repaired by welding.

3.12.8.4 Repair of defects in zone *C*.

In zone *C*, repair welds are generally permitted.

3.12.8.5 Repair welding.

The welding procedure and welding consumables used for defects repair shall be recognized by the Register in accordance with the requirements of Part XIV "Welding".

Prior to the beginning of works on the repair of defects by welding, it shall be submitted the detailed specification of a welding procedure, which shall include data on the welding position, welding process parameters, welding consumables, preheating, follow-up heat treatment and inspection of welding operations conducted. Welding shall be conducted under controlled conditions, which prevent an adverse exposure to weather.

Defects shall be repaired by welders of a proper qualification, allowed by the Register to perform such works.

Slag, undercuts and other flaws shall be repaired prior to the following pass.

Martensitic class steels after repair by welding are subject to annealing in a furnace.

The relief of local residual stresses with the minimum repair is subject to the special consideration by the Register.

Repaired surfaces after heat treatment shall be milled and ground. In all cases, the repair quality shall be checked by non-destructive testing methods.

A manufacturer shall maintain the system of defects recording, on which base the scope of a repair conducted, the type and schedules of heat treatment for any casting may be determined. The entire information on the casting being subject to the Register survey is produced to the Register representative. The approval of a welding procedure shall be based on the welding of test samples as shown in Fig. 3.12.8.5, having the thickness of 30 mm or more. Following welding, the test samples are subject to dye-penetrant testing.

The approval of a welding procedure is carried out in accordance with the requirements of Section 6, Part XIV "Welding" following the Register-approved program, which shall include, as a minimum, the following tests.

Macro-examination of a fusion line and heat-affected zone.

Carried out on two macro-sections. Cracks, pores, slag inclusions and other weld flaws over 3 mm in size are not permitted.

Tensile testing for determination of weld metal properties.

Carried out on two transverse specimens, which thickness in equal to that of a test sample, the width is 30 mm and the parallel test length is equal to the weld width plus 6 mm to each side (refer to 4.2.3.2.2, Part XIV "Welding"). Mechanical properties shall meet those required for the base metal.

The fracture area (weld metal, heat-affected zone or base metal) shall not beed in a test protocol.

Bend testing.

Carried out on two transverse specimens made in accordance with the requirements of 2.2.5.1. The test

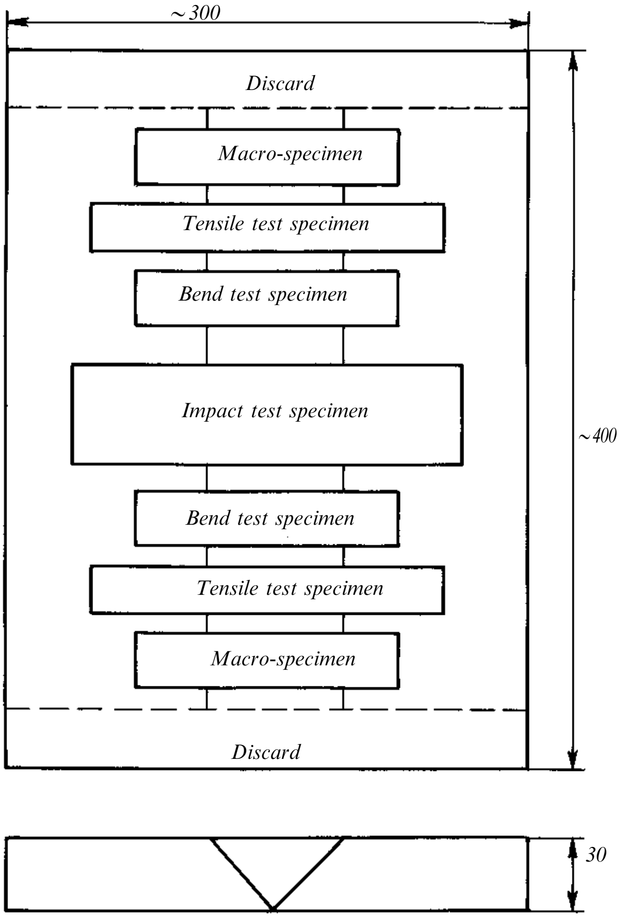


Fig. 3.12.8.5

is conducted on a mandrel four thickness in diameter excepting austenitic steels, for which the mandrel diameter shall be equal to three thicknesses. After the tests, the specimen surface shall be free from tension fractures and cracks of more than 2 mm long.

Impact testing.

The tests are not generally required excepting the cases when a base metal was subjected to these tests. Where necessary, impact tests are conducted on specimens made in accordance with 2.2.3 and Fig. 2.2.3.1-2.

The tests shall be conducted on one batch of specimens notched in the weld centre and on another one notched in the fusion line. The temperature and results of the tests shall meet those required for the base metal.

Hardness testing according to Vickers (HV5).

Carried out on macro-sections as specified in Fig. 6.3.1.10, Part XIV "Welding". Three measurements each are, as a minimum, made on the weld metal, heat-affected zone, at both sides of a weld and in the base metal. The measurements are noted in a test protocol.

3.12.9 Identification and marking.

3.12.9.1 Identification.

A monitoring system enabling to check the castings manufacture at any stage since metal making shall be used at the works manufacturing propellers. The confirmation of the availability of such system at the manufacturer's shall be submitted to the Register representative on his demand.

3.12.9.2 Marking.

A casting shall be properly marked prior to its presentation in the finished condition to the Register representative. In addition to specified in 1.4, the marking shall include the following data:

casting number and other designations allowing tracing all the stages of manufacture;

number of the Register Certificate;

skew angle (for high-skew propellers);

ice class symbol, where applicable;

date of casting acceptance.

The Register stamp is put following the final survey and the acceptance of a casting by the Register representative.

3.12.9.3 Manufacturer's Certificate of Quality.

The Certificate of Quality for a casting shall be submitted to the Register representative simultaneously with the presentation of the casting in the finished condition or in geed time. The Certificate shall be verified by the quality service of a works and witnessed by the person authorized for this by the works. The Certificate shall contain the following data:

manufacturer's name and order number;

shipbuilding project number, if known;

description of the casting with drawing number;

propeller diameter, number of blades, pitch and directions of turning;

final weight;

grade and type of alloy, number of a cast and chemical composition;

identification number;

heat treatment schedule;

results of mechanical tests;

result of non-destructive testing (satisfactory or unsatisfactory), if applied.

3.12.9.4 The Register Certificate.

Each casting or the batch of small castings shall be accompanied with the Register Certificate. In addition to the special number, the requisites of the Register representation or location, the place and date of issue, the Register Certificate is, as a minimum, to contain the following data:

manufacturer's name and order number;

shipbuilding project number, if known;

number of the certificate of quality of the casting manufacturer;

final weight;

identification number and casting number;
drawing number.

The Manufacturer's Certificate of Quality shall be the mandatory appendix to the Register Certificate.

Test protocols witnessed by the Register representative may also be part of the appendix to the Register Certificate on the purchaser's demand.

3.13 HIGH STRENGTH STEEL FOR WELDED STRUCTURES

3.13.1 General.

The present requirements apply to weldable plates and wide flats of high strength steel up to 70 mm thick subject to the survey by the Register during manufacture and intended for the manufacture of hull structures and other welded structures. On agreement with the Register, the requirements may be applied to rolled products more than 70 mm thick of shapes other than above, for instance, sections, pipes in structures, etc.

Proceeding from the minimum yield stress guaranteed the steel is subdivided into six strength levels: 420, 460, 500, 550, 620 and 690 MPa; proceeding from the impact test temperature, four Grades A, D,E and F have been established for each strength level.

Steel, of which the mechanical properties, chemical composition, etc. differ from the requirements set forth below, is subject to special consideration by the Register. High strength steel is manufactured at works recognized according to 1.3.1.2.

3.13.2 Chemical composition.

The chemical composition of steel shall be determined by the manufacturer from each cast or ladle in an adequately equipped laboratory with competent staff. The chemical composition of steel shall be in accordance with specification approved by the Register and the limiting values to be found in Table 3.13.2.

Table 3.13.2

Strength level of steel, in MPa	Steel grade	Content of elements, %, max					
		C	Si	Mn	P	S	N
420 — 690	A	0,21	0,55	1,70	0,035	0,035	0,020
	D, E	0,20	0,55	1,70	0,030	0,030	0,020
	F	0,18	0,55	1,60	0,025	0,025	0,020

The steel shall be fully killed and fine grain treated.

The content of alloying and grain-refining elements shall be in accordance with specification approved by the Register.

To estimate the cold-cracking resistance of steel proceeding from the chemical analysis of a ladle sample, a factor, which accounts for steel embrittlement as a result of structural transformations, shall be determined from the formula below

$$P_{CM} = C + Si/30 + Mn/20 + Cu/60 + Cr/20 + Mo/15 + V/10 + 5B\ \%.$$

The maximum value of P_{CM} shall be agreed with the Register and included in the Register-approved specification.

3.13.3 Mechanical properties.

For the purpose of tensile and impact testing, the mechanical properties of steel shall be in accordance with Tables 3.13.3-1 and 3.13.3-2.

Where rolled products of other shapes (sections, construction pipes, etc.) are tested, the elongation required for longitudinal specimens shall exceed that stated in Tables 3.13.3-1 and 3.13.3-2 by 2 per cent.

3.13.4 Condition of supply.

The steel shall be quenched and tempered. For steels up to 50 mm thick, thermo-mechanically controlled processing (TMCP) may be permitted by the Register after special consideration.

3.13.5 Sampling.

The axes of specimens to undergo the tensile test shall be perpendicular to the direction of the last rolling except for wide flats 600 mm or less wide, sections and bars, for which the orientation of specimen is determined on agreement with the Register. As a rule, flat tensile specimens shall be machined in such a way that the rolled surface is preserved on one side at least. If tensile testing is effected on cylindrical specimens the axes of the latter shall be 1/4 of the thickness dimension from the surface or as close to that position as possible.

Unless otherwise agreed with the Register, the impact testing of steel plates and wide flats more than 600 mm in width shall be effected on specimens prepared in accordance with 2.2.3.1-2, the longitudinal axis of which is perpendicular to the direction of rolling (transverse specimens). Where rolled products of another cross-sectional shape are concerned the impact testing shall be effected on longitudinal specimens.

The specimens shall be dimensioned and tests shall be conducted in compliance with the requirements of 2.2. Where test results are unsatisfactory, retesting shall be conducted in compliance with the requirements of 1.3.4.2.

3.13.6 Scope of testing.

Each plate (rolled length) shall undergo tensile and impact testing after heat treatment.

For rolled products quenched and tempered in continuous furnaces, the scope of testing, including the number of specimens and the direction of their cutting out, is determined on the basis of specifica-

Table 3.13.3-1

Mechanical properties with maximum thickness of 70 mm, %

Steel grade	Tensile test			Impact test		
	Yield stress R_{eH} or $R_{p0,2}$, MPa, min	Tensile strength R_m, MPa	Elongation A_5, %, min	Test temperature, °C	Impact energy KV, J, min	
					longitudinal specimen	transverse specimen
A420 D420 E420 F420	420	530 — 680	18	0 −20 −40 −60	42	28
A460 D460 E460 F460	460	570 — 720	17	0 −20 −40 −60	46	31
A500 D500 E500 F500	500	610 — 770	16	0 −20 −40 −60	50	33
A550 D550 E550 F550	550	670 — 830	16	0 −20 −40 −60	55	37
A620 D620 E620 F620	620	720 — 890	15	0 −20 −40 −60	62	41
A690 D690 E690 F690	690	770 — 940	14	0 −20 −40 −60	69	46

Notes: 1. The Register may require for a specific value of tensile strength to be established.
2. Where tensile tests are made on full-thickness specimens 25 mm broad and 200 mm long, the minimal elongation shall be in accordance with Table 3.13.3-2.
3. Based on satisfactory control test results and on agreement with the Register, the scope of impact testing may be reduced for Grade A steel.

Table 3.13.3-2

Minimal elongation values for standard specimens of full thickness with design length of 200 mm, %

Strength level of steel	Thickness t, mm						
	⩽10	>10 ⩽15	>15 ⩽20	>20 ⩽25	>25 ⩽40	>40 ⩽50	>50 ⩽70
420	11	13	14	15	16	17	18
460	11	12	13	14	15	16	17
500	10	11	12	13	14	15	16
550	10	11	12	13	14	15	16
620	9	11	12	12	13	14	15
690	9	10	11	11	12	13	14

tion approved by the Register, after special consideration.

Out of each test sample, at least one tensile specimen and three impact test specimens shall be machined.

If required by the Register, tensile testing shall be made on specimens with their longitudinal axes perpendicular to the plate surface and the reduction of cross-sectional area shall be determined.

3.13.7 Inspection.

Rolled products shall be in accordance with all the requirements of 3.2.7 taking the provisions below into consideration.

When surface defects are eliminated by grinding, the thickness of the rolled products at the ground spot shall not exceed permitted tolerances. When required by the Rules, the rolled products shall undergo the ultrasonic examination in conformity with standards approved by the Register.

3.13.8 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 3.2.8.

3.14 Z-STEEL

3.14.1 General.

The present requirements apply to steel of normal, higher (refer to 3.2 and 3.5), high strength (refer to 3.13) having thickness equal to or more than 15 mm. On agreement with the Register, application of the requirements set forth is possible also for rolled steel with thickness less than 15 mm.

Z-steel is recommended for use for welded structures taking up considerable stresses perpendicular to rolled surface. The present requirements define two levels of Z-properties for steel. Two relevant notations: Z25 and Z35 are introduced.

Rolled products shall be manufactured by works recognized by the Register (refer to 1.3.1.2). The Manufacturer shall prove that the manufacturing process provides guaranteed plastic properties in the through rolling thickness direction.

At appropriate guarantees of the manufacturer a supply of steel with determination of the relative narrowing (Z_z) of the rolled products with a thickness specified in the documentation agreed with the Register is permitted.

Provision is made for calcium treatment, vacuum degassing, argon stirring, sulphur segregation control, etc.

3.14.2 Chemical composition.

Z-steel shall be fully killed and fine grain treated.

The contents of elements shall comply with the national or international standards recognized by the Register.

The content of sulphur (ladle sample) in Z-steel shall not exceed 0,008 per cent.

3.14.3 Mechanical properties.

The mechanical properties of the steel, unless otherwise specified, shall meet the requirements of 3.2, 3.5 and 3.13.

For the appropriate level of Z-properties, the average value of the reduction of area Z_z obtained upon tension of three specimens, the longitudinal centreline of which is perpendicular to rolled surface, shall comply with Table 3.14.3-1. Table 3.14.3-1 gives for each level of Z-properties the value of the reduction of area to which the area is allowed to reduce on one of the specimens.

Table 3.14.3-1

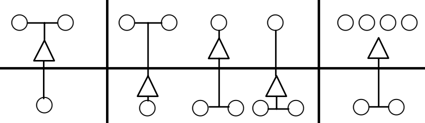
Level of Z-properties	Z25, %	Z35, %
Minimum average value of the reduction of area	25	35
Minimum allowable value of the reduction of area on one specimen	15	25

The need for retest on additional set of three specimens cut out from the same rolled product (refer to 2.2.2.5) and acceptance of test results including also retest results as satisfactory is shown in Table 3.14.3-2.

The Table 3.14.3-2 gives boundary cases taken into account by the Rules:

Table 3.14.3-2

	Tests		Retest
	Acceptable result	Unacceptable result where retest is required	Acceptable result
Minimum required value of the reduction of area			
Minimum allowable value of the reduction of area on one specimen			



Symbols:
○ — individual result;
△ — average result.

case of satisfactory tests on three specimens;

three cases where retest is permitted;

case of retest of six specimens (three completed plus three additional).

The retest results are considered to be satisfactory and the rolled product/batch is accepted for supply, provided:

the average value of the reduction of area Z_z, obtained as a result of testing six specimens exceeds the required minimum average value (refer to Table 3.14.3-2),

the results less than the mentioned required value have been obtained on not more than two specimens out of six.

Where the retest results are unsatisfactory the rolled product/batch submitted shall be rejected. Additional tests (on the same conditions) are permitted for each rolled product (other than that already tested) out of the batch rejected.

3.14.4 Sampling and scope of testing.

The scope of testing depends on the type of rolled product and content of sulphur (ladle sample).

The scope of testing shall be determined in accordance with Table 3.14.4.

Samples shall be taken from one end of the semi-finished product submitted for tests, as indicated in 2.2.2.5.

Table 3.14.4

Type of rolled product	Content of sulphur, %	
	S > 0,005	S ⩽ 0,005
Plate	Each plate	One plate out of maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of thickness $t \leqslant 25$ mm	Maximum 10 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of thickness $t > 25$ mm	Maximum 20 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment

3.14.5 Inspection.

Besides fulfilment of the requirements of 3.2.7, all the rolled products shall be subject to ultrasonic inspection at the final stage of manufacture.

The ultrasonic inspection shall be carried out in accordance with the requirements of standard EN 10160, level S1/E1, or ASTM A578, level C with a frequency of 4MHz.

3.14.6 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 3.2.8.

Besides, to the steel designation mentioned Z25 or Z35 shall be added, respectively, (e.g., DH36225).

3.15 WIRE ROPES

3.15.1 General.

3.15.1.1 The present requirements apply to ropes, subject to the Register survey, which are intended for cargo-handling gear, life-saving appliances and other ship appliances.

3.15.1.2 The ropes shall be manufactured and tested in conformity with standards approved by the Register and by works recognized by that body according to 1.3.1.2.

3.15.2 Manufacture.

3.15.2.1 For the manufacture of ropes, wire of round cross-section shall be used with a coating to protect it from corrosion and a tensile strength of 1180 to 1770 MPa.

3.15.2.2 The organic fibre core of ropes shall be manila, sizal, hemp or synthetic fibre. Ropes with the diameter more than 12 mm shall have a core of three strands.

3.15.2.3 The wires of a finished rope shall be covered with a lubricant.

Cores of organic fibre shall be impregnated or lubricated with corrosion preventive or anti-rot substances not solvable in sea water and containing no acids or alkalis. The lubricant for the ropes and the impregnant for the organic-fibre cores shall be compatible by their physical and chemical properties.

3.15.3 Sampling.

For testing purposes, from each rope 2000 m or less long a sample length shall be taken, and from ropes longer than 2000 m a sample length shall be taken from both ends. The sample lengths shall be long enough to make all the required testing possible.

3.15.4 Scope of testing.

3.15.4.1 After manufacture, each rope shall undergo the following tests:

breaking test of rope as a whole;

tensile test (ultimate strength being determined), bend test, twisting test and testing of the bond between the coating and steel core on wires from the rope.

The number of wires to be tested may be determined on the basis of standards, but not less than 10 per cent of the total number of wires in a group of wires of a particular diameter shall be tested.

3.15.4.2 Testing shall be conducted in accordance with approved standards.

The breaking test of the rope as a whole shall be effected by means of a breaking machine having the distance between the clamps not less than 50 rope diameters. If during testing the rope breaks less than 50 mm away from the grip the test shall be repeated.

3.15.4.3 The test results shall be in accordance with standards.

3.15.4.4 Under conditions of an established manufacturing process and in the event of testing equipment of the required capacity being not available to enable the breaking test of a rope as a whole the breaking load may be determined proceeding from the results of the tensile test, F, in kN, of all the wires making up the rope on the basis of the formula

$$F = c\sum_{1}^{i}[(\sum_{1}^{m}F_m)\, n/z] \qquad (3.15.4.4)$$

where c = wire efficiency factor for the rope, which shall be adopted on the basis of standards or calculated as the ratio of the breaking load of the rope as a whole to the total breaking load of all the wires making up the rope, both the values being stipulated by the standards;

i = number of groups of wires of the same diameter;

m = number of wires from each group of a particular diameter, subjected to tensile testing, which conform to standards;

F_m = the greatest load, during the tensile test of a wire, kN, after which the specimen breaks;

n = number of wires in each group of a particular diameter;

z = number of wires from each group of a particular diameter subjected to tensile testing.

On agreement with the Register and proceeding from the intended application of the rope, the number of wires to be tensile tested may be reduced, but in no case to less than 25 per cent of the total number of wires in the rope.

3.15.5 Inspection.

3.15.5.1 The compliance of the structure, diameter and other parameters of the rope to standards shall be confirmed by visual inspection and measurements.

3.15.5.2 When bends or burn-off spots are removed from the ends of unstrandable ropes the strands and wires in the strands shall not uncoil or may uncoil in such a way that they can be easily returned to their initial position.

3.15.5.3 The rope diameter shall be determined on a slack rope at right angles to the axis between two opposite strands in two positions.

The rope diameter shall not exceed the design value by more than 6 per cent.

3.15.5.4 On the rope surface, twisting and bending of strands, sinking, crossing, corrosion and breaking of wires in strands that prevent using the rope in accordance with the purpose are not permitted.

3.15.6 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 1.4.

3.16 STAINLESS STEEL

3.16.1 General.

3.16.1.1 These requirements apply to stainless steel subject to the Register survey during its manufacture as required in other Parts of the Rules and intended for:

structures of cargo and process vessels under pressure and without pressure, systems and pipes for chemicals, petroleum products, liquefied gases or fresh water, de-activating solutions, etc;

hull structures;

ballast, cooling, sounding, fire fighting and other systems and pipes;

machine-building products.

For stainless steel products having contact with sea water electromechanical protection shall be used.

The Chapter includes the requirements for stainless steel rolled plates and bars, forgings and pipes of martensitic (M), martensitic + ferritic (MF), ferritic (F), austenitic + martensitic (AM), austenitic (A) and austenitic + ferritic (AF) classes. The assumed classification of stainless steel depending on its chemical composition and structure is given in Table 3.16.1.1.

Steel designations are based on the designations used in international standards.

Designations of national marks are now given in accordance with the Russian standard.

3.16.1.2 Stainless steel shall be manufactured under the Register technical supervision by manufacturers recognized in compliance with 1.3.1.2.

Materials meeting the Register requirements shall be supplied with the Register Certificates.

Manufacturers' Certificates for ingots and blanks with indication of the manufacturer, steel mark,

Table 3.16.1.1

Assumed classification of stainless steel depending on chemical composition and structure

Steel classification	Steel designation	Steel mark		Temperature range for application, °C
		AISI / UNS	National	
M-l	X20Cr13 X7CrNiNbl6 4	410 420 —	20X13 30X13 07X16H4Б	−20 ÷ +450 −60 ÷ +350
MF-2	X15CrNi17	431	14X17H2	−20 ÷ +350
F-3	X8CrTi17	430Ti	08X17T	0 ÷ +600
AM-4	X8CrNiTi17 6	—	08X17H6T	−60 ÷ +250
A-5	X10CrNiTi18 10 X2CrNil9 11	321, 347 304L, 304LN	08X18H10T 12X18H10T —	−165 ÷ +600 −165 ÷ +600
A-6	X10CrNiMo17 13 2 X2CrNiMol8 13 3 X10CrNiMoTil7 13 3	316L,316LN 317L,317LN —	03X17H14M3 — 10X17H13M3T	−165 ÷ +600 −165 ÷ +600 −165 ÷ +600
A-7	X2CrNiMoCu20 18 6 X2CrNiMoCu21 23 4 2	S31254 N08904	— —	−165 ÷ +600 −165 ÷ +600
AF-8	X2CrNiMo22 5 3 X3CrNiMo25 6 3 X4CrNiVo25 5 3 X2CrNiMo25 7 4 X3CrNiMo25 7 3 X10CrNiTi22 6 X10CrNiMo21 6 2	S31803 S31260 S32550 S32750 S32760 — —	03X22H6M2 — — — — 08X22H6T 08X21H6M2T	−40 ÷ +250 −40 ÷ +250 −40 ÷ +250 −40 ÷ +250 −40 ÷ +250 −40 ÷ +250 −40 ÷ +250

heat No., chemical composition and documentation, in compliance with which ingots/blanks were manufactured, shall be submitted to the Surveyor to the Register who carries out the survey at the manufacturer's where there are no melting processes. The ingot/blanks manufacturer shall be recognized by the Register.

3.16.1.3 The use of stainless steel not meeting the requirements for chemical composition, mechanical properties and/or condition of supply is subject to special consideration by the Register in each particular case, including the detailed study of steel properties under conditions, for which the steel is intended.

3.16.1.4 Tests of stainless steel for susceptibility to intergranular, through, crevice and pitting corrosion as well as metallographic examination, α-phase determination, etc shall be carried out according to the procedures given in the standards recognized by the Register.

3.16.1.5 Chemical composition and mechanical properties.

Chemical composition and mechanical properties of semi-finished products of stainless steel as well as steel resistance to environmental effects shall meet the requirements of this Part of the Rules and also the requirements of national and international standards or other special documents recognized by the Register.

The chemical composition of stainless steel to be determined for each heat shall meet the requirements of Table 3.16.1.5. Where necessary, test assemblies may be taken, on the Register request, directly from a semi-finished product (plate, forging, etc).

The requirements for mechanical properties of semi-finished products depending on their type are given in Tables 3.16.2.2-1, 3.16.3.2-1, 3.16.3.2-2 and 3.16.4.2.

3.16.1.6 Condition of supply.

All semi-finished products shall be supplied in heat-treated condition.

Heat treatment conditions are specified in accordance with standards recognized by the Register or other normative documents.

Where heat treatment conditions are not indicated in the standards, such conditions shall be specified by the manufacturer.

Steel plates and flats of 4 mm in thickness and less may be supplied in semi-cold-worked or cold-worked condition.

Type or conditions of heat treatment shall be indicated in the Semi-Finished Certificate.

3.16.1.7 Sampling.

Test assemblies are taken from a semi-finished product.

For forgings separately forged test assemblies made from the metal of the same heat and with the same degree of deformation as the semi-finished product submitted for the tests may be used. In such case, dimensions of test assembly in terms of their thickness and diameter may vary from the maximum dimensions of the forging itself by not more than 25 per cent.

Test assemblies for preparation of specimens shall be cut out upon completion of all types of heat treatment.

Separately forged test assemblies shall be subjected to all types of process heating and heat treatment in one charge with the forging submitted for the tests.

The dimensions of test assemblies shall provide performance of the required and possible retests.

Unless expressly provided otherwise, test assemblies shall be taken as follows:

rolled stock — in compliance with 3.2.5. Test assemblies for impact tests shall be cut in such a manner that the longitudinal axis of specimens is transverse to the last direction of rolling. For steel sections and bars longitudinal specimens may be used. For a semi-finished product having a size (diameter, square side, diameter of inscribed circle) under 40 mm the specimen axis shall coincide with the axis of the semi-finished product;

forgings — in compliance with 3.7.5.1, sample being taken from the feed head of the ingot. On agreement with the Register test assemblies may be taken at a distance of 1/3 of the radius or 1/6 of the diagonal from the outer surface of the forging or from the centre of the forging;

pipes — in compliance with 3.4.5 and 3.4.6.

Test assemblies for intergranular corrosion tests shall be taken similarly to those for tensile tests.

In any case, schemes of taking test assemblies and cutting out specimens shall be indicated on the sketch and approved by the Surveyor to the Register.

3.16.1.8 Scope of tests.

3.16.1.8.1 Types of tests, to which stainless steel can be subjected, are given in Table 3.16.1.8.1. Tests, to which stainless steel supplied under the Register technical supervision shall be subjected, are marked with "+".

As a rule semi-finished products of stainless steel are submitted for tests in batches or individually.

A batch shall consist of semi-finished products of the same steel mark, the same heat, the same condition of supply, one shape (type) and size and made using the same production process.

Forgings of one batch shall be made according to the sketch and heat-treated in one charge.

Pipes included in the batch shall have the same wall thickness.

Steel plates and forgings intended for use at temperatures below zero shall be submitted for tests individually.

Table 3.16.1.5

Chemical composition of stainless steel

Steel class and mark	Content of elements, %									
	C, max	Si	Mn	P	S	Cr	Ni	Mo	N	Other
Martensitic										
410	0,12	1,0	1,0	0,045	0,03	12,0 — 14,0	—	—	—	—
420	0,17	1,0	1,0	0,045	0,03	12,0 — 14,0	—	—	—	—
Martensite - ferritic										
431	0,23	1,0	1,0	0,045	0,03	16,0 — 18,0	1,5 — 2,5	—	—	—
Ferritic										
431Ti	0,1	1,0	1,0	0,045	0,03	16,0 — 18,0	—	—	—	Ti × C
Austenitic										
304L	0,03	1,0	2,0	0,045	0,03	17,0 — 20,0	8,0 — 13,0	—	0,10	—
304LN	0,03	1,0	2,0	0,045	0,03	17,0 — 20,0	8,0 — 12,0	—	0,10 — 0,22	—
316L	0,03	1,0	2,0	0,045	0,03	16,0 — 18,5	10,0 — 15,0	2,0 — 3,0	0,10	—
316LN	0,03	1,0	2,0	0,045	0,03	16,0 — 18,5	10,0 — 14,5	2,0 — 3,0	0,10 — 0,22	—
317L	0,03	1,0	2,0	0,045	0,03	18,0 — 20,0	11,0 — 15,0	3,0 — 4,0	0,10	—
317LN	0,03	1,0	2,0	0,045	0,03	18,0 — 20,0	12,5 — 15,0	3,0 — 4,0	0,10 — 0,22	—
321	0,08	1,0	2,0	0,045	0,03	17,0 — 19,0	9,0 — 12,0	—	0,10	Ti ⩾ 5 × C ⩽ 0,70
347	0,08	1,0	2,0	0,045	0,03	17,0 — 19,0	9,0 — 13,0	—	0,10	Nb ⩾ 10 × C ⩽ 1,0
UNS S31254	0,02	0,8	1,0	0,03	0,01	19,5 — 20,5	17,5 — 18,5	6,0 — 6,5	0,18 — 0,22	Cu 0,50 — 1,0
UNS N08904	0,02	1,0	2,0	0,04	0,025	19,0 — 23,0	23,0 — 28,0	4,0 — 5,0	0,15	Cu 1,00 — 2,0
Austenite - ferritic (duplex)										
UNS S31260	0,03	0,75	1,0	0,03	0,03	24,0 — 26,0	5,5 — 7,5	2,5 — 3,5	0,10 — 0,30	Cu 0,2 — 0,8 W 0,1 — 0,5
UNS S31803	0,03	1,0	2,0	0,03	0,02	21,0 — 23,0	4,5 — 6,5	2,5 — 3,5	0,08 — 0,20	—
UNS S32550	0,04	1,0	1,5	0,04	0,03	24,0 — 27,0	4,5 — 6,5	2,0 — 4,0[1]	0,10 — 0,25	Cu 1,5 — 2,5
UNS S32750	0,03	0,8	1,2	0,035	0,02	24,0 — 26,0	6,0 — 8,0	3,0 — 5,0	0,24 — 0,32	Cu 0,50, not more
UNS S32760	0,03[2]	1,0	1,0	0,03	0,01	24,0 — 26,0	6,0 — 8,0	3,0 — 4,0	0,20 — 0,30	Cu 0,50 — 1,0 W 0,50 — 1,0

[1]For pipes content of Mo is taken equal to 2,90 to 3,90.
[2]For pipes content of C is ⩽ 0,05.

National stainless steels

Steel class and mark	Content of elements, %							
	C	Si, max	Mn, max	Cr	Ni	Ti	Mo	S, max	P, max
Martensitic									
20X13	0,16 — 0,25	0,8	0,8	12,0 — 14,0	—	—	—	0,025	0,030
30X13	0,26 — 0,35	0,8	0,8	12,0 — 14,0	—	—	—	0,025	0,030
07X16H4Б	0,05 — 0,10	0,6	0,2 — 0,5	14,0 — 16,5	3,5 — 4,5	Nb 0,2 — 0,4	—	0,020	0,025
Martensite - ferritic									
14X17H2	0,11 — 0,17	0,8	0,8	16,0 — 18,0	1,5 — 2,5	—	—	0,025	0,030
Ferritic									
08X17T	max 0,08	0,8	0,8	16,0 — 18,0	—	5 × C — 0,8	—	0,025	0,030
Austenite - martensitic									
08X17H6T	max 0,08	0,8	0,8	16,5 — 18,0	5,5 — 6,5	0,15 — 0,35	—	0,020	0,035
Austenitic									
08X18H10T	max 0,08	0,8	2,0	17,0 — 19,0	9,0 — 11,0	5 × C — 0,7	—	0,020	0,035
12X18H10T	max 0,12	0,8	2,0	17,0 — 19,0	9,0 — 11,0	5 × C — 0,8	3,0 — 4,0	0,020	0,035
10X17H13M3T	max 0,10	0,8	2,0	16,0 — 18,0	12,0 — 14,0	5 × C — 0,7	2,2 — 2,8	0,020	0,035
03X17H14M3	max 0,03	0,4	1,0 — 2,0	16,8 — 18,3	13,5 — 15,0	—	—	0,020	0,030
Austenite - ferritic									
08X22H6T	max 0,08	0,8	0,8	21,0 — 23,0	5,3 — 6,3	5 × C — 0,65	—	0,025	0,035
08X21H6M2T	max 0,08	0,8	0,8	20,0 — 22,0	5,5 — 6,5	0,20 — 0,40	1,8 — 2,5	0,025	0,035
03X22H6M2	max 0,03	0,4	1,0 — 2,0	21,0 — 23,0	5,5 — 6,5	—	1,8 — 2,5	0,020	0,035

Table 3.16.1.8.1

Types of semi-finished products of stainless steel tests

Characteristics to be determined	Classification of steels							
	M-1	MF-2	F-3	AM-4	A-5	A-6	A-7	AF-8
Mechanical properties at 20 °C:								
tensile strength, R_m	+	+	+	+	+	+	+	+
yield stress, $R_{p0,2}$	+	+	+	+	+	+	+	+
elongation, A_5	+	+	+	+	+	+	+	+
reduction, Z	+	+	+	+	+	+	+	+
Same at operating temperature	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]
Impact toughness at +20 °C, $KCV^{+20\ °C}$	+	+	+	+	—	—	—	+
Impact toughness at a temperature below, KCV	+[1]	+[1]	—	+[1]	+[1]	+[1]	+[1]	+[1]
Impact energy at a temperature below, KV	—	—	—	—	+[1]	+[1]	+[1]	+
Susceptibility to intergranular corrosion	+[2]	+	+	+	+	+	+	+
Macrostructure examination	+	+	+	+	+	+	+	+
α-phase examination	—	—	—	—	+[1]	+[1]	+[1]	—
Grain size control	—	—	+	+[1]	+[1]	+[1]	+[1]	+[1]
Process tests	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]
Non-destructive examination	+	+	+	+	+	+	+	+
Control of non-metallic inclusion content	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]	+[1]
Determination or confirmation of brittleness critical temperature	+[1]	+[1]	+[1]	+[1]	—	—	—	—

[1]On the Register request.
[2]Only for steel mark 07X16H4Б.

Sizes of batches, number and procedure of taking samples for steel plates, sheet steel and bars are given in 3.16.2.3, for forgings — in 3.16.3.3, for pipes — in 3.16.4.3.

3.16.1.8.2 Tests for the recognizing an enterprise as a manufacturer of stainless steel in accordance with 3.16.1.2 shall be carried out under a program approved by the Register and generally shall include:

chemical analysis;

determination of mechanical properties (R_m, $R_{p0,2}$, A_5, Z) at 20 °C and a design temperature;

determination or confirmation of the critical brittleness temperature (except for austenitic type steels);

metallographic examination and macrostructure examination to detect shrinkage cavities, bubbles, non-metallic inclusions, grain size;

tests for susceptibility to intergranular, through, crevice, pitting corrosion;

determination of α-phase amount (for austenitic type steels);

process tests (ring expanding, flattening, bending, etc) and plasticity assessment in case of cold stamping.

3.16.1.8.3 Testing procedures, types and dimensions of specimens shall comply with the requirements of Section 2 of the present Part or national and international standards recognized by the Register.

Retests aiming to check mechanical properties shall be carried out in compliance with 1.3.5.2. During retests those characteristics shall be determined, for which negative results were obtained.

In case of negative results of intergranular corrosion tests and retests for determination of mechanical properties obtained even for one specimen, the blanks shall be subjected to repeated heat treatment and submitted for tests as new ones. Not more than three complete heat treatments are allowed.

3.16.1.9 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 1.4.

Every semi-finished product of stainless steel shall have the Register brand.

3.16.2 Rolled products.

3.16.2.1 These requirements apply to stainless steel plates, flats and sections with a thickness up to 50 mm as well as to hot-rolled and forged steel of round, square or rectangular section with a diameter or thickness up to 200 mm.

3.16.2.2 Mechanical properties of steel at 20 °C shall not be worse than given in Table 3.16.2.2.1.

In determining mechanical properties of rolled products (bars) using transverse specimens, the requirements may be reduced in accordance with the provisions of national or international standards.

3.16.2.3 Scope of tests.

The number of specimens and batch size for rolled products shall be determined in the following way:

for steel plates and wide flats (⩾600 mm) more than 20 mm in thickness, more than 10 m long and more than 5 tons in mass test assemblies are taken from both ends of each rolled product. In other cases, a test assembly is taken from one end of the rolled product;

Table 3.16.2.2.1

Mechanical properties of stainless steel rolled products

Steel mark	Tensile strength R_m, MPa, min	Yield stress, $P_{p0,2}$, MPa, min	Elongation A_5, %, min
M-l	650	440	16
	850	735	13
MF-2	690	540	12
F-3	440	—	18
A-5	440	175	45
	490	195	35
A-6	440	185	40
	510	200	35
A-7	650	300	35
AF-8	580	340	20
	650	450	25
	760	550	15

for steel plates and wide flats (⩾600 mm) less than 20 mm in thickness, test assemblies are taken from one end of the plate of the batch containing not more than 20 plates;

for rolled steel, test assemblies are taken from both ends of each roll;

for steel plates and sections, test assemblies are taken from one end of one semi-finished product of the batch containing not more than 50 pieces, having a mass not more than 5 tons.

On agreement with the Register plates that vary in thickness by not more than 5 mm may be combined in one batch.

As a rule, the following specimens shall be prepared from each test assembly of steel plates, wide flats and bars:

one specimen for tensile test;

two specimens for impact toughness test;

one set of specimens (at least two pieces) for austenitic steels, two sets of specimens (at least four pieces) for austenitic — ferritic and austenitic — martensitic steels, one of which is a check specimen, for intergranular corrosion tests;

at least one template for macrostructure control.

3.16.2.4 Examination.

All the plates and rods of the batch shall undergo surface inspection and verification of dimensions. Rolled products shall not have any defects preventing them from use for intended applications. The absence of defects shall be the manufacturer's responsibility and may be proved by non-destructive testing. Non-destructive testing shall be performed according to national standards. Surface imperfections resulted from the manufacturing process used are permitted, provided they are within permissible limits, counting from the nominal thickness.

Defective areas may be welded in cases where the depth of the chipped areas after rectifying defects does not exceed 20 per cent of the nominal thickness of the billet, and the total chipped area does not exceed 2 per cent of the total area of the billet. Where projections of welded areas coincide in thickness on both sides of the blank, the permissible chipped areas shall not exceed in total the depth permissible on one side the billet.

Welding, control of welded areas and heat treatment (if necessary) shall be performed according to the manufacturer's documentation agreed with the Surveyor to the Register with the following marking of welded areas in the Certificate.

3.16.3 Forgings.

3.16.3.1 These requirements apply to semi-finished products manufactured by forging and hot stamping.

3.16.3.2 Mechanical properties of forgings and stampings, to which intergranular corrosion requirements apply, shall not be lower than that given in Table 3.16.3.2-1. Mechanical properties of forgings and stampings, to which intergranular corrosion requirements do not apply, shall meet the requirements of Table 3.16.3.2-2.

Table 3.16.3.2-1

Mechanical properties of stainless steel forgings and stampings, to which intergranular corrosion requirements apply

Steel mark	Tensile strength R_m, MPa, min	Yield stress $P_{p0,2}$, MPa, min	Elongation A_5, %, min
M-l	880	690	12
MF-2	690	540	12
AM-4	730	540	12
A-5	490	190	38
A-6	510	210	38
AF-8	590	340	17

Table 3.16.3.2-2

Mechanical properties of stainless steel forgings and stampings to which intergranular corrosion requirements do not apply

Steel mark	Tensile strength, R_m, in MPa, min	Yield stress, $P_{p0,2}$, in MPa, min	Elongation A_5, in %, min
M-l	650	440	13
MF-2	690	540	12
AM-4	730	630	10
	880	730	12

In the above tables mechanical properties determined on longitudinal specimens are given for semi-finished products, the diameter (thickness) of which does not exceed 300 mm. Mechanical properties of bigger forgings are subject to special consideration by the Register.

In determining mechanical properties of forgings using transverse, radial or tangential specimens the requirements for mechanical properties may be reduced in accordance with provisions of national and international standards or by values given in Table 3.16.3.2-3.

Table 3.16.3.2-3

Permissible reduction of mechanical characteristics when using transverse, radial and tangential specimens, in %

Mechanical properties	Specimen type			
	Trans-verse	Radial	Tangential specimens for ingots having diameter (thickness), mm	
			under 300	over 300
Yield stress, $R_{p0,2}$, in MPa	10	10	5,0	5,0
Tensile strength, R_m, in MPa	10	10	5,0	5,0
Elongation, A_5, in %	50	35	25	30
Reduction, Z, in %	50	40	25	30
Impact toughness KCV, in J/cm^2	50	40	25	30

Notes: 1. For forgings of "ring" type with a diameter more than 1000 mm produced by drawing, the requirements for mechanical properties obtained in testing tangential specimens are based on the requirements for longitudinal specimens.

2. In any case impact toughness shall not be less than 30 J/cm^2 and elongation shall not be less than 9 per cent.

3.16.3.3 Scope of tests.

The number of samples and batch size of stainless steel forgings and stampings shall be determined as follows:

for forgings and stampings of 20 kg in mass or less — from one semi-finished product of the batch consisting of not more than 30 pieces. Samples are taken from one end of the semi-finished product;

for forgings and stampings having a mass from 20 to 1000 kg — from one semi-finished product of the batch consisting of not more than 10 pieces. Samples are taken from one end of the semi-finished product;

for forgings and stampings of more than 1000 kg in mass — from each forging. Where a length is 3 m and more, from both ends of each forging.

On agreement with the Register forgings made according to different drawings but close in shape and varying in section by not more than 25 per cent may be combined in one batch.

As a rule, the following specimens shall be prepared from each sample:

for tensile test — one specimen;

for impact toughness — two specimens;

for intergranular corrosion test — four specimens, two of which are check specimens;

for macrostructure control — at least one specimen.

3.16.3.4 Inspection.

All forgings and stampings of the batch are subject to inspection of a surface and dimensions. Absence of inadmissible defects shall be guaranteed by the manufacturer and may be proved by non-destructive testing, if specified by order specification or on the Register request.

Welding of defects is subject to special consideration by the Register in each particular case and is generally restricted to the rectification of the defects of minor nature and in areas of low working stresses. The repairing technique and testing procedure are subject to the Register agreement.

After welding the location of all repairs and the results of inspection shall be shown in the drawing or sketch of the forging and annexed to the Certificate.

3.16.4 Pipes.

3.16.4.1 These requirements apply to hot- and cold-formed pipes of stainless steel.

3.16.4.2 Mechanical properties of pipes shall not be lower than that given in Table 3.16.4.2.

Table 3.16.4.2

Steel mark	Tensile strength R_m, MPa, min	Yield stress $P_{p0,2}$, MPa, min	Elongation A_5, %, min
A-5	490	175	30
	549	186	35
A-6	490	185	30
	529	216	30
AF-8	580	200	20
	690	450	25
	760	550	15
	800	550	25

3.16.4.3 Scope of testing.

The size of the batch shall be determined as follows:

where the outside diameter is 76 mm and less — 300 pieces;

where the outside diameter is over 76 mm — 200 pieces.

Samples are taken from one end of at least two pipes of the batch.

Unless expressly specified otherwise by the Register or standards, the following specimens shall be taken from each sample:

for tensile test — 1 specimen;

for flattening or expansion of rings — 1 specimen;

for flaring — 1 specimen;

for intergranular corrosion test of pipes made of austenitic steel — 1 set of specimens (at least 2 pieces); for pipes of austenitic + ferritic pipes — 2 sets of specimens (at least 4 pieces), one of which is a check set;

each pipe shall be subjected to a hydraulic pressure test and ultrasonic testing.

3.16.4.4 Inspection.

All pipes and tubes shall undergo external and internal examination of the surface. Absence of inadmissible defects shall be guaranteed by the the manufacturer and proved by non-destructive testing.

4 COPPER AND COPPER-BASE ALLOYS

4.1 SEMI-FINISHED PRODUCTS OF COPPER AND COPPER-BASE ALLOYS

4.1.1 General.

These requirements apply to semi-finished copper and copper-base products (rolled, forged, drawn, press-formed, etc.) and castings, which are used in shipbuilding and marine engineering, and the manufacture of which is subject to the Register survey. Semi-finished products of copper and copper-base alloys shall be manufactured at works recognized according to 1.3.1.2.

4.1.2 Chemical composition and mechanical properties.

The chemical composition and mechanical properties of copper and copper-base alloy products such as pipes, plates, bars, rolled sections, forgings and castings shall meet the requirements of appropriate standards or specifications approved by the Register.

When selecting copper-base alloys, one shall consider the required level of mechanical properties at indoor or higher temperatures, corrosion resistance, and other properties determined by their application.

4.1.3 Condition of supply.

If, in the process of manufacture, parts made of copper and copper-base alloys are subjected to heat treatment, the type of heat treatment shall be reported to the Register and stated in the material certificate.

Rolled products made of CuZn alloys (brasses) shall be annealed for stress relieving.

Products in solid and semi-solid condition may be used only upon agreement with the Register.

4.1.4 Sampling.

Tensile test samples shall be cut from sheet material transversely to the direction of rolling (forging), and from tubes, rods, sections and forgings — longitudinally to the direction of rolling.

Tubes, rods and sections with a diameter (or thickness) of 40 mm and less may be subjected to tensile tests in the rough condition.

Forging samples may be forged separately or forged on the forgings. The samples shall have the same degree of upsetting as the forging in its highest loaded cross-section.

Casting samples may be cast separately, gated to the casting or taken directly from its body.

In any case, the samples shall be cut after the final heat treatment (in the supply condition).

4.1.5 Scope of testing.

If not otherwise specified, the following samples shall be selected from each lot:

for determination of chemical composition (heat analysis);

for determination of mechanical properties (R_{eH}, R_m, A_5);

for fabrication testing.

The scope of testing for semi-finished products (rolled products, forgings, castings) shall be determined according to standards recognized by the Register.

CuZn alloy tubes for heat exchangers shall be subjected to the following tests:

mercuric nitrate or ammonia treatment according to the requirements of appropriate standards (one specimen per lot);

flattening (two specimens cut from two tubes, $H = 3t$);

expanding (two specimens from two tubes, with the angle of mandrel taper $\alpha = 45°$, and the expansion degree of 30 per cent);

microstructure check (one specimen per lot).

Average grain diameter shall be 0,01 to 0,05 mm.

Tubes shall be subjected to hydraulic testing; the test pressure shall be determined by standards or specifications.

The test pressure for heat exchanger tubes shall be 5 MPa, and for tubes (bushes) intended for propeller shaft linings — 2 MPa.

Substitution of non-destructive testing for hydraulic testing is, in each case, subject to special consideration by the Register.

4.1.6 Inspection.

Products submitted for the Register inspection shall comply with the requirements of corresponding standards or specifications, on the basis of which they are accepted.

The products shall not have defects, which are detrimental for their intended use.

4.1.7 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 1.4.

4.2 PROPELLER CASTINGS

4.2.1 General.

4.2.1.1 These requirements apply to castings intended for cast propellers, blades and bosses of propellers with detachable blades.

The requirements are applicable to moulding, casting, inspection of new propellers, blades and bosses as well as repair of new propellers in the course of their manufacture. Upon special consideration these requirements may also be applied for the repair and inspection of propellers becoming damaged during service.

4.2.1.2 All propellers and their components shall be cast by foundries approved by the Register in compliance with 1.3.1.2. The application for approval shall be accompanied by specifications of the propeller materials, manufacturing procedures, repair, NDT inspection procedures and a description of the foundry facilities, including the maximum capacity of the ladles.

4.2.1.3 The approval tests shall be carried out in compliance with 1.3.5 under the programme approved by the Register. The purpose of the tests shall verify that the castings and their quality, including chemical composition and mechanical properties, comply with these requirements.

4.2.1.4 The foundry shall have an adequately equipped laboratory, manned by experienced personnel, for the testing of moulding materials, chemical analyses, mechanical testing and microstructural testing of metallic materials. Provision shall be made for NDT inspection. If these test facilities are not available, details shall be provided of an approved local laboratory which will provide such services. The laboratory, shall be recognized by an authorized national body and/or Register.

4.2.1.5 The pouring shall be carried out into dried moulds using degassed liquid metal. The pouring shall be controlled as to avoid turbulences of flow. Special devices and/or procedures shall prevent slag flowing into the mould.

4.2.1.6 Subsequent stress relieving heat treatment may be performed to reduce the residual stresses. For this purpose, the manufacturer shall submit a specification containing the details of the heat treatment to the Register for approval (refer to Tables 4.2.8.5-1 and 4.2.8.5-2).

4.2.2 Chemical composition and structure characteristics.

4.2.2.1 The chemical composition of typical copper propeller alloys shall comply with the requirements of Table 4.2.2.

N o t e. The main constituents of the microstructure in the copper-based alloys categories CU1 and CU2 are alpha and beta phase.

Important properties such as ductility and resistance to corrosion fatigue are strongly influenced by the relative proportion of beta phase (too high percentage of beta phase having a negative effect on these properties). To ensure adequate cold ductility and corrosion fatigue resistance, the proportion of beta phase shall be kept low. The concept of the zinc equivalent shall be used as control since it summarizes the effect of the tendency of various chemical elements to produce beta phase in the structure.

The structure CU1 and CU2 type alloys shall contain an alpha phase component of at least 25 per cent. The content of alpha phase shall be measured by the manufacturer. The zinc equivalent defined by the following formula shall not exceed a value of 45 per cent.

$$\text{Zinc equivalent (\%)} = 100 - \frac{100\%\ \text{Cu}}{100 + A}\ ,\ \%$$

where A is the algebraic sum of the following values:

1 × % Sn,

5 × % Al,

−0,5 × % Mn,

−0,1 × % Fe,

−2,3 × Ni.

The negative sign in front of the elements Mn, Fe and Ni signifies that these elements tend to reduce the proportion of beta phase.

Copper alloys of chemical composition different from those given in Table 4.2.2.1 may be allowed only after their approval by the Register.

4.2.3 Mechanical properties.

Mechanical properties of standardized alloys as applied to test specimens taken from separately cast samples shall comply with Table 4.2.3.

These properties are a measure of the mechanical quality of each heat; and they are generally not representative of the mechanical properties of the propeller casting itself, which may be up to 30 per cent lower than that of a separately cast test coupon.

The requirements for mechanical properties of integrally cast test specimens or taken directly from the casting are specially to be agreed upon with the Register.

Copper alloys with mechanical characteristics different from those given in Table 4.2.3 may be allowed only after their approval by the Register in compliance with 1.3.2.

Table 4.2.2

Alloy type	Chemical composition of copper propeller alloys, %							
	Cu	Al	Mn	Zn	Fe	Ni	Sn	Pb
CU1	52 — 62	0,5 — 3,0	0,5 — 4,0	35 — 40	0,5 — 2,5	max 1,0	0,1 — 1,5	max 0,5
CU2	50 — 57	0,5 — 2,0	1,0 — 4,0	33 — 38	0,5 — 2,5	3,0 — 8,0	max 0,15	max 0,05
CU3	77 — 82	7,0 — 11,0	0,5 — 4,0	max 1,0	2,0 — 6,0	3,0 — 6,0	max 0,1	max 0,03
CU4	70 — 80	6,5 — 9,0	8,0 — 20,0	max 6,0	2,0 — 5,0	1,5 — 3,0	max 1,0	max 0,05

N o t e. Chemical composition shall be determined for the metal of each ladle.

Table 4.2.3
Mechanical characteristics of cast copper alloys for propellers (separately cast test coupons)

Alloy type	Proof stress $R_{p0,2}$, MPa, min	Tensile strength R_m, MPa, min	Elongation A_5, %, min
CU1	175	440	20
CU2	175	440	20
CU3	245	590	16
CU4	275	630	18

4.2.4 Sampling.

Separately cast samples for determining the mechanical properties of propeller alloys shall be taken from each ladle and shall have the dimensions as shown in Fig. 4.2.4. Samples may be prepared in accordance with the standards approved by the Register. Use of integrally cast test specimens or specimens taken directly from a casting is subject to special consideration by the Register. For the purpose of approval of a foundry the tests indicated in Table 4.2.1.3 may be carried out on separately cast coupons and specimens of integrally cast metal or casting metal.

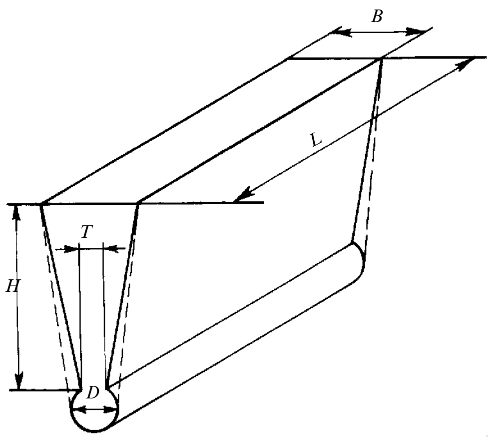


Fig. 4.2.4
Separately cast sample with dimensions in mm:
$H = 100$; $B = 50$; $L > 50$; $T = 15$; $D = 25$

4.2.5 Scope of tests.

Out of each sample at least one cylindrical specimen is machined to undergo the tensile test (refer to Table 2.2.2.3). The tensile strength, 0,2 per cent proof stress and elongation shall be determined by tensile test.

Generally, the specimens shall be taken from separately cast sample pieces (refer to 4.2.4). The test samples shall be cast in moulds made of the same material as the mould for propeller. They shall be cooled down under the same conditions as the propeller. If propellers are subjected to a heat treatment the test samples shall be heat treated together with them. Where use of integrally cast test specimens is approved by the Register, they shall, wherever possible, be located on the blades in an area lying between 0,5R to 0,6R, where R is the radius of the propeller. The test sample material shall be removed from the casting by non-thermal procedures. For CU1 and CU2 alloy types the proportion of alpha phase is determined. For this purpose, at least one specimen shall be taken from each heat. The proportion of alpha phase shall be determined as the average value of 5 counts. The requirements of 4.2.2.1 shall be fulfilled.

4.2.6 Severity zones (repair zones).

4.2.6.1 In order to relate the degree of inspection to the criticality of defects in propeller blades and to help reduce the risk of failure by fatigue cracking after repair, propeller blades are divided into the three zones designated A, B and C (refer to Figs. 4.2.6.2-1 and 4.2.6.3).

N o t e . Propellers are divided into high skew propellers, i.e. propellers with a skew angle greater than 25°, and low skew propellers with a skew angle of up to 25°.

The skew of the propeller is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline, which acts as a tangent to the locus of the mid-points of the helical blade section (refer to Fig. 4.2.6.1).

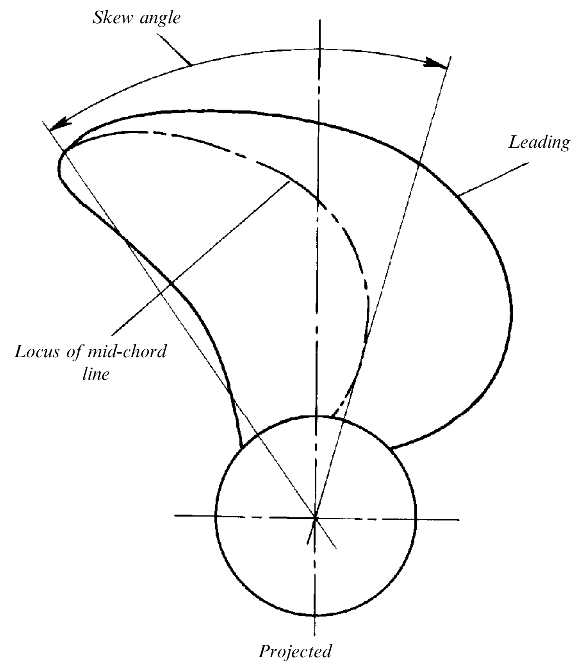


Fig. 4.2.6.1 Definition of skew angle

4.2.6.2 Severity zones for low-skew propeller blades.

Z o n e A is in the area on the pressure side of the blade, from and including the fillet to 0,4R, and bounded on either side by lines at a distance 0,15 times the chord length C_r from the leading edge and 0,2 times C_r from the trailing edge, respectively, as shown in Fig. 4.2.6.2-1 (C_r is the chord width of the blade on radius 0,4R).

Where the hub radius (R_b) exceeds 0,27R, the other boundary of zone A shall be increased to 1,5R_b.

Zone A also includes the parts of the separate cast propeller hub, which lie in the area of the windows as described in Fig. 4.2.6.2-2, and the flange and fillet area of controllable pitch and built-up propeller blades as described in Fig. 4.2.6.2-3.

Zone B is the area on the pressure and suction sides of the blade. On the pressure side zone B is the remaining area up to 0,7R (the area within the boundaries of 0,4R and 0,7R plus areas on the leading and trailing edges bounded by lines 0,15C_r and 0,2C_r, respectively, and the line over the blade length with a radius of 0,4R) as described in Fig. 4.2.6.2-1.

On the suction side zone B is the area from the fillet to 0,7R.

Zone C is the area outside 0,7R on both pressure and suction sides of the blade (between 0,7R and R) as described in Fig. 4.2.6.2-1. It also includes all the surfaces of the hub other than those designated zone A above.

4.2.6.3 Severity zones for high-skew propellers.

Zone A is the area on pressure and suction sides of the blade as described in Fig. 4.2.6.3.

On the pressure face zone A is contained within the blade root-fillet and a line running from the junction of the leading edge with the root fillet to the trailing at 0,9R and at passing through the mid-point of the blade chord at 0,7R and a point situated at 0,3 of the chord length from the leading edge at 0,4R. Zone A also includes an area between the above line and the edge from the root to the chord at 0,4R.

Zone A includes an area along the trailing edge on the suction side of the blade from the root to 0,9R and with its inner boundary at 0,15 of the chord lengths from the trailing edge.

Zone B is the area of the pressure and suction sides of the blade as described in Fig. 4.2.6.3.

Zone B includes the blade surfaces not included in zone A.

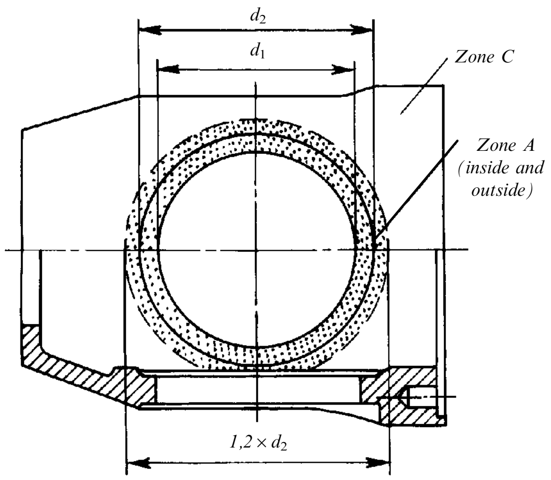


Fig. 4.2.6.2-2 Severity zones for controllable pitch propeller boss

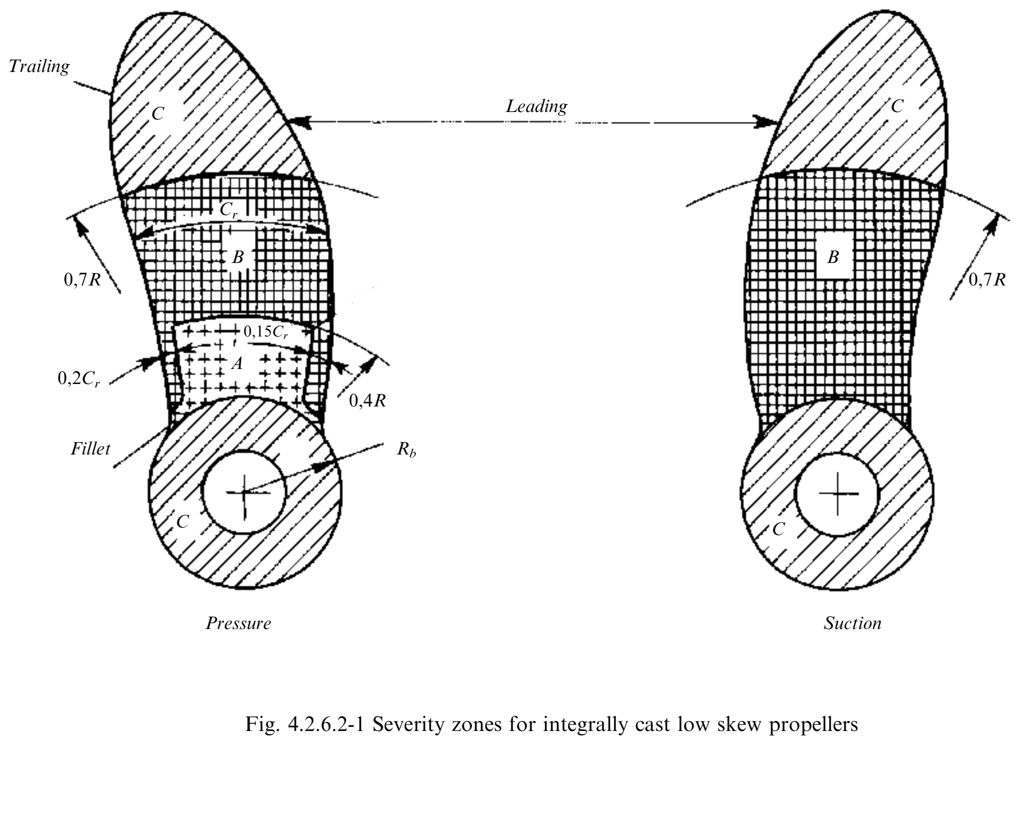


Fig. 4.2.6.2-1 Severity zones for integrally cast low skew propellers

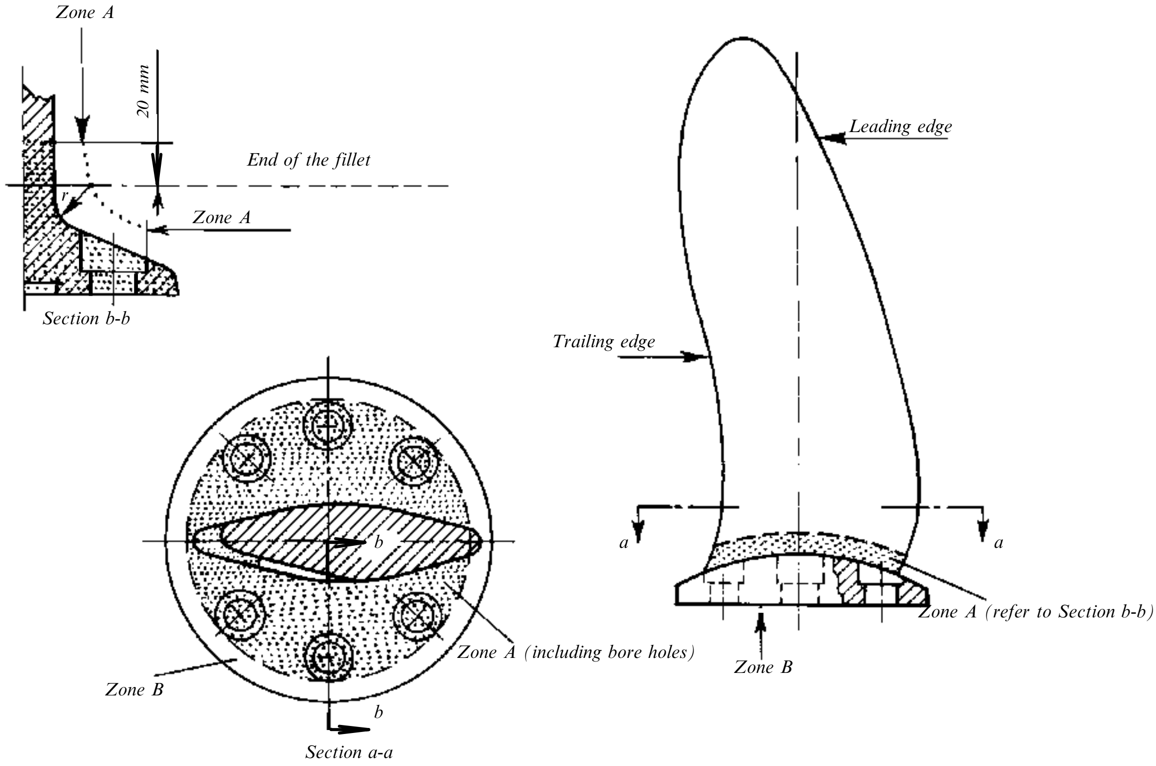


Fig. 4.2.6.2-3 Severity zones for controllable pitch and built-up propeller

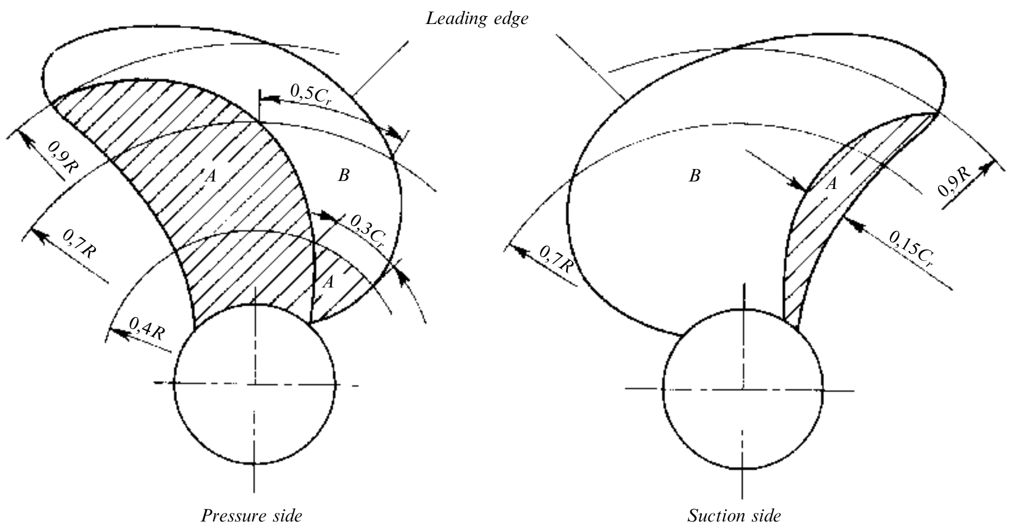


Fig. 4.2.6.3 Severity zones in blades with skew angles greater than 25°

4.2.6.4 Zone *A* is a region characterized by the highest operating stresses and the greatest thicknesses, and therefore it requires the highest degree of inspection and performance of all repair works.

Zone *B* is also a region where the operating stresses may be high, and therefore welding shall preferably be avoided in repair works.

Zone *C* is a region, in which the operating stresses are low and where the blade thicknesses are relatively small. Repair welding is safer and is permitted in accordance with a procedure approved by the Register.

4.2.7 Inspection.

4.2.7.1 Propeller castings shall be visually inspected at all stages of manufacture. The castings shall be subjected to a comprehensive visual inspection in the finished condition by the Surveyor to the Register. At the final stage of manufacture the inspection shall include the bore. The castings subject to inspection shall be fettled and their surface prepared for visual inspection and non-destructive testing. The surface shall be free from defects liable to result in damage of propellers in the course of operation.

N o t e . Casting defects, which may impair the serviceability of the castings, e.g. major non-metallic inclusions, shrinkage cavities, blow holes and cracks, are not permitted. These defects may be removed by one of the methods described in 4.2.8 and repaired within the limits and restrictions for the severity areas. Full description and documentation shall be presented to the Surveyor to the Register before commencement of works.

4.2.7.2 The dimensions and the dimensional and geometrical tolerances shall comply with the requirements of the drawings approved by the Register and order documentation. The above documents and the results of measurements and inspection drawn up in the form of a report shall be submitted to the Surveyor to the Register at the time of the test. Unless expressly provided otherwise, the accuracy and verification of the dimensions are the responsibility of the manufacturer.

Static balancing shall be carried out on all the propellers in accordance with the documentation approved by the Register. Dynamic balancing is necessary for propellers running above 500 rpm.

4.2.7.3 Non-destructive testing.

4.2.7.3.1 Dye-penetrant inspection.

The severity zones *A* (refer to 4.2.6) shall be subjected to a dye-penetrant inspection in the presence of the Surveyor to the Register. In zones *B* and *C* the dye-penetrant inspection shall be performed by the manufacturer and may be witnessed by the surveyor upon his request.

If repairs have been made either by grinding or by welding the repaired areas shall be additionally subjected to the dye-penetrant inspection independent of their location and/or severity zone.

The dye-penetrant inspection shall be carried out in accordance with a standard or specification approved by the Register. The following definitions shall be applied:

I n d i c a t i o n is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied. The shape of indications shall be determined in accordance with Fig. 4.2.7.3.1.

R e f e r e n c e a r e a is an area of 100 cm^2, which may be square or rectangular with the major dimension not exceeding 250 mm.

For evaluation of surface quality by a dye penetrant inspection method the entire surface to be inspected shall be divided into reference area. The area shall be taken in the most unfavourable locations relative to the indication being evaluated i.e. the shape and dimensions of each reference area are chosen so that they cover the maximum number of defects without their distribution to an adjacent reference area.

The indications detected in each of such areas are, with respect to their size and number, shall not exceed the values given in Table 4.2.7.3.1.

Areas, which are prepared for welding, shall, independent of their location, always be assessed according to zone *A*. The same applies to the welded areas after being finished machined and/or grinded.

4.2.7.3.2 Radiographic and ultrasonic inspection.

Where serious doubts exist that the castings are not free from internal defects further radiographic and/or utrasonic inspections shall be carried out upon request of the Register. The evaluation and acceptance criteria shall be agreed between the manufacturer and the Register in accordance with the standards approved by the Register.

It shall not beed that the absorption of the X-rays and gamma-rays is stronger in copper-based alloys than in a steel. For propeller bronzes, 300 kV X-rays can normally be used up to 50 mm and Co 60 gamma-rays up to 160 mm thickness. Due to

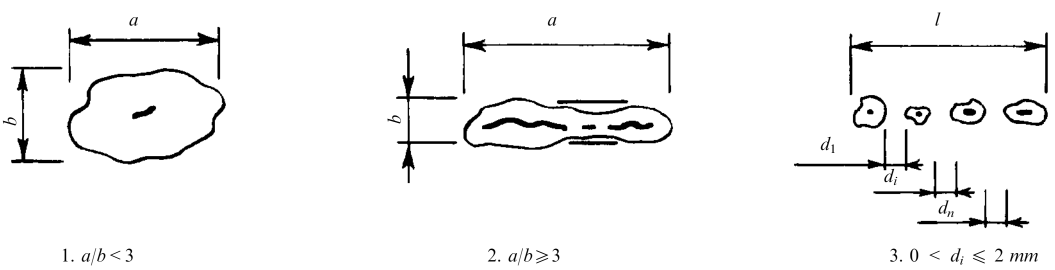


Fig. 4.2.7.3.1 Shape of indications: 1 — circular; 2 — linear; 3 — aligned

Table 4.2.7.3.1
Allowable number and size of indications in a reference area of 100 cm^2, depending on the severity zones

Severity zones	Max. total number of indications	Type of indication	Max. number of each type of indications	Dimension *a* or *l*
A	7	circular	5	4
		linear	2	3
		aligned	2	3
B	14	circular	10	6
		linear	4	6
		aligned	4	6
C	20	circular	14	8
		linear	6	6
		aligned	6	6

Notes: 1. Singular circular idications less than 2 mm for zone A and less than 3 mm for the other zones may be disregarded.
2. The total number of circular indications may be increased to the maximum total number represented by the absence of linear/aligned indications. The total number of circular indications may also be increased due to the absence of part of linear and/or

the limited thicknesses that can be radiographed as well as for other practical reasons radiography is generally not a realistic method for checking of the thickest parts of large propellers.

As a general rule, ultrasonic testing of CU1 and CU2 is not feasible due to the high damping capacity of these materials. For CU3 and CU4, ultrasonic inspection of subsurface defects is possible.

4.2.8 Repair of defects.

4.2.8.1 Discontinuities of the surface causing indications when a dye-penetrant inspection is carried out and not meeting the requirements of Table 4.2.7.3.1, such as cracks, shrinkage cavities, sand, slag and other non-metallic inclusions, blow holes, etc., which may impair the safe service of the propeller, shall be eliminated or welded.

Dimensions, number and location of defects allowable without repairs, as well as of those subject to repair shall be determined on agreement with the Register.

In general the repairs shall be carried out by mechanical means, e.g. by grinding, chipping or milling. Welding may be applied subject to agreement with the Surveyor to the Register if the requirements stated here will be complied with.

After milling or chipping grinding shall be applied for such defects, which shall not be welded. Grinding shall be carried out in such a manner that the contour of the ground depression is as smooth as possible in order to avoid stress concentrations or to minimize cavitation corrosion.

Welding of areas less than 5 cm^2 shall be avoided.

4.2.8.2 Repair of defects in zone *A*.

In zone A, repair welding is not allowed.

Grinding shall be carried out to an extent, which maintains the blade thickness of the drawing approved by the Register. The possible repair of defects, which are deeper than those referred to above, shall be specially considered by the Register.

4.2.8.3 Repair of defects in zone *B*.

Defects that are not deeper than $dB = t/40$ mm (t = minimum local thickness, in mm, according to the Rules) or 2 mm (whichever is greater) shall be removed by grinding. Those defects, which are deeper than allowable for removal by grinding, may be repaired by welding.

4.2.8.4 Repair of defects in zone *C*.

In zone *C*, repair welds are generally permitted.

4.2.8.5 Repair welding.

The welding procedure and welding consumables used in repair welding shall be recognized by the Register as required by Part XIV "Welding".

Defects shall be repaired by welders of adequate qualification, allowed by the Register to perform such works.

The approval of the welding procedure shall be based on welding of test samples as shown in Fig. 4.2.8.5-1, which shall be subjected to a non-destructive testing (dye-penetrant inspection and radiography).

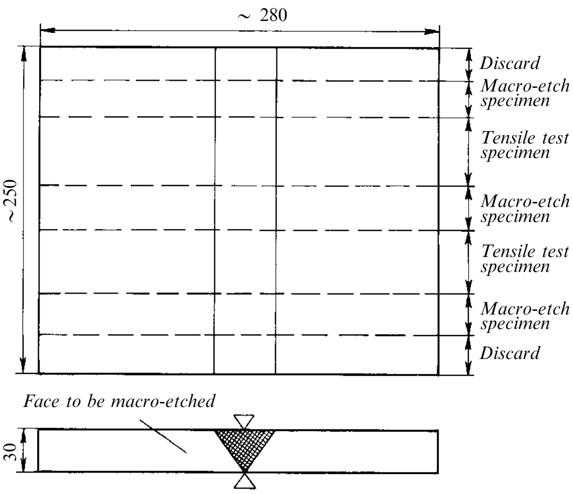


Fig. 4.2.8.5-1

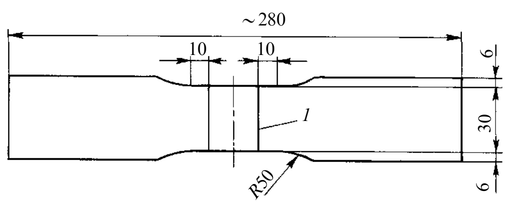


Fig. 4.2.8.5-2 Tensile test specimen: *1* — weld edge

Two transverse round tensile test specimens shall be taken from test samples as shown in Fig. 2.2.2.3, *b* and three macro-etch specimens shall be prepared. As an alternative, tensile test specimens may be prepared in compliance with the methods approved by the Register or the recognized standards.

The above works shall be performed by the manufacturer before commencement of welding operations.

Welding specification to be submitted to the Register for approval shall be made taking into account the following requirements and recommendations:

defects shall be repaired by mechanical means in accordance with 4.2.8, using dye-penetrant method for determination of the complete removal of the defects;

selection of welding consumables, selection of preheat temperature and heat treatment temperature for stress relief shall be made in compliance with the requirements of Table 4.2.8.5-1. It shall noted that with the exception of alloy CU3 all weld repairs shall be stress relief heat treated, in order to avoid stress corrosion cracking;

Table 4.2.8.5-1

Recommended filler metals and heat treatments

Alloy type	Filler metal	Preheat temperature, °C, min	Interpass temperature, °C, max	Stress relief temperature, °C	Hot straightening temperature, °C
CU1	Al-bronze[1]	150	300	350-550	500-800
	Mn-bronze	150	300	350-550	500-800
CU2	Al-bronze	150	300	350-550	500-800
	Ni-Mn-bronze	150	300	350-550	500-800
CU3	Al-bronze	50	250	450-500	700-900
	Ni-Al-bronze[2]	50	250	450-500	700-900
	Mn-Al-bronze	50	250	450-500	700-900
CU4	Mn-Al-bronze	100	300	450-600	700-850

[1] Ni-Al-bronze and Mn-Al-bronze are acceptable.
[2] Stress relieving is not required.

where stress relief heat treatment of alloy CU3 propeller castings is required after major repairs in zone *B* and/or zone *A* (the latter requires special approval by the Register) or if a welding consumable susceptible to stress corrosion cracking is used, the propeller shall be either stress relief heat treated in the temperature 450 to 500 °C or annealed in the temperature range 650 to 800 °C, depending on the extent of repair (refer to Table 4.2.8.5-1);

the defects shall be repaired as far as possible in the down-hand position, using arc welding with coated electrodes or "wire — shielded gas" combination.

Where the down-hand position is impossible for repairs, only "wire — shielded gas" combination shall be used;

Note. Use of argon-shielded tungsten welding is not recommended due to the higher specific heat input of this process.

for CU1 and CU2 materials having a thickness 30 mm and less gas welding may give a satisfactory weldment;

the soaking times for stress relief heat treatment of copper alloy propellers is determined in accordance with Table 4.2.8.5-2. The cooling rate shall not exceed 50 °C/h until the temperature of 200 °C is reached.

Table 4.2.8.5-2

Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief temperature, °C	Alloy grade CU1 and CU2		Alloy grade CU3 and CU4	
	Hours per 25 mm thickness	Max. recommended total time, hours	Hours per 25 mm thickness	Max. recommended total time, hours
350	5	15	—	—
400	1	5	—	—
450	0,5	2	5	15
500	0,25	1	1	5
550	0,25	0,5	0,5[1]	2[1]
600	—	—	0,25[1]	1[1]

[1] 550 and 600 °C only applicable to CU4 alloys.

Table 4.2.8.5-3

Required tensile strength values

Alloy type	Tensile strength, MPa
C1	370
C2	410
C3	500
C4	550

4.2.8.6 Straightening.

For hot and cold straightening, static loading only shall be used.

Straightening of a bent propeller blade or pitch modification shall be carried out after heating the bent region and approximately 500 mm wide zones on either side of it. The temperature range shall comply with the requirements of Table 4.2.8.5-1; the heating shall be slow and uniform.

The concentrated flame such as oxy-acetylene and oxy-propane shall not be used.

Cold straightening shall be used for minor repairs of tips and edges only. Cold straightening on CU1 and CU2 as well as CU4 bronze shall be always followed by a stress relieving heat treatment in accordance with Table 4.2.8.5-1.

4.2.9 Identification and marking.

4.2.9.1 Identification.

The manufacturer's shall employ a monitoring system, which enables all castings to be traced back to their heat. The confirmation of the availability of such system at the manufacturer's shall be given to the Surveyor to the Register at his request.

4.2.9.2 Marking.

Marking shall be made in compliance with the requirements of 1.4. Besides, marking shall contain the following data:

number of the Register Certificate;

skew angle for high-skew propellers;

ice class symbol, where applicable.

4.2.9.3 The Manufacturer's Certificate to be submitted to the Surveyor to the Register shall contain the following details:

purchaser and order number;

shipbuilding project number, if known;

description of the casting with drawing number;

diameter, number of blades, pitch, direction of turning;

grade of alloy and chemical composition of each heat;

heat and casting number;

final weight;

results of non-destructive tests, if used;

portion of alpha phase for CU1 and CU2 alloys;

results of the mechanical tests;

casting identification number;

skew angle for high-skew propellers.

5 ALUMINIUM ALLOYS

5.1 WROUGHT ALUMINIUM ALLOYS

5.1.1 General.

The present requirements apply to semi-finished products of wrought aluminium alloys (plates, sections, panels etc.) of 3 to 50 mm in thickness intended for ship hulls, superstructures and other marine constructions. The requirements are not applicable to aluminium alloys for constructions serving at low, cryogenic temperatures.

Designation of aluminium alloys is based on the designations of the Aluminium Association. Designation of national alloys approved by the Register is given in accordance with the Russian standards.

The use of wrought aluminium alloys, which don't comply with the present requirements in respect of chemical composition, mechanical properties or temper conditions, is the matter of special consideration by the Register in each case, which implies thorough examination of alloy properties, corrosion resistance, welding technology features, as well as study of alloys behaviour in the working conditions. Alloys shall be approved by the Register in accordance with 1.3.1.2.

All aluminium alloys shall be manufactured under the technical supervision of the Register at the enterprises recognised by the Register in accordance with 1.3.1.2. The material complying with the Register requirements shall be supplied with the Register certificates and marks.

Certificates of ingot, slab and billet manufacturers with the indication of the manufacturer's name, alloy grade, number of cast and chemical composition shall be available to the Surveyor performing survey at the enterprise with no melting facilities. Information about the system, which is capable of ingot, slab and billet identification, shall be provided.

The enterprise, which performs aluminium alloys melting, shall be approved by the Register.

The requirements of the present Part apply to the following aluminium alloys:

.1 *rolled products (plates, strips and sheets):*

5083, 5086, 5383, 5059, 5754, 5456;

temper conditions: O/H111/H112, H116, H321;

national alloys:1530,1550,1561,1561H,1575;

temper conditions: O/H111/H112, H32/H321;

.2 *pressed sections (full sections, hollow sections, panels, angles and bars etc.):*

5083, 5383, 5059, 5086;

temper conditions: O/H111/H112; 6005A, 6061, 6082;

temper conditions: T5, T6;

national alloys: 1530, 1550, 1561, 1575;

temper conditions: O/H111/H112.

Alloys 6005A, 6061 and 6000 series shall not be used in direct contact with sea water unless protected by anodes and/or coating system.

5.1.2 Chemical composition.

The chemical composition of wrought aluminium alloys determined for each cast shall meet the requirements of Table 5.1.2.

If necessary, upon the Register requirement the samples for testing of chemical composition shall be blanked directly from the semi-finished products (plates, panels etc.).

5.1.3 Mechanical properties.

Mechanical properties of wrought aluminium alloys shall meet the requirements of Tables 5.1.3-1 and 5.1.3-2.

5.1.4 Condition of supply.

Condition of supply shall be specified in accordance with EN515. National aluminium wrought alloys shall be delivered with indication of condition of supply in accordance both with EN515 and applicable national standards.

Table 5.1.2

Chemical composition

Grade	Al, %	Si, %	Fe, %	Cu, %	Mn, %	Mg, %	Cr, %	Zn, %	Ti, %	Other elements, %		Note
										Each	Total[1]	
5083	Base	≤0,40	≤0,40	≤0,10	0,4 —1,0	4,0 — 4,9	0,05 — 0,25	≤0,25	≤0,15	≤0,05	≤0,15	—
5383	Base	≤0,25	≤0,25	≤0,20	0,7 — 1,0	4,0 — 5,2	≤0,25	≤0,40	≤0,15	≤0,05[4]	≤0,15[4]	—
5059	Base	≤0,45	≤0,50	≤0,25	0,6 — 1,2	5,0 — 6,0	≤0,25	0,4 — 0,9	≤0,20	≤0,05[5]	≤0,15[5]	—
5086	Base	≤0,40	≤0,50	≤0,10	0,20 — 0,7	3,5 — 4,5	0,05 — 0,25	≤0,25	≤0,15	≤0,05	≤0,15	—
5754	Base	≤0,40	≤0,40	≤0,10	≤0,50	2,6 — 3,6	≤0,30	≤0,20	≤0,15	≤0,05	≤0,15	0,10≤Mn + Cr≤0,60
6005A	Base	0,50 — 0,90	≤0,35	≤0,30	≤0,50	0,040 —0,7	≤0,30	≤0,20	≤0,10	≤0,05	≤0,15	0,12≤Mn + Cr≤0,50
6061	Base	0,40 — 0,80	≤0,7	0,15 — 0,40	≤0,15	0,8 — 1,2	0,04 — 0,35	≤0,25	≤0,15	≤0,05	≤0,15	—
6082	Base	0,70 — 1,30	≤0,50	≤0,10	0,4 — 1,0	0,6 — 1,2	≤0,25	≤0,20	≤0,10	≤0,05	≤0,15	—
National alloys												
1530	Base	0,50 — 0,80	≤0,50	≤0,10	0,30 — 0,60	3,2 — 3,8	≤0,05	≤0,20	≤0,10	≤0,05	≤0,15	—
1550	Base	≤0,50	≤0,50	≤0,10	0,30 — 0,80	4,8 — 5,8	—	≤0,20	≤0,10	≤0,05	≤0,15	—
1561	Base	≤0,40	≤0,40	≤0,10	0,70 — 1,10	5,5 — 6,5	—	≤0,20	—	≤0,05	≤0,15	Zr(0,02 — 0,12)
1561H	Base	≤0,40	≤0,40	≤0,10	0,5 — 0,8	5,5 — 6,5	—	≤0,20	—	≤0,05	≤0,15	Zr(0,10 — 0,17)
1575	Base	≤0,20	≤0,30	≤0,10	0,35 — 0,6	5,4 — 6,4	0,05 — 0,15	≤0,01	≤0,07	≤0,05	≤0,15	Zr(0,1 — 0,1)

[1] Including Ni, Ga, V and other elements not given here.
[2] Mn + Cr: 0,10 — 0,60.
[3] Mn + Cr: 0,12 — 0,50.
[4] Zr: maximum 0,20. The total for other elements does not include Zirconium.
[5] Zr: 0,05 — 0,25. The total for other elements does not include Zirconium.

The parameters of thermal and thermomechanical treatment providing alloys properties are determined by semi-finished products manufacturer.

Condition of supply is specified in the certificate for semi-finished product.

5.1.5 Sampling.

Samples for mechanical properties determining shall be taken so that the longitudinal axis of the test specimen is oriented as follows:

for rolled products, as a rule, — across the direction of rolling. If the width of rolled products is insufficient for cutting off of specimens or if their are special national standards — the production of longitudinal samples is allowed;

for pressed sections (full sections, hollow sections, bars etc.) — along the main axis of the semi-finished product;

for pressed sections for welding of hollow sections — perpendicular to the section axis.

The test samples shall be taken at one third of the width from a longitudinal edge of rolled products.

In the range 1/3 to 1/2 of the distance from the edge to the centre of the semi-finished product test samples shall be taken at the thickest part of it.

Blanking of specimens as well as production of specimens for tests shall be made by the methods preventing the possible change of alloys properties because of hardening.

Each specimen shall be marked so that after its manufacture and cleaning it is posssible to identify it with the specific semi-finished product and to determine the place where it was blanked and orientation of it.

The requirements for tensile test specimens are set forth in 2.2.2.5, and the general requirements for the tests — in 2.1.

5.1.6 Scope of testing.

Semi-finished products of wrought aluminium alloys are submitted for testing in batches.

A batch shall consist of semi-finished products of the same grade (the same cast), of the same form and dimensions (for plates — of the same thickness), of the same temper condition and manufactured by the same technological process.

5.1.6.1 Rolled products.

One tensile test specimen is taken from each 2000 kg. If the weight of the batch exceeds 2000 kg, one extra tensile testing shall be carried out for each 2000 kg (full or not).

For plates, strips or coils weighting more than 2000 kg each, only one tensile test specimen shall be taken.

5.1.6.2 Pressed sections (full sections, hollow sections, bars etc.).

One tensile test specimen shall be taken from each batch:

of 1000 kg — for products weighting less than 1 kg;

of 2000 kg — for products weighting from 1 to 5 kg;

of 3000 kg — for products weighting more than 5 kg.

If the weight of semi-finished products batch exceeds the specified figures, an additional testing shall be carried out for each batch (full or not).

If the test results are unsatisfactory, the testing shall be repeated in accordance with the requirements of 1.3.5.2.

Table 5.1.3-1

Mechanical properties of rolled products with a thickness from 3 to 50 mm inclusive

Grade	Condition of supply	Yield strength R_{p02}, MPa, min	Tensile strength R_m, MPa	Elongation, %, min		
				t, mm	A_{50mm}	A_{5d}
5083	O/H111	125	275 — 350	⩽12,5	16	—
				> 12,5	—	15
	H112	125	⩾275	⩽12,5	12	—
				> 12,5	—	10
	H116	215	⩾305	⩽12,5	12 (10 at t⩽6)	—
				> 12,5	—	10
	H32 or H321	215 — 295	305 — 380	⩽12,5	10 (8 at t⩽6)	—
				> 12,5	—	9
5383	O/H111	145	290	3 < t < 50		17
	H116/H321	220	305	3 < t < 50		10
5059	O/H111	160	330	3 < t < 50		24
	H116/H321	270[1]	370[1]	3 < t < 50		10
5086	O/H111	100	240 — 310	⩽12,5	17	—
				> 12,5	—	16
5086	H112	125	> 250	⩽12,5	8	—
		105	> 240	> 12,5	—	9
5086	H116	195	⩾275	⩽12,5	10	—
				> 12,5	—	9
5086	H32/H321	185	275 — 335	⩽12,5	10 (8 at t⩽6)	—
				> 12,5	—	9
5754	O/H111	80	190 — 240	⩽12,5	18	—
				> 12,5	—	17
National alloys						
1530	O/H111/H112	80	⩾185	⩽12,5	15	—
		60	⩾165	> 12,5	—	11
1550	O/H111/H112	125	⩾275	⩽12,5	15	—
		110	⩾255	> 12,5	—	12
1561	O/H111/H112	175	⩾335	⩽12,5	12	—
				> 12,5	—	10
1561H	H32/H321	245	⩾355	⩽12,5	10	—
		225	⩾335	> 12,5	—	12
1575	O/H111/H112	295	⩾400	⩽12,5	11	—

[1] For thickness exceeding 20 mm, the minimum yield strength and the minimum tensile strength required shall be 260 MPa and 360 MPa accordingly.

[2] For thickness exceeding 6,3 mm, the required yield strength and the required tensile strength shall be within 125 to 205 MPa and 285 to 360 MPa accordingly.

[3] For thickness equal to or less than 30 mm, the minimum yield strength and the minimum tensile strength required shall be 230 MPa and 315 MPa accordingly.

[4] For thickness exceeding 40 mm, the minimum yield strength and the minimum tensile strength required shall be within 200 to 295 MPa and 285 to 370 MPa accordingly.

Table 5.1.3-2

Mechanical properties of pressed semi-finished products with a thickness from 3 to 50 mm inclusive

Grade	Condition of supply	Yield strength R_{p02}, MPa, min	Tensile strength R_m, MPa	Elongation, %, min		
				t, mm	A_{50mm}	A_{5d}
5083	H111	110	⩾270	⩽12,5	10	—
				> 12,5	—	12
	O/H112	125	⩾270	⩽12,5	10	—
				> 12,5	—	12
5383	O/H11	145	290	3⩽t⩽50		17
	H112	190	310	3⩽t⩽50		13
5059	H112	200	330	3⩽t⩽50		10
5086	O/H111	95	⩾240	⩽12,5	15	—
				> 12,5	—	18
	H112	95	⩾260	⩽12,5	10	—
				> 12,5	—	12
6005A	T5/T6	215	⩾260	⩽12,5	8	—
				> 12,5	—	6
6061	T5/T6	240	⩾260	⩽12,5	10	—
				> 12,5	—	8
6082	T5/T6	260	⩾310	⩽12,5	10	—
				> 12,5	—	8
National alloys[1]						
1530	O/H111/H112	80	⩾175	⩽12,5	12	—
				> 12,5	–	12
1550	O/H111/H112	125	⩾255	⩽12,5	13	—
				> 12,5	—	13
1561	O/H111/H112	205	⩾335	⩽12,5	11	—
				> 12,5	—	11
1575	O/H111/H112	295	⩾400	⩽12,5	11	—
				> 12,5	—	11

[1] Given mechanical properties of national alloys also apply to hollow sections made of these alloys if the cut of section does not exceed 60 mm^2 or if the diameter of the circumference is equal or less than 250 mm.

N o t e . The values are applicable for longitudinal and transverse tensile test specimens as well.

5.1.7 Quality testing of welded joints of hollow sections made by welding.

The manufacturer shall carry out macrosection tests and drift expansion tests confirming that there is no lack of fusion in each batch of closed sections.

Sections for testing shall be submitted in batches consisting of no more than five semi-finished products. One section from each batch is submitted to testing. If the lengths of sections exceed 6 m every semi-finished product shall be tested.

The length of specimens shall comply with 2.2.

The test samples from each semi-finished product submitted to testing shall be cut from the each end perpendicular to the axis of the section. In any case the length of the specimen shall not be less than 50 mm.

Drift expansion testing shall be carried out at ambient temperature by means of a hardened steel conical mandrel (of at least 60°).

Testing is considered unsatisfactory if the specimen fails with a clean split along the weld line, which confirms lack of fusion.

5.1.8 Corrosion testing.

Rolled alloys of type 5083, 5383, 5059 and 5086 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected shall be corrosion tested in the above medium with respect to exfoliation and intergranular corrosion resistance.

During the initial works survey for the purpose of its recognition, the manufacturer shall provide data concerning the relationship between microstructure and resistance to corrosion.

Reference photomicrographs taken at 500x, shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples, which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET). The samples shall also have exhibited resistance to intergranular corrosion at a mass loss no greater than $15 mg/cm^2$, when subjected to the test described in ASTM G67. The tests for exfoliation corrosion and intergranular corrosion may be conducted in accordance with other national standards recognized by the Register.

The documentation (reports) relating to the test results and the established relationship between microstructure and resistance to corrosion submitted by the manufacturer shall be approved by the Register. Any changes in production practices of the material shall require respective examinations to be carried out and documentation exhibiting evidence of alloy corrosion resistance to be reapproved.

For rolled alloys of type 5083, 5383, 5059 and 5086 in the H116 and H321 tempers, comparative metallographic examination of one sample selected from mid width at one end of a batch coil (semi-finished product) shall be carried out.

A longitudinal section perpendicular to the rolled surface shall be prepared for comparative metallographic examination. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the metal tested at the initial approval, the batch shall either be rejected or, at discretion of the Register, tested for exfoliation-corrosion resistance and intergranular corrosion resistance. The methods and assessment criteria of corrosion resistance test results shall be in accordance with ASTM G66 and G67 or the standards recognized by the Register.

If the results from testing satisfy the above criteria, the batch is accepted.

As an alternative to metallographic examination, each batch may be tested for exfoliation-corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 or the standards recognized by the Register.

5.1.9 Inspection.

Semi-finished products of wrought aluminium alloys prepared for delivery shall have no internal and external defects negatively affecting their direct use.

All semi-finished products are liable to visual examination.

The application of non-destructive testing is not required if not specially indicated. Still it is supposed that manufacturers use the required non-destructive testing during manufacturing of wrought aluminium alloys in order to maintain products quality at the appropriate level.

It is allowed to rectify the detected surface defects by grinding or flogging provided this corrections doesn't change the size of semi-finished products out of the allowed tolerances.

Ultimate negative thickness tolerances for rolled aluminium alloys are given in Table 5.1.9. Rolling with tolerances in compliance with recognized national or international standards is allowed upon agreement with the Register.

Table 5.1.9

Ultimate negative thickness tolerances for rolled products

Nominal thickness t, mm	Ultimate tolerances in relation to rolled products thickness, mm		
	⩽1500	> 1500 ⩽ 2000	> 2000 ⩽ 3500
$3 \leqslant t \leqslant 4$	0,10	0,15	0,15
$4 < t \leqslant 8$	0,20	0,20	0,25
$8 < t \leqslant 12$	0,25	0,25	0,25
$12 < t \leqslant 20$	0,35	0,40	0,50
$20 < t \leqslant 50$	0,45	0,50	0,65

Ultimate negative thickness tolerances for pressed semi-finished products shall be in compliance with the requirements of recognized international or national standards.

Manufacturer of the material is responsible for dimensions of semi-finished products and the appropriate allowed tolerances.

5.1.10 Marking.

The main requirements for marking are set out in 1.4.

Each semi-finished product shall be clearly identified by the agreed method and in the agreed place by the marks of the manufacturer and the Register.

Marking shall include as a minimum:

name and/or identification of the manufacturer;

alloy grade and temper conditions in accordance with the requirements of the present Chapter;

batch number, semi-finished product number and identification number in accordance with the system adopted by the enterprise to trace back the whole production process.

It is allowed to put marks on labels if semi-finished products are delivered in bundles.

5.1.11 Documents.

Each batch or semi-finished product (if products are delivered in pieces) tested in accordance with 5.1.6 shall have the Register Certificate or the manufacture's document attested by the Register representative. As a minimum, the Register Certificate shall contain the following:

order number;

construction of the ship or floating facility number, when known;

name, number, dimensions and weight of the semi-finished product;

alloy designation (grade) and temper condition;

batch number or semi-finished product number, or identification number, which allows to identify the material delivered.

The results of chemical analysis and mechanical testing confirming that the material meets the Register requirements are the mandatory supplement to the Register Certificate (the supplement may be the Manufacturers' Certificate and/or testing protocols).

If materials are supplied with the Manufacturer's Certificates attested by the Register representative, its form and content shall be agreed with the Register and the customer.

5.2 CAST ALUMINIUM ALLOYS

5.2.1 General.

The requirements of the present Chapter apply to parts and structures of cast aluminium alloy used in hull and ship machinery construction and manufactured under survey by the Register. Semi-finished products of cast aluminium alloys shall be manufactured at works recognized according to 1.3.1.2.

5.2.2 Chemical composition and mechanical properties.

The chemical composition and mechanical properties of items cast of aluminium alloys shall meet the requirements of Table 5.2.2.

When chill or pressure casting is employed, the Register may require higher values of mechanical properties. In this case, the mechanical properties required and the sampling procedure to be used shall be agreed with the Register.

The use of alloys with chemical composition and mechanical properties differing from those indicated in Table 5.2.2 is in each case subject to special consideration by the Register.

For new alloys having a modified chemical composition the Register may require a check of corrosion resistance.

5.2.3 Heat treatment.

If castings of aluminium alloys are heat treated the type of heat treatment is chosen by the maker and recorded in the material certificate.

Table 5.2.2

Chemical composition and mechanical properties of cast aluminium alloys

Grade	Chemical composition, %		Condition of supply	Mechanical properties, min			
	Basic elements	Allowable residual elements (max)		$R_{p0,2}$, MPa	R_m, MPa	A_5, %	*HB*
1	Mg — 2,0...4,5 Si — 0,05...1,3 Mn — 0,05...0,6 Al — remainder	Cu — 0,10 Fe — 0,50 Zn — 0,20 Ti — 0,20	Untreated	70	140	3	50
			Solution-treated with slow cooling down	125	210	1	65
2	Mg — 4...6 Si — 0,5...1,3 Mn — 0,05...0,5 Al — remainder	Cu — 0,10 Fe — 0,50 Zn — 0,10 Ti — 0,20	Untreated	80	150	2	55
3	Mg — 9...11,5 Si — 1,3 (max) Mn — 0,4 (max) Al — remainder	Cu — 0,10 Fe — 0,50 Zn — 0,10 Ti — 0,15	Solution-treated and hardened	145	270	8	60
4	Si — 7...11 Mg — 0,5 (max) Mn — 0,15...0,5 Al — remainder	Cu — 0,10 Fe — 0,60 Zn — 0,30 Ti — 0,15	Untreated	90	150	2	50
			Solution-treated with slow cooling down	165	200	1,5	70
5	Si — 10...13,5 Mn — 0,5 (max) Al — remainder	Cu — 0,10 Fe — 0,60 Zn — 0,30 Ti — 0,15	Untreated	70	150	2	50
			Solution-treated and hardened	80	160	3	50

5.2.4 Sampling.

The samples may be cast on to the castings or cast separately. The sample thickness shall not be less than the minimum wall thickness of the casting. Whenever possible, the cooling of the samples will be effected in conditions similar to the cooling of castings.

In the case of castings for parts operating under high loads the thickness of the samples shall not be less than the thickness of the highest loaded zone of the castings and it shall be specified in the drawing.

5.2.5 Scope of testing.

Depending on their application the castings of aluminium alloys shall be divided into test groups and tested accordingly within the scope indicated in Table 5.2.5.

The scope of testing for castings with cast-on samples shall be agreed with the Register.

Tensile tests are conducted to determine the yield stress, tensile strength and elongation, but in certain cases, the Register may agree to omit the yield stress determination.

When castings for small-size pistons are checked, the Register may also allow to omit the tensile test being satisfied with the hardness test alone.

5.2.6 Inspection.

The castings shall be submitted for inspection in the fettled condition with sprues, heads and burrs removed. They shall be free of any defects detrimental to their application and strength.

Surface defects within the dimensional tolerances may be either ignored or removed by machining.

Certain casting defects may be repaired by welding, the procedure of which shall be agreed with the Register.

If the material of the castings is tested for soundness by hydraulic pressure, the casting drawing shall contain information on the working pressure in the tested space and on the test pressure employed at testing.

The test pressure value is selected on the basis of the requirements of the relevant parts of the Rules or on agreement with the Register.

The Register may require non-destructive testing to be conducted on castings intended for items, which operate under high loads.

5.2.7 Marking and documentation.

Identification, marking and issued documentation — in accordance with the requirements of 3.8.8.

Table 5.2.5

Test groups for cast aluminium alloys

Test group	Conditions of application	Examples of application	Tests	Scope of testing	
				Batch size	Number of tests
I	Cast items subjected to loads and exposed to corrosion	Parts of internal combustion engines, pumps, compressors, fans, valves	Determination of chemical composition	Per cast	
			Tensile test	1 cast	2
II	Parts operating at high temperature and exposed to fuel oil, petroleum products, etc.	Pistons of internal combustion engines, compressors	Determination of chemical composition	Per cast	
			Tensile test	Each casting	1
			Hardness test		1

6 PLASTICS AND MATERIALS OF ORGANIC ORIGIN

6.1 GENERAL

6.1.1 The present Section contains requirements for plastics and materials of organic origin used in hull and ship machinery construction for the manufacture of parts and structures, which are subject to survey by the Register.

The requirements of the present Section may be also applied to plastics and materials of organic origin used in structures and products not normally surveyed by the Register, if their application has considerable effect on the safety of the ship as a whole.

As a rule, manufacture of all materials and items regulated by the present Part shall be carried out in accordance with the documentation, approved by the Register, at works having the quality system approved by the Register and the Type Approval Certificate issued by the Register for the manufactured type of products.

6.1.2 All plastics and materials of organic origin shall satisfy the following requirements unless there are special provisions regarding them in the chapters of the Section:

.1 their combustibility, flame spread, ignatability and also by the volume of smoke and quantity of toxic substances shall be assessed in conformity with 1.6, Part VI "Fire Protection";

.2 they shall ensure reliable operation of items and structures on the open deck at temperatures from -40 to $+70$ °C and in the interior spaces of the ship at temperatures from -10 to $+70$ °C unless their service conditions provide for lower or higher operating temperatures;

.3 they shall resist embrittlement and reduction of mechanical properties in service by more than 30 per cent in comparison with the original values;

.4 they shall resist decay and destruction by fungi and not to affect adversely the materials, with which they come into contact.

6.1.3 Scope of technical supervision.

6.1.3.1 The main provisions defining the scope and procedure of technical supervision are stipulated in 1.1.5 and 1.3 of the present Part and Section 3, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

6.1.3.2 Technical supervision over manufacture of materials and products at works includes:

.1 review and analysis of the manufacturer's application with attachments thereto (refer to 6.1.3.2.2);

.2 survey of the works including the quality system assessment and control testing (refer to 6.1.3.2.3);

.3 issue of the Type Approval Certificate (refer to 6.1.3.2.4).

6.1.3.2.1 To obtain the Register approval of the manufacturer's products, as satisfying the requirements of the Rules, and to get the documents mentioned in 1.1.5, the manufacturer shall apply to the Register with a request.

6.1.3.2.2 Application of the manufacturer shall be supplemented by the following documents:

.1 information describing the works and its products (documents confirming the works status, its structure, production and control management schemes);

.2 list of manufactured materials and products;

.3 information on the staff of employees and their qualification;

.4 information on qualification of the personnel involved in the product quality system;

.5 the availability of the quality system at works in compliance with ISO 9001 standard, confirmed by a certificate issued by the authorized organization, may be accepted by the Register as an evidence of the required level of the quality systems at works without additional requirements in this respect;

.6 information on available approvals by other classification societies and results of earlier tests, also data on practical application of materials and products indicated in the application confirming the possibility of their application for intended purpose;

.7 Quality Manual with description of quality policy;

.8 procedures and instructions describing production processes, sources of supply and stockyards of source materials, storage of finished products;

.9 data on periodical control equipment and devices employed in the process of production, as well as equipment of the works laboratory;

.10 specifications or other technical documents describing materials and products mentioned in the application and defining their main characteristics and conditions of manufacture;

.11 rules for safe utilization of materials or products;

.12 program of testing the specimens of materials or products compiled on the basis of requirements of the present Rules and technical documentation for materials or products.

6.1.3.2.3 If the results of consideration of the submitted documentation are positive, a survey of the manufacturer's works is undertaken; it is aimed at establishing the actual condition of organization and quality control processes including products manufacture, as well as control tests in accordance with the program approved by the Register.

If the tests of products in question cannot be conducted at the manufacturer's works, it can be done at a laboratory approved by the Register.

The availability at the manufacturer's of the quality system complying with ISO 9001 standards confirmed by the document issued by the authorized organization, may be considered by the Register an evidence of the necessary level of monitoring systems implemented at the manufacturer's without any additional requirements in this respect.

6.1.3.2.4 Where results of the manufacturer's survey are satisfactory, the Type Approval Certificate for the products is issued.

The terms of validity of Type Approval Certificate, as well as procedure and conditions of their application shall be agreed upon at issue of this document with regard to the assessment of the manufacturer's quality system.

If the manufacturer has already got the quality system approved and it was confirmed during the survey that a system of testing and control ensuring the required level of manufactured products quality is actually in operation, a Type Approval Certificate may be issued on the basis of satisfactory results of the technical documentation consideration and products control testing.

6.1.3.2.5 The products shall be supplied with the copy of the Type Approval Certificate.

6.2 MATERIALS FOR REINFORCED PLASTIC STRUCTURES

6.2.1 General.

The present requirements cover materials for the manufacture of glass-fibre reinforced ship structures and systems, and of other items subject to survey by the Register.

6.2.2 Glass-reinforcement material.

6.2.2.1 As reinforcement material, glass-fibre materials in the form of rovings, roving cloths, twisted composite filaments, mats and chemically bonded roving lengths (not less than 25 mm long) may be used.

6.2.2.2 The application of a reinforcement material other than glass fibre may be permitted by the Register on the case-to-case basis.

6.2.2.3 Reinforcement materials shall be manufactured from non-alkaline aluminoborosilicate glass (SiO_2 52 — 56 %, CaO 16 — 25 %, Al_2O_3 12 — 16 %, B_2O_3 6 — 12 %, MgO 0 — 6 %, Na_2O+K_2O 0 — 1 %).

6.2.2.4 Individual elementary fibres shall have a diameter of 5 to 15 μm.

6.2.2.5 The moisture content in the reinforcement material shall not exceed 0,2 per cent of the mass of the material.

6.2.2.6 Cloths of reinforcement material shall be treated with water-repellent adhesive compound to ensure a secure bond with the resin.

6.2.2.7 The adhesive, by which the bondage of roving lengths is ensured in mats, shall be well soluble in the resin without any adverse effect on its properties. A rapid solution of the adhesive shall not result in the mat collapsing while it is impregnated with the resin.

6.2.2.8 The mechanical properties of reinforcement materials shall be in compliance with the Register-approved documentation.

6.2.2.9 Each batch of reinforcement material shall be provided with the maker's certificate stating the following:

manufacturer;

mark;

type of cloth;

weight per unit length or area;

N_2O + K_2O content (alkalinity);

type of resin, for which the water-repellent adhesive treatment was made;

test results.

6.2.3 Bonding agent.

6.2.3.1 When manufacturing reinforced plastic structures, polyester resins approved by the Register and produced by Register-approved manufacturers shall be used.

6.2.3.2 Application of epoxy resins may be permitted by the Register on the case-to-case basis.

6.2.3.3 The physical and mechanical properties of the resin shall be in accordance with the requirements of Table 6.2.3.3.

Table 6.2.3.3

Gelation time, min, min	Minimal temperature of thermal deformation for resin in solid condition, °C, min	Modulus of elasticity in bending, MPa, min	Water absorption in 24 h, %, max
20	70	3000	0,3

6.2.3.4 Addition of pigments and other colouring agents adversely affecting the resin properties is permitted for the decorative layer compound only, and their content shall not exceed 15 per cent of the resin weight.

6.2.3.5 Under the effects of sea water in conformity with 2.3.12.1, oil products in conformity with 2.3.11.2 and ageing in conformity with 2.3.10.1, the mechanical properties of resin shall not deteriorate by more than 25 per cent as compared to their initial values.

6.2.3.6 To verify the resin adaptability to manufacture and the resin properties, the Register may require plastic specimens, reinforced with several layers of glass mats, to be prepared and tested. After the complete hardening of the specimen, its bending strength shall not be less than 90 MPa.

6.2.3.7 When the resin is approved by the Register, instructions on the application and storage of technical documentation for the resin shall be submitted together with the documentation proper, in which, among other things, the chemical resistance of the resin to the attack of various aggressive media shall be indicated.

6.2.3.8 Each batch of resin shall be provided with the maker's certificate stating the following:

manufacturer;

mark;

test results.

6.3 LAMINATED TEXTILES

6.3.1 General.

The present requirements apply to textiles subject to survey by the Register, which have a rubber or plastic watertight coating and are intended for structures that are under pressure during their service.

6.3.2 Properties.

6.3.2.1 Laminated textiles shall be air-tight and shall comply with the requirements of Table 6.3.2.1.

Table 6.3.2.1

Mechanical properties

Tensile strength, kN/5, cm		Breaking elongation, %		Tear propagation strength, N		Coating adhesion, N/cm
warp	weft	warp	weft	warp	weft	
min		max		max		
1	2	3	4	5	6	7
2,0		35		40		10

N o t e . On agreement with the Register, the tensile strength may be reduced to equal the strength required by the Register for the envelopes of particular structures, but not more than to four times the hoop stress developed in gas-filled pipes under the pressure, at which safety valves open.

6.3.2.2 After ageing and bend test, the change of tensile strength in laminated textiles shall not be more than 10 per cent of that before ageing, and the difference of dimensions along the warp and weft before and after ageing shall not be more than 2 per cent.

When the adhesive joints of laminated textiles are tensile-tested before and after ageing, the rupture shall occur in the base material.

6.3.2.3 No stickiness, cracks, delaminations or colour modifications shall be observed on the surface of laminated textiles after testing for bending, ageing, creasing and shape stability after ageing, oil resistance, cold resistance, resistance to ozone and sea water.

6.3.2.4 The colouring agents applied shall not detrimentally affect the properties of the base material.

6.3.3 Sampling.

Sampling for test specimens shall be effected from each batch of laminated textiles 0,1 m from the edge and at least 1 m from the roll end. Samples shall be taken 24 h after fabrication at the earliest.

6.3.4 Scope of testing.

6.3.4.1 Laminated textiles are submitted for tests in batches. A batch consists of one roll fabricated during one manufacturing cycle.

If the results of mechanical testing are continuously satisfactory, the mass of material comprising the batch may be increased on agreement with the Register.

6.3.4.2 For each batch, tensile tests to determine breaking elongation as stated in 2.3.2.2, test to determine tear propagation strength as stated in 2.3.2.3 on ten specimens each (five along the warp and five along the weft), delamination test as stated in 2.3.2.4 on three specimens and air permeability test as stated in 2.3.13 on two specimens shall be effected, and the material mass shall be determined in accordance with a recognised standard.

6.3.4.3 For the purpose of laminated textiles approval, tensile test after ageing in accordance with 2.3.10.2, bend test in accordance with 2.3.5.3, test of the bond joints of laminated textiles before and after ageing in accordance with 2.3.2.5 on ten specimens each (five along the warp and five along the weft), creasing and shape stability test after ageing in accordance with 2.3.10.3, oil product resistance test in accordance with 2.3.11.2, sea water resistance test in accordance with 2.3.12.2, cold resistance test in accordance with 2.3.14 and ozone resistance test in accordance with 2.3.15 shall be effected in addition to those mentioned under 6.3.4.2.

6.3.4.4 The test results shall comply with the requirements of 6.3.2.

6.3.5 Inspection.

On the surface of laminated textiles, damage, recesses, dead folds, textile flaw marks, spots, blisters, porosity or other defects, which may preclude their application in accordance with the purpose, are not permitted.

6.3.6 Marking.

Marking of laminated textiles is effected in accordance with 1.4. In addition, the mass of material per unit of area shall be stated.

6.4 FOAM PLASTICS

6.4.1 General.

The present requirements apply to foam plastics used for the manufacture of items subject to survey by the Register.

6.4.2 Properties.

6.4.2.1 By their properties and conditions of application, foam plastics are subdivided into three grades:

grade 1 is represented by rigid foam plastics for filling up the spaces between supporting surfaces of sandwich structures,

grade 2 is represented by rigid foam plastics for filling up the air chambers of lifeboats and other similar hollow spaces,

grade 3 is represented by elastic foam plastics for the manufacture of buoyant material for life jackets.

6.4.2.2 Foam plastics shall chiefly have closed-cell structure.

6.4.2.3 The shrinkage of grades 1 and 2 foam plastics shall not result in poor adhesion to boundary surfaces.

6.4.2.4 The physical and mechanical properties of grade 1 foam plastics shall be in accordance with Table 6.4.2.4.

Table 6.4.2.4

Apparent density, g/cm^3, min	Bending strength, MPa, min	Modulus of elasticity in bending, MPa, min	Compression strength, MPa	Modulus of elasticity in compression, MPa, min	Water absorption in 24 h, kg/m^2, max
0,8	0,3	12	0,7	30	0,2

6.4.2.5 The physical and mechanical properties of grades 2 and 3 foam plastics shall be in accordance with the Register-approved documentation.

6.4.2.6 Under the effects of sea water and petroleum products, the mechanical properties of grade 1 foam plastics shall not deteriorate by more than 25 per cent as compared to the initial values.

6.4.2.7 Under the effects of 10 cycles of temperature variation in conformity with 2.3.1, high-octane petrol in conformity with 2.3.11.3 and fresh water as stated in 2.3.9.2, the buoyancy of grade 2 foam plastics shall not be reduced by more than 5 per cent of the initial value.

6.4.2.8 When approving foam plastics of grade 2, they shall also be tested by conditioning in oil products in conformity with 2.3.11.4.

6.4.2.9 Under the effects of 10 cycles of temperature variation in conformity with 2.3.16 and of fresh water as stated in 2.3.9.2, the floatability of grade 3 foam plastics shall not be reduced by more than 5 per cent, and if they come additionally under the effects of diesel oil in conformity with 2.3.11.3, it shall not be reduced by more than 16 per cent of the initial value.

6.4.2.10 The cyclic effects of temperature, oil products and fresh water shall not bring about a deterioration of the mechanical properties of grades 2 and 3 foam plastics.

6.4.3 Sampling.

Samples shall be cut out in the middle of a foam-plastic block, and a section with the most uniform cell structure shall be chosen for the purpose.

6.4.4 Scope of testing.

6.4.4.1 Testing of grade 1 foam plastics.

6.4.4.1.1 Compression strength is determined on three specimens in compliance with 2.3.3.2, and for this purpose the maximum load causing an abrupt failure of the foam plastic structure is determined, which shall be reached within 1 min approximately.

6.4.4.1.2 Apparent density is determined on three specimens in compliance with 2.3.7.

6.4.4.1.3 Bending strength is determined on three specimens in compliance with 2.3.5.1.

6.4.4.1.4 Water absorption is determined on five specimens in compliance with 2.3.9.

6.4.4.1.5 Resistance to oil products is determined in conformity with 2.3.11.2, and to sea water, in conformity with 2.3.12.1. Each of the tests is made on three specimens only at the time of the foam plastic approval.

6.4.4.2 Grade 2 and 3 foam plastics are tested in conformity with technical documentation approved by the Register.

6.4.5 Inspection.

During the inspection, the surface structure of the foam plastic shall be checked at cross section for closed cells.

Under the cyclic effects of temperatures, oil products and fresh or sea water, no cracks, bulges or disintegration shall be visible on the foam plastic surface.

6.4.6 Marking.

The marking of foam plastics is effected in conformity with 1.4.

The test results shall be entered in the Certificate.

6.5 CORROSION-RESISTANT COATINGS

6.5.1 Hull structures corrosion-resistant coatings shall be subject to the Register survey according to the requirements of Part II "Hull", Part XVII "Common Structural Rules for Double Hull Oil Tankers" and Part XVIII "Common Structural Rules for Bulk Carriers".

6.5.2 The approval procedure for the hull structures corrosion-resistant coatings shall comply with 3.1, Part III "Technical Supervision during Manufacture of Materials" of Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

6.5.3 Ship's corrosion-resistant coatings shall be supervised in compliance with the requirements of Section 2, Part V "Technical Supervision during Construction of Ships" of Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

6.6 ROPES OF NATURAL AND SYNTHETIC FIBRE

6.6.1 The present requirements apply to ropes, subject to survey by the Register, which are intended for cargo handling gear, life-saving appliances and other ship appliances.

6.6.2 The ropes shall be manufactured and tested in conformity with standards approved by the Register.

The breaking load on a rope is determined by testing the rope as a whole.

6.6.3 The breaking load on a rope F, in kN, may be determined by the following formula:

$$F = c(\sum_{1}^{m} F_m)n/z \qquad (6.6.3)$$

where c = yarn efficiency factor for the rope, which shall be adopted on the basis of standards or calculated as the ratio of the breaking load on the rope as a whole to the total breaking load on all the yarns making up the rope, both the values being stipulated by the standards;
m = number of yarns, subjected to tensile testing, which conform to standards;
F_m = the greatest load, during the tensile test of a yarn, in kN, after which the specimen breaks;
n = number of yarns in a rope;
z = number of yarns subjected to tensile testing, which is adopted equal to 0,5n for ropes below 80 mm in diameter, 0,3n for ropes 80 to 115 mm in diameter and 0,1n for ropes over 115 mm in diameter.

6.6.4 A rope of synthetic fibre shall undergo testing to determine elongation at breaking.

The mean elongation of a rope at breaking σ_m, in per cent, is determined by the formula

$$\sigma_m = (l_p - l_0)/l_0 100 \qquad (6.6.4)$$

where l_0 = initial length of the rope specimen tested, cm;
l_p = length of the same rope specimen under the load equal to the breaking load on the rope as a whole, which shall be found in the standard, cm.

6.6.5 The compliance of the structure diameter and other parameters of the rope to the standard shall be confirmed by visual inspection and measurements.

On the surface of a finished rope, no brown spots, mould, burned spots or smell of fume or rot shall be detectable.

The colour of the rope shall be uniform along its whole length and shall not differ from that of the yarn or synthetic fibre, of which the rope is manufactured.

6.6.6 The marking of the ropes is effected in conformity with 1.4.

6.6.7 The test results shall be entered in the Certificate of Test, the contents of which shall be agreed with the Register.

6.7 RETRO-REFLECTIVE MATERIALS FOR LIFE-SAVING APPLIANCES

6.7.1 General.

6.7.1.1 The present requirements apply to the retro-reflective materials of life-saving appliances subject to survey by the Register.

6.7.1.2 Proceeding from their service conditions, retro-reflective materials are divided into two types:

type 1 includes materials to be fitted on elastic surfaces occasionally exposed to the weather,

type 2 includes materials to be fitted on rigid surfaces continuously exposed to the weather.

6.7.2 Properties.

6.7.2.1 The tensile strength of retro-reflective materials with an adhesive layer shall not be less than 16 N/25 mm, and of those with a warp for mechanical attachment — 330 N/25 mm in the longitudinal direction and 200 N/25 mm in the transverse direction.

6.7.2.2 Proceeding from the entrance angle and observation angle, the values of the retro-reflection factor R, in cd $lx^{-1}\cdot m^{-2}$, shall not be less than those to be found in Table 6.7.2.2.

Table 6.7.2.2

Entrance angle, deg.	Observation angle, deg.			
	0,1	0,2	0,5	1
5	180	175	72	14
30	140	135	70	12
45	85	85	48	9,4

6.7.2.3 When the material is under a water film and after ageing, the retro-reflection factor may be lowered by not more than 20 per cent as compared to Table 6.7.2.2, and after the abrasion test, it may be lowered by not more than 50 per cent.

6.7.2.4 Exposure to sea water, mildew, salt fog and ultimate temperatures shall not lower the retro-reflection factor of the material.

6.7.2.5 For retro-reflective materials with an adhesive layer, the strength of adhesion to different surfaces shall not be less than 16 N/25 mm.

6.7.2.6 Exposure to ultraviolet irradiation, sea water and distilled water shall not lower the adhesion properties of retro-reflective materials with an adhesive layer.

6.7.3 Sampling.

The sample for the preparation of specimens is taken from each batch of retro-reflective materials at least one metre from the roll end.

Before the specimens have been prepared, the sample is conditioned in conformity with 2.3.1.1 during 24 hours.

6.7.4 Scope of testing.

6.7.4.1 Retro-reflective materials are submitted for testing in batches. A batch comprises one roll manufactured during one production cycle.

Where the test results are stable, the bulk of the batch may be increased on agreement with the Register.

6.7.4.2 Each batch of the material is tensile-tested in conformity with 2.3.2.6, and the strength of adhesion to different surfaces is determined in conformity with 2.3.2.7 for the material with an adhesive layer, as well as the retro-reflection factor in conformity with 2.3.18.1.

6.7.4.3 When approving retro-reflective materials, besides the tests metnioned in 6.7.4.2, the retro-reflection factor is determined for the material under a water film in conformity with 2.3.18.2, after ultraviolet irradiation in conformity with 2.3.10.4, abrasion in conformity with 2.3.22, sea-water conditioning in conformity with 2.3.12.3, exposure to salt fog in conformity with 2.3.12.4, to ultimate temperatures in conformity with 2.3.16 and mildew in conformity with 2.3.21. Besides, the bend test in conformity with 2.3.19, adhesion test in conformity with 2.3.20 and contaminant-resistance test in conformity with 2.3.23 are conducted.

For retro-reflective materials with an adhesive layer, the strength of adhesion to different surfaces shall be determined in conformity with 2.3.2.7 after exposure to the ultraviolet irradiation in conformity with 2.3.10.4 and to distilled and sea water in conformity with 2.3.12.5.

6.7.4.4 Each type of tests shall be conducted at least on three specimens.

6.7.4.5 The test results shall comply with the requirements of 6.7.2.

6.7.4.6 Under the effects of seawater during 10 min, salt fog and ultimate temperatures during 4 h, and after the bend and adhesion tests, no cracks, delamination, bulging, stickiness or change of colour shall be observed on the surface of retro-reflective materials, and their size shall be the same.

6.7.5 Examination.

The surface of retro-reflective materials shall be free from injuries, recesses, creases, delaminations, stains or other defects, which might adversely affect their application in accordance with the purpose.

6.7.6 Marking.

The marking of retro-reflective materials shall be effected in conformity with 1.4.

The test results shall be entered in the Certificate.

6.8 PLASTIC PIPES AND FITTINGS

6.8.1 General.

Plastic pipes shall comply with the requirements of standards approved by the Register.

6.8.2 Strength.

6.8.2.1 The strength of pipes shall be determined by hydraulic failure testing of specimens.

6.8.2.2 The strength of fittings and joints shall not be less than that of pipes.

6.8.2.3 The nominal pressure p_{nom} shall be determined from the following conditions:

for internal pressure

$$p_{nom} < p_{sth}/4 \text{ or } p_{nom} < p_{lth}/2{,}5$$

where p_{sth} = short-term hydraullic test failure pressure;
p_{lth} = long-term hydraulic test failure pressure (more than 100 000 h);

for external pressure

$$p_{nom} < p_{col}/3$$

where p_{col} = pipe collapse pressure.

6.8.2.4 In any case the collapse pressure shall not be less than 0,3 MPa.

6.8.2.5 The maximum working external pressure is a sum of internal vacuum and external pressure of the pipe tested.

6.8.2.6 The maximum permissible working pressure shall be determined taking into account the maximum possible working temperatures in accordance with the manufacturer's recommendations.

6.8.3 Axial strength.

The sum of longitudinal stresses because of pressure, weight and other loads shall not exceed the allowable stress in the longitudinal direction.

For fibre reinforced plastic pipes the sum of longitudinal stresses shall not exceed the half of nominal circumferential stresses determined under nominal pressure.

6.8.4 Impact resistance.

Plastic pipes shall have an impact resistance sufficient for preserving the integrity of piping under external effects likely to occur in service, such as tods falling on them, for instance.

6.8.5 Temperature.

6.8.5.1 The permissible working temperature depending on the working pressure shall be determined in accordance with the manufacturer's recommendations, but in any case it shall be at least 20 °C lower than the minimum heat distortion temperature of the pipe material.

6.8.5.2 The minimum heat distortion temperature shall not be less than 80 °C.

6.8.6 Fire protecting coatings.

Where fire protecting coatings of pipes and fittings are used for achieving the required fire resistance level, they shall comply with the requirements of 6.8.6.1 to 6.8.6.4.

6.8.6.1 As a rule pipes shall be delivered from the Manufacturer with fire protecting coatings on.

6.8.6.2 Fire protecting properties of coatings shall not be diminished when exposed to sea water or oil products. It shall be demonstrated that the coating is resistant to products likely to come into contact.

6.8.6.3 In considering fire protecting coatings such characteristics as thermal expansion, resistance against vibrations and elasticity shall be taken into account. It is advisable that these characteristics are close to the similar characteristics of pipes.

6.8.6.4 Fire protecting coatings shall have the sufficient impact resistance. It is advisable that this characteristic is close to the similar characteristic of the pipe.

6.8.7 Materials approval and quality control during manufacture.

6.8.7.1 Plastic pipes and fittings shall be manufactured by the works having the quality system approved by the Register. The Register-confirmed compliance of the works' quality management system with ISO 9001 shall be considered acceptable.

6.8.7.2 Specimens of pipes and fittigs of each type and size shall be tested for compliance with the requirements of the Rules.

6.8.7.3 Serial specimens of pipes and fittings for tests determining strength, fire resistance and low surface flame spread characteristics, electrical resistance (for electrically conductive pipes) shall be chosen in accordance with the procedure approved by the Register.

6.8.7.4 Each pipe and fitting shall be tested by the manufacturer under hydraulic pressure not less than 1,5 times higher than the nominal pressure.

6.8.7.5 Pipes and fittings shall be permanently marked with identification in compliance with the approved standard. Identification shall include the nominal pressure, the design standard, in accordance with which the pipe is manufactured, and the pipe material.

6.8.7.6 In case the manufacturer does not have the quality system approved by the Register, each batch of pipes and fittings shall be tested for compliance with the requirements of the Rules under the technical supervision of the Surveyor to the Register.

7 ANCHOR AND MOORING CHAIN CABLES

7.1 ANCHOR CHAIN CABLES AND ACCESSORIES

7.1.1 General.

7.1.1.1 The present requirements apply to the materials, design, manufacturing and testing of anchor chain cables and accessories used for ships. The requirements for the chafing chain for emergency towing arrangements are given in 7.1.6.

Unstudded chain cables used for ships in exceptional cases and by the separate agreement with the Register may be manufactured according to the international or national standards recognized by the Register.

7.1.1.2 Chain cables and accessories shall be made and tested by the manufacturers recognized in accordance with 1.3.1.2. In addition to the mentioned in 1.3.1.2, the request shall indicate the material grade, nominal dimensions and, if necessary, specification for the material. If there are several chain cable grades in the request, tests may be conducted only for the highest grade, provided the chain cable material, manufacturing methods and heat treatment are unchanged.

7.1.1.3 Depending on the tensile strength of the chain cable steel used for manufacture, stud link chain cables and accessories are subdivided into grades 1, 2 and 3.

7.1.2 Materials for chain cables and accessories.

7.1.2.1 All the materials used for the manufacture of chain cables shall be made by the manufacturers recognized in accordance with 1.3.1.2.

7.1.2.2 Unless otherwise stated, the rolled products, forgings and castings for chain cables and accessories shall meet the requirements of 3.6.

The Grade 1 rolled products may be used for the manufacture of chain cables with manufacturer's certificates.

7.1.2.3 The studs shall be made of steel corresponding to that of the chain cable links or from rolled, forged or cast carbon steels.

The use of other materials, e.g. grey or nodular cast iron is not permitted.

7.1.3 Design and manufacture.

7.1.3.1 Chain cable links are manufactured by flash butt welding using bar material. Manufacture of the links by drop forging or steel casting is permitted.

Studless links of 26 mm diameter and below may be manufactured by pressure butt welding.

7.1.3.2 Accessories such as kenter and joining shackles, swivels and swivel shackles shall be forged or cast in steel of at least grade 2.

The welded construction of these parts may also be approved.

7.1.3.3 The design of chain cable links and accessories shall comply with specifications approved by the Register bearing in mind Figs. 7.1.3-1 to 7.1.3-7

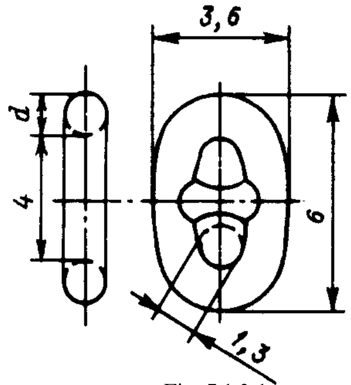


Fig. 7.1.3-1
Common link

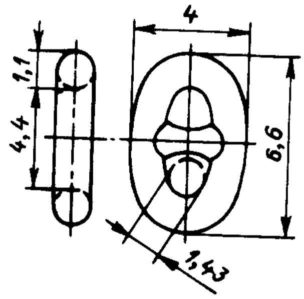


Fig. 7.1.3-2
Enlarged link

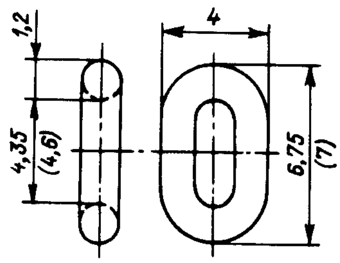


Fig. 7.1.3-3
Studless link

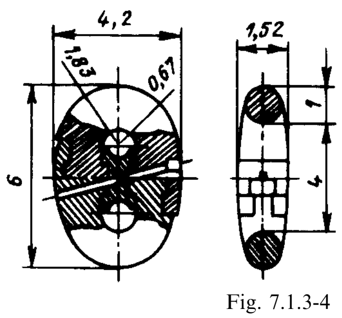


Fig. 7.1.3-4
Kenter joining link

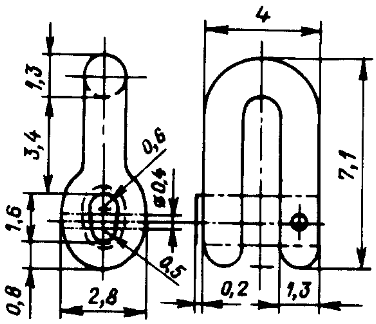


Fig. 7.1.3-5
Joining shackle

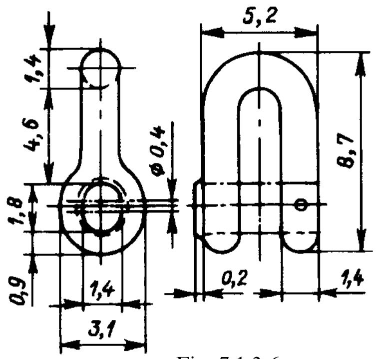


Fig. 7.1.3-6
End shackle

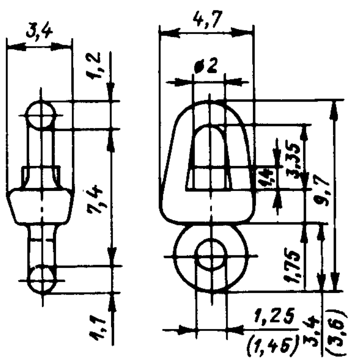


Fig. 7.1.3-7
Swivel

Table 7.1.3.4

Steel grade	Condition of supply	
	Chain cable	Accessories
1	As welded or normalized	Not regulated
2[1]	As welded or normalized	Normalized
3	Normalized, normalized and tempered or quenched and tempered	Normalized, normalized and tempered or quenched and tempered

[1] Chain cables made by forging and casting shall be supplied in the normalized condition.

(dimensions on all figures are given multiple to the nominal diameter of the usual link), and length of chain cable shall comprise an odd number of links.

Where designs do not comply with this and where accessories are of welded construction, relevant drawings shall be submitted to the Register, and the specification shall include full details of the manufacturing process and the heat treatment.

7.1.3.4 According to the grade of steel, chain cables and accessories shall be supplied in one of the conditions specified in Table 7.1.3.4.

The heat treatment shall be performed prior to mechanical tests and also prior to the breaking load and proof load testing.

7.1.3.5 The mechanical properties of the material of a finished chain cable and accessories shall be in accordance with Table 7.1.4.3.3.

7.1.3.6 Chain cables and accessories shall be manufactured in a manner such as to withstand the proof and breaking loads indicated in Tables 7.1.4.1.2-1 and 7.1.4.1.2-2 depending on the relevant chain cable grade.

7.1.3.7 All chain links and accessories shall have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects impairing the performance of the product. The flashes produced by upsetting or drop forging shall be properly removed. Minor surface defects may be fround off so as to leave a gentle transition to the surrounding surface. Remote from the crown local grinding up to 5 per cent of the nominal link diameter or item thickness may be permitted.

7.1.3.8 The dimensions of stud chain links and accessories shall comply with Figs. 7.1.3-1 to 7.1.3-7 and with approved specifications.

The dimensions of studless links shall comply with the requirements of recognised standards, and they are in each case subject to the special consideration of the Register.

7.1.3.9 Allowable tolerances of chain link dimensions.

7.1.3.9.1 Diameter tolerances in the elbow outside the link contact area shall comply with the requirements of Table 7.1.3.9.1.

Table 7.1.3.9.1
Allowable tolerances of chain link diameter

Nominal link diameter, mm	Allowable tolerances[1], mm
Up to 40	–1
Over 40 up to 84	–2
Over 84 up to 122	–3
Over 122	–4

[1]The plus tolerances shall not exceed 5 per cent of the nominal diameter.

7.1.3.9.2 The cross-sectional area of the elbow shall have no negative tolerance.

For the purpose of determining the cross-sectional area the diameter adopted is an arithmetic mean of four values measured at points uniformly distributed along the cross section perimeter.

7.1.3.9.3 Allowable tolerance on assembly measured over a length of 5 links shall not exceed +2,5 per cent of the nominal length (measured with the chain under tension after proof load test).

7.1.3.9.4 Studs shall be located in the link centrally and perpendicular to longitudinal axis of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the kenter and joining shackles. The following tolerances are permitted provided, that the stud fits snugly and its ends lie practically flush against the inside of the link:

maximum off-centre distance X: 10 per cent of the nominal diameter d;

maximum deviation α from the 90° — position: 4°.

The tolerances shall be measured in accordance with Fig. 7.1.3.9.4.

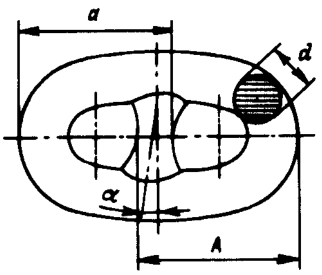


Fig. 7.1.3.9.4:

$$X = \frac{A - a}{2}$$

7.1.3.10 The following tolerances are applicable in accessories:

nominal diameter + 5 per cent ±0;

other diameter −2,5 per cent.

7.1.3.11 The welding of studs shall be in accordance with procedure approved by the Register subject to the following conditions.

The studs shall be of weldable steel in accordance with 7.1.2.3.

The studs shall be welded at one end only, i.e. opposite to the weldment of the link. The stud ends shall fit the inside of the link without appreciable gap.

The welds, preferably in the downhand position, shall be executed by qualified welders using suitable welding consumables.

All welds shall be carried out before the final heat treatment of the chain cable.

The welds shall be free from defects liable to impair the proper use of the chain cable. Undercuts, end craters and similar defects shall, where necessary, be ground off.

If required by the Register, a procedure for the welding of chain studs shall be effected.

7.1.4 Testing of finished chain cables.

7.1.4.1 Proof and breaking load testing.

7.1.4.1.1 All finished chain cables shall be subjected to the tests specified below in the presence of a Surveyor to the Register. To ensure the proper visual inspection of the chain cable and of its weld in particular, if present, the chain cables shall be submitted for tests free from paint and anti-corrosion media.

The tests shall be conducted on the equipment approved by the relevant competent organizations in the laboratory recognized by the Register and be witnessed by the Register representative.

7.1.4.1.2 Each chain cable length (27,5 m) shall be subjected to a loading test at the proof load in accordance with the requirements of Table 7.1.4.1.2.

7.1.4.1.3 For the breaking load test, one sample comprising at least of three links shall be taken from every four length of the chain cable. The links concerned shall be made in a single manufacturing cycle together with the chain cable and be welded and heat-treated together with it. The breaking load according to Table 7.1.4.1.2 shall be maintained for a minimum of 30 seconds.

7.1.4.1.4 If the tensile loading capacity of the testing machine is insufficient to apply one breaking load for chain cables of large diameter, another equivalent testing method shall be agreed with the Register.

7.1.4.2 Retests.

7.1.4.2.1 Shall a breaking load test fail, a further test specimen may be taken from the same length of chain cable and tested. The test shall be considered successful if the requirements are then satisfied.

If the retest fails, the length of chain cable concerned shall be rejected. If the manufacturer so wishes, the remaining three lengths belonging to the unit test quantity may then be individually subjected

Table 7.1.4.1.2

Test	Steel grade		
	1	2	3
Proof load, kN Breaking load, kN	$0{,}00686d^2 \times (44 - 0{,}08d)$ $0{,}00981d^2 \times (44 - 0{,}08d)$	$0{,}00981d^2 \times (44 - 0{,}08d)$ $0{,}001373d^2 \times (44 - 0{,}08d)$	$0{,}01373d^2 \times (44 - 0{,}08d)$ $0{,}01961d^2 \times (44 - 0{,}08d)$
Note. d = nominal diameter, mm.			

to test at the breaking load. If one such test fails to meet the requirements, the entire unit test quantity is rejected.

7.1.4.2.2 Shall a proof load test fail, the defective link (links) shall be replaced, a local heat treatment to be carried out on the new link (links) and the proof load test shall be repeated. An investigation shall be made to identify the cause of the failure.

7.1.4.3 Tensile and impact testing of specimens cut out of a finished chain cable.

7.1.4.3.1 For Grade 2 and 3 chain cables, mechanical test specimens shall be taken from every four lengths according to the requirements of Table 7.1.4.3.1.

For forged and cast chain cables, the tests shall be carried out on the metal of each heat and charge (heat treatment). Sampling is effected according to 3.6.5 and retesting — according to 3.6.5.4. The Register may require a tensile test transverse to the weld and an impact test with a notch along the weld for specimens taken from the weldment. Testing and retesting are conducted in the presence of the Register representative.

7.1.4.3.2 For the purpose of test specimen preparation, provision shall be made for an additional link (or where the chain diameter is small, several links) in a length of chain cable. The additional link shall be manufactured by the same procedure as the specimen for breaking test in accordance with 7.1.4.1.3.

7.1.4.3.3 The test results shall comply with the requirements of Table 7.1.4.3.3 and shall be indicated in the certificate.

7.1.4.4 Chain cables shall be marked at both ends of each length, and the marking shall include certificate number, chain cable grade and the Register stamp. The arrangement of symbols comprising the marking shall be in accordance with Fig. 7.1.4.4.

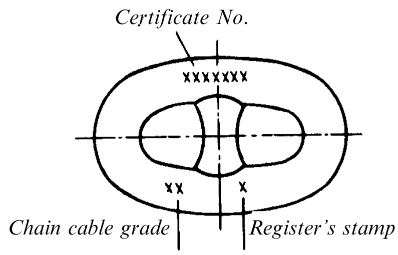


Fig. 7.1.4.4

Table 7.1.4.3.1

Number of mechanical test specimens for finished chain cables and accessories

Steel grade	Manufacturing method	Condition of supply	Number of test specimens		
			Tensile test for base metal	Charpy V-notch impact test	
				Base metal	Weldment
1 2	Flush-butt welded	AW N	Not required	Not required	Not required
3	Flush-butt welded	AW	1	2	3
		N	Not required	Not required	Not required
	Forged or cast	N	1	3 (Not required for chain cables)	3
	Flush-butt welded	N NT QT	1	3	3
	Forged or cast	N NT QT	1	3	Not required
Symbols: AW = as welded; N = normalized; NT = normalized and tempered; QT = quenched and tempered.					

Table 7.1.4.3.3

Mechanical behaviour of finished chain cables and accessories

Steel grade	Yield stress R_{eH}, N/mm^2, min	Tensile strength R_m, N/mm^2	Elongation A_5, %, min	Reduction of area Z, %, min	Charpy V-notch impact test[1], KV		
					Test temperature, ℃	Impact energy value, J, min	
						Base metal	Weldment
1	Not required	Not required	Not required	Not required	Not required	Not required	Not required
2	295	490—690	22	Not required	0	27	27
3	410	690 min	17	40	0 –20	60 35	50 27

[1] If required by the Register, the impact tests for Grade 3 are carried out at a temperature of –20 ℃.

7.1.5 Testing of accessories.

7.1.5.1 Proof and breaking load testing.

7.1.5.1.1 All chain cable accessories are subject to the tests below witnessed by the Register representative. To ensure the proper visual inspection, of weldments in particular, if present, the accessories shall be submitted for tests free from paint and anticorrosion media.

7.1.5.1.2 All accessories are tested by the proof load in accordance with the above requirements and those in Table 7.1.4.1.2.

7.1.5.1.3 For breaking load test in accordance with Table 7.1.4.1.2, the accessories shall be submitted in batches.

A batch of shackles, swivels, swivel shackles, large links and end links shall comprise not more than 25 items and one consisting of Kenter shackles shall comprise 50 items of the same grade and size, which were manufactured from material of the same heat and heat treated in the same furnace charge.

Out of each batch, one item is subjected to the breaking load test and after testing, the use of the items according to the purpose is not permitted.

7.1.5.1.4 On agreement with the Register, breaking load test may be waived if:

the breaking load is confirmed by the positive results of the initial testing of the item when the manufacturer is approved by the Register; and

the results of mechanical testing in accordance with 7.1.5.2 are satisfactory for each batch; and

the parts are subjected to suitable non-destructive testing in accordance with a procedure approved by the Register.

7.1.5.1.5 Notwithstanding the above, at the discretion of the Register, the items, which withstood the tests with a breaking load prescribed for the particular chain cable, may be used for the intended purpose, provided the following conditions were met in manufacturing of the items:

.1 the material, of which the items are made, meets more severe requirements than those prescribed for the chain cable, with which the items are expected to be used (e.g., material corresponds to grade 3 where the required grade is 2);

.2 the material, of which the items are made, corresponds to the grade required for the item but the item has greater dimensions than those required and has withstood the tests with breaking load at least 1,4 times over the prescribed one.

7.1.5.2 Mechanical tests.

7.1.5.2.1 Unless otherwise stated, forgings and castings after heat treatment shall meet the requirements of Table 7.1.4.3.3. For test sampling, castings and forgings of similar dimensions originating from the same heat treatment charge and the same heat of steel may be combined into batches. Testing and retesting shall be witnessed by the Register representative. From each manufacturing batch in one material grade, one tensile test specimen and the set of three-impact test specimens are taken in accordance with Table 7.1.4.3.1. Specimens are machined in accordance with 3.6.5; the retests are performed according to 3.6.5.4. Enlarged links and end links need not be tested, provided they are manufactured and heat treated together with the chain cable.

7.1.5.2.2 The results of the mechanical tests shall comply with the requirements of Table 7.1.4.3.3.

7.1.5.3 Each item of accessories shall be marked, and the marking shall include the certificate number, grade and the Register stamp.

7.1.6 Chafing chain for emergency towing arrangements.

7.1.6.1 General.

The present requirements apply to the chafing chain for chafing gear of emergency towing arrangements (ETA) with specified safe working load of 1000 kN (ETA1000) and 2000 kN (ETA2000). Chafing chains other than, those specified are subject to the special consideration by the Register.

7.1.6.2 Chafing chains shall be manufactured only by the works recognized by the Register according to 7.1.1.2.

7.1.6.3 The materials used for the manufacture of the chafing chain shall meet the requirements of 7.1.2.

7.1.6.4 The chafing chain shall be designed, manufactured and tested in accordance with the requirements of 7.1.3 to 7.1.5.

7.1.6.5 One end of the chafing chain shall be suitable for connection to the strongpoint of a towed vessel, and the other end of the chafing chain shall be fitted with a pear-shaped open link allowing connection to a shackle (refer to Fig. 7.1.6.5).

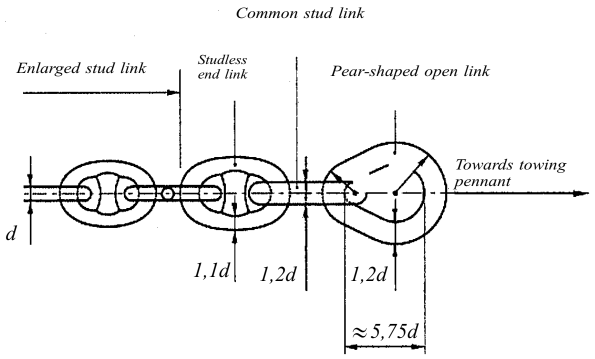


Fig. 7.1.6.5

7.1.6.6 The chafing chain for emergency towing arrangements shall be of Grade 2 or 3 and withstand a breaking load of at least twice the safe working load. For each type of ETA, the nominal diameter of a common link shall be in accordance with Table 7.1.6.6.

Table 7.1.6.6

Type of ETA	Nominal diameter of common link, *d*, mm, min	
	Grade 2	Grade 3
ETA1000	62	52
ETA2000	90	76

7.1.7 Documents.

Chafing chains complying with the above requirements shall have the Register certificates containing as a minimum the following data:

certificate number;

order number;

manufacturer's name;

grade;

chemical composition (including the total content of aluminium);

nominal diameter/weight;

proof/breaking load;

type of heat treatment;

manufacturing method;

chain marking;

length;

mechanical properties if needed.

If required, protocols of tests performed may be attached to the certificate.

7.2 MOORING CHAIN CABLES AND ACCESSORIES

7.2.1 General.

7.2.1.1 Scope of application.

These requirements apply to the materials, design, manufacture and testing of mooring chain cables and accessories intended for applications such as mooring of mobile offshore and jack-up type drilling units and fixed offshore platforms.

In the general case, accessories comprise the following: common links, connecting common links (splice links), enlarged links, end links, detachable connecting links (shackles), end shackles, swivels and swivel shackles.

7.2.1.2 Chain grades.

Depending on the tensile strength of steels used for manufacture, chain cables and accessories shall be subdivided into grades R3, R3S and R4.

7.2.1.3 Recognition of chain manufacturers.

Mooring chain cables and accessories shall be manufactured only by works recognized in accordance with 1.3.1.2. For this purpose, approval tests shall be carried out when performing the survey of works, which shall generally include proof and breaking load tests, mechanical tests of the chain cable material, and control of measurements shall be performed.

Manufacturers shall submit information on the works and manufacturing process in compliance with Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships; besides, documentation on the details of the following manufacturing processes shall be submitted:

bar heating and bending including method, temperatures, temperature control and recording;

flash welding including current, force, time and dimensional variables as well as control and recording of parameters;

flash removal including method and inspection;

stud insertion method and inspection;

heat treatment including furnace types, means of specifying, controlling and recording of temperature and methods, quenching medium, cooling methods;

proof and break loading including method/machine, method of measurement, recording;

non-destructive testing procedures and areas of application.

7.2.1.4 Approval of quality assurance system at chain manufacturers.

Chain manufacturers shall have a documented and effective system of quality control approved by the Register. The provision of such a system is required in addition to, and not in lieu of, tests stipulated in this Chapter.

7.2.1.5 Recognition of rolled bar manufacturers.

7.2.1.5.1 Rolled steel bars for chain cables shall be manufactured only by the mills recognized by the Register, which hold a Recognition Certificate for Manufacturer (refer to 1.3.2 and 3.6). If a chain manufacturer receives rolled steel from a number of suppliers, each supplier shall be recognized by the Register and shall have the Recognition Certificate for Manufacturer. The Recognition Certificate for Manufacturer and supplier of rolled steel bars may be issued to the works only after successful testing of completed chain made of supplied rolled steel. The thickness of rolled steel bars indicated in the Recognition Certificate for Manufacturer shall be limited to the thickness of the bars tested.

The bar manufacturer shall provide evidence that the material is resistant to strain ageing, temper embrittlement and hydrogen embrittlement (refer to 3.6.5.3).

7.2.1.5.2 Forgings and castings intended for the manufacture of finished or semi-finished chain accessories shall be manufactured at works surveyed by the Register. When the results of the survey are satisfactory, the Recognition Certificate for Manufacturer may be issued. Documentation for supply of finished or semi-finished chain accessories, including sketches and drawings, shall be agreed with the Register.

7.2.2 Materials for chain cables and accessories.

7.2.2.1 The material for chain cables shall comply with the requirements specified in the present Chapter and in 3.6, and the mechanical properties shall be in compliance with Table 3.6.3.

When rolled steel is supplied, the batch presented for testing shall include semi-finished products of the same grade, originating from the same heat of steel, the same furnace charge and having the same nominal dimensions.

7.2.2.2 Unless otherwise specified, steel forgings and castings for chain accessories shall comply with the requirements of 3.7 and 3.8, respectively.

7.2.2.3 After heat treatment the mechanical properties of forging and casting material shall comply with the requirements of Table 3.6.3. For steel castings of R3 and R3S grades chain cables, it is permitted to lower the reduction of area, Z, down to 40 per cent and down to 35 per cent for grade R4.

Forgings and castings are presented for testing in batches. A batch of forgings or castings shall include semi-finished products of the same grade, similar dimensions, originating from the same heat of steel and the same furnace charge. The number of heats in a batch may exceed one. The diameters of forgings in a batch shall not differ by more than 25 mm.

7.2.2.4 Steel forgings and castings for chain accessories shall undergo 100 per cent ultrasonic testing according to the procedure approved by the Register.

7.2.2.5 The studs shall be made of the steel used for common links or the like according to technical documentation approved by the Register.

The carbon content in the metal of studs, being subjected to welding in links, shall not exceed 0,25 per cent.

7.2.3 Design and manufacture of chain cables and accessories.

7.2.3.1 The design of chain cable links and accessories shall meet the requirements in 7.1.3.3.

The studs shall be impressed in the chain link to secure their position. The shape and depth of the studs impression shall not cause any harmful effect on links quality. Machining of kenter shackles shall result in fillet radius not less than 3 per cent of link diameter.

7.2.3.2 Chain cables shall be manufactured from rolled steel bars in continuous lengths by flash butt welding.

It is permitted to manufacture a chain cable from separate lengths using connecting links, but not more than 3 links in each 100 m of chain.

7.2.3.3 In the case of electric resistance heating or furnace heating, the heating phase shall be controlled with an optical heat sensor or a contact thermocouple, respectively. The temperature of the surface shall be checked at least once every 8 hours and records shall be made. The following welding parameters shall be controlled during the flash-butt welding of each link:

platen motion;

current as a function of time;

hydraulic pressure.

The controls shall be checked at least every 4 hours, and records shall be made.

The chains shall generally be austenitized. Temperature and time or temperature and chain speed shall be controlled and continuously recorded throughout heat treatment process.

Methods of heat treatment shall comply with the documentation approved by the Register.

7.2.3.4 The mechanical properties of the finished chain and accessories shall meet the requirements of Table 3.6.3.

7.2.3.5 Depending on the grade, chain cables and accessories shall withstand the proof and breaking loads given in Table 7.2.3.5.

Table 7.2.3.5

Test load for chain cables

Parameters	Grade R3	Grade R3S	Grade R4
Proof test load, kN	$0{,}0148d^2 \times (44-0{,}08d)$	$0{,}0180d^2 \times (44-0{,}08d)$	$0{,}0216d^2 \times (44-0{,}08d)$
Break test load, kN	$0{,}0223d^2 \times (44-0{,}08d)$	$0{,}0249d^2 \times (44-0{,}08d)$	$0{,}0274d^2 \times (44-0{,}08d)$
Chain weight, kg/m	$0{,}0219d^2$		
Length over 5 links, mm: min max	$22d^2$ $22{,}55d$		

7.2.3.6 The dimensions of chain cable links and accessories shall comply with Figs. 7.1.3.1 to 7.1.3.7 or technical documentation approved by the Register.

7.2.3.7 The design and dimensions of links and accessories shall comply with ISO 1704:1991 or to the relevant documentation approved by the Register.

The following tolerances are applicable to links:

.1 diameter measured at the crown:

up to 40 mm: – 1 mm;

over 40 up to 84 mm: – 2 mm;

over 84 up to 122mm: – 3 mm;

over 122 mm: – 4 mm.

The plus tolerance may be up to 5 per cent of the nominal diameter.

The cross sectional area of the crown shall have no negative tolerance;

.2 diameter measured at locations other than the crown:

the diameter shall have no negative tolerance;

the plus tolerance may be up to 5 per cent of the nominal diameter.

In chain-cable supply documentation submitted for approval, the plus tolerance shall be indicated by the manufacturer with regard to the welding area;

.3 the allowable tolerance on a length of 5 links, indicated by the manufacturer, shall not exceed 2,5 per cent and shall not be negative;

.4 all other link dimensions appropriately specified by the manufacturer shall not exceed 2,5 per cent;

.5 requirements for measurements and allowable tolerances of studs are specified in 7.1.3.9.4.

Allowable tolerances for chain accessories shall not exceed those specified in 7.1.3.10.

7.2.3.8 For grade R3 and R3S chain cables, the welding of studs is permitted according to 7.1.3.11. Welding of studs in grade R4 chain cables shall not be effected without prior agreement of the procedure by the Register.

The welds shall be made by qualified welders using an approved procedure and low-hydrogen consumables.

The size of fillet welds shall, as a minimum, be in compliance with API Specification 2 (refer to Fig. 7.2.3.8). The welds shall be of good quality and free from defects such as cracks, lack of fusion, gross porosity and undercuts exceeding 1 mm.

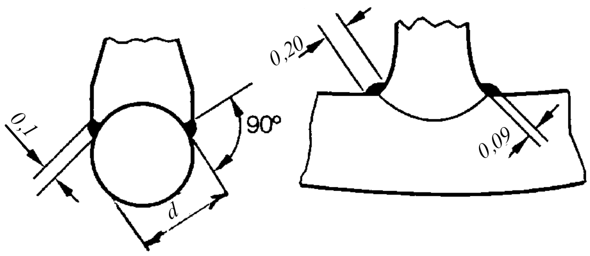


Fig. 7.2.3.8

All stud welds shall be visually examined. At least 10 per cent of all stud welds within each length of chain shall be examined by the magnetic particle or dye penetrant method after proof testing.

7.2.3.9 Connecting common links.

7.2.3.9.1 To replace defective chain cable links, connecting common links may be used manufactured according to the procedure, approved by the Register, which makes the chain cable heat treatment unnecessary.

The terms of connecting common links use, including their number and type, shall be agreed with the Customer.

7.2.3.9.2 The connecting common link material shall be similar to that of the chain cable.

7.2.3.9.3 When the connecting common links are manufactured, inserted and heat treated, the temperature of adjoining links shall not exceed 250 °C.

7.2.3.9.4 In all other respects the connecting common links shall comply with the requirements of 7.2.3.4 to 7.2.3.8.

7.2.3.9.5 Along with each connecting common link being inserted, the test link according to the same technology is manufactured for testing.

If agreed with the Register, when two or more connecting common links are inserted, the test links number may be reduced. Generally, each connecting common link shall be subjected to the appropriate proof load as indicated in Table 7.2.3.5 and non-destructive examination in accordance with 7.2.6. The test link shall be tested and inspected in accordance with 7.2.4.3 and 7.2.6.

7.2.4 Testing of finished chain cables.

7.2.4.1 Following the final heat treatment, all finished chain cables shall be subjected to tests in the presence of a Surveyor to the Register. For this purpose, the chain cables shall be free from paints and scale.

7.2.4.2 Breaking and proof load testing.

Where the manufacturer has an operative and appropriately documented system for proof load testing and recording relevant parameters, which is approved by the Register as a result of the survey of chain cable manufacture, proof load testing may be conducted in the absence of the Register representative.

7.2.4.2.1 A breaking load test shall be performed on a break-test specimen consisting of 3 links at least, which shall be either taken from the chain intended for supply or produced at the same time and in the same manner as the chain. The test frequency and the number of test specimens consisting of 3 links, taken from the chain shall be based on the requirements specified in Table 7.2.4.2.1, provided that each cast is represented by a specimen consisting of 3 links. The results of testing are considered acceptable when each specimen withstands the specified breaking load for 30 seconds without fracture and crack in the weld.

Table 7.2.4.2.1

Length of chain cable for proof load test specimens and determination of mechanical properties

Chain diameter, mm	Length of chain cable section, m
Up to — 48	91
49 — 60	110
61 — 73	131
74 — 85	152
86 — 98	175
99 — 111	198
112 — 124	222
125 — 137	250
138 — 149	274
150 — 162	297
163 — 175	322

When the required breaking load cannot be achieved due to insufficient tensile loading capacity of the testing machine, other equivalent testing methods may be considered by the Register.

7.2.4.2.2 The entire length of chain cable shall withstand the proof load specified in Table 7.2.3.5.

On agreement with the Register, the actual proof load may exceed the specified, but not more than by 10 per cent.

Where plastic deformation is observed in a number of studs, the applied load shall not be greater than that applied during initial chain testing conducted during the process of works recognition.

The results of testing are considered acceptable when no specimen shows fracture and crack in the weld.

7.2.4.2.3 After proof load testing measurements shall be taken on at least 5 per cent of the links in accordance with 7.2.3.7.

The entire chain shall be checked for the length, five links at a time. By the five link check five links set following the initial five links of the chain shall be subject to the first measurement. From the next set of five links, at least two links from the previous five links set shall be included, etc. The measurements shall be taken preferably while the chain is stretched by loading of 5 to 10 per cent of the minimum proof load.

7.2.4.3 Mechanical tests of finished chain cable material.

7.2.4.3.1 From rolled products of every cast for sampling length specified in Table 7.2.4.2.1, one link at a time is taken for making test specimens according to Fig. 3.6.5.2 in the following quantity:

one tensile specimen and one test unit consisting of impact specimens taken in the link side opposite the weld;

one test unit consisting of impact specimens taken from the link bend region;

one test unit consisting of impact specimens taken across the weld notched in the middle.

7.2.4.3.2 Test specimens from each test link, made according to 7.2.3.9.5, are taken as specified in 7.2.4.3.1.

7.2.4.3.3 The mechanical test results shall meet the requirements of Table 3.6.3.

7.2.4.3.4 If production is steady and satisfactory test results are stable, the Register may permit to reduce the impact test extent.

7.2.4.4 Retests.

7.2.4.4.1 If a break load test fails and also if one of the links fails during proof load testing, a break load retests are performed on two test specimens out of three links.

Specimens are taken from both ends of the same length of chain cable or from both sides of the link failed.

If at least one of test specimens fails, the sampling length of chain is rejected.

The final decision on acceptance of the given sampling length of chain may be taken only following a full investigation of link failure causes in the presence a Surveyor to the Register and a thorough examination of other links.

7.2.4.4.2 If test results of tensile and impact specimens are unsatisfactory, retests are carried out according to 1.3.4.2.

7.2.4.4.3 The lengths of chain cable failed during retesting shall be replaced.

The connecting common links used therewith shall be subjected to local heat treatment and proof load testing according to Table 7.2.3.5.

7.2.4.4.4 If single links are found to be defective by any controlled parameters, the defective links may be cut out and a connecting common link inserted in their place in accordance with 7.2.3.9. Other methods for repair are subject to the agreement by the Register and the Customer.

7.2.5 Testing of accessories.

7.2.5.1 Following the final heat treatment all accessories shall be subjected to tests described below in the presence of a Surveyor to the Register.

For this purpose, the accessories shall be free from paint and scale. All non-machined surfaces of accessories shall be sand blasted.

7.2.5.2 Breaking load and proof load test are carried out in accordance with Table 7.2.3.5. Items shall withstand the loads prescribed for each grade and size.

7.2.5.2.1 One breaking load test is performed for each 25 items that make a batch. As a rule, items in the batch shall be fabricated from the metal of the same heat and the same type of heat treatment.

Where items are produced individually or in small lots the scope of testing is subject to special consideration by the Register in each particular case.

The items that were subjected to breaking load tests may not be used for the intended purpose and shall be annihilated, except for the cases referred to in 7.2.5.2.2.

7.2.5.2.2 At the discretion of the Register, the items that have the dimensions greater than prescribed for the particular chain cable or that have been made from the material with higher mechanical properties and that withstood the tests satisfactorily may be allowed for use as accessories for the chain cable, for which the accessories have been intended. The tests conducted shall prove that resistance to breaking is at least 1,4 times over the breaking load required for the particular chain cable.

7.2.6 Examination.

7.2.6.1 Following proof load testing chain cables and accessories shall be subjected to a visual and non-destructive examination and also to checking of dimensions and of mutual mobility of elements and accessories.

7.2.6.2 Visual examination and non-destructive testing.

7.2.6.2.1 All chain links and accessories shall be subjected to a visual examination.

Links shall be free from mill defects, surface cracks, dents and also from other defects preventing their use.

Link studs shall be securely fastened.

7.2.6.2.2 Link surface at the flash weld, including the area gripped by clamping dies during welding and also in the area of studs welding, shall be subjected to 100 per cent checking by dye penetrant and magnetic particles methods approved by the Register.

Weld surface shall be free from cracks, lacks of fusion and large clusters of porosity.

If the results of weld surface 10 per cent checking in the area of studs welding are acceptable, the further inspection for defects may be omitted.

7.2.6.2.3 The welds fusion area of chain links, including connecting common links and test links, shall be subjected to 100 per cent checking by ultrasonic method approved by the Register.

Results of inspection for defects shall comply with the requirements of normative documentation approved by the Register. When during ultrasonic inspection a weld is found to contain injurious internal defects, the instructions given in 7.2.4.4.4 may be performed.

7.2.6.2.4 The surface defects detected during visual or non-destructive testing may be removed by local grinding within tolerance for the given chain cable diameter. Dye penetrant or magnetic particles shall be employed for checking the removal of all defects.

7.2.6.3 Dimensional inspection.

7.2.6.3.1 After proof load testing measurements shall be taken on at least 5 per cent of the links in accordance with 7.2.3.7.

If results for any parameter in one of the sample links are unsatisfactory, at least 40 links (20 on each side of the affected link) shall be subjected to additional examination.

If an additional examination reveals unsatisfactory results for any parameter in more than 2 of the sample links, all links shall be examined.

7.2.6.3.2 The entire chain shall be checked for the length, five links at a time. By the five link check five links set following the initial five links of the chain shall be subject to the first measurement. From the next set of five links, at least two links from the previous five links set shall be included, etc. The measurements shall be taken preferably while the chain is stretched by loading of 5 to 10 per cent of the minimum proof load.

If the length of the particular five links set is less than required, the chain may be stretched by loading exceeding the proof load. The value of that loading and ways of its application shall be agreed by the Register.

If the length of a five links set exceeds the preset tolerances, defective links may be cut out in accordance with 7.2.4.4.

7.2.6.3.3 At least one accessory out of each batch shall be checked for dimensions according to 7.2.3.

7.2.6.4 The chain links, rejected as a result of the inspection according to 7.2.6.2 and 7.2.6.3, are subjected to replacement with connecting common links, according to 7.2.3.9, with the following local heat treatment, proof load testing and inspection in compliance with 7.2.6.2.

7.2.7 Marking.

7.2.7.1 The chain cable marking is made on links studs at the following places:

at each chain cable end,

at each end of chain cable length,

on each connecting common link,

on links next to connecting common links.

The chain cable shall be marked as follows:

chain grade;

certificate No.;

Register's stamp;

link ordinal number in chain cable length;

ordinal number of connecting common link in chain cable length;

ordinal number of chain cable length.

7.2.7.2 Each accessory including studs shall be made on each product and shall be marked as follows:

chain grade;

certificate No.;

Register's stamp.

All detachable component parts shall be marked with an ordinal number.

7.2.7.3 The marking shall be made in a way that any item may be readily traced, the leading and tail end of the chain cable and also the ordinal number of the chain cable length or connecting common link may be recognized.

The symbols used for marking shall be stated in certificates for the chain cable and accessories.

7.2.8 Documentation.

A complete inspection and testing report of the chain cable and accessories in booklet form shall be provided by the manufacturer. This booklet shall include all dimensional checks, test and inspection reports, NDT reports, process records as well as any non-conformities, corrective actions and repair work.

Each type of accessory shall be covered by a separate certificate. All accompanying documents and reports shall carry reference to the original certificate number.

The manufacturer shall be responsible for storing, in a safe and retrievable manner, all documentation on the manufacture and supply of chain cable and accessories for a period of 10 years.

PART XIV. WELDING

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to the following items, which are subject to survey by the Register:

.1 ship hulls;

.2 machinery and machinery installations;

.3 steam boilers, heat exchangers and pressure vessels;

.4 piping;

.5 ship equipment and arrangements.

1.1.2 The requirements of the present Part shall establish requirements for welding consumables manufacture, welding procedures, and testing of welded structures stated in 1.1.1.

1.1.3 The requirements of the present Part shall be applied when designing, building and manufacturing items stated in 1.1.1.

1.1.4 The requirements of the present Part may be applied when carrying out repairs of structures stated in 1.1.1 as well, to an extent, which is deemed necessary and advisable.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations pertaining to the general terminology of the Rules shall be found in Part I "Classification".

Besides, for the purpose of the present Part the following definitions and explanations have been adopted.

High temperature brazing (hard brazing) is a brazing method, at which the melting temperature of the solder is above 450 °C.

Heat-affected zone is the layer of the base metal adjacent to a weld (or to the deposited metal) where structural changes were caused by the welding heat.

Weld metal is the metal obtained by the merging of the fused base metal and the deposited metal, or by fusion of the base metal only.

Deposited metal is the metal obtained by melting of electrodes or welding wire and containing no appreciable admixture of the base metal.

Base metal is the metal of items being welded.

Penetration is the merging of the base metal into the deposited one or the merging of the fused metal of both the components being welded.

Welding consumables include electrode, welding wire, flux and schielding gas used in welding.

1.3 GENERAL

1.3.1 Welding of items stated in 1.1.1 shall be effected by certified welders (operators) and Register-approved welding works (shops, bays) using welding consumables and welding procedures approved by the Register.

The application of each of the welding procedures (or its variant) at a particular works shall be backed up by the results of testing conducted in accordance with a program agreed with the Register.

Welding consumables shall be approved in compliance with the requirements of Section 4.

1.3.2 Welding operation on structures subject to survey by the Register shall be performed by those welders only who stood the tests prescribed by Section 5.

1.4 SCOPE OF SURVEYS

1.4.1 General provisions concerning survey during manufacture of materials and equipment shall be found in General Regulations for the Classification and Other Activity.

1.4.2 As far as structures stated in 1.1.1 are concerned, the following is subject to survey by the Register:

.1 welding consumables;

.2 technological procedures of welding (choosing of welding consumables, preparation of parts for welding assembly, pre- and postheating, heat treatment);

.3 methods and scope of non-destructive testing and criteria for evaluation of welded joints.

1.5 TECHNICAL DOCUMENTATION

1.5.1 The scope of technical documentation on welding, which shall be agreed as part of the ship design, is set out in Part I "Classification". Technical documentation on items specified in 1.1.1 shall include information on welding required by those parts of the Rules, which cover the items concerned.

1.5.2 The composition of technical documentation for welding consumables being approved shall be determined proceeding from 4.1.2.1.

2 TECHNOLOGICAL REQUIREMENTS FOR WELDING

2.1 GENERAL

2.1.1 The present technological requirements shall be applied when welding structures mentioned in 1.1.1.

To effect welding operations and non-destructive testing of welded joints in structures subject to survey by the Register the works shall have adequate equipment.

2.1.2 Where welding is performed at low temperature, working conditions shall be provided to enable the welder to produce sound welds. The welding site shall be protected from draught and precipitation.

2.1.3 When welding is performed at low temperature, the weld, if necessary, shall be protected from excessively rapid cooling.

2.1.4 On condition proper quality of welded joints is ensured welding operations on structures specified in 1.1.1 of hull structural steel of normal and higher strength 20 mm or below in thickness are permitted at ambient air temperature -25 °C, provided the welding consumables have been tested at this temperature according to the requirements of 4.2.2.4. If this is not feasible, the minimum permissible temperature of welding without preheating shall be established proceeding from standards or by the welding consumables manufacturer and recorded at approving the welding consumables after appropriate testing.

Under following circumstances the edges of parts to be welded shall be preheated at least to 20 °C over a width of 75 mm to either side of the joint at ambient air temperature:

.1 below -15 °C when forgings and castings used for ship hull shall be welded;

.2 below -10 °C when semi-killed or rimming steel is welded;

.3 below -5 °C when low alloy boiler steel shall be welded or when boilers and pressure vessels are fabricated.

2.1.5 The welding of piping made of low alloy steel, piping of the steam main as well as piping, which shall operate at temperatures above 350 °C, shall not be conducted at temperatures below zero.

2.1.6 The structural requirements for welds aimed at ensuring their strength shall be found in the relevant parts of the Rules.

2.1.7 The edge preparation of the parts to be welded shall be effected in conformity with standards or with drawings approved by the Register.

2.1.8 The edges of parts to be welded shall be prepared by methods, which ensure the required quality of welded joints in accordance with the requirements of the Rules.

2.1.9 From the edges of the parts to be welded, oil, moisture, scale, rust, paint and other contaminating substances shall be removed.

Steel parts coated with a primer may be welded without removing it; in this case, the primer shall be of a type approved by the Register after testing in accordance with Procedure for Determining the Influence upon Weldability of Protective Primers not Removed before Welding described in Collection of Regulating Documents of the Register (Book 4).

2.1.10 When welding of structures is effected at temperatures below zero the edges being welded shall be free from snow, hoar-frost, ice and be dry.

2.1.11 When structures are welded, the sequence of welding operations shall be such as to ensure the absence of excessive residual stresses or distortions.

2.1.12 When it is necessary to preheat the parts to be welded, the preheating temperature shall be determined taking into account chemical composition of metal, welding procedure, thickness of parts to be welded, level of weld stresses and conditions of heat transfer through the structure from the weld zone.

When complex structures are welded, the preheating temperature is, in each case, subject to special consideration by the Register.

2.1.13 Instances of welding and cutting under water as well as welding operations on structures, on the reverse side of which water is present during welding, shall be specially considered by the Register.

2.1.14 When plates, sheets and the like shall be welded into a rigid contour, technological measures shall be taken to reduce the stresses caused by welding. An opening with closed perimeter is considered to have the rigid contour if any of its dimensions is less than 60 plate thicknesses in the considered spot. For complex structures a contour may be regarded as rigid even at greater ratios of opening dimensions.

2.1.15 Dressing of welded structures is permitted within reasonable limits only. Hot dressing with mechanical effect and without one is permitted. When doing this, no damage to the joint or plate surface is admissible. For hot dressing, the temperature shall not exceed 650 °C, but in no case shall the heating involve changes in the metal structure.

2.1.16 Postweld heat treatment is required to eliminate residual stresses.

The type of heat treatment shall be determined by the Manufacturer proceeding from the properties of material, and it shall be agreed upon with the Register.

2.1.17 Welding of components made of cold-bent hull structural steel may be effected without any heat treatment if the inner radius of bending complies with standards. In case no such standards are available the said radius shall be equal to at least the triple thickness of the plate.

2.1.18 Welding consumables with controllable hydrogen content in the deposited metal shall be stored and calcinated before use in compliance with the manufacturer's recommendations.

2.2 WELDING OF SHIP HULL AND EQUIPMENT

2.2.1 The parts shall be assembled in such a way that the stresses arising during assembly and welding are as low as possible. Tack welding shall be performed only by persons possessing the necessary qualifications. Tack welding shall be carried out using welding consumables of the grades required for welding structural components. Tack welds shall be free from any defects, which could impair the quality of welded joints.

If required by the Surveyor to the Register, the tack welds shall be checked for freedom from cracks or other defects. When cracks occur in way of tack welds, they shall be cut out to sound metal and rewelded. Temporary fittings used for assembly shall be kept to a minimum and be welded and tack-welded in conformity with the requirements stated above.

Excessive cutouts and other damage to the base metal that occurs while removing temporary fittings shall be rewelded and the rectified areas dressed to ensure gradual transition to the base metal. In doing so, the reduction of the base metal thickness shall not exceed the permissible tolerances for plate thickness specified in the standards.

Protruding remainders of welds used for the attachment of temporary fittings to the hull structure parts listed below shall be removed and then dressed (the permissible reinforcement shall not exceed the tolerances for butt weld reinforcement for the structures concerned):

.1 strength deck (plating and longitudinal framing members including continuous side coamings of cargo hatches);

.2 bottom (plating and longitudinal framing members);

.3 sides;

.4 sheerstrake and bilge strake (plating and longitudinal framing members);

.5 bulkheads forming boundaries of tanks;

.6 deep framing members in tanks;

.7 structures in areas of intensive vibration.

For other structures the necessity of dressing the welds after removal of temporary fittings shall be determined by the customer.

2.2.2 When butt joints are being assembled, mutual misalignment of plates up to 0,1 of their thickness but not over 3 mm is admissible.

2.2.3 When it is necessary to deposit metal on the edges to eliminate the inaccuracies of machining or assembly of the parts to be joined, this improvement may be carried out only on agreement with a Surveyor to the Register. On agreement with the Register, undercuts in excess of values stated in Tables 3.3.2-1 and 3.3.2-2 may be rewelded or grounded.

2.2.4 Choice of welding consumables grades for welding of normal and higher strength steel structures.

Welding consumables shall be employed for welding those steel grades, for which they were permitted by the Register in accordance with Table 2.2.4. Besides the following requirements shall be followed:

.1 when joining normal to higher strength hull structural steel, welding consumables of the lowest acceptable grade, according to Table 2.2.4 and this paragraph, for either steel being joined may be used (for instance, for welded joint of Grades D and E32 steels, the welding consumables of Grade 2Y may be used);

.2 when joining steels of the same strength level but with different requirements for impact test temperature, welding consumables of the lowest acceptable grade, according to Table 2.2.4, for either steel being joined may be used (for instance, for welded joint of Grades D32 and E32 steels, the welding consumables of Grade 2Y may be used);

.3 when joining higher strength hull structural steel to the same or normal strength hull structural steel, controlled diffusible hydrogen type welding consumables, according to Table 4.2.1.4, shall be used. Other welding consumables may be used only on the special permission of the Register for steels having the carbon equivalent (refer to 3.2.2, Part XIII "Materials") $C_{eq} \leqslant 0,41$ following tests according to the program agreed with the Register;

.4 the welding consumables approved for steel Grades A40, D40, E40 and/or F40 may also be used for welding of the corresponding Grades A, B, D, E of normal strength steels subject to the special permission of the Register for particular welding consumables grades;

.5 when joining higher strength steels using Grades 1YS, 1YT, 1YM, 1YTM, 1YV grade welding consumables, the material thickness shall not exceed 25 mm;

.6 the welding consumables in Table 2.2.4 may also be used for welding of steel other than that

Table 2.2.4

Grade of welding consumables	Hull structural steel											
	normal strength				higher strength							
	A	B	D	E	A32, A36	D32, D36	E32, E36	F32, F36	A40	D40	E40	F40
1, 1S, 1T, 1M, 1TM, 1V	+	–	–	–	–	–	–	–	–	–	–	–
1YS, 1YT, 1YM, 1YTM, 1YV	+	–	–	–	+[1]	–	–	–	–	–	–	–
2, 2S, 2T, 2M, 2TM, 2V	+	+	+	–	–	–	–	–	–	–	–	–
2Y, 2YS, 2YT, 2YM, 2YTM, 2YV	+	+	+	–	+	+	–	–	–	–	–	–
2Y40, 2Y40S, 2Y40T, 2Y40M, 2Y40TM, 2Y40V	Refer to 2.2.4.4				+	+	–	–	+	+	–	–
3, 3S, 3T, 3M, 3TM, 3V	+	+	+	+	–	–	–	–	–	–	–	–
3Y, 3YS, 3YT, 3YM, 3YTM, 3YV	+	+	+	+	+	+	+	–	–	–	–	–
3Y40, 3Y40S, 3Y40T, 3Y40M, 3Y40TM, 3Y40V	Refer to 2.2.4.4				+	+	+	–	+	+	+	–
4Y, 4YS, 4YT, 4YM, 4YTM, 4YV	+	+	+	+	+	+	+	+	–	–	–	–
4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V	Refer to 2.2.4.4				+	+	+	+	+	+	+	+

[1] Refer to 2.2.4.5.

shown in Table if the mechanical properties and chemical composition of such a steel are equivalent to the same of the steel, for which the given welding consumable was approved;

.7 rutile electrodes shall not be used for welding the following joints:

mounting butt joints of ship sections;

all butts and seams of the ice belt of shell plating;

butt joints of longitudinal members;

butt joints of hull structure more than 20 mm thick;

solid structures (sternframe, stem, etc.), as well as butt joints to be welded in a rigid contour (a contour is considered rigid when the ratio of its minimal dimension to the plate thickness is less than 60 mm);

.8 oxide-coated electrodes shall not be used for welding of structures regulated by Part II "Hull".

2.2.5 Choice of welding consumables grades for welding of high strength steel structures.

Welding consumables shall be employed for welding those high strength steel grades, for which they were permitted by the Register according to Tables 2.2.5-1 and 2.2.5-2.

Besides, the following restrictions and requirements shall be followed:

.1 in some cases the Register may limit the scope of application of the particular welding consumable grade only to one base metal strength grade and not extend the approval to the high strength steel lowest grades according to Table 2.2.5-2;

.2 when joining high strength hull structural steel to the same and also joining high strength steel to higher or normal strength hull structural steel, controlled diffusible hydrogen type welding consum-

Table 2.2.5-1

Identification of welding consumables grades by test temperature	Identification of high strength steel grades by impact test temperature			
	A(420/690)	D(420/690)	E(420/690)	F(420/690)
3Y (42/69)	+	+	–	–
4Y (42/69)	+	+	+	–
5Y (42/69)	+	+	+	+

Table 2.2.5-2

Identification of welding consumables grades by strength level	Identification of high strength steel grades by strength level					
	(A/F)420	(A/F)460	(A/F)500	(A/F)550	(A/F)620	(A/F)690
(3Y/5Y)42	+	–	–	–	–	–
(3Y/5Y)46	+	+	–	–	–	–
(3Y/5Y)50	+	+	+	–	–	–
(3Y/5Y)55	–	–	+	+	–	–
(3Y/5Y)62	–	–	–	+	+	–
(3Y/5Y)69	–	–	–	–	+	+

ables, having the classification indices HHH or HH, according to Table 4.2.1.4, shall be used;

.3 the use of a single-run and two-run welding technique for high strength steel welded joints is not recommended. It may be approved by the Register only when based on additional tests according to the special program agreed with the Register;

.4 the use of an electroslag and electrogas welding for high strength steel welded joints is not recommended. It may be approved by the Register only when based on additional tests according to the special program agreed with the Register;

.5 the use of a multi-arc and one-side welding on backs of different types for high strength steel welded joints is not recommended. It may be approved by the Register only when based on additional tests according to the special program agreed with the Register;

.6 rutile and oxide-coated electrodes shall not be used for high strength steel structures welding;

.7 the use of all grades welding consumables, tested according to requirements in 4.6, for high strength steel welding is permitted only for base metal joints up to 70 mm thick. The use of welding consumables for welding of steel over 70 mm thick is subject to special consideration by the Register and demands additional tests according to the special program agreed with the Register.

2.2.6 Choice of welding consumables grades for welding of hull structural steel structures operating at low temperatures.

Welding consumables for welding of hull steel structures operating at low temperatures shall be used in accordance with requirements in Table 2.2.6. Besides, when grades of welding consumables for welding of higher strength steels with the index F are specified, the requirements listed in 2.2.4 shall be followed including the following additions:

Table 2.2.6

Grade of welding consumables	Grade of hull structural steel		
	F32	F36	F40
4Y, 4YS, 4YT, 4YTM, 4YV	+	+	–
4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V	+	+	+
5Y, 5YS, 5YT, 5YM, 5YTM, 5YV [1]	+	+	–
5Y40, 5Y40S, 5Y40T, 5Y40M, 5Y40TM, 5Y40V [1]	+	+	+
4Y42, 4Y42S, 4Y42MM	–	+	+
5Y42, 5Y42S, 5Y42M [1]	–	+	+
4Y46, 4Y46S, 4Y46M	–	+ [2]	+
5Y46, 5Y46S, 5Y46M [1]	–	+ [2]	+

[1] Refer to 2.2.6.1.
[2] Refer to 2.2.6.2.

.1 depending on the function and operational conditions of structures, the Register may specify the higher grade of welding consumables (for instance, 5Y instead of 4Y and 5Y40 instead of 4Y40);

.2 the use of Grades 4Y46 and 5Y46 welding consumables, intended for high strength steel welding, is subject to additional agreement with the Register.

2.3 WELDING IN SHIP MACHINERY CONSTRUCTION

2.3.1 The present requirements apply to the welding of ship machinery sructures manufactured using base materials and welding consumables, which are in accordance with Part XIII "Materials" and the present Part. Manufacturing of structures from materials not regulated by the Rules shall be effected on agreement with the Register.

2.3.2 Welding consumables for machinery and machinery installations shall be chosen on the basis of steel grades used for the manufacture bearing the requirements of 2.2.4 to 2.2.6 in mind.

2.3.3 When structures are intended for operation at high temperatures or in a chemically aggressive medium, those conditions shall be taken into account when selecting the welding consumables.

2.3.4 For welding of steel parts 30 mm and more in thickness used in ship machinery construction, welding consumables shall be applied, which would guarantee the cold cracking resistance of the weld, or the manufacturer shall take technological measures (preheating, heat treatment, limiting of ambient air temperature during welding, etc.) to eliminate cold cracking.

2.3.5 The welds in structures, which shall be exposed to dynamic loads, shall be executed with full penetration. The transition from the base metal to the weld shall be smooth.

2.3.6 When shafts for ship shafting or crankshafts are fabricated, the application of welding shall be specially considered by the Register in each case.

For this purpose, the necessary conditions are that all the welds were subjected to non-destructive testing and the fatigue strength of welded joints adopted in the calculations were guaranteed.

The amount of experimental welding necessary and the test program shall be agreed with the Register before welding is commenced.

2.3.7 The application of welding including building-up, metal pulverization and other similar methods, when manufacturing or repairing ship machinery items, may be permitted if tests carried out in accordance with the procedure agreed with the Register and confirming the possibilities of applying the method in question at a particular works yield good results.

Repairs to ship shafts of carbon steel (with up to 0,45 per cent carbon content), which are worn or have surface cracks, may be performed by building-up, provided the amount of wear or the depth of cracking does not exceed 5 per cent of the shaft diameter, but it shall not be over 15 mm.

2.4 WELDING OF STEAM BOILERS AND PRESSURE VESSELS

2.4.1 Welded joints of boilers shall be so marked as to make it possible to identify the operator having performed the welding.

Longitudinal and circumferential welds of boiler shells shall be made with a back-sealing run except when the efficiency factor of welded joints φ according to Table 2.1.6.1-1, Part X "Boilers, Heat Exchangers and Pressure Vessels" is adopted to be 0,7 or less.

Cuts and openings in the boiler shell shall not, as far as possible, cross circumferential or longitudinal joints in the shell.

The possibilities of fixing, by welding, any fastenings, catches and the like parts for erecting purposes on the boiler shell shall be specially considered by the Register in each case.

The longitudinal and circumferential joints of headers, boiler shells and pressure vessels shall be butt-welded. If butt welding cannot be applied, the type of weld shall be specially considered by the Register.

2.4.2 Welding consumables for boilers and pressure vessels shall be chosen on the basis of steel grades used for the manufacture bearing the requirements of 2.2.4 to 2.2.6 in mind.

2.4.3 Rutile and oxide-coated electrodes are not permitted for the welding of boilers and pressure vessels of Class I (refer to 1.3.1.2, Part X "Boilers, Heat Exchangers and Pressure Vessels"). They are permitted for boilers and pressure vessels of Class II and Class III, provided those structures are manufactured of carbon steel and the thickness of parts to be welded is not in excess of 20 mm.

2.4.4 The heat treatment of boilers and pressure vessels shall be determined according to standards or by the data presented by steel works.

The welded joints in parts, which cannot be heat treated as a whole for stress relieving because of their dimensions or inappropriate structure, may be subjected to local heat treatment on agreement with the Register. Such a treatment shall be performed by uniform warming-up of a sufficiently wide area along the weld (for a distance about 6 times the plate thickness on both sides of the joint) so as to prevent the spread of thermal stresses to other areas of the parts involved. Local treatment by means of a welding torch is prohibited.

2.4.5 When openings in boilers are closed up by means of plugs fixed by welding, the requirements of national standards shall be met.

2.4.6 Worn-out shell plates of boilers and pressure vessels may be repaired by building-up only on agreement with the Register. The built-up area shall not exceed 500 cm^2, and its depth shall not be over 30 per cent of the plate thickness. If these conditions cannot be met, the faulty area shall be repaired by inserting a new plate.

2.4.7 When manufacturing boilers, heat exchangers and pressure vessels belonging to Class I or Class II (refer to 1.3.1.2, Part X "Boilers, Heat Exchangers and Pressure Vessels"), test samples shall be prepared to check up the mechanical properties of welded joints in the case of unique products being manufactured, serial production, on the prototype product, alterations in the structure of main units and parts, application of new materials and welding procedures.

Test samples for products belonging to Class III shall be prepared, if required by the Register.

2.4.8 The test samples shall be attached to the longitudinal joint of a boiler or pressure vessel in such a way that the test plate joint is a continuation of the joint of the boiler or pressure vessel. The welding technique shall be the same as employed in the welding of the boiler or pressure vessel joint.

A test assembly thus prepared shall provide one transverse tensile test piece, two transverse bend test pieces, three impact test pieces cut out according to Fig. 4.2.4.2.

Specimens for structures belonging to Class III shall be prepared, if required by a Surveyor to the Register. The requirements for cutting specimens from the test assembly and for testing them shall be in accordance with the requirements of 4.2.3.2 and 4.2.3.3.

2.5 WELDING OF PIPELINES

2.5.1 The type of welded joints in pipes shall comply with standards.

2.5.2 Welding consumables for pipelines shall be chosen on the basis of steel grades used for the manufacture bearing the requirements of 2.2.4 to 2.2.6 in mind.

2.5.3 In the welded butt joints of pipes complete root penetration shall be provided. Welding with the use of removable backing rings is permitted.

2.5.4 The use of the remaining backing rings in butt joints is permitted in pipelines where those rings do not adversely affect the performance. The remaining backing rings shall not be used for flange-to-pipe butt joints.

2.5.5 The welded joints in pipes shall be heat treated in the case of pipes of low-alloyed steels and in the case of gas welding of main steam pipelines operating at temperatures above 350 °C.

2.5.6 When welding pipes of chrome-molybdenum steel containing 0,8 per cent or more of chromium and more than 0,16 per cent of carbon, the edges to be welded shall be preheated to a temperature 200 to 230 °C. This temperature shall be maintained during welding.

2.5.7 Before welding, the edges of copper pipes with a wall thickness 5 mm and over shall be heated to a temperature 250 to 350 °C. Nickel-copper pipes shall be welded without preheating. For connecting of nickel-copper pipelines the use of brazing is not permitted.

2.5.8 The repair of pipelines by welding of damaged areas is in each case subject to special consideration by the Register.

2.6 WELDING OF CASTINGS AND FORGINGS

2.6.1 Regardless of ambient air temperature, the welding of steel castings and forgings shall be effected with preheating, or other technological measures shall be taken to guarantee that the requirements for welded joints are satisfied in the following cases:

.1 for steel castings and forgings with carbon content exceeding 0,25 per cent;

.2 for steel castings and forigngs with carbon content exceeding 0,23 per cent when those castings and forgings are part of the hull structure of ships with the ice categories **Arc4** to **Arc7** (castings and forgings of sternframes, stems, propeller shaft brackets, etc.).

2.6.2 The temperature of preheating and the heat treatment procedure for castings and forgings shall be determined depending on the design, size and service conditions of the structure concerned in accordance with 2.1.4, 2.1.12, 2.1.16.

2.6.3 The faults in castings and forgings may be repaired by welding only when the steel in question has been previously checked for weldability with due regard to the service conditions of the cast or forged part.

Repairs of faults by welding shall generally be undertaken prior to the final heat treatment. After it, rewelding is permitted only by way of exception. Repetitive faults in castings and forgings are not permitted for repair by welding.

2.6.4 The rewelding of faults in castings shall be made after sprues and heads have been removed and the castings thoroughly cleaned of sand, scale and extraneous inclusions. The surface subject to repair shall be ground to sound metal so as to provide for full penetration throughout the welded area.

The surfaces of areas to be rewelded shall be gently sloped and shall not have sharp corners.

2.7 WELDING OF CAST IRON

2.7.1 Repair of cast iron by welding is permitted on agreement with a Surveyor to the Register using a welding procedure approved by the Register and proceeding from the results of testing by a program agreed with the Register.

2.8 WELDING OF CLAD STEELS

2.8.1 Methods of welding clad steel shall be approved in accordance with Section 6, the welding consumables — in accordance with Section 4.

The edge preparation for welding shall be in accordance with national standards or drawings approved by the Register.

Preparation of the edges shall be effected by machining or grinding. The edges of parts to be assembled shall fit each other closely and shall not be out of alignment on the clad surface.

2.8.2 The corrosion resistance of weld metal on the clad side shall be equal to that of the cladding. The thickness of the corrosion-resistant layer of the weld shall not be less than that of the cladding.

The chemical composition of weld metal on the clad size (except the root zone) shall correspond to the chemical composition of the cladding metal.

2.8.3 As a rule, the weld shall be made first on the plate surface, which is opposite to the clad surface and then on the clad side. Welding on the non-clad side shall be so done that no melting of the cladding layer occurs. Prior to welding on the clad side the root of an unalloyed weld shall be cut out to sound metal by machining or grinding. For a back-sealing run the same welding consumables shall be used as for welding the cladding layer. The cladding layer shall be welded so as to reduce, as far as possible, the interpenetration of alloyed and unalloyed materials. For welding the cladding layer, welding electrodes and wires of the smallest diameter possible shall be used. The welding shall be carried out, as far as possible, at a low rate of energy input. The weld on the clad surface shall be made up of two layers at least. In welding the cladding layer, transverse weaving of electrode is not permitted. Where the top layer width is such that it shall be deposited in several runs, the last run shall be made along the middle of the weld.

2.8.4 In welding pipes of clad steel, where welding on both sides is not feasible, the entire joint shall be welded with the use of welding consumables suitable for the cladding material. When welding clad sheet steel, the entire joint shall also be welded with the use of welding consumables suitable for the cladding material.

2.9 BRAZING

2.9.1 Brazed joints in structures specified in 1.1.1 are subject to survey by the Register. They shall be executed in conformity with standards or technical documentation agreed with the Register.

2.10 WELDING OF ALUMINIUM AND ITS ALLOYS

2.10.1 Welding operations shall be performed by the most expedient method, which would ensure good quality joints of required strength with their chemical composition similar to that of the base metal and having sufficient corrosion resistance.

2.10.2 Wherever possible, welded joints shall be located in areas exposed to the lowest stresses.

As a rule, welding shall be effected in the downhand position. Weld reinforcement may be removed only subject to the special approval of the Register.

2.10.3 Immediately before welding (tack welding) the edges of aluminium or aluminium alloy components shall be degreased with special solvents (acetone, alcohol, etc.) and then cleaned with wire brushes. Jacked spots are also to be cleaned with a steel wire brush before welding. In the case of multirun welding, each run of deposit shall be brushed before the next run is applied.

2.10.4 Welding consumables of aluminium and aluminium alloys shall have their surfaces cleaned from dirt and oxide film.

2.10.5 For aluminium alloys, welding on remaining or removable backings is permitted. The backings to be removed after welding shall be of stainless steel. The backings that are not removed shall be made of the same kind of alloy as that used for the parts to be welded.

2.10.6 In the case of a double-welded joint, before a sealing run is applied to the back of the weld, a groove shall be made by root-run chipping, planing or milling to clean metal. Cutting out of the root by means of abrasive disks is not permitted.

2.10.7 Hot straightening of structures made of aluminium and aluminium alloys is permitted. The heating temperature range for straightening shall be within the limits corresponding to the properties of the alloy.

2.10.8 Where a flux is used, it shall, as a rule, be neutral. If, by way of an exception, the flux used was not neutral, it shall be carefully removed after welding.

2.10.9 On riveted structures made of aluminium alloys, all major welding operations shall be completed before riveting.

2.11 WELDING OF COPPER AND COPPER ALLOYS, HEAVY METALS AND OTHER NON-FERROUS METALS

2.11.1 Welding of copper and copper alloys as well as of heavy metals and other non-ferrous metals shall be carried out according to national standards, and if those standards are not available, it will be specially considered by the Register.

2.12 WELDING OF HIGH STRENGTH STEELS

2.12.1 The welding consumables designed for welding of high strength steels shall be approved in accordance with 4.6, and the welding methods — in accordance with Section 6.

2.12.2 The method and procedure of welding shall be approved by the Register after fabrication testing by an agreed program. For this, the manufacturer of welded structures shall submit the documented preheating temperature, linear power comsumption during welding, postweld heat treatment, and temperature between runs.

The manufacturer shall use a welding condition recording system including the temperature between runs and submit the inspection results to the Register upon request.

2.12.3 Welded joints shall be made by multirun welding.

Single-run welding may be permitted only on agreement with the Register.

Each run shall be continuous with minimum arc fluctuations.

2.12.4 Arc firing outside the edges prepared for welding is not permitted.

Welding-on of temporary mounting fittings may be permitted on special agreement with the Register with the requirements being fulfilled for consumable materials and the local heating temperature.

As a rule, temporary fittings are removed by machining with subsequent dressing flush with the base metal surface.

Preliminary gas cutting shall be followed by the machining of the remaining part and by dressing.

2.12.5 The edges prepared by gas cutting shall be machined after such cutting. Roots shall be removed by machining only. The heating temperature for straightening is subject to approval by the Register in each case. The required properties of the base metal and welded joint shall be ensured.

3 INSPECTION OF WELDED JOINTS

3.1 GENERAL

3.1.1 Inspection of welding operations and welded joints during fabrication of structures and components shall be performed by the inspection authorities of the works. The results of the inspection shall be registered according to the procedure adopted at the works, filed until the commissioning of the item and submitted to the Surveyor of the Register at his request for examination.

3.1.2 Non-destructive testing of welds may be effected by the following methods:

.1 visual examination;

.2 magnetic particle examination;

.3 dye penetrant examination;

.4 radiographic examination (X- or gamma-ray examination);

.5 ultrasonic examination.

The use of a particular non-destructive testing method is set down in the technical documentation of the design depending on the importance of the structure and type of welded joint.

Other methods of testing may be used subject to special consideration by the Register in each case.

Non-destructive testing shall be effected according to standards and procedures approved by the Register.

If heat treatment of welded assemblies is required, final non-desctructive testing of welded joints shall be carried out upon its completion.

For welding of high strength steels and complex shape structures, non-destructive testing shall be performed not earlier than 72 hours after welding is completed.

Non-destructive testing of welded joints shall be effected by laboratories recognized by the Register.

The personnel effecting inspection of welds and evaluation of their quality shall have qualifications confirmed by competent authorities and complying with the requirements of specifications for the respective testing methods.

3.1.3 Upon completion of welding operations on a structure the inspection authority of the works shall determine the non-destructive testing locations according to an inspection plan approved by the Register. The Surveyor to the Register may require additional weld lengths to be examined.

3.1.4 Where impermissible defects are found, testing shall go on along both sides of the area in question until satisfactory results are obtained. In addition, the Surveyor to the Register may require two extra lengths of the same weld to be tested in other areas in connection with each radiograph, for which the mark was unsatisfactory.

The results of additional testing shall be submitted before the defects have been rectified, together with the documents of initial testing. Where the scope of initial and additional testing covers more than 50 per cent of the weld length, the weld shall be additionaly tested along its whole length.

Unacceptable defects shall be rectified, and rectification for a second time is subject to special agreement with the Register.

3.1.5 In well-substantiated cases, the Surveyor may require examination of the same weld length by both ultrasonic and radiographic methods.

3.1.6 When shell plating welds are tested, the radiograph shall be located at the intersection on the butt axis so as to partially cover also the seam as shown in Fig. 3.1.6-1. In ultrasonic examination, lengths 100 mm wide shall be examined on each side of the butt as shown in Fig. 3.1.6-2.

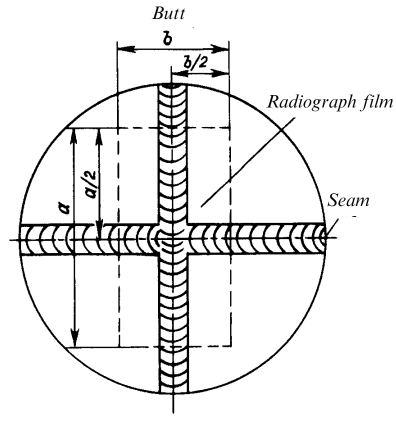


Fig. 3.1.6-1:
a — length of radiograph film equal to ≈500 mm;
b — width of radiograph film equal to ≈100 mm

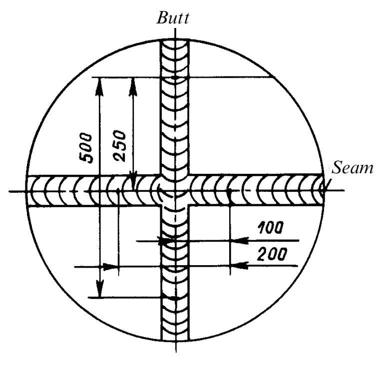


Fig. 3.1.6-2

3.2 SCOPE OF NON-DESTRUCTIVE TESTING

3.2.1 The scope of non-destructive testing of hull welds in the inspection plan approved by the Register shall be determined in accordance with Table 3.2.1.

The number of weld lengths in shell plating for 0,4L amidships to undergo radiographic or ultrasonic examination shall be determined by the following formula:

$$N = \frac{L(B+D)}{45} T \quad (3.2.1)$$

where N = number of controlled weld lengths;
L = length of ship, in m;
B = breadth of ship, in m;
D = depth of ship, in m;
T = factor depending on ship type and manufacturing conditions and determined at the approval of the inspection plan. Following are the maximum values of the factor T for various ship types:
up to 0,7 for ships having the length L < 60 m;
up to 0,9 for ships having the length 60 m $\leqslant L <$ 80 m;
up to 1,1 for dry cargo ships, bulk carriers, special purpose ships, supply vessels, fishing vessels and ro-ro ships;
up to 1,2 for ships for carriage of heavy bulk cargoes, ore carriers, ore or oil carriers and oil or bulk dry cargo carriers;
up to 1,3 for oil tankers and container ships.

Table 3.2.1

Nos.	Test location	Weld type	Scope of inspection		
			visual examination, %[1, 2]	radiographic and ultrasonic testing, number of radiographs	
			Ship area		
			fore-and-aft	within 0,4L amidships	outside 0,4L amidships
1	Plating butts (mainly intersections with seams): strength deck outside hatch line sheerstrake (in area 0,1D below strength deck) bilges (in area 0,1D above bottom) bottom Butts: of hatch side coamings of thickened deck plates in way of hatchway corners and at ends of superstructures of longitudinal bulkheads (in area 0,1D below strength deck)	Butt weld	100	About 0,60N	Random[3]
2	Hull plating butts - remaining[4] (mainly intersections with seams)	Butt weld	100	About 0,20N	Random[3]
3	Hull plating seams	Butt weld	100	About 0,20N	Random[3]
4	Welded joints of longitudinal stiffeners (in longitudinal framing): of strength deck outside hatch line of sheerstrake (in area 0,1D below strength deck) of bilge (in area 0,1D above bottom) of longitudinal bulkheads (in area 0,1D below strength deck) of bottom	Butt weld	100	1 radiograph per 5 butts (mainly mounting butts)	Random[3]
5	Welded joints of longitudinal stiffeners (in longitudinal framing) in other places not specified under item[4]	Butt weld	100	1 radiograph per 10 butts (mainly moun-ting butts)	Random[3]
6	Welded joints of transverse stiffeners (in transverse framing)	Butt weld	100	1 radiograph per 10 butts	Random[3]
7	Welded joints on sternframe	Butt weld	100	—	50 per cent of hull plating welded joints in way of sterntube
8	Welded joints between deck stringer and sheerstrake[5] (in way of intersection with butt welds)	Fillet weld or T-joint, full penetration	100	4 controlled lengths along the 1st plate[6]	Random[3]

[1] Where there are doubts as to the results of visual examination, dye penetrant or magnetic particle examination may be carried out on agreement with the Surveyor to the Register.
[2] All welded joints (including those not specified in the table) shall undergo testing.
[3] The number of weld lengths undergoing testing shall be up to 20 per cent of the lengths specified for the area 0,4L amidships.
[4] Where ice strengthened, the ice belt butts shall mainly be controlled.
[5] Intersections between seams and butts shall be controlled.
[6] Ultrasonic examination is recommended.

For ships not listed above, the factor T is determined on agreement with the Register.

It is assumed in the calculation that the controlled weld length is 0,5 m.

3.2.2 The welded joints of steam boilers, pressure vessels and heat exchangers shall be subjected to non-destructive testing within the scope specified in Table 3.2.2 depending on the class of structure (refer to 1.3.1.2, Part X "Boilers, Heat Exchangers and Pressure Vessels").

Table 3.2.2

Class of structure (boilers, pressure vessels and heat exchangers)	Type of welded joint	Scope of welded joint examination as percentage of total weld length	
		visual [1]	radiographic or ultrasonic
I	Longi-tudinal	100	100
II			25
III			On agreement with the Register
I	Circular		50
II			25
III			On agreement with the Register

[1] In case of doubts in the results of visual examination, dye penetrant or magnetic particle examination may be carried out on agreement with the Surveyor to the Register.

3.2.3 The welded joints of piping, depending on their class indicated in Table 1.3.2, Part VIII "Systems and Piping", shall be subjected to non-destructive testing within the scope specified in Table 3.2.3.

Table 3.2.3

Class of piping	Outer diameter of pipe, mm	Scope of welded joint examination as percentage of total weld length	
		visual[1]	radiographic or ultrasonic
I	$\leqslant 75$	100	10[2]
	> 75		100
II	$\leqslant 100$		Random
	> 100		10[2]
III	Any		Random

[1] In case of doubts in the results of visual examination, dye penetrant or magnetic particle examination may be carried out on agreement with the Surveyor to the Register.
[2] But not less than one welded joint made by a particular welder.

3.2.4 Besides the structures specified in Tables 3.2.1 to 3.2.3, such elements of machinery and gear as joints in cargo masts and posts, etc. are subject to non-destructive examination. The controlled weld lengths in these structures shall be established upon agreement with the Surveyor.

3.2.5 The Surveyor may determine a distribution of non-destructive testing weld lengths differing from that specified in the approved inspection plan depending on the particular conditions, under which welding is carried out.

3.2.6 The works shall determine, on the basis of radiographic and ultrasonic examination, the percentage of welded joint defects not less than once in six months and report the results to the Register.

The percentage of defects in welded joints shall be determined by the following formula:

$$K = 100l/s \tag{3.2.6}$$

where K = welded joint defect percentage;
l = total length of controlled welds found unsatisfactory, in m;
s = total weld length controlled, in m.

If the percentage of defects is more than 5, the Register is entitled to require, for every per cent of rejected welds exceeding this value, an increase in the number of controlled weld lengths by 10 per cent.

The number of controlled weld lengths may be reduced if the Surveyor finds the general standard of welding operations satisfactory.

3.2.7 For the purpose of conversion and repair of ships and craft, the number of controlled weld lengths is determined by the Register proceeding from the scope of welding and the importance of structures bearing the above in mind.

3.3 ASSESSMENT OF WELDED JOINT QUALITY IN HULL STRUCTURAL STEEL

3.3.1 The assessment of welded joint quality by means of radiography or ultrasonic examination may be performed by a five-mark or a three-mark grading system, or using other criteria approved by the Register.

The assessment criteria by the five-mark system shall be adopted according to standards recognized by the Register.

The assessment criteria by the three-mark system shall be determined as specified in 3.3.3.

The quality assessment using other methods of control shall be performed with regard to known acceptable sizes of defects or on the basis of standards or other criteria approved by the Register.

3.3.2 The assessment criteria for particular methods of inspection and the acceptable marks are specified in Tables 3.3.2-1 and 3.3.2-2.

Table 3.3.2-1

Method of examination	Type of defect or method of its classification	Acceptable size of defect or minimum mark of welded joint for ships with length:			
		$L \leqslant 250$ m		$L > 250$ m	
		within 0,4L amidships	outside 0,4L amidships	within 0,4L amidships	outside 0,4L amidships
Visual	Weld appearance	Weld to be uniform and smoothly transient into base metal			
	Cracks	Not accepted			
	Undercuts [1]	10% of t but not over 1,0 mm	20% of t but not over 1,5 mm	5% of t but not over 0,5 mm	10% of t but not over 1,0 mm
	Shrinkage grooves in the roots of single-sided welds [2]	10% of t but not over 1,5 mm	20% of t but not over 2,0 mm	5% of t but not over 1,0 mm	10% of t but not over 1,5 mm
	Surface defects	According to recognized standards			
Radiographic	By recognized standard by five-mark system	3	4	2	3
	By three-mark system	II	I[3]	III	II
	By standard reference radiographs	On agreement with the Register at approval of inspection plan			
Ultrasonic	By recognized standard by five-mark system	3	4	2	3
Penetrant or magnetic particle	By recognized standard	Cracks not accepted			

[1] The maximum length of a single undercut shall not exceed $t/2$, the total length of undercuts at each controlled weld length not exceeding 5 per cent of this weld length.
[2] The maximum length of a single defect shall not exceed t, the total length of defects at each controlled weld length not exceeding 5 per cent of this weld length.
[3] For locations with high stresses or vibration, the mark may be raised.
N o t e . t is the thickness of the welded metal, in mm.

Table 3.3.2-2

Method of examination	Type of defect or method of its classification	Acceptable size of defect or minimum mark of welded joint						
		Boilers, heat exchangers			Piping			Machinery and gear components
		Class of structure						
		I	II	III	I	II	III	
Visual	Appearance of joint	Weld to be uniform and smoothly transient into base metal						
	Cracks	Not accepted						
	Undercuts [1]	Not accepted	5% of t, but not over 0,5 mm		Not accepted	5% of t, but not over 1,0 mm		On agreement with the Register
	Shrinkage grooves in the roots of single-sided welds [2]	Not accepted	5% of t, but not over 0,5 mm		Not accepted	5 % of t, but not over 1,0 mm		
	Surface defects	According to recognized standards						
Radiographic	By recognized standard by five-mark system	2	3		2	3		On agreement with the Register
	By three-mark system	III	II		III	II		
	By standard reference radiographs	On agreement with the Register at approval of inspection plan						

Table. 3.3.2-2 - continued

Method of examination	Type of defect or method of its classification	Acceptable size of defect or minimum mark of welded joint						
		Boilers, heat exchangers			Piping			Machinery and gear components
		Class of structure						
		I	II	III	I	II	III	
Ultrasonic	By recognized standard by five-mark system	2	3		2	3		On agreement with the Register
Pentrant or magnetic particle	By recognized standard	Cracks not accepted						

[1] The maximum length of a single undercut shall not exceed $t/2$, the total length of undercuts at each controlled weld length not exceeding 5 per cent of this weld length.

[2] The maximum length of a signle defect shall not exceed t, the total length of defects at each controlled weld length not exceeding 5 per cent of this weld length.

N o t e . t is the thickness of the welded metal, in mm.

After the inspection has been completed, a protocol shall be issued specifying defective weld lengths, size, type and mark of defects as well as their location.

3.3.3 Three-mark grading system of welded joint quality assessment.

3.3.3.1 Mark III.

The welded joint is free from internal defects or the following defects are present:

.1 isolated gas or metal (tungsten) inclusions, each with dimensions up to 0,1 of the weld thickness, but not over 2 mm;

.2 isolated slag inclusions, each with dimensions up to 0,3 of the weld thickness, but not over 3 mm, with the area not exceeding 5 mm^2.

The average number of defects specified above shall not exceed one for every 100 mm of weld length.

3.3.3.2 Mark II.

The welded joint is free from cracks, pipes, lack of fusion or poor fusion. The maximum permissible length, width and total length of pores, slag or tungsten inclusions, lines and clusters of these defects and oxide inclusions for any 100 mm of controlled weld length are given in Table 3.3.3.2.

T a b l e 3.3.3.2

Thickness of welded elements, mm	Pores and inclusions		Clusters	Lines	Total length, mm
	width (diameter), mm	length, mm	length, mm		
Up to 5	0,6	2,0	2,5	4,0	6,0
Over 5 up to 10	1,0	3,0	4,0	6,0	10,0
Over 10 up to 20	1,5	5,0	6,0	9,0	15,0
Over 20 up to 25	2,0	6,0	8,0	12,0	20,0
Over 25 up to 35	2,5	8,0	10,0	15,0	25,0
Over 35 up to 45	3,0	9,0	12,0	18,0	30,0
Over 45 up to 65	4,0	12,0	16,0	20,0	40,0
Over 65 up to 90	5,0	12,0	20,0	30,0	50,0

3.3.3.3 Mark I.

The welded joint has no cracks, pipes, lacks of fusion, or poor fusion. The maximum admissible length, width, and total length of pores, slag or tungsten inclusions, lines and clusters of these defects, and oxide inclusions for any 100 mm of controlled weld length are given in Table 3.3.3.3.

T a b l e 3.3.3.3

Thickness of welded elements, mm	Pores and inclusions		Clusters	Lines	Total length, mm
	width (diameter), mm	length, mm	length, mm		
Up to 5	0,8	2,5	4,0	6,0	8,0
Over 5 up to 10	1,2	3,5	6,0	10,0	12,0
Over 10 up to 20	2,0	6,0	10,0	15,0	20,0
Over 20 up to 25	2,5	8,0	12,0	20,0	25,0
Over 25 up to 35	3,0	10,0	15,0	25,0	30,0
Over 35 up to 45	4,0	12,0	20,0	30,0	40,0
Over 45 up to 65	5,0	15,0	25,0	40,0	50,0
Over 65 up to 90	5,0	15,0	25,0	40,0	60,0

3.4 ASSESSMENT OF WELDED JOINT QUALITY IN ALUMINIUM ALLOY HULL STRUCTURES

3.4.1 The assessment of welded joint quality in aluminium alloy hull structures, as part of radiographic, ultrasonic, dye penetrant or visual examination, may be effected on the basis of a three-mark system in accordance with Table 3.4.1 or of other criteria agreed with the Register.

The criteria for the three-mark assessment shall be found in 3.4.2.

Quality assessment of welded joints by other examination procedures shall be effected taking tolerances for imperfections into account on the basis of standards agreed with the Register.

Table 3.4.1

Type of imperfection	Extent of permissible weld imperfections in hull and superstructures	
	within 0,4*L* amidships	outside 0,4*L* amidships
Cracks	Not permitted	
Undercuts[1] (depth), in mm	Long - up to 0,1*t*, but not more than 0,4 mm, isolated - up to 1,0 mm	Long - up to 0,2*t*, but not more than 0,6 mm, isolated - up to 1,5 mm
Shrinkage grooves in the roots of single-sided welds[2] (depth), in mm	Up to 0,2*t*, but not more than 1,5 mm,	Up to 0,3*t*, but not more than 2,0 mm
Surface gas inclusions[3] (area), in mm^2	Up to 1*t*	Up to 2*t*
Other surface defects Appearance	In accordance with recognized standards, a weld shall be uniform, free of craters, arc-striking areas, tolerances shall be observed and a smooth transition to the base metal ensured.	

[1] The maximum length of an individual undercut shall not exceed the base metal thickness, and on each weld length controlled, the total extent of undercuts shall not exceed 20 per cent of the weld length.

[2] The extent of a defect shall not exceed the base metal thickness, and on each weld length controlled, the total extent of poor fusion shall not exceed 10 per cent of the weld length.

[3] The maximum permissible area of surface imperfections shall be reduced to 100 mm of the controlled weld length, and the diameter of gas inclusions shall not exceed 3 mm.

Notes: 1. *t* is the base metal thickness, in mm.

2. For structures subjected to high loads, vibration loads included, the permissible size of imperfections may be reduced.

3.4.2 Three-mark system of welded joint quality assessment in aluminium alloy structures.

3.4.2.1 Mark III Al.

The welded joints are free from internal defects, or the following is present:

.1 isolated gas inclusions of the maximum diameter $0,1t+0,5$ mm, but not more than 2,5 mm. On any 100 mm of controlled weld length, the maximum total area of gas inclusions shall not exceed 2*t*, in mm^2;

.2 isolated slag or oxide inclusions of the maximum extent up to 0,2*t*, in mm, but not more than 5 mm, or tungsten inclusions of the maximum length up to 0,05*t*, in mm, but not more than 0,8 mm. The number of inclusions shall not exceed one per 100 mm of controlled weld length.

3.4.2.2 Mark II Al.

The welded joints are free from cracks, pipes, lack of fusion or poor fusion between layers. The maximum permissible size of gas, slag, oxide and tungsten inclusions as well as the total extent of their clusters and lines on any 100 mm of controlled weld length shall be found in Table 3.4.2.2.

Table 3.4.2.2

Base metal thickness, mm	Isolated gas and other inclusions		Maximum size of cluster, mm	Maximum length of line, mm	Total extent of defects, mm
	width (diameter), mm	length, mm			
Under 5	0,6	2,0	2,5	4,0	6,0
5 — 10	1,0	3,0	4,0	5,0	10,0
10 — 20	1,5	5,0	6,0	9,0	15,0
20 — 25	2,0	6,0	8,0	12,0	20,0

3.4.2.3 Mark I Al.

The welded joints are free from cracks and poor fusion. The maximum permissible size of defects shall be found in Table 3.4.2.3.

Table 3.4.2.3

Base metal thickness, mm	Isolated gas and other inclusions		Maximum size of cluster, mm	Maximum length of line, mm	Total extent of defects, mm
	width (diameter), mm	length mm			
Under 5	0,8	2,5	4,0	5,0	8,0
5 — 10	1,2	3,5	6,0	10,0	12,0
10 — 20	2,0	6,0	10,0	15,0	20,0
20 — 25	2,5	8,0	12,0	20,0	25,0

4 WELDING CONSUMABLES

4.1 GENERAL

4.1.1 Welding consumables intended for welding the structures referred to in 1.1.1 shall be tested and approved by the Register. Based on the results of welding consumable approval the Register issues Certificate of Approval for Welding Consumables to the manufacturer.

4.1.2 Approval of welding consumables is generally granted on the basis of the following:

submission by the manufacturer of request with enclosed documents and information referred to in 4.1.2.1;

testing of welding consumables by the manufacturer or by the independent testing centre recognized by the Register in the scope of the requirements referred to in 4.2 to 4.7 to be in the presence of the Surveyor to the Register;

survey by the Register of welding consumable manufacturer's production potentialities and internal quality system.

4.1.2.1 The request to be submitted in the established form and the documentation enclosed thereto shall contain the following information:

name of manufacturer/manufacturing works (if required);

type of welding consumables;

manufacturer's trade mark;

range of sizes (diameter, length) of welding consumables subject to approval;

chemical composition (analytical tolerances) and minimum mechanical properties of the deposited metal guaranteed by the manufacturer, as well as guaranteed content of diffusible hydrogen in the deposited metal (if required);

grade according to the Register Rules, for which an approval is granted, including additional marks;

application range recommended by the manufacturer, including a grade (type) of the base material, welding technique, welding positions, heat treatment conditions and any special operating conditions (including low temperature restrictions for welding operations);

instructions/recommendations for use (welding current, polarity, hardening or baking conditions, etc.);

classification of a welding consumable according to international and national standards;

marking and packaging of welding consumables;

any previous approvals from other classification societies or technical supervision authorities;

proposed testing laboratory and date of tests.

Technical documentation subject to approval by the Register includes the following:

specifications and process instructions for fabrication and quality control;

manufacturer's specifications for a welding consumable;

latest publications of manufacturer's catalogues.

4.1.2.2 Tests of welding consumables for their approval and annual re-approval tests for the issued Certificate confirmation shall be witnessed by the Surveyor to the Register.

During the tests the manufacturer shall confirm the compliance of the welding consumables presented with the requirements of the Register and with the documentation submitted for approval or already approved.

4.1.2.3 Prior to survey of the manufacturer the following shall be submitted to the Register:

brief information on the production process with a list of the main production equipment and its characteristics;

documents on internal quality assurance system at the manufacturer's;

information on suppliers and specification on raw materials and/or semi-finished products used for fabrication of welding consumables.

4.1.2.4 Upon the successful conclusion on results of welding consumable tests and manufacturer survey the Register will issue Certificate of Approval for Welding Consumables.

4.1.2.5 With the Register approval, the manufacturer assumes responsibility for ensuring that during fabrication the composition and properties of the products will conform to those of the tested welding consumables (refer also to 4.1.4.1, 4.1.4.2).

4.1.2.6 The manufacturer shall state in their catalogues and on packaging (label, tag) the information on the Register approval by indicating "Approved by the Register, ..." and specifying the grade of the welding consumable according to the Approval Certificate. Besides, the information on storage conditions and use of welding consumables shall be indicated in the catalogue and on packaging.

4.1.3 Special cases of welding consumable approval.

4.1.3.1 Referred to special cases of welding consumable approval are:

upgrading/uprating of welding consumables at manufacturer's request;

approval of welding consumables for compliance with international or national standards;

approval of welding consumables for compliance with the properties guaranteed by the manufacturer, which exceed or supplement the requirements of the Register Rules or appropriate standards;

approval of welding consumables fabricated under license or manufacturer's subsidiary companies;

approval of welding consumables based on the tests carried out in the course of approval by the Register of the welding processes of the company using the welding consumables;

approval of welding consumables based on the results of the tests carried out by other classification societies or technical supervision authorities;

single permits for use of welding consumables having an approval of other classification societies or technical supervision authorities.

4.1.3.2 Tests on upgrading of welding consumables are carried out at the manufacturer's request and are generally combined with annual re-approval tests of the welding consumables. The scope of the tests for upgrading of welding consumables shall comply with the requirements of 4.2 to 4.7.

4.1.3.3 Welding consumables are generally approved by the Register for compliance with international or national standards in the following cases:

at the manufacturer's request;

in cases where requirements for welding consumables are not specially stated in the Register Rules.

In such cases, the scope and procedure of the tests shall meet the requirements of the appropriate standards.

4.1.3.4 Where welding consumables are approved by the Register for compliance with properties guaranteed by the manufacturer, which exceed or supplement the requirements of the Register Rules and/or appropriate standards, an adequate entry shall be made in the Certificate of Approval for Welding Consumables. The properties shall be confirmed by the test results.

4.1.3.5 Where a welding consumable of the same trade mark is fabricated in several factories of the same company, the complete approval test-series of the welding consumables may be carried out in one of the works only. In the other factories (subsidiary companies) a reduced test programme at least equivalent to annual re-approval tests is permitted.

The manufacturer shall submit the data to the Register, which confirm that materials used in terms of their composition, fabrication process and welding characteristics are identical to those used in the main works.

However, shall there be any doubt, complete test-series may be required by the Register.

These requirements are also applicable to all manufacturers producing welding consumables under license.

If a unique powder flux is combined with different wires coming from several factories belonging to the same firm for a combination "wire — flux", the flux may be approved by the Register on the basis of testing the wire delivered by one of the suppliers, if all the suppliers produce and deliver the wires according to the same specification.

4.1.3.6 For approval of welding consumables in conjunction with the tests of the welding processes (refer to Section 6) the User of the welding consumables shall be authorized by the manufacturer to perform such works (combination of tests).

The welding process approval test programme shall be extended and shall include the tests for determination of the deposited metal properties.

4.1.3.7 Where welding consumables have approvals from other classification societies, the scope of the tests to obtain the Register approval may be reduced to that required for re-approval tests of the welding consumables.

In such case, a copy of the detailed report on the tests performed shall be appended to the request for the Register approval.

The scope and results of the tests shall comply with the requirements of the present Part.

4.1.3.8 In special cases, provided the requirements of 4.1.3.7 are met, the Register may issue a single permit for use of welding consumables, which have been approved by other classification societies but do not have approval certificate of the Register. Such permit is limited:

by the scope of the consumables used;

by use;

by time of use.

The Register reserves the right to require check tests of the welding consumables at the User's within the scope of the tests for determination of the deposited metal properties, the results of which are presented in the form of Test Report certified by the Register.

4.1.4 Approval validity.

4.1.4.1 Certificate of Approval for Welding Consumables is issued for a period of up to five years and is subject to annual re-approval tests to be carried out under supervision of the Register.

The welding consumable re-approval tests shall be carried out at a yearly interval, and re-approval relates to the year when the tests are conducted. The tests shall be completed by the end of each calendar year at the latest.

Where conditions of re-approval are not met, the validity of the approval certificate is ceased, and the welding consumables indicated therein may no longer be used for fabrication of the structures subject to survey by the Register.

Upon expiry the approval certificate may be extended by the Register on the basis of the tests generally equivalent to the re-approval tests. Where the approval certificate ceases to be valid ahead of time, its extension requires the tests equivalent to those required for approval of welding consumables.

In case the manufacturer has and maintains the quality system recognized by the Register, the Surveyor to the Register may not be present during the tests, provided they are conducted by the manufacturer in compliance with the quality control system in force at the manufacturer's and the test results are checked.

4.1.4.2 During the certificate approval validity the Register may require from the manufacturer to confirm the stable quality of raw material and finished product composition and properties, as well as adherence to the production process.

Where the production process, quality control and acceptance procedures change as well as where suppliers of raw materials and appropriate specifications, which may impair the quality of the welding consumables produced by the manufacturer, are substituted, additional tests shall be conducted under the technical supervision of the Register.

4.1.4.3 Where proofs exist of a welding consumable unsatisfactory quality, which have been obtained during its acceptance for fabrication of the structures subject to survey by the Register, the approval certificate loses its validity. The Register approval may be resumed only provided the manufacturer submits adequate proofs showing that factors causing the production poor quality have been eliminated and new re-approval tests have been carried out.

4.1.4.4 In case re-approval tests show unsatisfactory results the grade of welding consumables shall be lowered according to the actual values of the properties obtained. The approval may be resumed not before three months' period after the manufacturer has taken measures for production quality stabilisation and performance of the tests for welding consumables upgrading in the established order.

4.1.4.5 Welding consumables approved by the Register on the basis of the test results conducted at the user's during the welding process approval shall be subjected to re-approval tests in the normal way either at the manufacturer's or, on its authorization, at the user's works.

4.1.4.6 Where welding consumables or welding process requirements are not governed by the Rules, the scope of their approval tests shall be agreed upon with the Register in each particular case.

4.2 WELDING CONSUMABLES FOR HULL STRUCTURAL STEEL

4.2.1 General.

4.2.1.1 Welding consumables for normal strength hull structural steel are divided into Grades 1, 2 and 3; those for welding higher strength hull structural steel — into Grades 1Y, 2Y and 3Y, those for welding high strength hull structural steel — into Grades 3Yxx, 4Yxx and 5Yxx. (The index xx is used to denote one of the six strength groups for deposited metal and weld in accordance with 4.6).

4.2.1.2 The mechanical properties and impact energy *KV* of the deposited metal shall conform to Table 4.2.1.2-1, those of the welded joint to Table 4.2.1.2-2 for appropriate grade of welding consumables.

4.2.1.3 Welding consumables for hull structural steel shall be chosen in accordance with Table 2.2.4.

4.2.1.4 Welding consumables, which according to 4.2.2.3 require determination of the diffusible hydrogen in the deposited metal in the grade identification symbol shall contain indices 15, 10 or 5, which depending on the diffusible hydrogen content correspond to the requirements of Table 4.2.1.4.

The method of determining the hydrogen content shall be indicated in the tests protocol. The diffusible hydrogen content calculation shall be reduced to standard conditions by temperature and pressure.

4.2.1.5 Welding consumables of any grade, if intended for welding normal strength steel with the carbon content of 0,22 per cent and over or for welding such steel to other steels, or for welding higher strength steel, shall ensure the absence of cold cracks in the weld metal and welded joint in case welding is conducted at a temperature down to minus 25 °C. The sulphur and phosphorus content in the weld metal shall not exceed 0,03 per cent each.

4.2.1.6 Welding consumables to be used for welding hull structures, which may come in direct contact with ice (ships with ice strengthening of categories **Arc5** to **Arc7** and icebreakers), shall be tested to determine the weld corrosion resistance in sea water, the welds being of steel grades adopted for the structures.

4.2.1.7 If requested by the manufacturer of the welding consumables, they may be transferred to a higher grade in case it is demonstrated by annual tests that they conform to the requirements for that higher grade.

4.2.1.8 Depending on the scope of approval of welding consumables their designation shall include the following indexes:

T — approval of welding consumables for two-run welding. This means welding simultaneously on

Table 4.2.1.2-1

Requirements for mechanical properties of deposited metal

Grade of welding consumables	Application of welding consumables	Tensile properties of deposited metal				Impact energy *KV* obtained at impact testing of deposited metal			
						Electrodes and combinations for semi-automatic welding		Combinations for automatic welding	
		Tensile strength R_m, MPa	Yield stress R_e, MPa	Percentage elongation A_5, %	Percentage reduction of area *Z*, %	Test temperature, °C	Average value for three test specimens, J, min	Test temperature, °C	Average value for three test specimens, J, min
			minimum						
1	For normal strength steel	400 — 560	305	22	45	+20	47	+20	34
2		400 — 560	305	22	45	0	47	0	34
3		400 — 560	305	22	45	–20	47	–20	34
1Y	For higher strength steel with $R_e \leqslant 355$ MPa	490 — 660	375	22	45	Not subject to classification		+20	34
2Y		490 — 660	375	22	45	0	47	0	34
3Y		490 — 660	375	22	45	–20	47	–20	34
4Y		490 — 660	375	22	45	–40	47	–40	34
2Y40	For higher strength steel with $R_e \leqslant 390$ MPa	510 — 690	400	22	45	0	47	0	39
3Y40		510 — 690	400	22	45	–20	47	–20	39
4Y40		510 — 690	400	22	45	–40	47	–40	39

Table 4.2.1.2-2

Requirements for welded joint mechanical properties

Grade of welding consumables	Application of welding consumables	Properties of welded joint (transverse specimen)		Impact energy *KV* obtained at impact testing of welded joint				
				Electrodes and combinations for semi-automatic welding			Combinations for automatic welding	
		Tensile strength, R_m, MPa	Angle of bending till the first crack appears, deg.	Test temperature, °C	Average value for three test specimens, J		Test temperature, °C	Average value for three test specimens, J, min
					downhand, horizontal and overhead positions	vertical position		
		minimum			minimum			
1	For normal strength steel	400	120	+20	47	34	+20	34
2		400	120	0	47	34	0	34
3		400	120	−20	47	34	−20	34
1Y	For higher strength steel with $R_e \leqslant 355$ MPa	490	120	Not subject to classification			+20	34
2Y		490	120	0	47	34	0	34
3Y		490	120	−20	47	34	−20	34
4Y		490	120	−40	47	34	−40	34
2Y40	For higher strength steel with $R_e \leqslant 390$ MPa	510	120	0	47	39	0	39
3Y40		510	120	−20	47	39	−20	39
4Y40		510	120	−40	47	39	−40	39

Table 4.2.1.4

Hydrogen content index	Hydrogen content in deposited metal (maximum, cm^3/100 g of deposited metal) determined by:	
	vacuum method	glycerine method
H15	15	10
H10	8	5
H5	5	Not to be used

both sides of the weld in one-run including one-run one-sided welding with back forming and the two-run double-sided welding without back welding and gouging of the weld root;

M — approval of welding consumables for multirun welding;

TM — approval of welding consumables for two-run and multirun welding;

S — approval of welding consumables for semi-automatic welding;

V — approval of welding consumables for electroslag or electrogas welding.

4.2.2 General provisions for testing.

4.2.2.1 For the purpose of welding consumable approval by the Register the following shall be generally determined in the course of tests:

mechanical properties of deposited metal;

mechanical properties of weld metal and butt weld;

weld metal and welded joint resistance to hot cracking when a tee-joint test assembly is being welded.

If required by this present Part or at the option of the manufacturer the following shall be determined when approving the welding consumables:

diffusible hydrogen content in the deposited metal (refer to 4.2.1.4 and 4.2.2.3);

weld metal and welded joint resistant to cold cracking during welding (refer to 4.2.1.5 and 4.2.2.4);

corrosion resistance of welded joint in sea water (refer to 4.2.1.6 and 4.2.2.5).

4.2.2.2 When annual tests for confirmation of the Certificate of Approval for Welding Consumables are conducted in compliance with 4.1.4.1, the scope of the appropriate welding consumable tests shall be determined according to the requirements of 4.2.4.4, 4.2.5, 4.2.6.4, 4.2.7.4, 4.2.8.3, 4.2.9, 4.5.5, 4.6.4.

4.2.2.3 Testing on determination of the diffusible hydrogen content in the deposited metal.

4.2.2.3.1 Testing on determination of the diffusible hydrogen content in the deposited metal shall be conducted relative to the coated electrodes and flux cored-wire of the following grades:

2 and 3, if applicable, (materials may be classified according to 4.2.1.4), in compliance with the application of the manufacturer;

2Y, 2Y40, 3Y, 3Y40, 4Y, 4Y40 as well as 5Y and 5Y40;

3Y (42/69), 4Y (42/69) and 5Y (42/69).

Requirement to conducting the tests and classification of welding consumables depending on the content of hydrogen, according to 4.2.1.4 is also used during approval of combinations "wire-flux" intended for welding of:

high strength steels (refer to 4.6.2);

higher strength steels relatively to manufacture of the MODU and FOP structures, (refer to 2.5.4.3, Part XIII "Welding" of the Rules for the Classification, Construction and Equipment of Mobile Offshore Drilling Units (MODU) and Fixed Offshore Platforms (FOP).

Relative to the combination of "wire (of continuous section)-shielded gas" it is not necessary to conduct the tests and classification of welding consumables with respect to the diffusible hydrogen content according to 4.2.1.4.

4.2.2.3.2 Testing on determination of the diffusible hydrogen content in the deposited metal are allowed with application of the following methods:

vacuum mercury method complying with the requirements of IS 3690-1977 Standard;

vacuum non-mercury method complying with the appropriate State Standard 23338-78 described in Collection of Regulating Documents of the Register (Book 3);

chromatographical method in compliance with the technique agreed with the Register, provided the results comply with the IS 3690-1977 Standard technique;

glycerine method in compliance with the technique agreed with the Register and satisfying the requirements to conducting the tests mentioned below.

4.2.2.3.3 Determination of the diffusible hydrogen content by the glycerine method shall be performed in compliance with the following requirements to technique of conducting the tests.

Subject to testing are four specimens with the dimensions as follows: thickness — 12 mm, width — 25 mm, length —about 125 mm.

Hull structural steel of normal or higher strength of any grade may be used as a base metal.

Prior to welding, after grinding and degreasing, the specimens shall be weighed with an accuracy of up to 0,1 g. On the sample surface with a size of 25 mm a single bead is welded with a length of about 100 mm using 4,0 mm diameter electrode. At that, the consumed length of electrode shall be approximately 150 mm. Welding is carried out at the minimum length of the arc and a welding current value equal to about 150 A. Prior to welding the electrodes, if envisaged by the manufacturer recommendations, may be subjected to calcination or drying.

During 30 s after completion of the welding operation every specimen shall be cleaned of slug and placed for cooling in a water reservoir with a temperature not higher than 20 °C.

During 30 s the specimen shall be cooled in water, washed, dried and placed into the device for gathering of the diffusible hydrogen by substitution (displacement) for glycerine.

When testing of the flux-cored wire, welding conditions shall comply with the recommendations of the welding consumables manufacturer and selected in such way as to provide a mass of the welded metal equal to that at welding by the coated electrodes.

In course of testing, device with glycerine shall be maintained at a temperature of 45 °C. All the four specimens shall be welded and placed into the separate hydrogen gathering devices for the period of time, which shall exclude any alternation of the hydrogen content, affected by the humidity alternation of the electrodes coating after calcination and execution of welding conditions. As a rule, this period shall not exceed 30 min.

The specimens shall be maintained submerged in glycerine at a temperature of 45 °C for 48 hours. After that the specimens shall be taken out of device, washed by water, dried by alcohol and weighed with an accuracy of up to 0,1 g for determination of the mass of welded metal. The quantity of evolved gas shall be weighed with an accuracy of up to 0,05 cm^3 and shall be recalculated for temperature of 0 °C and pressure of 760 millimeter of mercury.

4.2.2.4 Determination of the weld metal and welded joint resistance to cold cracking is conducted according to the procedure described in Collection of Regulating Documents of the Register (Book 3).

If agreed with the Register, it is permitted to make the tests according to alternative procedures; the welding operations shall be conducted under conditions similar to those of ship construction.

4.2.2.5 Determination of the welded joint corrosion resistance in sea water is conducted according to the procedure described in Collection of Regulating Documents of the Register (Book 3).

If agreed with the Register, testing according to alternative procedures is permitted.

4.2.3 Preparation of test assemblies and specimens and criteria for test results estimation.

4.2.3.1 Test assembly preparation.

4.2.3.1.1 In general, for all welding consumables, the test assemblies for determining deposited metal properties may be prepared from steel of any grade.

Butt and tee weld test assemblies shall be prepared from steel of the grade, for which the welding consumables are intended. In case the welding consumables are intended for steels of different grades, butt weld test assemblies shall be prepared from steel of the highest grade.

Welding of test assemblies shall be carried out at normal temperature and the subsequent run shall be made after the preceding one has cooled to at least 250 °C but not less than to 100 °C; welded test assemblies shall not be heat treated.

Before being cut to test specimens, butt weld test assemblies shall undergo radiographic inspection the results of which shall confirm freedom from impermissible defects.

Welding of test assemblies shall be made in the presence of a Surveyor to the Register or a person authorized by that body.

4.2.3.1.2 If welding consumables shall be admitted for d.c. and a.c. welding, test assemblies shall be a. c. welded. The Register may demand for the test assembly d. c. welding.

4.2.3.2 Specimen preparation.

4.2.3.2.1 For the weld metal test, longitudinal cylindrical test specimens shall be used in accordance with Fig. 2.2.2.3 (*a*), Part XIII "Materials" with dimensions: $d = 10$ mm, $L_0 = 50$ mm, $L_c = 60$ mm, $R \geqslant 5$ mm.

The longitudinal axis shall coincide with the centre of the weld and:

the mid thickness of the weld in the deposited metal test assemblies made following the multirun technology;

the mid thickness of the 2nd run in the two-run welded test assemblies.

Upon agreement with the Register in certain cases the use of the proportional ($L_0 = 5d_0$) longitudinal cylindrical test specimens is allowed according to 2.2.2.3, Part XIII "Materials", of other diameters (more or less than 10 mm).

The specimens may be heated to a temperature not exceeding 250 °C for a period not exceeding 16 hours for hydrogen removal prior to testing.

4.2.3.2.2 For testing of the butt weld, transverse flat tensile test specimens shall be used in accordance with Fig. 4.2.3.2.2. The upper and lower surfaces of the weld shall be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm.

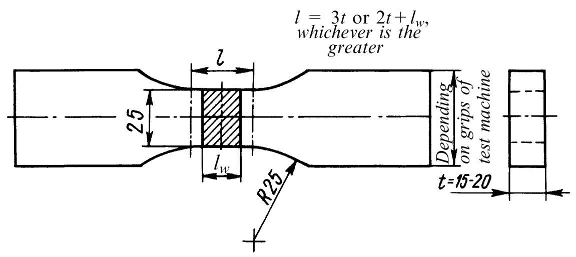


Fig. 4.2.3.2.2:
l_w — utmost weld width (upper side of weld)
$l = l_w + 12$ mm

4.2.3.2.3 Specimens for the bend tests of the weld shall be made in accordance with the requirements of Fig. 2.2.5.1, Part XIII "Materials". The upper and lower surfaces of the weld shall be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm.

If the test procedure allows for the bending of test specimen round the mandrel, then the test specimen length may exceed $11a_0$.

While tensile testing of transverse specimen and weld root, the specimen dimensions shall be as follows:

$a_0 = t$ — metal sheet thickness of the butt weld specimen,

$b_0 = 30$ mm.

If the thickness (a_0) is greater than 25 mm, it may be reduced to 25 mm by machining on the compression side of the bend specimen.

While side bend testing of transverse specimen, specimen dimensions shall be as follows:

$a_0 = 10$ mm,

$b_0 = t$ — metal sheet thickness of the butt weld specimen.

In the latter case at a sheet thickness of $t \geqslant 40$ mm it is allowed to divide the specimen in two parts of the width b_0 not less than 20 mm.

While bend testing of longitudinal specimens their dimensions shall be agreed upon with the Register.

4.2.3.2.4 Determining of the impact of the weld metal and metal of the butt weld shall be carried out on the specimens with the V — shape cut, which meet the requirements of 2.2.3, Part XIII "Materials".

The order of blanking specimens for impact testing from the weld metal and specimens of the butt weld manufactured according to the multirun technology shall meet requirements of Fig. 4.2.3.2.4-1.

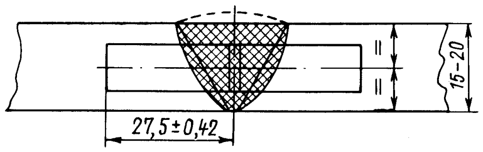


Fig. 4.2.3.2.4-1

While testing of the butt weld specimens manufactured according to the two-run technology the order of blanking specimens shall meet the requirements of Fig. 4.2.3.2.4-2.

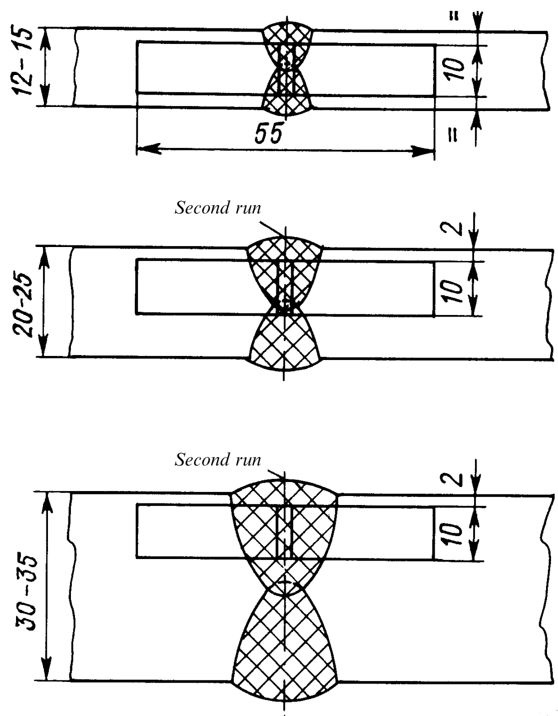


Fig. 4.2.3.2.4-2

4.2.3.3 Criteria for estimating test results.

4.2.3.3.1 Bend test results are considered satisfactory if, after bending through an angle of 120° over a mandrel having a diameter equal to three times the specimen thickness, no cracks appear on the specimen surface being in tension. Surface cracks less than 3 mm in length shall be ignored.

4.2.3.3.2 Where the tensile and bend test results do not agree with the requirements, the tests shall be repeated on a double number of specimens.

4.2.3.3.3 For impact testing, three specimens shall be chosen. The average impact energy value obtained shall be in accordance with Tables 4.2.1.2-1 and 4.2.1.2-2. The impact energy obtained on a particular specimen may be below the average value required, but not less than 70 per cent of that value. During the tests, the temperature of the specimens being tested shall be maintained within ± 2 °C.

4.2.3.3.4 Retesting is conducted in accordance with 1.3.4.2, Part XIII "Materials".

Decision on the performance of retesting and the extent of retesting are determined upon the agreement with the Register representative, but in any case the specimens shall be cut from a newly welded assembly and the tests may be conducted to a full extent including those, at which satisfactory results have been obtained.

Possibility of conducting further tests in case of obtaining unsatisfactory results for the first three and three additional specimens shall be agreed with the Register separately. At that, to conduct these tests a new welding specimen shall be cut, while its extent shall include all the types of tests, envisaged for the first specimen testing, including those, at which satisfactory results have been obtained.

4.2.3.3.5 The hot cracking test results will be considered satisfactory if no surface or internal cracks nor considerable porosities shall be found in the welds of the tee-joint test assembly.

4.2.3.3.6 The cold cracking test results shall be estimated by means of a procedure included in the program approved by the Register.

4.2.3.3.7 Proceeding from the results of testing the corrosion resistance of welded joints in sea water, the average corrosion rate for weld metal and heat-affected zone, base metal in weld zone and some distance away from the weld shall be determined. The ratio of corrosion rates of welded joints components shall be 0,9 to 1,1.

4.2.4 Testing of electrodes for manual arc welding.

4.2.4.1 Deposited metal tests.

Two test assemblies shall be prepared in the downhand position, one with 4 mm diameter electrodes and the other with the largest size manufactured. If an electrode is available in one diameter only, one test assembly is sufficient.

The deposited metal test assembly shall be as shown in Fig. 4.2.4.1.

The weld shall be made by several runs, the direction of each subsequent run being opposite to that of the preceding one. The thickness of each run shall be between 2 and 4 mm.

The test results shall comply with Table 4.2.1.2-1.

4.2.4.2 Butt weld tests.

To determine the weld properties in each welding position (downhand, vertical-upward, vertical-downward, overhead, horizontal-vertical), for which the electrodes are approved, one test assembly shall be welded in each position. Subject to the agreement of the Register, electrodes for downhand and vertical-upward positions may be used for horizontal-vertical welding.

If the electrodes are approved for downhand position only, two test assemblies shall be prepared in that position.

Butt weld test assemblies for electrode testing shall be as shown in Fig. 4.2.4.2.

For particular positions, preparation of test assemblies shall be effected taking the following into consideration.

4.2.4.2.1 Downhand position. The first run shall be made with 4 mm diameter electrode. Remaining runs (except the last two layers) shall be made with 5 mm diameter electrodes or larger.

The runs of the last two layers shall be made with the largest diameter of electrode manufactured.

4.2.4.2.2 Downhand position (where a second downhand test is required). The first run shall be made with 4 mm diameter electrode, the next run with an electrode of 5 mm or 6 mm diameter, and the remaining runs with the largest diameter of electrode manufactured.

4.2.4.2.3 Horizontal position. The first run shall be made with 4 mm or 5 mm diameter electrode, subsequent runs with 5 mm diameter electrodes.

4.2.4.2.4 Vertical-upward and overhead positions. The first run shall be made with 3,25 mm diameter electrode, and remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

4.2.4.2.5 Vertical-downward position. Electrode diameter and the sequence of welding the test assembly shall be those recommended by the manufacturer.

Back sealing runs shall be made with 4 mm diameter electrodes after dressing the root run to clean metal in the same welding position as the weld runs.

The test results shall comply with Table 4.2.1.2-2.

4.2.4.3 Hot cracking test of weld metal and weld as a whole.

To determine hot cracking resistance, three tee-joint test assemblies shall be prepared as shown in Fig. 4.2.4.3.

As far as possible, the test assemblies shall be welded with electrodes of different diameters.

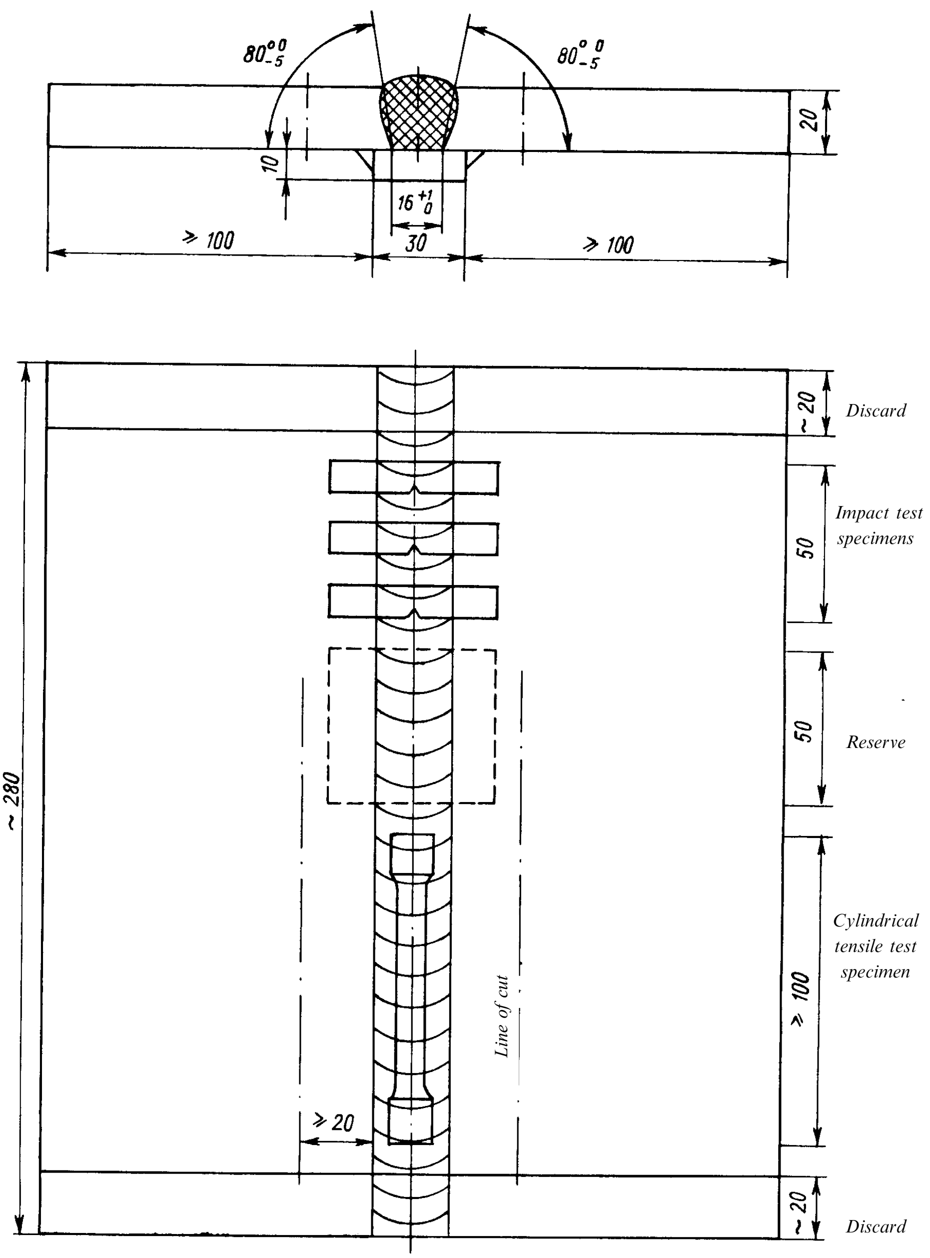


Fig. 4.2.4.1

The lower edge of the vertical plate shall be smooth and to fit closely to the lower plate surface. Uneven spots shall be removed before welding. Tack welds shall be made on the butt ends of the plates. The lower plate shall be stiffened additionally by welding three transverse ribs to it to protect it against deformation.

Welding shall be carried out in the gravity position. The fillets shall be signle-run welds joined at the maximum current recommended for the particular type and size of electrodes by the manufacturer.

The second fillet shall be welded immediately after the first one and shall end at that side of the test assembly where the first one was started. Both the fillets shall be executed at a constant speed and without weaving.

The length of electrode necessary to make a weld (refer to Fig. 4.2.4.3) is specified in Table 4.2.4.3.

After welding, the slag shall be removed from the fillets, and after complete cooling they shall be examined for cracks visually or by one of the non-destructive methods.

The first fillet is then machined or gouged and the second one is broken by closing the two plates together, submitting the weld root to tension.

4.2.4.4 The tests of electrodes during the welding consumable re-approval tests and the tests on their upgrading shall be carried out in compliance with the provisions of 4.2.4.4.1 and 4.2.4.4.2.

4.2.4.4.1 The annual tests programme of the electrodes intended for manual arc welding shall

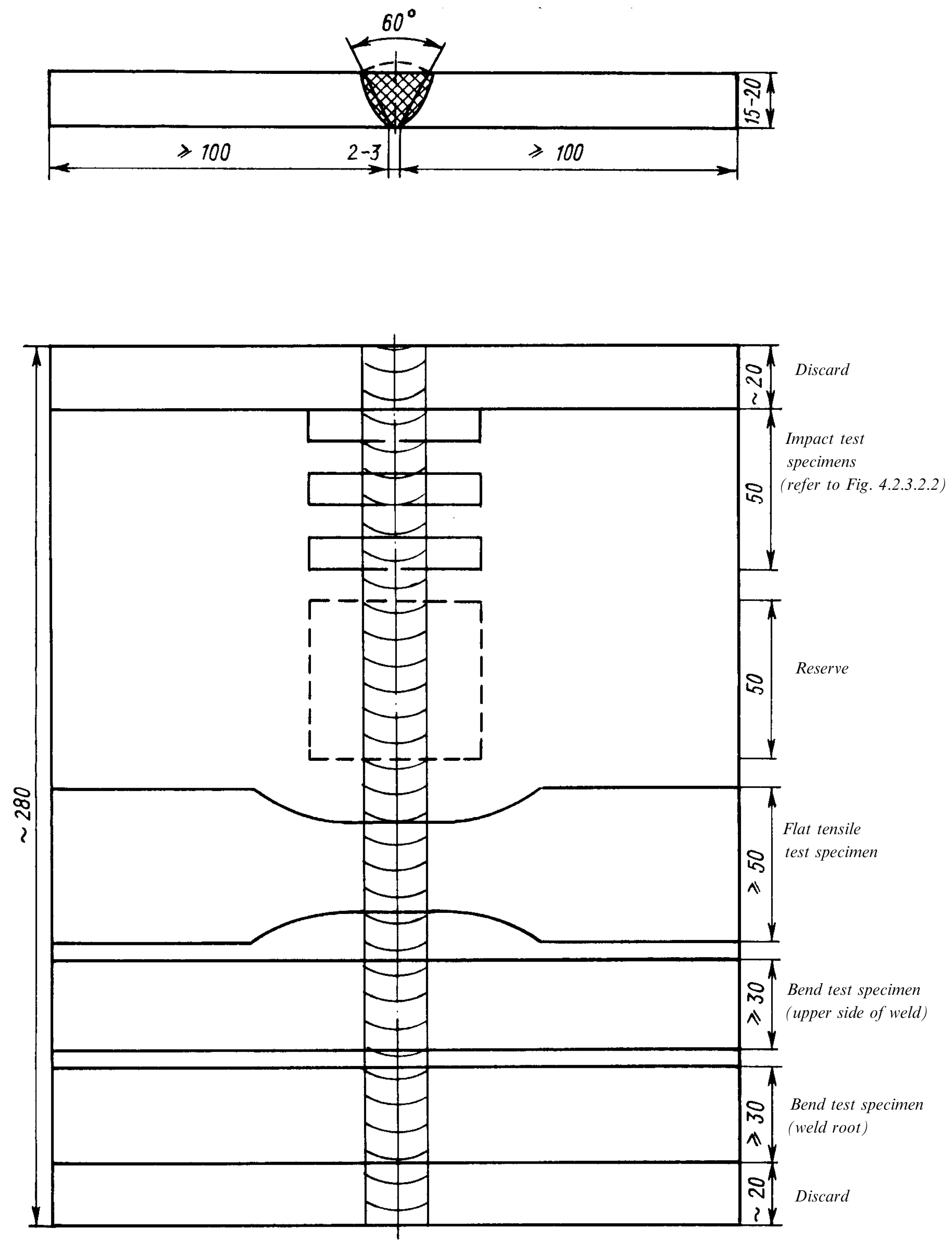


Fig. 4.2.4.2

Table 4.2.4.3

Diameter of electrode, mm	Consumed length of electrode, mm	
	First fillet	Second fillet
4	200	150
5	150	100
6	100	75

include two deposited metal test assemblies preparation in compliance with 4.2.4.1. On request of the Register welding of a weld test assembly in the downhand or vertical position may be included in the tests of the electrodes 4 mm in diameter instead of testing a deposited metal test assembly. The scope of the tests may be limited by fabrication of three impact specimens.

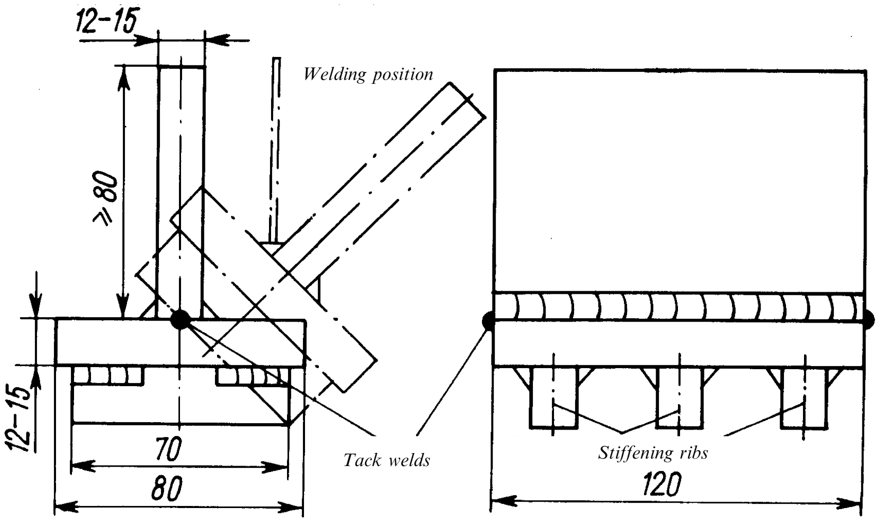


Fig. 4.2.4.3

Testing of consumables for diffusible hydrogen content in the deposited metal in accordance with 4.2.2.3 may be included in the annual test programme of the electrodes with controlled diffusible content having designations HH and HHH.

4.2.4.4.2 For upgrading of the electrodes tests on butt weld test assemblies shall be required, in addition to the normal annual re-approval tests of welding consumables in compliance with 4.2.4.4.1. One shall be guided by the following:

where upgrading deals only with a change of the impact test temperature without a change in the strength group, only additional impact tests of the specimens made of butt weld assemblies for each welding position specified in the Certificate of Approval for Welding Consumables shall be conducted;

in case upgrading of electrodes is associated with a change in the strength group, the complete test-series of the butt weld test assemblies shall be conducted in compliance with 4.2.4.2.

4.2.5 Testing of electrodes for fillet welding.

Electrodes for fillet welding including gravitation arc and fire-cracker welding shall undergo the following tests:

determination of weld metal properties according to 4.2.4.1;

tee-joint testing;

determination of hydrogen content according to 4.2.2.3.

Welding of tee joint shall be carried out as shown in Fig. 4.2.5.

Tee-joint test assemblies shall be prepared for each welding position, for which the electrode is recommended (downhand, vertical-upward, vertical-downward, overhead). The test assemblies shall be prepared using electrodes of the diameter recommended by the manufacturer for the particular welding position. The length of test assembly shall be sufficient to allow at least the deposition of the entire length of the electrode being tested. The first weld on the test assembly shall be made with an electrode of the largest diameter manufactured, and the second one with an electrode of the smallest diameter manufactured.

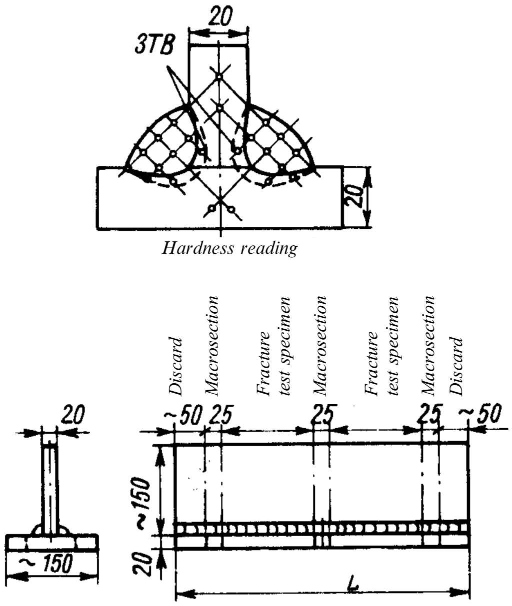


Fig. 4.2.5

From three sections about 25 mm wide, three macrosections shall be prepared.

On the macrosections, the hardness of weld metal, heat-affected zone and base metal shall be measured as shown in Fig. 4.2.5.

For welding hull structural steel of normal and higher strength, the average of weld metal and heat-affected zone hardness shall not exceed 350 HV (Vickers hardness, load 100 N).

After one of the welds has been gouged or machined, the fracture test shall be carried out submitting the root of the remaining weld to tension. The fractured surface shall be free of cracks and considerable porosity.

In re-approval of welding consumable annual tests of the electrodes intended for fillet welding shall be carried out in compliance with 4.2.4.4. For electrodes approved only for mechanized welding by a contact or gravity electrode the tests may be limited by welding of one test assembly, using electrodes of the maximum diameter.

Tests for uprating electrodes approved for fillet welding shall be conducted in the following way:

where the requirements for the impact test temperature only change the deposited metal tests shall be carried out at the upgraded temperature (i.e. without extension of the annual tests);

where the electrode strength group is changed the complete test-series required for the initial approval shall be carried out.

4.2.6 Testing of wire-flux combinations.

4.2.6.1 General.

The requirements below apply to wire-flux combinations for automatic multirun and two-run welding.

Where a combination is intended for both techniques, tests shall be carried out for each technique.

4.2.6.2 Combinations for multirun welding.

4.2.6.2.1 Deposited metal test.

A test assembly shall be prepared in the down-hand position as shown in Fig. 4.2.6.2.1.

The direction of each subsequent layer deposited in the test assembly shall be opposite to that of the preceding one. The thickness of each run shall not be less than the wire diameter nor less than 4 mm.

The results of testing specimens cut out of the test assembly as shown in Fig. 4.2.6.2.1 shall comply with Table 4.2.1.2-1.

4.2.6.2.2 Butt weld test.

A test assembly shall be prepared in the down-hand position as shown in Fig. 4.2.6.2.2. The results of testing specimens cut out of the test assembly as shown in Fig. 4.2.6.2.2 shall comply with Table 4.2.1.2-2.

4.2.6.3 Combinations for two-run welding.

Two test assemblies shall be prepared as shown in Fig. 4.2.6.3 using the following thicknesses:

for grades 1 and 1Y, 12 to 15 mm and 20 to 25 mm;

for grades 2, 2Y, 2Y40, 3, 3Y, 3Y40, 4Y, 4Y40, 20 to 25 mm and 30 to 35 mm.

Where approval is requested for welding of both normal strength and higher strength steel, two assemblies shall be prepared using higher strength steel. Two assemblies prepared using normal strength steel may also be required at the discretion of the Register.

The maximum diameter of wire, grades of steel plate and edge preparation to be applied shall be in accordance with Table 4.2.6.3.

The root gap shall not exceed 1 mm. The test assembly shall be welded in two runs. After completion of the first run and before the next one, the assembly shall be left in still air until it has cooled to 100 °C.

The test results obtained on specimens cut out of the assembly as shown in Fig. 4.2.6.3 shall comply with Tables 4.2.1.2-1 and 4.2.1.2-2.

4.2.6.4 The welding consumable re-approval tests shall be carried out according to the programme with regard to the following:

.1 for combinations intended for multi-run welding one deposited metal test assembly shall be welded, and one tensile specimen and three impact specimens shall be tested;

.2 for combinations intended for two-run welding one butt joint not less than 20 mm in thickness shall be welded, and one transverse tensile test specimen, two transverse bend test specimens and three impact test specimens shall be tested.

In case the combination is approved only for two-run welding one longitudinal cylindrical tensile test specimen shall be also tested.

4.2.6.5 For the purpose of the tests for upgrading the welding consumables one shall be guided by the following:

.1 where the requirements for the test temperature of the impact test specimens only change the tests for multi-run welding are similar to those required in 4.2.4.4.2; for two-run welding it is necessary to make a butt weld test assembly of the maximum thickness approved and to prepare impact test specimens according to Fig. 4.2.3.2.4-2;

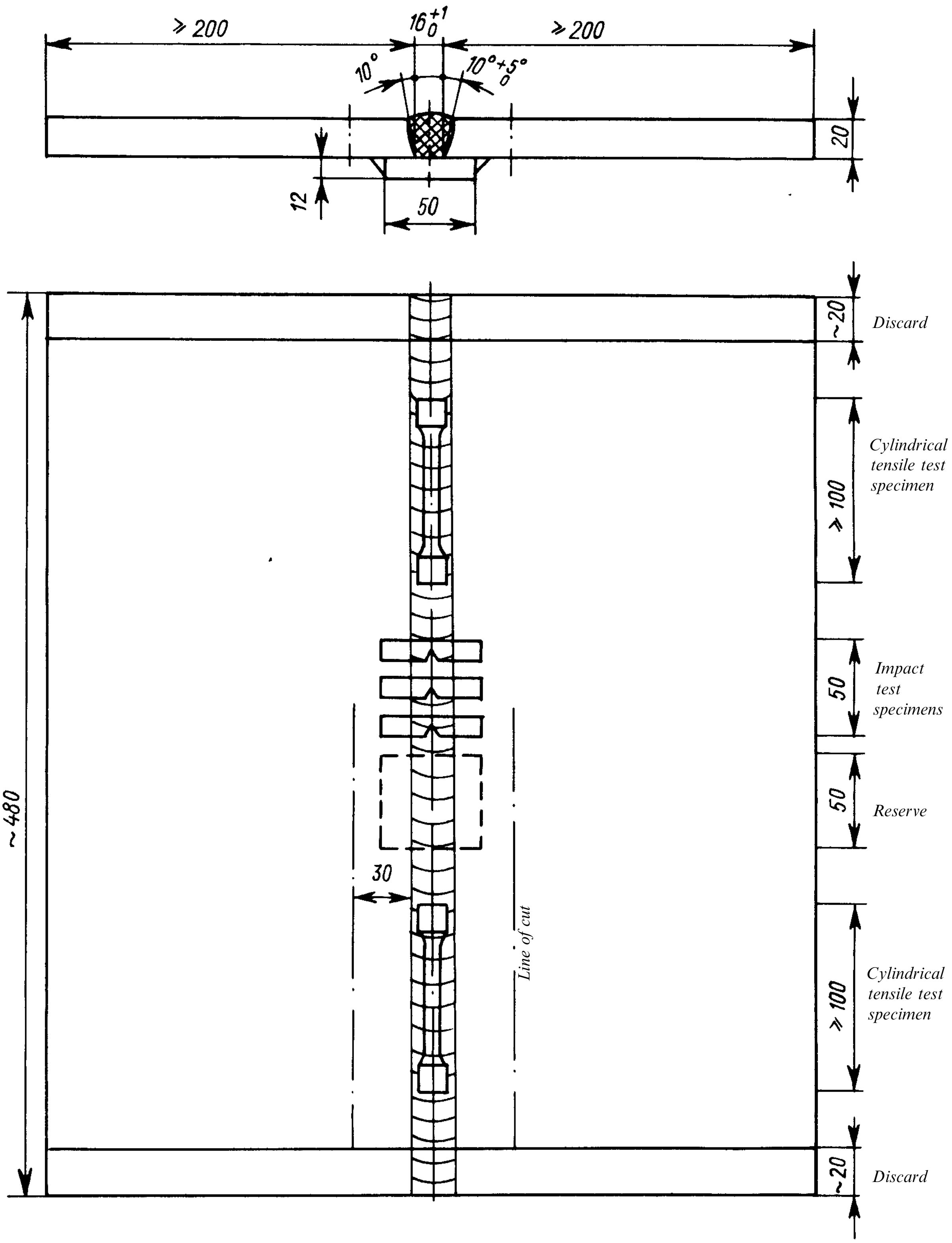
.2 in case of strength group uprating, complete test-series of butt weld test assemblies shall be carried out in compliance with the requirements of 4.2.6.2 and 4.2.6.3.

4.2.7 Testing of wire-gas combinations.

4.2.7.1 General.

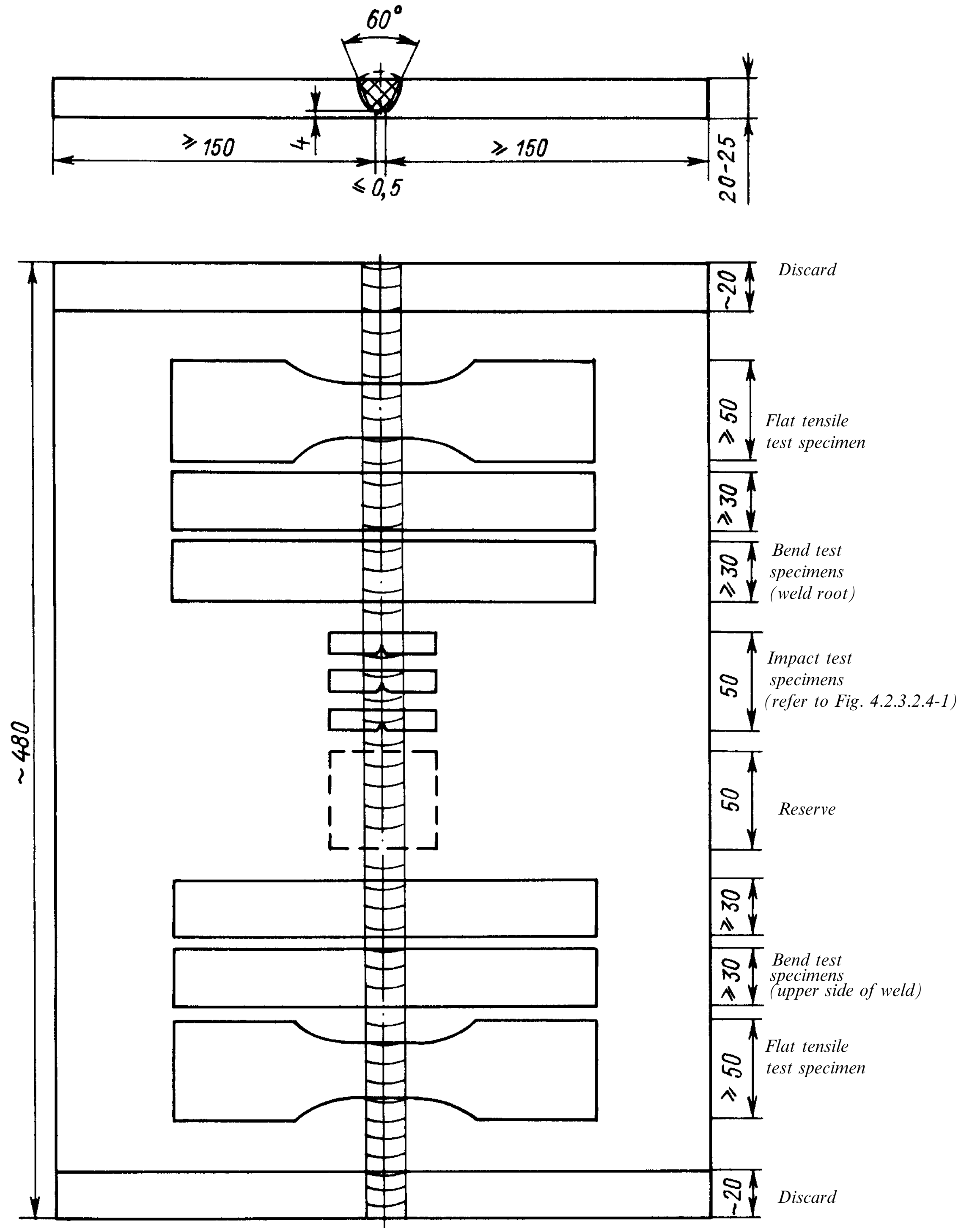
The requirements below apply to wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas).

The composition of the shielding gas used in the cobination shall be reported in Certificate of Ap-



⩾ 200
16^{+1}_{0}
⩾ 200
10°
$10°^{+5°}_{0}$
20
12
50
~20
Discard
Cylindrical tensile test specimen
⩾ 100
Impact test specimens
50
50
Reserve
~480
30
Line of cut
Cylindrical tensile test specimen
⩾ 100
~20
Discard

Fig. 4.2.6.2.1



60°
≥ 150
4
≥ 150
≤ 0,5
20-25
~480
~20
Discard
≥ 50
Flat tensile test specimen
≥ 30
≥ 30
Bend test specimens (weld root)
50
Impact test specimens (refer to Fig. 4.2.3.2.4-1)
50
Reserve
≥ 30
≥ 30
Bend test specimens (upper side of weld)
≥ 50
Flat tensile test specimen
~20
Discard

Fig. 4.2.6.2.2

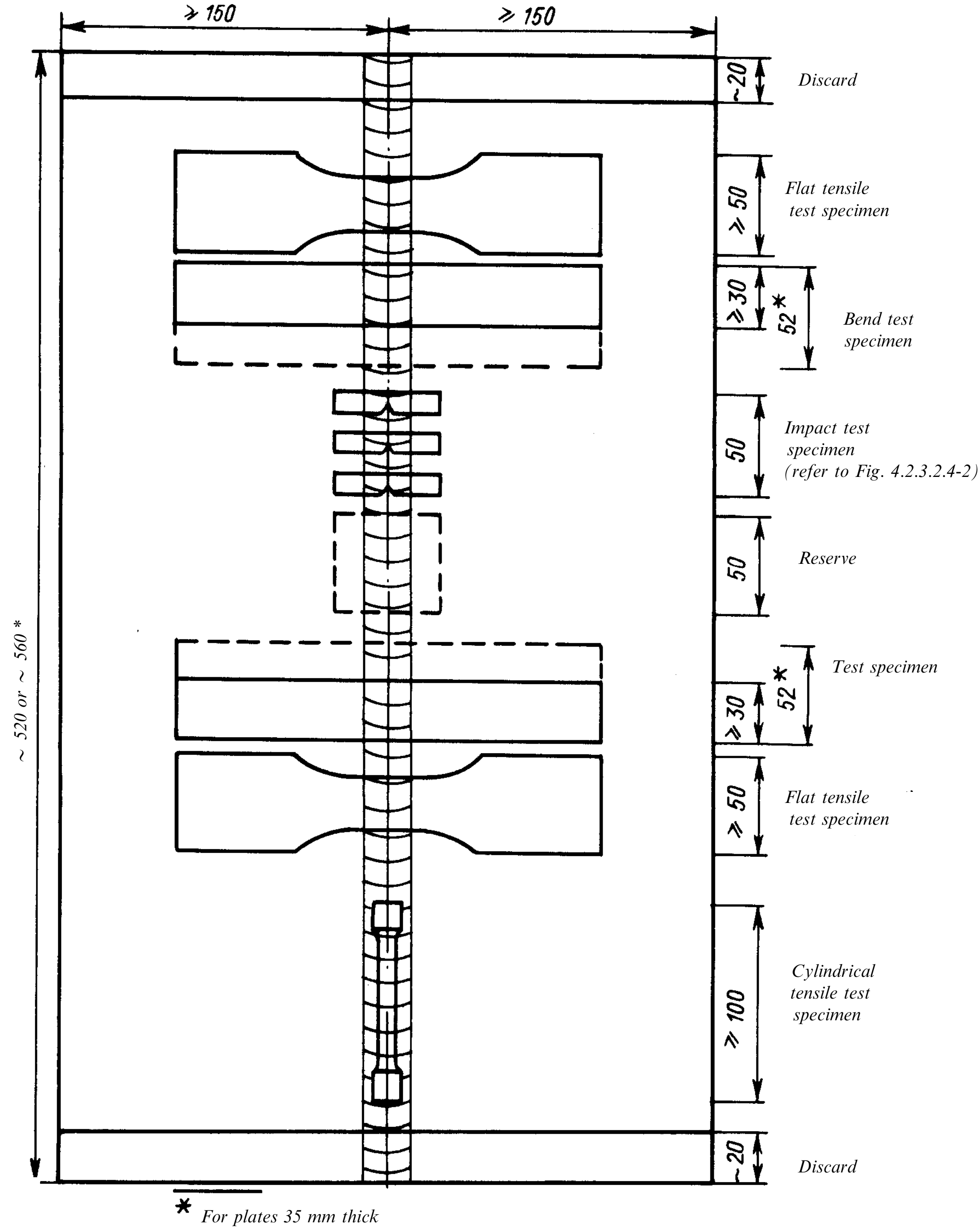
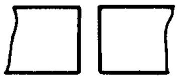
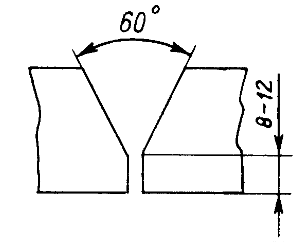
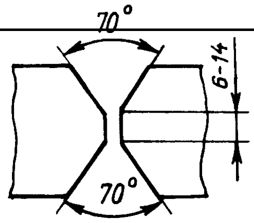

≥ 150
≥ 150
~20
Discard
≥ 50
Flat tensile test specimen
≥ 30
52*
Bend test specimen
50
Impact test specimen (refer to Fig. 4.2.3.2.4-2)
50
Reserve
52*
Test specimen
≥ 30
≥ 50
Flat tensile test specimen
≥ 100
Cylindrical tensile test specimen
~20
Discard
~ 520 or ~ 560 *
* For plates 35 mm thick

Fig. 4.2.6.3

Table 4.2.6.3

Plate thickness, mm	Edge preparation	Maximum diameter of wire, mm	Grade of welding consumables	Grade of steel on test assemblies: normal strength steel	Grade of steel on test assemblies: higher strength steel
12 —15		5	1 1Y	A —	— A32, A36
20 — 25		6	1 1Y	A —	— A32, A36
			2 2Y 2Y40	A, B or D — —	— A32, A36, D32, D36 A40, D40
			3 3Y 3Y40 4Y 4Y40	A, B, D, E — — — —	— from A32 to E36 A40, D40, E40 from A32 to F36 A40, D40, E40, F40
30 — 35		7	2 2Y 2Y40	A, B or D — —	— A32, A36, D32, D36, A40, D40
			3 3Y 3Y40 4Y 4Y40	A, B, D, E — — — —	— from A32 to E36 A40, D40, E40 from A32 to F36 A40, D40, E40, F40

proval for Welding Consumables. Additional approval tests are required when a shielding gas is used other than that used for the original approval tests.

When approving combinations for fillet welding, the requirements of 4.2.5 shall be complied with.

When approving combinations for automatic multirun welding, the requirements of 4.2.6.2 shall be complied with and when the deposited metal assembly is prepared the thickness of a layer shall be at least 3 mm.

A combination approved for semi-automatic multirun welding is approved for automatic welding without further testing.

4.2.7.2 Combinations for multirun welding.

4.2.7.2.1 Deposited metal test.

Two test assemblies shall be prepared in the downhand position as shown in Fig. 4.2.4.1, one using the smallest diameter, and the other using the largest diameter of wire. Where only one diameter is manufactured, only one deposited metal test assembly shall be prepared.

The thickness of each layer of weld metal shall be between 2 and 6 mm.

The results of testing specimens cut out of the test assemblies as shown in Fig. 4.2.4.1 shall comply with the requirements of Table 4.2.1.2-1.

4.2.7.2.2 Butt weld test.

Butt weld assemblies as shown in Fig. 4.2.4.2 shall be prepared for each welding position, for which the combination is recommended by the manufacturer.

The assembly shall be welded using, for the first run, wire of the smallest diameter manufactured and, for the remaining runs, wire of the largest diameter manufactured (downhand position) or the largest diameter of wire recommended by the manufacturer for the position concerned (positions other than downhand).

Where approval is requested only in the downhand position, an additional butt weld assembly shall be prepared in that position using wires of different diameter from those used for the first assembly.

Where only one diameter is manufactured, only one test assembly shall be prepared.

The results of testing specimens cut out of the test assembly as shown in Fig. 4.2.4.2 shall comply with the requirements of Table 4.2.1.2-2.

4.2.7.3 Combinations for automatic two-run welding.

Approval tests shall be carried out in accordance with the requirements of 4.2.6.3 taking the following into consideration.

Two test assemblies shall be prepared as shown in Fig. 4.2.6.3, using plates 12 to 15 mm and 20 to 25 mm in thickness.

If approval is requested for welding plates thicker than 25 mm, one assembly shall be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness, for which approval is requested.

Proceeding from the thickness of the assembly to be welded, the edge preparation shall be as shown in Fig. 4.2.7.3.

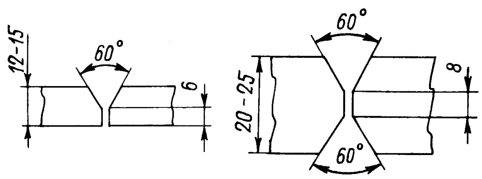


Fig. 4.2.7.3

4.2.7.4 The welding consumable re-approval tests shall be carried out according to the programme with regard to the following:

.1 for combinations intended for semi-automatic multi-run welding or simultaneously for semi-automatic and automatic multi-run welding one deposited metal test assembly shall be made in accordance with Fig. 4.2.4.1, and one tensile test specimen and three impact test specimens shall be tested. The diameter of the welding wire shall correspond to that indicated in the Certificate of Approval for Welding Consumables for semi-automatic welding;

.2 for combinations intended for automatic multi-run welding one deposited metal test assembly shall be made in accordance with Fig. 4.2.6.2.1, and one tensile test specimen and three impact test specimens shall be tested. The diameter of the welding wire shall correspond to that indicated in the Certificate of Approval for Welding Consumables for automatic welding;

.3 for combinations intended for automatic two-run welding one butt weld test assembly of 20 to 25 mm in thickness shall be prepared, in accordance with Fig. 4.2.6.3 and one transverse tensile test specimen, two transverse bend test specimens and three impact test specimens as well as one longitudinal cylindrical tensile test specimen in case the combination is approved only for automatic two-run welding shall be tested. The diameter of the welding wire shall be indicated in the Test Report;

.4 for flux-cored wires with controlled diffusible hydrogen content, having designations HH and HHH, the Register may require to include testing of consumables for diffusible hydrogen content in the deposited metal in the annual test programme in accordance with 4.2.2.3.

4.2.7.5 For the purpose of upgrading of welding consumables one shall be guided by the following:

.1 where the requirements for the test temperature of the impact test specimens only change the tests are similar to those required in 4.2.4.4.2 for multi-run welding; for two-run welding it is necessary to make a butt weld test assembly of 20 to 25 mm in thickness and to prepare impact test specimens according to Fig. 4.2.3.2.4-2;

.2 in case of combination strength group upgrading, the complete test-series of the butt weld test assemblies shall be carried out in compliance with the requirements of 4.2.7.2 and 4.2.7.3.

4.2.8 Testing of consumables for use in electroslag and electrogas welding.

4.2.8.1 To above welding consumables, the requirements of 4.2.6.3 are applicable, and the requirements of 4.2.8.2 shall be considered.

4.2.8.2 Two test assemblies shall be prepared as shown in Figs. 4.2.8.2-1 and 4.2.8.2-2, one of them with plates 25 mm thick, the other with plates 35 to 40 mm thick. The grade of steel to be used for each one of these assemblies shall be selected according to the requirements given in Table 4.2.6.3.

For specimens cut out of the test assemblies as shown in Figs. 4.2.8.2-1 and 4.2.8.2-2, the test results shall comply with Tables 4.2.1.2-1 and 4.2.1.2-2 for automatic welding.

4.2.8.3 The welding consumable re-approval tests shall be carried out according to the programme, which includes welding of one butt weld test assembly 20 to 25 mm in thickness according to 4.2.8.2 and preparation of the following test specimens:

one longitudinal cylindrical tensile specimen from the axis of the weld;

one transverse tensile test specimen;

two side-bend specimens;

three Charpy-V specimens notched at the centre of the weld;

three Charpy-V test specimens cut out transverse to the weld with their notches at 2 mm from the fusion line, in the weld (refer to Fig. 4.2.8.2-2);

macrosection.

4.2.8.4 In upgrading of welding consumables all the tests required for approval of electrogas and electroslag welding shall be carried out in compliance with 4.2.8.1 and 4.2.8.2. The results of the tests for the particular welding consumables during approval of other welding techniques with the use thereof are not taken into account.

4.2.9 Testing of welding consumables for one-side backing welding.

The scope and conditions of testing shall be determined on the basis of the requirements of 4.2.4 to 4.2.6 for appropriate welding procedures taking the provisions below into consideration.

The assembly for deposited metal test shall be prepared as shown in Figs. 4.2.4.1 and 4.2.6.2.1 depending on the welding procedure.

Two butt-weld test assemblies of minimum and maximum thickness shall be prepared as shown in Fig. 4.2.9.

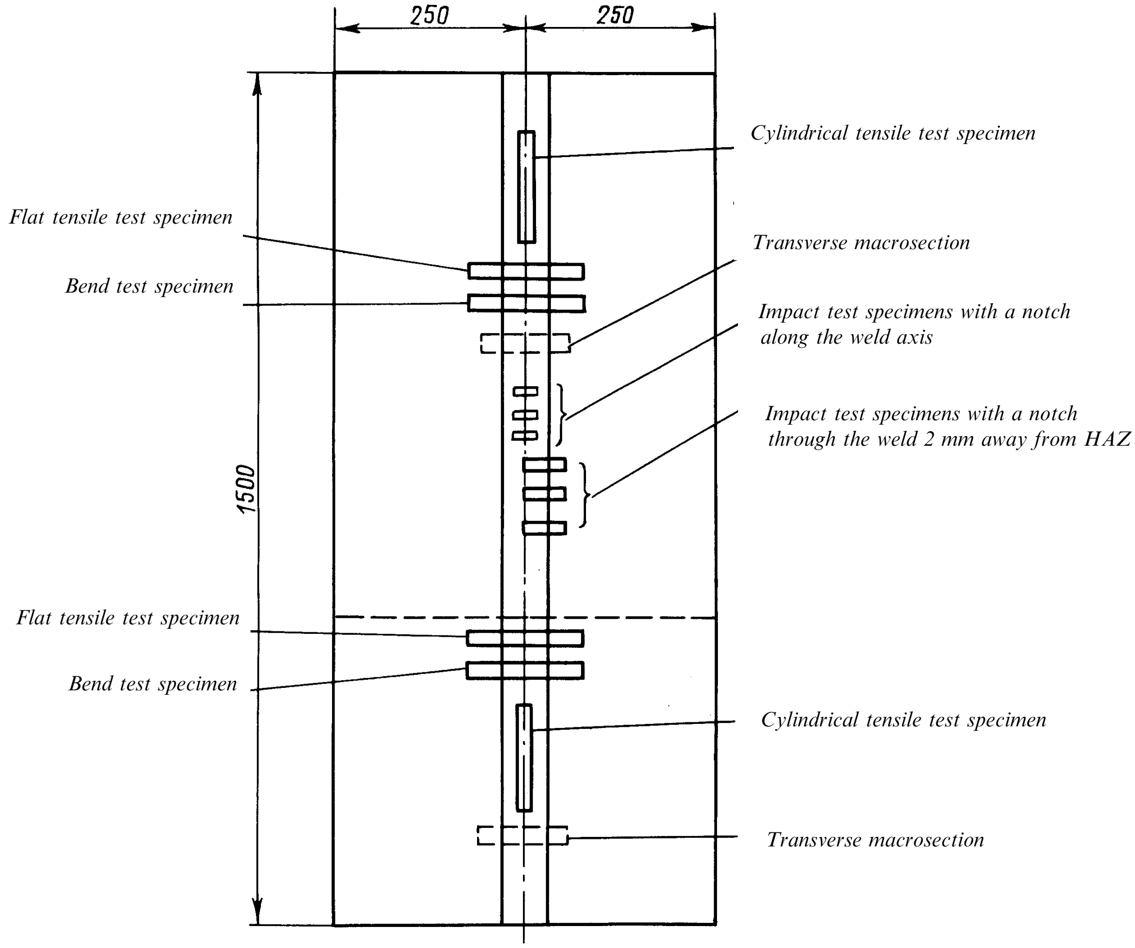


Fig. 4.2.8.2-1

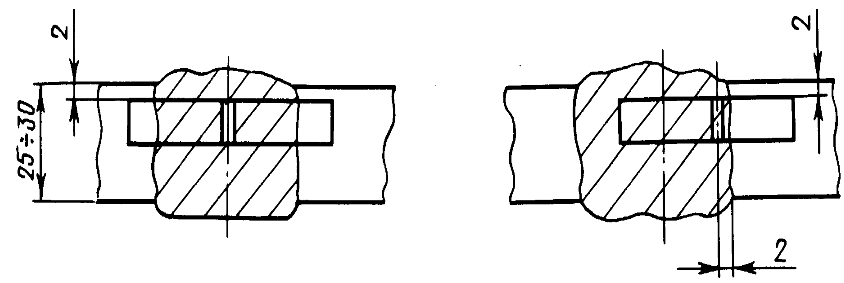


Fig. 4.2.8.2-2

Edge preparation, gap dimensions and welding methods shall be those recommended by welding consumables manufacturer.

The mechanical properties of deposited metal shall comply with Table 4.2.1.2-1 and those of welded joint, with Table 4.2.1.2-2 for appropriate grades of welding consumables.

In case welding consumables were approved by the Register earlier for welding in accordance with standard procedure (without backing), only the assembly for testing the weld as shown in Fig. 4.2.9 shall be prepared.

Welding consumable re-approval tests shall be carried out according to the programme, which includes welding of one butt weld test assembly 20 to 25 mm in thickness and preparation of the following specimens:

one longitudinal cylindrical tensile specimen along the axis of the weld;

one transverse tensile specimen;

two side-bend specimens;

three Charpy-V specimens from root part of the weld (refer to Fig. 4.2.9).

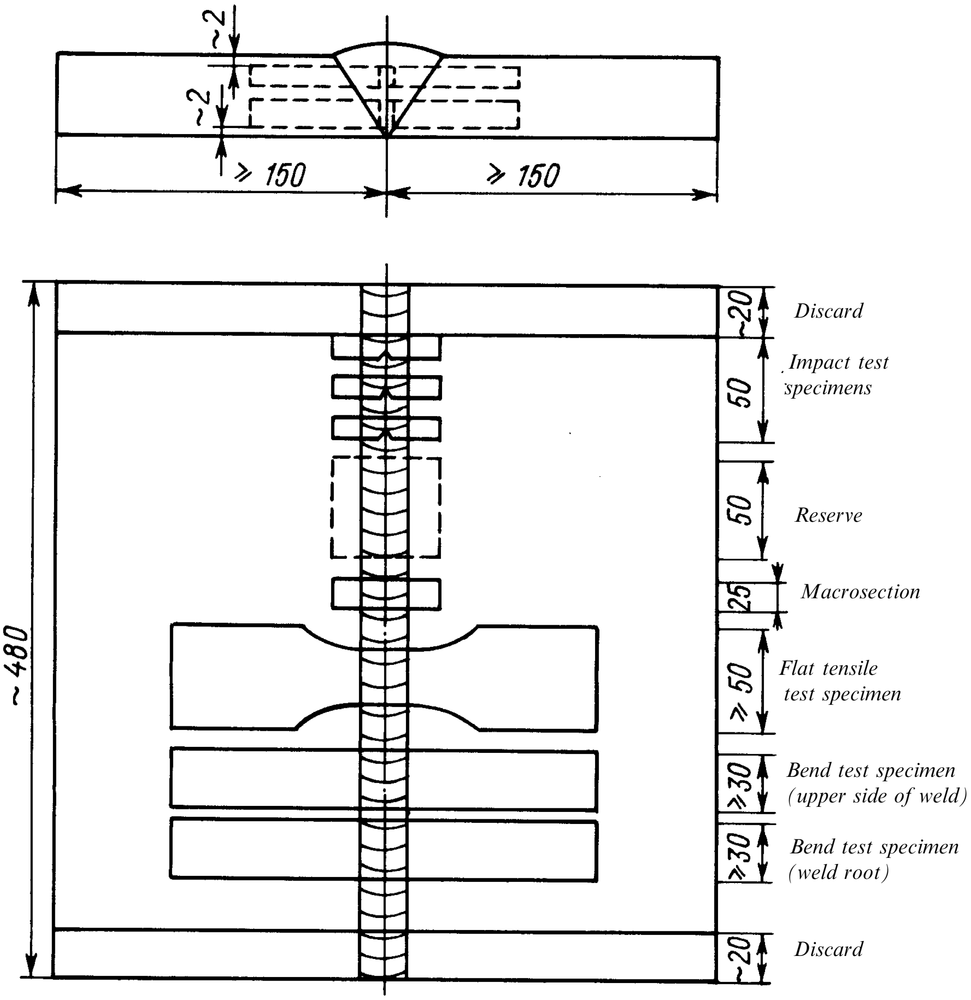


Fig. 4.2.9

Upgrading of welding consumables associated with a change in the requirements for test temperature of impact test specimens requires performance of the following tests, in addition to re-approval tests:

preparation of deposited metal test assembly (only for multi-run welding) and testing of three impact test specimens;

preparation of butt weld test assembly 20 to 25 mm in thickness and testing of three impact test specimens from the upper part of the weld.

Where the maximum approved thickness of the base metal exceeds 30 mm for multi-run welding, a butt weld test assembly corresponding to the maximum thickness with layer-by-layer cutting (in three layers) of nine impact specimens shall be additionally welded.

In upgrading welding consumables for single-pass welding the full tests (with regard to annual re-approval tests) shall comply with the above requirements for approval of the welding consumables concerned.

4.3 WELDING CONSUMABLES FOR BOILER STEEL

4.3.1 For welding consumables intended for boiler steel, the requirements of 4.2 for hull structural steel apply, except for the requirement of cold cracking resistance as well as the provisions of the present Chapter.

4.3.2 For the purpose of testing the welding consumables for boiler steel an additional set of specimens for impact testing after ageing in accordance with 2.2.3.4, Part XIII "Materials" shall be chosen from the deposited metal test assemblies and butt welds.

4.3.3 When testing, welding consumables, intended for steels to be used at 350 °C and above, the Register may require a tensile test at the maximum working temperature during which proof stress at 0,2 per cent elongation at elevated temperature ($R_{p0,2/t}$) shall be determined.

Testing and considering of the test results shall be carried out on the basis of standards approved by the Register.

4.4 WELDING CONSUMABLES FOR WELDING OF STEEL INTENDED FOR MACHINERY, ARRANGEMENTS, OUTFIT, EQUIPMENT AND PIPING

4.4.1 Welding consumables approved for hull structural and boiler steel may be approved without additional testing for welding steel intended for machinery, arrangements, outfit, equipment and piping if such structures are manufactured from steel, which is equivalent to hull structural steel or similar to it by its properties.

In all other cases, the welding consumables for these structures shall be tested on steels, for the welding of which they are intended. The tests shall be carried out according to the program agreed with the Register.

4.5 WELDING CONSUMABLES FOR HULL STRUCTURAL STEELS INTENDED FOR LOW TEMPERATURE SERVICE

4.5.1 Welding consumables for hull structural steels intended for low temperature service, which conform to 3.5, Part XIII "Materials", shall be tested in accordance with 4.2 and the additional requirements stated below.

4.5.2 Mechanical properties and impact energy of deposited metal and welded joint for welding consumables of Grades 5Y and 5Y40 shall meet the requirements of Tables 4.5.2-1 and 4.5.2-2, respectively.

The impact test temperature for lower design temperatures is subject to agreement with the Register.

4.5.3 When testing welding consumables intended for important structures of hull structural steel to operate at $-30\,^{\circ}$C and below the Register may require the resistance of welded joints to brittle fracture to be confirmed either by impact testing of specimens with increased cross-section or by dropweight testing as well as by using fracture mechanics methods or other methods agreed with the Register.

Satisfactory results shall be obtained at a testing temperature not less than $5\,^{\circ}$C lower than the lowest design temperature.

Table 4.5.2-1

Grade of welding consumables	Application of welding consumables	Tensile properties of deposited metal				Impact energy KV obtained at impact testing of deposited metal			
						Electrodes and combinations for semi-automatic welding		Combinations for automatic welding	
		Tensile strength R_m, MPa	Yield stress R_e, MPa	Elongation A_5, %	Reduction of area Z, %	Test temperature, °C	Average value for three test specimens, J, min	Test temperature, °C	Average value for three test specimens, J, min
			minimum						
5Y	For steel of Grades F32, F36	490 — 660	375	22	65	−60	47	−60	36
5Y40	For steel of Grade F40	510 — 690	400	22	65	−60	47	−60	39

Table 4.5.2-2

Grade of welding consumables	Application of welding consumables	Properties of welded joint (transverse specimen)		Impact energy KV obtained at impact testing of welded joint				
				Electrodes and combinations for semi-automatic welding			Combinations for automatic welding	
		Tensile strength R_m, MPa	Angle of bending till the first crack appears, deg.	Test temperature, °C	Average value for three test specimens, J, min		Test temperature, °C	Average value for three test specimens, J, min
					downhand, horizontal and overhead positions	vertical position		
		minimum						
5Y	For steel of Grades F32, F36	490	120	−60	47	36	−60	36
5Y40	For steel of Grade F40	510	120	−60	47	41	−60	39

4.5.4 The lowest permissible design temperature shall be stated in the type approval certificate for the welding consumables and in the accompanying documentation of the manufacturer.

4.5.5 The programme for welding consumable re-approval tests of Grades 5Y and 5Y40 shall comply with the requirements of 4.2 for appropriate welding techniques and types of welding consumables with regard to the requirements of 4.5.2 for the deposited metal and weld properties.

4.6 WELDING CONSUMABLES FOR HIGH STRENGTH STEELS

4.6.1 Testing of deposited metal.

Preparation of test assemblies, their number and size, and testing of deposited metal shall comply with 4.2.3.1, 4.2.4.1, 4.2.6.2.1 and 4.2.7.2.1 depending on the welding consumables used.

The results of specimen testing shall comply with the requirements of Table 4.6.1.

Table 4.6.1

Requirements for mechnaical properties of deposited metal

Grade of welding consuma-bles	Tensile properties of deposited metal			Impact energy *KV* obtained at impact testing of deposited metal	
	Yield stress R_e or $R_{p0,2}$, MPa	Tensile strength R_m, MPa[1]	Elonga-tion A_5, %	Test tempera-ture, °C	Average value for three test specimens, J, min
	minimum				
3Y42	420	530	20	-20	47
4Y42	420	530	20	-40	47
5Y42	420	530	20	-60	47
3Y46	460	570	20	-20	47
4Y46	460	570	20	-40	47
5Y46	460	570	20	-60	47
3Y50	500	610	18	-20	50
4Y50	500	610	18	-40	50
5Y50	500	610	18	-60	50
3Y55	550	670	18	-20	55
4Y55	550	670	18	-40	55
5Y55	550	670	18	-60	55
3Y62	620	720	18	-20	62
4Y62	620	720	18	-40	62
5Y62	620	720	18	-60	62
3Y69	690	770	17	-20	69
4Y69	690	770	17	-40	69
5Y69	690	770	17	-60	69

[1] On agreement with the Register it is permitted to reduce by 10 per cent the tensile strength minimum value for a deposited metal if the relevant requirement for a welded joint in Table 4.6.2 is followed. This provision is valid only for welding of metal under 50 mm thick.

4.6.2 Weld tests.

Preparation of test assemblies, their size and number, and testing of welds shall comply with 4.2.3.1, 4.2.4.2, 4.2.6.2.2 and 4.2.7.2.2 depending on the welding consumables used.

Test assemblies shall be made of high strength steels with a minimum tensile strength complying with the specified grade.

The results of specimen tests shall comply with the requirements of Table 4.6.2.

Table 4.6.2

Requirements for mechnaical properties of welded joints

Grade of welding consu-mables	Tensile strength R_m, MPa	Bend test		Impact energy *KV* obtained at impact testing of welded joint	
		Angle of bending till the first crack appears, deg.	Elonga-tion, % [1]	Test tempera-ture, °C	Average value for three test speci-mens, J, min
		minimum			
3Y42	530 — 680	120	20	-20	47
4Y42	530 — 680	120	20	-40	47
5Y42	530 — 680	120	20	-60	47
3Y46	570 — 720	120	20	-20	47
4Y46	570 — 720	120	20	-40	47
5Y46	570 — 720	120	20	-60	47
3Y50	610 — 770	120	18	-20	50
4Y50	610 — 770	120	18	-40	50
5Y50	610 — 770	120	18	-60	50
3Y55	670 — 830	120	18	-20	55
4Y55	670 — 830	120	18	-40	55
5Y55	670 — 830	120	18	-60	55
3Y62	720 — 890	120	18	-20	62
4Y62	720 — 890	120	18	-40	62
5Y62	720 — 890	120	18	-60	62
3Y69	770 — 940	120	17	-20	69
4Y69	770 — 940	120	17	-40	69
5Y69	770 — 940	120	17	-60	69

[1] The elongation requirement is compulsory if the angle of bending, till the first crack appears, has not been attained. Elongation is measured at the gauge length L_0, which is determined by the formula

$$L_0 = L_s + t,$$

L_s = width of weld on the surface of a bend test specimen;
t = specimen thickness.

4.6.3 Welding consumables shall be subjected to tests for determination of diffusible hydrogen content by the vacuum method according to 4.2.2.3.

Besides, the welding consumable classification index according to Table 4.2.1.4 shall correspond with HH for Grades (3Y/5Y) 42...50 and with HHH for Grades (3Y/5Y) 55...69.

4.6.4 The programme for welding consumable re-approval tests for higher strength steels shall comply with the requirements of 4.2 for appropriate welding techniques and types of welding consumables with regard to the requirements of 4.6.1 to 4.6.3.

Upgrading of welding consumables shall be made in accordance with the programme agreed upon with the Register and generally requires performance of the complete test-series necessary for approval of the welding consumables concerned.

4.7 WELDING CONSUMABLES FOR ALUMINIUM ALLOYS

4.7.1 General.

4.7.1.1 These requirements apply to welding consumables intended for welding ship hull structures and superstructures of aluminium alloys meeting the requirements of 5.1, Part XIII "Materials".

The Chapter contains conditions of approval and inspection of welding consumables. In preparation of test assemblies and performance of special tests the appropriate provisions of 4.2 may be used.

4.7.1.2 Welding consumables are graded in accordance with composition and strength level of the base material used for approval tests according to Tables 4.7.1.2-1 and 4.7.1.2-2 for international and national alloys, respectively.

4.7.1.3 Welding consumables for welding aluminium alloys are approved by the Register as follows:

W = wire electrode and wire-gas combinations for automatic and semi-automatic metal-arc electrode inert gas welding (MIG, 131 according to ISO 4063);

wire electrode and wire-gas combinations for automatic tungsten inert gas arc welding (TIG, 141 according to ISO 4063);

wire electrode and wire-gas combinations for automatic for plasma arc inert gas welding (15 according to ISO 4063);

R = rod gas combinations for tungsten inert gas arc welding (TIG, 141 according to ISO 4063);

rod gas combinations for plasma arc inert gas welding (15 according to ISO 4063).

Table 4.7.1.2-1

Consumable quality grade	Base metal for tests and direct approval of international alloys		Scope of application of approval for other alloys	
	Numerical designation	Chemical symbol	International	National
RA/WA	5754	AlMg3	—	1530
RB/WB	5086	AlMg4	5754	1530
RC/WC	5083	AlMg4,5Mn 0,7	5754, 5086	1530, 1550
	5383	AlMg4,5 Mn 0,9	5754, 5086, 5083, 5456	1530, 1550
	5456	AlMg 5	5754, 5086, 5083, 5383	1530, 1550
	5059	—	5754, 5086, 5083, 5383, 5456	1530, 1550 1561
RD/WD	6005A	AlSiMg (A)	6061, 6082	(AlSi1 MgMn)
	6061	AlMg1SiCu	6005A, 6082	
	6082	AlSi1MgMn	6005A, 6061	

Note. Approval of welding consumables for AlMg alloys also cover their combinations (heterogeneous combinations) with AlSi alloys.

Table 4.7.1.2-2

Consumable quality grade	Base metal for tests and direct approval of international alloys		Scope of application of approval for other alloys	
	Numerical designation	Chemical symbol	International	National
R1/W1	1530	AlMg3,5 Si0,6	5754	—
R2/W2	1550	AlMg5,0 Mn0,6	5754, 5086, 5083	1530
R3/W3	1561	AlMg6,0 Mn1	5754, 5086, 5083, 5383, 5456	1530, 1550
R4/W4	1575	AlMg6,0 Mn0,5Sc	5754, 5086, 5083, 5383, 5456, 5059	1530, 1550, 1561
R5/W5	—	AlSi1MgMn	6005A, 6061, 6082	—

Note. Approval of welding consumables for AlMg alloys also cover their combinations (heterogeneous combinations) with AlSi alloys.

4.7.1.4 Shielding gases and their mixtures to be used for welding aluminium alloys in accordance with the requirements of Table 4.7.1.4 are divided into groups of standard composition, for which welding consumables are approved. Shielding gases that do not fall into classification given in Table 4.7.1.4 refer to "special" gases designated with group sign "S" and their composition may be specified according to EN 439:1994.

Table 4.7.1.4

Group of gases	Gas composition (Vol. %)[1]	
	Argon	Helium
I-1	100	—
I-2	—	100
I-3	Rest	> 0 to 33
I-4	Rest	> 33 to 66
I-5	Rest	> 66 to 95
S	Special gases, the composition of which shall be specified in accordance with EN 439:1994	

[1]Gases of other chemical composition (mixed gases) may be considered as "special gases" and approved by the Register on the basis of the special test results.

4.7.1.5 General requirements for approval procedure of welding consumables and their manufacturer shall meet the requirements of 4.1.

4.7.2 Scope of tests and requirements for preparation of test assemblies.

4.7.2.1 When the Register approves welding consumables for aluminium alloys the following shall be determined:

chemical composition of the deposited metal;

mechanical properties of butt-weld metal.

On the Register request, the following may be additionally included in the testing program of welding consumables:

determination of mechanical properties of the weld metal by means of a tensile test of longitudinal cylindrical samples from butt-weld test pieces not more than 10 mm thick;

determination of corrosion, and corrosion and mechanical properties of welded joints;

assessment of susceptibility of the weld metal and welded joint to hot crack formation.

4.7.2.2 Test assemblies for determination of deposited weld metal properties for all types of welding consumables may be prepared of an aluminium alloy of any grade.

Butt-weld test assemblies shall be prepared of the alloy of that grade, for welding of which the welding consumable is intended. Where the welding consumable to be approved is intended for aluminium alloys of different grades, butt-weld test assemblies shall be prepared from a higher grade alloy.

Test assemblies shall be welded in the presence of the Surveyor to the Register or a person duly authorized by the Register.

The base metal for preparation of test assemblies depending on the welding consumable grade shall be chosen according to Tables 4.7.1.2-1 and 4.7.1.2-2.

4.7.2.3 For determination of the deposited weld chemical composition a test assembly shall be prepared according to Fig. 4.7.2.3. The dimensions of the test assembly shall provide steady welding process and sufficient quantity of pure deposited weld metal for performance of the chemical analysis. In any case, the length of the test assembly shall not be less than 150 mm for manual processes and shall not be less than 300 mm for mechanized welding methods.

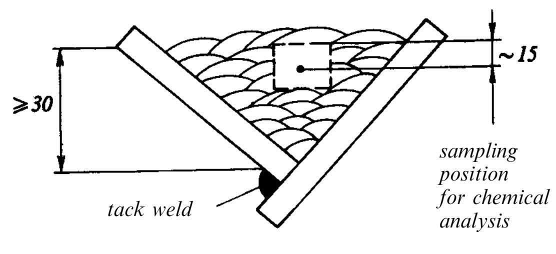


Fig. 4.7.2.3
Deposited weld metal test assembly

The chemical composition of the deposited weld metal shall be determined by the methods based on the standards or procedures approved by the Register. The number of the prepared test assemblies shall be determined with regard to a range of welding wire (rod) diameters to be approved by the Register. Recommendations given in Table 4.7.2.3 shall be observed.

Table 4.7.2.3

Welding process	Welding method	Welding wire (rod) diameter, mm	
		to be approved	to be used for welding deposited weld metal test assembly
Semi-automatic and automatic	131	from 0,8 to 2,5	1,2 or 2,0
Manual	141	from 2,0 to 5,0	3,0 or 4,0
Automatic	141	from 1,6 to 3,0	2,0 or 3,0
Manual and automatic	141	from 0,6 to 5,0	2,0 and 4,0
Manual	15	from 2,0 to 5,0	3,0 or 4,0
Automatic	15	from 1,6 to 3,0	2,0 or 3,0
Manual and automatic	15	from 1,6 to 4,0	2,0 and 4,0

4.7.2.4 For determination of properties of butt-weld joints test assemblies according to Figs. 4.7.2.4-1 and 4.7.2.4-2 shall be made. The length of the test assembly shall provide stable welding process under steady conditions and shall be enough for preparation of the following specimens:

two transverse flat tensile test specimens according to Fig. 4.2.3.2.2 with weld reinforcement removed;

two transverse flat tensile test specimens according to Fig. 4.2.3.2.2 with weld reinforcement as required by national standards for the particular type of welded joint;

two transverse root bend test specimens according to Fig. 2.2.5.1, Part XIII "Materials" and provisions of 4.2.3.2.3 of the present Part;

two transverse face bend test specimens (only for specimens with a thickness of 20 to 25 mm) according to Fig. 2.2.5.1, Part XIII "Materials" and provisions of 4.2.3.2.3 of the present Part;

macrographic section.

The butt-weld test assemblies shall be prepared with the following thickness and in the following number:

one test assembly of 10 to 12 mm for each welding position, for which welding consumables are certified. On agreement with the Register approval of welding in the downward and vertical-upward positions may be extended to the horizontal-vertical position without preparation of the appropriate test assembly;

one test assembly with a thickness of 20 to 25 mm to be welded in the downward position.

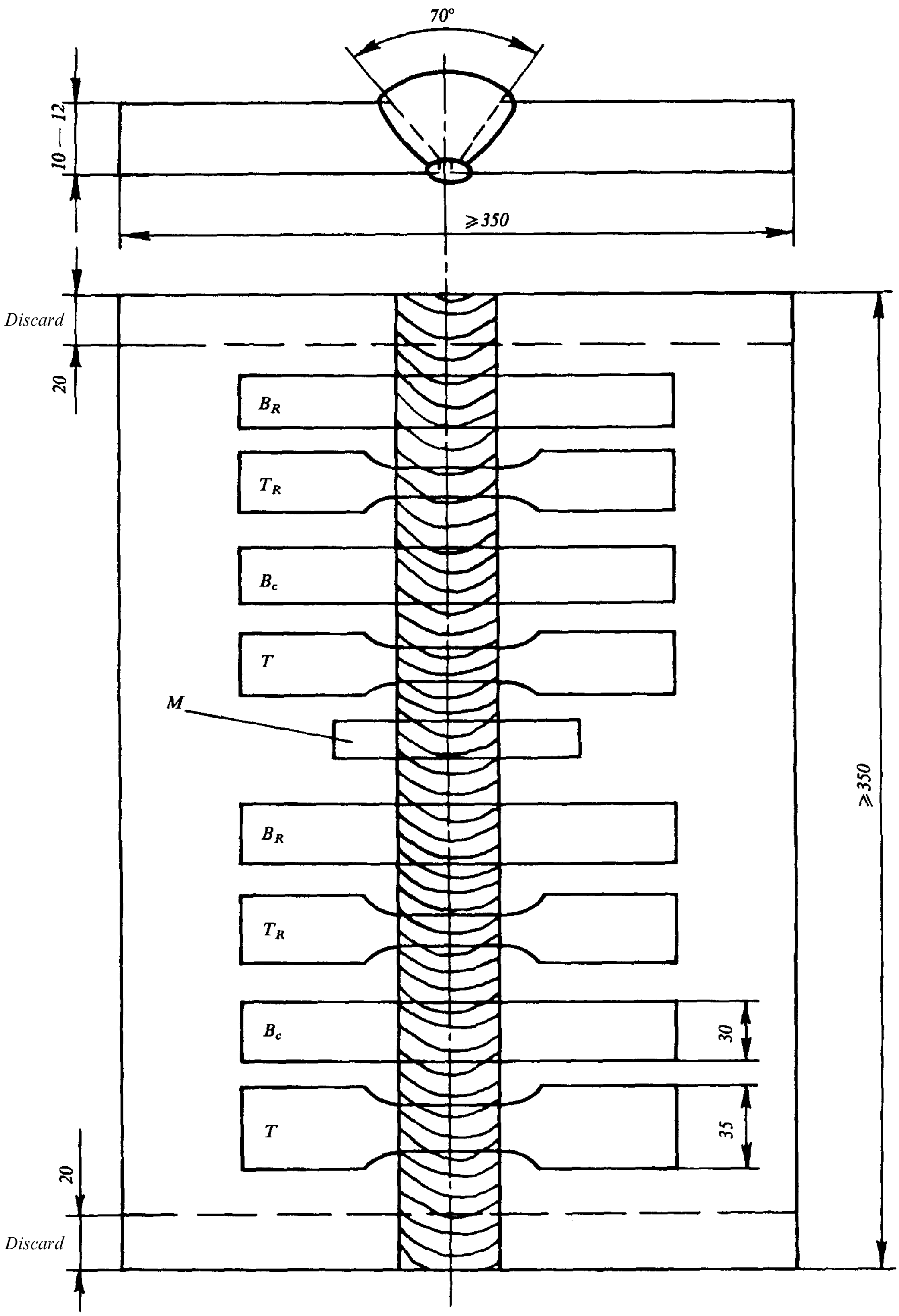


Fig. 4.7.2.4-1
Butt-weld test assembly with a thickness of 10 to 12 mm:
T = transverse flat tensile specimen with weld reinforcement removed;
T_R = transverse flat tensile specimen with weld reinforcement according to national standards;
B_c = transverse face bend specimen (without reinforcement);
B_R = transverse root bend specimen (without reinforcement);
M = macrographic section

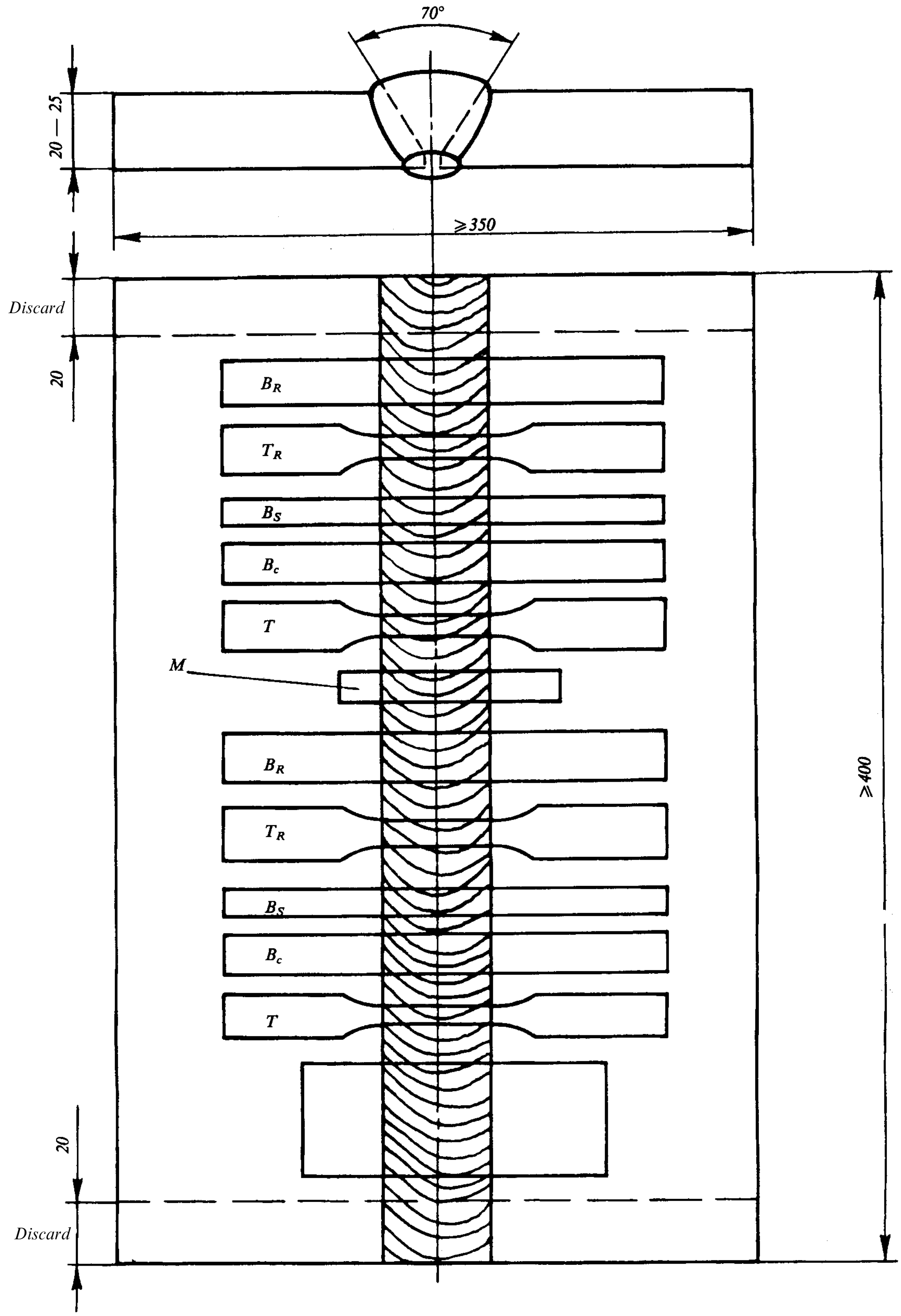


Fig. 4.7.2.4-2
Butt-weld test assembly with a thickness of 20 to 25 mm:
T = transverse flat tensile specimen with weld reinforcement removed;
T_R = transverse flat tensile specimen with weld reinforcement according to national standards;
B_c = transverse face bend specimen (without reinforcement); B_R = transverse root bend specimen (without reinforcement);
B_S = transverse side face bend specimen; M = transverse macrographic section

For welding test assemblies wire (rods) of the maximum diameter approved according to Table 4.7.2.3 shall be used or, on agreement with the Register, by one type and size less (e.g., 3,0 mm instead of 4,0).

Welding conditions of test assemblies shall be in line with recommendations contained in the technical documentation on welding of aluminium alloys approved by the Register.

The preparation of test assemblies and testing procedure shall comply with the requirements of 4.2.3.2. Specimens of welded test assemblies made of alloys AlSi1MgMn (6082) and their combinations with alloys AlMgMn shall be tested after natural ageing (conditioning after completion of welding) for a minimum period of 72 hours.

Note. In view of a substantial difference in mechanical properties of the base metal, weld metal and near-weld area of aluminium alloy weld joints in bend tests according to ordinary three-point scheme, early fracture formation is likely to occur, in particular, with a fairly high rate of deformation. Therefore in testing welded specimens it is recommended to use bend test procedure where a specimen is bent around the mandrel in accordance with Fig. 4.7.2.4-3.

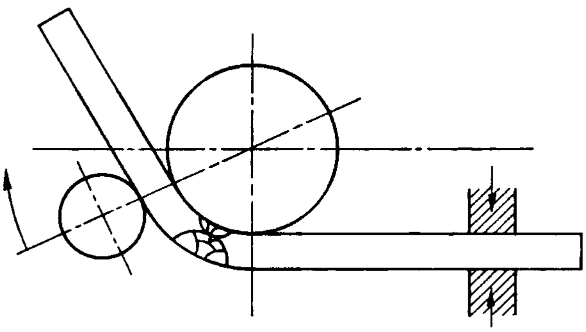


Fig. 4.7.2.4-3
Bend test scheme according to the procedure where a specimen is bent around a fixed mandrel

4.7.3 Assessment criteria of test results.

Mechanical properties of welded joints in testing tensile and bend specimens shall comply with the requirements of Table 4.7.3. The failure area of welded specimens shall be indicated in the Test Report. Inspection of macrographic section shall prove the absence of inadmissible welding defects.

Before cutting for specimens welded joint test assemblies shall be subjected to X-ray testing, the results of which shall prove the absence of inadmissible defects. According to the requirements of 3.4, Mark III Al shall be considered as a pass mark.

The content of main components and impurities in the deposited metal shall not exceed the values guaranteed by technical documentation on delivery of welding consumables.

The assessment criteria of test results of aluminium alloy welded specimens not indicated in Tables 4.7.1.2-1 and 4.7.1.2-2 are subject to special consideration by the Register but in any case they shall comply with the requirements of EN 288-4:1992 for aluminium alloy arc welding processes.

Table 4.7.3

Consumable quality grade	Base metal for tests	Tensile strength, R_m, MPa, min	Bend test	
			Mandrel diameter	Bending angle[2], deg., min
RA/WA	5754	190	3t	
RB/WB	5086	240	5t	
RC/WC	5083	275	6t	
	5383 or 5456	290	6t	180
	5059	330	6t	
RD/WD	6061, 6005A or 6082	170	6t	
National alloys				
R1/W1	1530	185[1]	3t	
R2/W2	1550	275[1]	6t	
R3/W3	1561	305	6t	180
R4/W4	1575	360	5t	
R5/W5	(AlSi1MgMn)	170	6t	

[1] For welded joints with a thickness up to and including 12,5 mm.
[2] At assessment of the test results the following considerations shall be taken into account:
on the specimen surface there shall be no single crack more than 3 mm in length extending in any direction;
cracks on the specimen edges may be neglected,
provided their appearance was not caused by lack of penetration.
Note. t = specimen thickness.

4.7.4 Scope of welding consumables approval based on test results.

The scope of approval of welding consumables according to base metal grades shall meet the requirements of Tables 4.7.1.2-1 and 4.7.1.2-2; as to welding methods and types of consumables (wire or rod), it is determined by the requirements given in Table 4.7.4.

Table 4.7.4

Welding of test assemblies		Scope of approval based on test results				
Welding method	Welding consumables	131	141		15	
		W	W	R	W	R
131	*W*	+	—	—	—	—
141	W(∅2–3mm)	—	+	×	×	×
15	R(∅2–5mm)	—	×	+	×	×
	W	—	×	×	+	×
	R	—	×	×	×	+

Symbols:
W = wire, R = rods.
"+" = approval based directly on test results.
"×" = approval according to scope of approval for other welding methods and welding consumables.
"—" = absence of the Register approval.

The scope of welding consumables approval based on a welding electrode diameter in case of fulfilment of the requirements of 4.7.2.3 and 4.7.2.4 covers the whole range of types and sizes specified by the Manufacturer. In other cases, this is subject to special consideration by the Register in each particular case. As a rule the approval may cover at least one type and size up and down the nominal value, for which the tests were carried out (e.g., the range of approval from 2,0 to 4,0 mm corresponds to the test nominal diameter of 3,0 mm).

The approval of welding consumables is valid only to the group of shielding gas standard composition (refer to Table 4.7.1.4), for which tests were carried out. The extension of the range of approval to other groups with special composition is subject to special consideration by the Register in each particular case.

4.7.5 Annual retests.

The annual retests of welding consumables shall entail the preparation and testing of one deposited weld metal test assembly (refer to 4.7.2.2) and one downward butt-weld test assembly with a thickness 10 to 12 mm according to 4.7.2.3.

4.8 WELDING CONSUMABLES FOR WELDING OF CORROSION-RESISTANT (STAINLESS) STEEL AND FOR SURFACING

4.8.1 General.

4.8.1.1 The present requirements apply to welding consumables intended for welding of corrosion-resistant (stainless) steels meting the requirements of 3.16, Part XIII "Materials", also for metal deposition to ship machinery items.

The present Chapter contains provisions related to approval and testing of welding consumables. When preparing the test assemblies and conducting individual types of tests, one shall be guided by respective provisions of 4.2.

4.8.1.2 The welding consumables for welding of corrosion-resistant steels are divided into grades depending on the structure and composition of steels to be welded in accordance with directions of Table 4.8.1.2. It is assumed that the weld metal has the alloying system similar to that of the base metal and provides mechanical properties and corrosion resistance identical to those of the base metal.

In cases, when the welding consumables are employed for deposition or for welding dissimilar joins, the classification presented in Table 4.8.1.2 is retained, but serving as the basis for it is the chemical composition and structure of the deposit or weld metal (and not of assembled or deposited parts).

4.8.1.3 Designation of the grade of welding consumables intended for welding of corrosion-resistant steels and for deposition shall include, additionally, identification (in brackets) of typical (brand) chemical composition of deposited metal, as specified in 3.16.1.1, Part XIII "Materials" for steels.

Example: A-6 (x5CrNiMo 19 11 3), where:

A-6 is a grade of welding consumable according to classification given in Table 4.8.1.2;

x5 is carbon fraction of total mass, in per cent;

Cr, Ni, Mo are symbols of respective alloying elements (chrome, nickel, molybdenum);

19, 11, 3 are fractions of total mass of the above alloying elements (Cr, Ni and Mo, respectively).

4.8.1.4 The requirements of the present Chapter apply to the following welding consumables and welding methods:

coated electrodes for manual arc welding;

combinations "wire-flux" for automatic and semi-automatic welding;

combinations "strip-flux" for automatic deposition;

combinations "wire-gas" for semi-automatic and automatic active and inert-gas metal-arc active or inert-gas welding;

combinations "wire-gas" for automatic tungsten inert-gas arc welding;

combinations "rod-gas" for manual tungsten inert-gas welding;

combinations "wire-gas" for automatic inert-gas plasma-arc welding;

flux-cored wire for automatic and semi-automatic metal arc welding with or without gas shield.

4.8.1.5 The requirements for welding consumables' approval procedure and also for survey of manufacturers and procedure of issuing the Certificates of Approval of Welding Consumables shall comply with the directions of 4.1.

4.8.2 Scope and types of tests for welding consumables.

4.8.2.1 Welding consumables for welding of corrosion-resistance steels.

As a rule, the welding consumables intended for welded joints on corrosion-resistant steels shall be subjected to the following tests:

for determination of deposited metal properties;

for determination of butt-welded joint properties;

testing of weld metal for resistance to intercrystalline corrosion (ICC);

testing for resistance to hot cracking.

For respective grades of welding consumables, in accordance with a separate requirement of the Register or as required in accordance with the scope of approval requested by the manufacturer, additional corrosion tests are conducted. For example: (1) determination of resistance to pitting corrosion initiated by chlorides (sea water); (2) testing on stress-corrosion cracking in environments containing hydrogen sulphide at room and higher temperatures, etc.

Actual scope of tests for different grades of welding consumables intended for welding of corro-

Table 4.8.1.2

Grade of welding consumable	Welded steel: Designation	Welded steel: Brand AISI/UNS	Welded steel: Brand National	Scope of application (grade of steel): AISI/UNS	Scope of application (grade of steel): National
M-1	x20 Cr13 x30 Cr13	410 420	20X13 30X13	410 420	20X13 30X13
	x7 CrNiNb 16 4	—	07X16H4Б	—	07X16H4Б
MF-2	x15 CrNi 17 2	431	14X17H2	431	14X17H2
	x10 CrNi 13 1 x8CrNi 13 4	414, 410S	08X14HДЛ 05X12H2T 06X13H4ДМ	414, 410S	08X14HДЛ 05X12H2T 06X13H4ДМ
	x10 CrNi 15 4	429	08X15H4ДМЛ	429	08X15H4ДМЛ
F-3	x8 CrTi 17	430T	08X17T	430T	08X17T
AM-4	x8 CrNiTi 17 6	—	08X17H6T	—	08X17H6T
A-5	x2 CrNi 19 11 x10 CrNiTi 18 10 x10 CrNiNb 18 10	304L, 304LN 321 347	— 08X18H10T 12X18H10T 08X18H10Б	304, 304L, 304LN, 321[1], 347[1], 308, 308L	08X18H10T 12X18H10T 08X18H10Б
A-6	x2 CrNiMo 17 13 2	316L, 316LN	03X17H14M3	304, 304L, 304LN, 316, 316L, 316LN[1], 316Ti, 316Cb, 317, 317L, 317LN[1], 321, 347	08X19H10T 12X18H10T 08X18H10Б 03X17H14M3 10X17H13M3T 08X17H13M2T 03X15H16M3Б
	x2 CrNiMo 18 13 3	317L, 317LN	—		
	x10 CrNiMoTi 17 13 3	—	10X17H13M3T		
	x6 CrNiMoTi 17 12 2 x6 CrNiMoNb 18 16 3	316Ti —	08X17H13M2T 03X16H15M3Б		
A-7	x2 CrNiMoCu 20 18 6	S31254	—	S31254	—
	x2 CrNiMoCu 20 25 4 2	N08904	—	S31254 N08904	
AF-8	x2 CrNiMo 22 5 3	S31803	03X22H5AM3	S31803	03X22H5AM3
	x3 CrNiMo 25 6 3 x4 CrNiMo 25 5 3	S31260 S32550	— —	S31260 S32550	—
	x2 CrNiMo 25 7 4 x3 CrNiMo 25 7 3	S32750 S32760	— 03X25H7AM4	S32750 S32760	— 03X25H7AM4
	x10 CrNiTi 22 6 x10 CrNiMo 21 6 3	— —	08X22H6T 08X21H6M2T	— —	08X22H6T 08X21H6M2T
A-9sp (special)	x2 CrNi 24 12 x10 CrNi 24 12 x10 CrNiCb 24 12	309L 309S 309Cb	— — —	309L, 309S, 309 SCb, also for: welding of dissimilar welded joints; welding of intermediate runs in welding of clad steels; deposition of intermediate (backing) layer	
A-10sp (special)	Deposit metal: x8 CrNiMo 16 25 6 x1 CrNi 26 22	— —	— —	For welding of: dissimilar welded joints; welding of intermediate runs of clad steels; steels of Grades M1, MF2, F-3 and AM-4 (filler runs)	

[1] Scope of application is valid under condition of meeting the requirements for mechanical properties according to Tables 4.8.4.1-1 and 4.8.4.1-2.

sion-resistant steels shall be defined in accordance with the requirements of Table 4.8.2.1.

4.8.2.2 Welding consumables for deposition of corrosion-resistant cladding layers.

The welding consumables intended for deposition of corrosion-resistant cladding layers to ship machinery items, as a rule, shall be subjected to the following tests:

for determination of deposited metal properties;

for determination of technological strength of the cladding layer in static bending tests;

testing of cladding metal layer for resistance to intercrystalline corrosion;

testing for resistance to hot cracking.

Additional corrosion tests of the cladding layer are conducted in accordance with a separate requirement of the Register in compliance with the directions of 4.8.2.1.

Actual scope of testing for welding consumables of different grades intended for deposition jobs shall be determined in accordance with the requirements of Table 4.8.2.2.

Table 4.8.2.1

Scope and types of tests of welding consumables for corrosion-resistant steels

Types of test assembly and characteristics to be determined	Grades of welding consumables									
	M-1	MF-2	F-3	AM-4	A-5	A-6	A-7	AF-8	A-9sp	A-10sp
Sample of deposited metal:										
R_m	+	+	+	+	+	+	+	+	+	+
$R_{p0,2}$	+	+	+	+	+	+	+	+	+	+
$R_{p1,0}$	-	-	-	-	+	+	-	-	-	-
A_5	+	+	+	+	+	+	+	+	+	+
KV^{+20}	+	+	+	+	+	+	+	+	+	+
KV below zero	-	-	-	-	+	+	-	-	-	-
chemical composition of deposited metal	+	+	+	+	+	+	+	+	+	+
Test assembly of butt weld:										
$R_m^{cond.}$ with recording of specimen failure point location	+	+	+	+	+	+	+	+	+	+
angle of V-bend in static bending test	+	+	+	+	+	+	+	+	+	+
weld metal resistance to ICC (intercrystalline corrosion)	+ [3]	-	+	+	+	+	+	+	+ [3]	+ [3]
weld metal resistance to pitting corrosion	-	-	-	-	-	-	+	+	-	-
weld metal resistance to stress corrosion in presence of hydrogen sulphide	-	-	-	-	-	-	+	+	-	-
α-phase content in weld metal	-	-	-	-	+	+	-	+	+	-
Technological test assembly for determination of tendency to hot cracking[1]	+	+	+	+	+	+	+	+	+	+
Multilayer deposition[2]:	-	-	-	-	+	+	-	+	+	-
α-phase content										
chemical check analysis	+	+	+	+	+	+	+	+	+	+
resistance of deposited metal to ICC	+ [3]	-	+	+	+	+	+	+	+ [3]	+ [3]

[1] By agreement with the Register the tee-joint test assembly may be replaced by layer-by-layer control of other types of assemblies.
[2] The multi-layer deposition is performed in accordance with a separate Register requirement, for example, when it is necessary to carry out a check analysis of α-phase content using the volumetric magnetic method.
[3] Tests for resistance to ICC are conducted only for welding consumables, the composition which, as guaranteed by the manufacturer, ensures the required properties, for example, M-1 (X7CrNiNb 164), A-9sp (X2CrNiNb 24 12), A-10sp (X1CrNi 26 22).

Table 4.8.2.2

Scope and types of tests of welding consumables for deposition to ship machinery items

Type of test assembly and characteristics to be determined	Grades of welding consumables					
	A-5	A-6	A-7	AF-8	A-9sp	A-10sp
Deposited metal test assembly[1]:						
R_m	+	+	+	+	+	+
$R_{p0,2}$	+	+	+	+	+	+
$R_{p1,0}$	+	+	-	-	-	-
A_5	+	+	+	+	+	+
$KV^{+20°}$	+	+	+	+	+	+
Chemical composition of deposited metal	+	+	+	+	+	+
Simulation test assembly of cladding deposit:						
static bending test	+	+	+	+	+ [2]	+ [2]
α-phase content	+	+	-	+	+	-
chemical check analysis	+	+	+	+	-	-
resistance of deposited metal to ICC	+	+	+	+	+ [3]	+ [3]
resistance of cladding metal to pitting corrosion	-	-	+	+	-	-
resistance of deposited metal to stress corrosion in presence of hydrogen sulphide	-	-	+	+	-	-
layer-by-layer checking for appearance of hot cracks	+	+	+	+	+	+

[1] For combinations "strip-flux" the specimens intended for determination of the above characteristics shall be taken from multi-layer deposited metal samples.
[2] Tests shall be carried out using combinations with other consumables forming the clad layer.
[3] The test for resistance to ICC is mandatory, when the scope of approval requested by the manufacturer includes both the transition and main layers of the deposited metal consisting of corrosion-resistant material of type A-9sp (X2CrNiNb 24 12), A-10sp (X1CrNi 26 22).

4.8.3 Requirements to preparation of the samples.

4.8.3.1 General.

The types of test assemblies and requirements to their manufacture, in accordance with directions of 4.2, are also valid for welding consumables intended for welding of corrosion-resistant steels and deposition operations.

In addition to those the following specific features of application of high-alloy welding consumables shall be taken into account:

possibility of lower resistance to inter-crystalline corrosion in the heat-affected zone of the base metal, especially in welding with high heat input;

increased tendency of high-alloy weld metal to hot cracking in comparison with low-alloy welding consumables;

higher degree of weld metal contraction in comparison with low-alloy welding consumables and, as a result, considerable angular and linear strains in the process of welding;

higher yield of melted metal requiring limitation of the melted weld pool volume and use of smaller diameter welding wire in comparison with low-alloy materials in identical conditions of welding;

higher specific resistance and lower values of thermal conductivity of high-alloy welding consumables, which requires limitation of the current unit load.

4.8.3.2 Testing of deposited metal.

To test the deposited metal, the following test assemblies shall be prepared and welded in down-hand position:

one test assembly, as shown in Fig. 4.2.4.1, intended for manual and semi-automatic welding;

one test assembly, as shown in Fig. 4.2.6.2.1, intended for automatic welding.

As the base metal for preparation of the test assemblies a steel shall be used, which corresponds to the grade of welding consumable indicated in Table 4.8.1.2. As an alternative for preparation of the test assemblies, hull structural steel of normal or higher strength of any grade may be used, with preliminary facing of weld edges with welding consumables to be certified or of similar grade. As shown in Fig. 4.8.3.2, three layers shall be deposited: the first one with consumables for padding of transition layers of Grade A-9sp or A-10sp, and then two cladding layers, using the welding method and consumables to be certified.

In this case, subject to permission of the Register, the deposition by submerged arc (combination "wire-flux") may be replaced with deposition of the cladding layer using combination "wire-gas" or coated electrodes of similar grade and of similar chemical composition.

After deposition of metal layers to the edges of the weld it is recommended to dress the buttered edges with abrasive tools or to perform machining of the edges and the backing strip to restore the geometrical parameters of the prepared edges shape.

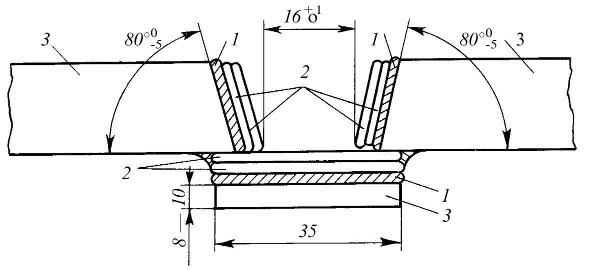


Fig. 4.8.3.2 Diagram of edge preparation by deposition for testing of deposited metal

1 — transition layer/backing (welding consumables of Grades A-9sp and A-10sp);

2 — main cladding layer (welding consumables to be certified);

For welding of the assembly with deposited metal it is recommended, depending on the welding method and process employed to select the welding wire (or filler rods) with diameter corresponding to values indicated in Table 4.8.3.2. The welding conditions shall comply with directions of the welding consumables manufacturer and with the technical documentation for welding of structures approved by the Register.

Table 4.8.3.2

Welding procedure	Welding technique (standard ISO 4063)	Diameter of welding wire (rod), mm	
		for facing of edges	for filling of the groove
Manual	111	2,5 — 3,0	3,0 — 4,0
Automatic	12	2,0	2,5 — 3,2
Semi-automatic and automatic	131 135	1,0 — 1,2 1,0 — 1,2	1,4 — 1,6 1,4 — 1,6
Manual	141	2,0 — 2,4	2,5 — 3,2
Automatic	141	1,0 — 1,6	1,2 — 1,6
Automatic and semi-automatic	114 136 137	0,9 — 1,4 0,9 — 1,2 0,9 — 1,2	1,2 — 1,6 1,2 — 1,6 1,2 — 1,6
Manual	15	2,0 — 2,4	2,0 — 3,0
Automatic	15	1,0 — 1,2	1,2 — 1,6

Heat treatment after welding of deposited metal assemblies is not used normally. Exception is made for welding consumables employed for metal deposition on ship machinery articles. In this case the assemblies are subjected after welding to imitated single-time tempering of welded joint at 630 to 650 °C during 40 min with subsequent cooling in the air. The temperature inside the furnace before loading of the specimens shall not exceed 350 °C.

4.8.3.3 Butt weld tests.

To determine the weld properties, it is necessary to carry out welding of assemblies, the quantity and dimensions of which are indicated in 4.2 for respective welding consumables and welding processes. By agreement of the Register the quantity of test assemblies may be reduced within the following limits:

for welding consumables intended for downhand welding only one test assembly is sufficient;

for combinations "wire-gas" (welding processes 131, 135, 141 and 15 by ISO 4063) two assemblies are required. In this case the properties of butt welds shall be determined with respect to downhand and vertical (vertical-upward) welding positions.

For welding of joint assemblies it is recommended to use welding wire with diameters, as specified in Table 4.8.3.2:

for root passes follow the directions given for facing of edges of deposited metal test assemblies;

for filling of the grooves follow the respective directions for deposited metal test assemblies.

The butt-welded test assemblies shall be prepared using the steel of the same grade, which is specified for the welding consumables. When selecting the base metal for a butt-welded test assembly, one shall take into account the necessity to ensure the level of the weld properties specified in Table 4.8.4.1-2 for the grade of welding consumables to be certified.

For welding consumables of Grades A-9sp and A-10sp intended for dissimilar joints and deposition of intermediate layers, the butt-welded test assemblies may be prepared in two ways:

one side of the test assembly is produced from corrosion-resistant steel of Grade A-5 or A-6, the other side from higher or high strength steel with ultimate breaking strength at least equal to that of deposited metal;

both sides of the test assembly are produced from higher or high strength steel with the level of strength corresponding to the welding consumable to be certified.

4.8.3.4 Hot cracking test.

The welding consumables intended for corrosion-resistant steels shall be subjected to hot cracking test estimated on test results of tee-joint test assemblies. In case of manual or semi-automatic welding for each welding consumable to be approved, three test assemblies shall be welded, their dimensions as shown in Fig. 4.2.4.3, in case of automatic welding — one test assembly of $L \geqslant 500$ mm shown in Fig. 4.2.5.

The base metal for manufacture of test assemblies, as well as diameters of welding wire/rods, shall be selected as specified in 4.8.3.3.

For welding consumables intended exclusively for deposition operations, manufacture of tee-joint test assemblies may be omitted. In this case the resistance to hot cracking is estimated with the use of layer-by-layer control method for the deposited metal and also in the process of side-bend testing of specimens with cladding deposit.

4.8.3.5 Static bending test for fusion-clad layers.

4.8.3.5.1 Bend testing of fusion-clad layers is performed for estimation of clad layer plastic properties, bond surface, as well as heat affected zone.

This type of testing may be done in the following ways:

bending with tensioning of the clad layer (the load is applied normally to the bond surface) and with strain orientation normally to the direction of welding in the process of deposition;

bending with tensioning of the clad layer (the load is applied parallel to the bond surface) and with strain orientation along the direction of welding in the process of deposition;

side-bend testing of specimens (the load is applied parallel to the bond surface). In this case the bending load may either coincide with the direction of welding, or be perpendicular to it.

Testing of fusion-clad layer shall be performed by side-bend method with the load applied normally to the direction of welding. In static bending other types of tests employed, as required by the Register in cases of ambiguity of the main test results.

N o t e . The side-bend testing with load application parallel to the direction of welding is performed, as a rule, in approval of welding deposition technological processes, as this is the most objective method for estimation of internal defects (poor fusion, cracks, etc.) caused directly by technological factors.

4.8.3.5.2 To conduct static bending test of fusion-clad layers, an assembly-imitator of the cladding deposit shall be manufactured, as required by 4.8.3.5.2. The cladding layer shall be deposited on hull structural steel of any grade of higher or high strength ensuring proper testing with a mandrel of required diameter (refer to Fig. 4.8.4.2). The deposition shall be performed with observation of the requirements and recommendations given below.

The first layer (sublayer) shall be deposited using welding consumables of group A-9sp. The thickness of the first layer shall be 3 to 4 mm. The corrosion-resistant deposit shall be made with welding consumables to be approved in 2 or 3 layers, with overlapping of the beads. The plan of deposition beads application shall keep deformation of the main plate to a minimum. The total thickness of the cladding layer after machining shall not exceed 10 mm.

The arrangements for static bending specimens cutting from the imitation test assembly are shown in Fig. 4.8.3.5.2.

If the range of approval for welding consumables permits heat treatment of fusion-clad items, the imitation assembly, before cutting the specimens out of it, shall be subjected to single-time tempering at 630 to 650 °C during 40 min with subsequent cooling in the air. To avoid distortion of the plate, the temperature in the furnace at loading of the test

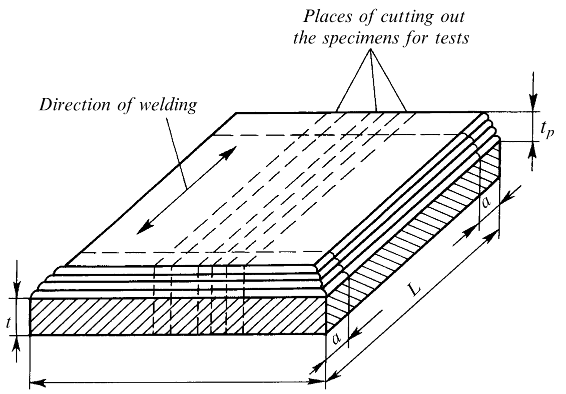


Fig. 4.8.3.5.2 Assembly imitating cladding deposit
t — thickness of base metal;
t_p — thickness of cladding layer after machining;
b — width of assembly; L — length of assembly; a — waste.

Note. Requirements to dimensions, in mm:
a) for manual and semi-automatic deposition:
$t = 14 — 16$, $6 \leqslant t_p \leqslant 10$, $b \geqslant 60$, $L \geqslant 200$, $a \approx 25$;
b) for automatic submerged-arc deposition with welding wire:
$t = 16 — 20$, $6 \leqslant t_p \leqslant 10$, $b \geqslant 100$, $L \geqslant 480$, $a \approx 50$;
c) for automatic submerged-arc deposition with strip electrode:
$t = 16 — 20$, $6 \leqslant t_p \leqslant 10$, $b \geqslant 120$, $L \geqslant 480$, $a \approx 50$

assembly into it shall not exceed 350 °C. Depending on the scope of approval requested by the manufacturer the following ways of heat treatment are possible:

after deposition of intermediate layer;

after deposition of intermediate layer and of all cladding layers;

two-stage heat treatment: after deposition of sublayer, then after deposition of all cladding corrosion-resistant layers.

4.8.3.6 Test assemblies for preparation of specimens tested for resistance to intercrystalline corrosion.

In testing of welding consumables resistance to ICC may be estimated using specimens of weld metal or deposited metal. In such circumstances the testing of consumables employed exclusively for deposition jobs (for example, for compositions "strip-flux") may be limited to deposited metal only. In all other cases, unless otherwise agreed upon with the Register, used as the main method of testing for resistance to ICC shall be the method, which involves testing of the weld metal in accordance with directions of 4.8.3.6.1.

4.8.3.6.1 Butt joint test assembly for testing of weld metal resistance to ICC.

Testing for resistance of weld metal to ICC shall be carried out by welding of test assemblies having dimensions as shown in Fig. 4.8.3.6.1.

In automatic and mechanized welding processes the beginning and the end of the weld shall be executed on extended backing strips with dimensions ensuring steady welding process and absence of inadmissible defects on the controlled length of the test assembly (but not less than 100 × 100 × 10 mm).

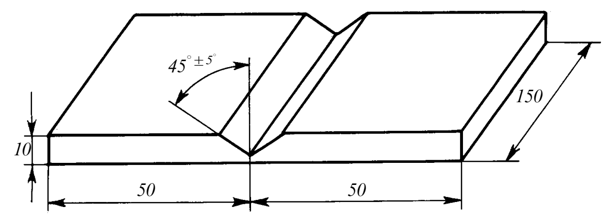


Fig. 4.8.3.6.1 Welded joint test assembly for cutting out specimens to be tested for resistance to ICC

The backing strip edge preparation shall have a depth of not less than 6 mm and groove angle similar to that of the test assembly (90°).

Used as the base metal shall be a corrosion-resistant steel complying in its grade and chemical composition with the filler material to be approved. The following limitations shall be observed in the process:

the corrosion-resistant steel shall be also resistant to ICC, even after provoking heating;

the base metal shall provide satisfactory results in bend-over tests when using a mandrel of the required diameter;

the mechanical properties of the base metal shall ensure uniform distribution of the residual plastic strain over the weld and zone adjacent to the weld when testing static bending specimens.

To fully meet the above requirements to the base metal, it is permitted to use plates of corrosion-resistant steels differing in grade from the filler material under condition that plate edges are buttered previously with tested filler materials (or materials similar in chemical composition).

The Register may require heat treatment after welding, if this appears necessary for the scope of approval requested by the manufacturer of the materials.

4.8.3.6.2 Test assembly for deposited metal testing for resistance to ICC.

The checking of deposited metal in the cladding layer for resistance to ICC shall be conducted on the checking test assemblies prepared with the use of welding consumables to be certified. General requirements for welding of the test assemblies are similar to those indicated in 4.8.3.2 and 4.8.3.5. The test assemblies are manufactured by downhand arc deposition of metal to a plate with thickness of at least 20 mm made of steel of any grade/brand. Dimensions of the checking test assemblies shall ensure stability of the deposition process, as well as a possibility to produce four specimens to be tested for resistance to ICC and a possibility of repeated testing of the twice this number of specimens.

The need for heat treatment of the test assemblies before testing for resistance to ICC depends on the scope of approval requested by the applicant (as required in 4.8.3.5.2). The conditions and quantity of heat treatments for test assemblies to be tested for resistance of the deposited metal to ICC shall be additionally approved by the Register. As a rule, if a heat treatment after deposition of the main layer is permitted by the manufacturer of welding consumables or by the documentation for their application, the checking test assembly or blanks of specimens (prior to mechanical finishing) shall be subjected to two-time tempering at 630 to 650 °C during 40 min with subsequent cooling in the air.

The arrangement for cutting of ICC specimens and dimensions of the deposit shall be in accordance with directions of Fig. 4.8.3.6.2.

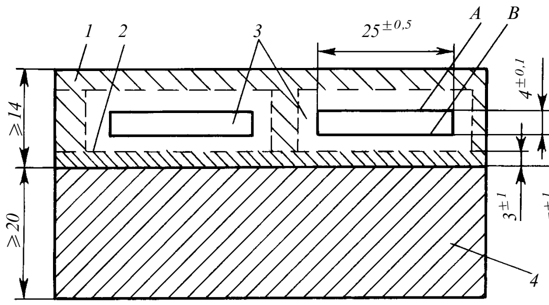


Fig. 4.8.3.6.2 Arrangements for cutting out the specimens when testing the deposited metal for resistance to ICC:
1 — deposited metal of the main layer; *2* — metal of deposited sublayer; *3* — blanks for preparation of specimens; *4* — base metal (plate); *A* and *B* — specimen surfaces

4.8.4 Methods of testing and evaluation of test results.

4.8.4.1 Determination of mechanical properties of deposited metal and welded joint.

Cut out from the deposited metal test assembly and tested shall be longitudinal cylindrical proportional specimens, shown in Fig. 2.2.2.3 (*a*), Part XIII "Materials" and having dimensions:

$d_m = 10$ mm, $L_m = 50$ mm, $L_c = 60$ mm and $r \geqslant 5$ mm.

The longitudinal axis of the specimen shall coincide with the centre of the weld and the middle point of the metal deposit thickness. One specimen is required (when testing specimens with working part diameter of 6 mm, three specimens from each sample shall be tested).

The impact energy for deposited metal is determined on V-notch specimens meeting the requirements of 2.2.4, Part XIII "Materials". The plan of specimens cutting out is shown in Fig. 4.2.3.2.2-1. Three specimens are taken from each test assembly.

A butt weld test assembly is employed for preparation and testing of:

2 transverse flat fracture specimens with dimensions as shown in Fig. 4.2.3.2.1;

2 transverse static bend specimens in accordance with Fig. 2.2.5.1, Part XIII "Materials" complying with the directions of 4.2.3.2.3 (specimen dimensions: $a_m = t$ — thickness of the sample metal, $b_m = 30$ mm);

3 Charpy impact test specimens. They shall be cut out as shown in Fig. 4.2.3.2-1, their type shall meet the requirements of 2.2.3, Part XIII "Materials".

For dissimilar welded joints, made with the use of welding consumables of Grade A-9sp or A-10sp, in static bending tests instead of transverse specimens longitudinal specimens shall be used, in compliance with Fig. 4.8.4.1. Length of the sample shall be sufficient for manufacture of such specimens.

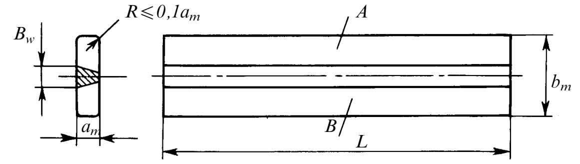


Fig. 4.8.4.1 Specimen with longitudinal weld for static bend testing of metal of dissimilar welded joint:
A — part of the test assembly made of corrosion-resistant steel;
B — part of the test assembly made of higher or high strength hull structural steel; $a_m = t$ — thickness of base metal; $b_m = 30$ mm but not less than $(B_w + 24)$ mm; $L \geqslant D_m + 9a_m \approx 12a_m$, where D_m is diameter of mandrel used in bending tests

General requirements for test procedures and for evaluation of test results are given in 4.2.3, and criteria for evaluation of test results are contained in Tables 4.8.4.1-1 and 4.8.4.1-2.

4.8.4.2 Static bend tests for specimens with cladding deposit.

Tested by static bend shall be three specimens with cladding deposit and with loading arrangements aimed at load application parallel to the bond surface (side bend) and perpendicular to the direction of welding in the process of deposition.

Dimensions of the specimens and parameters of testing shall comply with the data shown in Fig. 4.8.4.2.

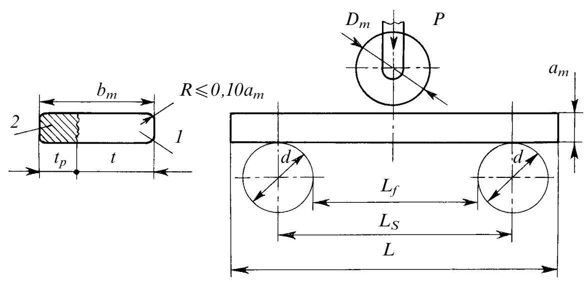


Fig. 4.8.4.2 Specimen with cladding deposit for side-bend testing
1 — base metal, *2* — cladding deposit;
$a_m = 10^{+0,1}$ mm is thickness of the specimen;
$b_m = t + t_p \leqslant 35$ mm is width of the specimen (where t is thickness of the base metal; $6 \leqslant t_p \leqslant 10$ is thickness of the cladding deposit);
$D_m = 3a_m = 30$ mm is diameter of bending mandrel;
$d = 30$ mm is diameter of supporting rollers;
$L_f = D_m + 3a_m = 60$ mm is free interval between the rollers;
$L \geqslant 160$ mm is length of the specimen;
$R \leqslant 0,1a_m$ is permissible radius of rounding-off of specimen's free edges;
P is bending load applied to the specimen

Table 4.8.4.1-1

Requirements to mechanical properties of deposited metal

Grade of welding consumable	Designation of welded steel	Static stress test				Impact test		Range of approval (steel brand)	
		$R_{p0,2}$, MPa	$R_{p1,0}$, MPa	R_m, MPa	A_5, %	Temperature, °C	KV, J, minimum	AISI/UNS	National
		minimum							
1	2	3	4	5	6	7	8	9	10
M-1	x20 Cr13, x30 Cr13	440	—	650	16	+20	60	410 420	20X13 30X13
	x7 CrNiNb 16 4	735	—	850	13	+20	60	—	07X16H4Б
MF-2	x10 CrNi 13 1	460	—	590	16	–10	20	414, 410S	08X14НДЛ 05X12H2T
	x10 CrNi 15 4 x15 CrNi 17 2	550 540	— —	750 690	12 16	–10 +20	30 60	429 431	08X15H4ДМЛ 14X17H2
F-3	x8 CrTi 17	360	—	480	16	+20	60	430T	08X17T
AM-4	x8 CrNiTi 17 6	630	—	730	12	+20	60	—	08X17H6T
A-5 and A-6	x2 CrNi 19 11 x10 CrNiTi 18 10 x10 CrNiNb 18 10 x2 CrNiMo 17 13 2 x2 CrNiMo 18 13 3 x10 CrNiMoTi 17 13 3 x6 CrNiMoTi 17 12 2 x6 CrNiMoNb 18 16 3	270	310	510	30	+20 –196[1]	80 50[1]	304, 304L 316, 316L 317, 317L 308, 308L	08X17H13M2T 03X17H14M3 10X17H13M3T 03X16H15M3
		290	330	550	30	+20 –196[1]	80 50[1]	Ditto plus 321, 347	Ditto plus 08X18H10T 08X18H12Б
		305	—	580	30	+20	60	Ditto plus 316LN, 317LN	Ditto
A-7	x2 CrNiMoCu 20 18 6 x2 CrNiMoCu 20 25 4 2	300 270	340 310	650 510	30 30	+20 +20	60 80	S31254 N08904	— —
AF-8	x2 CrNiMo 22 5 3	480	—	680	25	+20 –60[1]	80 40[1]	S31803	03X22H6M2
	x2 CrNiMo 25 7 4 x2 CrNiMo 25 7 3	550	—	780	20	+20 –60[1]	80 40[1]	S32750 S32760 S32550 S31260	08X21H6M2T Ditto Ditto Ditto
A-9sp (special)	Weld metal x2 CrNi 24 12 x10 CrNi 24 12 x10 CrNiCb 24 12 and analogue	350	470	520	30	+20	80[2]	For welding of: dissimilar welded joints; intermediate runs; clad steel joints; deposition of intermediate (transitional) sublayer; steels of brands 309L, 309S, 309SCb.	
A-10sp (special)	Weld metal x8 CrNiMoV 16 25 6 x8 CrNiMoVN 16 25 6 x1 CrNi 26 22	390 490 390	— — —	610 680 550	26 26 30	+20 –80[1] +20 –80[1] +20	80 60[1] 80 60[1] 60	For welding of: intermidiate runs (with clad steel); for filling passes with steels of Grades M-1, MF-2, F-3 and AM-4.	

[1] Tests at below-zero temperature are carried out in accordance with a special requirement of the Register depending on the range of approval requested by the manufacturer.
[2] In initial as-welded condition (without heat treatment).

It is recommended to separate test specimens from the sample by mechanical cutting. In case of using the isolating plasma cutting the allowance for machining shall be such as to make the specimen completely free from heat affected zone.

The test procedure shall consist of two stages:

static bend to an angle of about 90° with recording of the intermediate test result (without dismantling of the specimen);

Table 4.8.4.1-2

Requirements to mechanical properties of butt weld metal

Grade of welding consumable	Steel to be welded		Static tension (transverse specimens) R_m, MPa, minimum	Impact test		Static bend test		
	Designation	Brands by AISI/ UNS		Tempera-ture, °C	*KV*, J minimum	Type of specimen	Mandrel diameter	Bend-over angle, deg., minimum
1	2	3	4	5	6	7	8	9
M-1	x20 Cr13 x30 Cr13 x7 CrNiNb 16 4	410 420 —	650 650 850	+20 +20 +20	60 60 60	Transverse Ditto Ditto	4t 4t 6t	120° 120° 120°
MF-2	x10 CrNi 13 1 x10 CrNi 15 4 x15 CrNi 17	414, 410S — 431	540 740 690	–10 –10 +20	20 30 60	Ditto " — " " — "	4t 4t 4t	120° 120° 120°
F-3	x8 CrTi 17	430Ti	440	+20	60	" — "	4t	120°
AM-4	x8 CrNiTi 17 6	—	730	+20	60	" — "	4t	120°
A-5 and A-6	x2 CrNi 18 10 x2 CrNiMo 17 13 2 x2 CrNiMo 18 13 3 x6 CrNi 20 11	304, 304L 316, 316L 317, 317L 308, 308L	440	+20 –196[1]	80 50[1]	" — "	2t	120°
	x10 CrNiTi 18 10 x10 CrNiNb 18 10	321, 347	490	+20 –196 [1]	80 50[1]	" — "	2t	120°
	x2 CrNiMoN 17 13 2 x2 CrNiMoN 18 13 3	316LN, 317LN	540	+20	60	" — "	3t	120°
A-7	x2 CrNiMoCu 20 18 6 x2 CrNiMoCu 20 25 4 2	S31254 N08904	620 510	+20 +20	80 80	" — "	3t	120°
AF-8	x2 CrNiMo 22 5 3 x2 CrNiMo 25 7 4 x3 CrNiMo 25 7 3	S31803 S32750 S32760	650 720 720	+20 +20 +20	80 60 60	" — "	4t	120°
A-9sp	Dissimilar, for example A-6 + D36		Not less than R_m^{min} of base metal	+20	80[2]	Longitudinal	3t	120°
A-10sp	Ditto		Ditto	+20 –80	80 60[1]	Longitudinal	3t	120°
[1] Refer to Notes 1 and 2 to Table 4.8.4.1-1.								

continuation of the test until the final bend angle (not less than 120° is obtained, dismantling of the specimens, recording of the test result.

If, prior to obtaining the required bend angle, and inadmissible crack appears in the test zone, the testing shall be stopped. The following defects are considered inadmissible during this type of tests:

transverse cracks of 3 mm and more in length;

longitudinal discontinuities opening in the process of specimen bending and having a length equal to 20 per cent or more of the specimen width.

4.8.4.3 Tests defining resistance to intercrystalline corrosion.

4.8.4.3.1 The tests intended to define resistance of the weld metal and deposited metal to intercrystalline corrosion shall be carried out observing the requirements of national or international standards specifying immersion of the specimens in boiling aqueous solution of copper sulphate and sulphuric acid in presence of copper as metal with subsequent bending of the specimens to 90° angle in order to reveal indications of intercrystalline corrosion (Strauss method). At initial approval of welding consumables a variety of this method shall be used, in which the specimens are immersed in the boiling solution for at east 24 h; at repeated tests it is permissible, by agreement with the Register, to employ an accelerated test procedure, with the specimens kept in the boiling solution for a period from 8 to 15 h.

4.8.4.3.2 Unless otherwise agreed upon with the Register, the dimensions of specimens for ICC testing (refer to Fig. 4.8.4.3.2) and diameters of bending mandrels shall correspond to values in Tables 4.8.4.3.2-1 and 4.8.4.3.2-2.

The resistance of weld metal to ICC is evaluated on the basis of test results obtained from three specimens subjected to tensioning of the weld top layer, which corresponds to testing of the base metal plate initial surface (not subjected to machining intended for reduction of specimen thickness). In

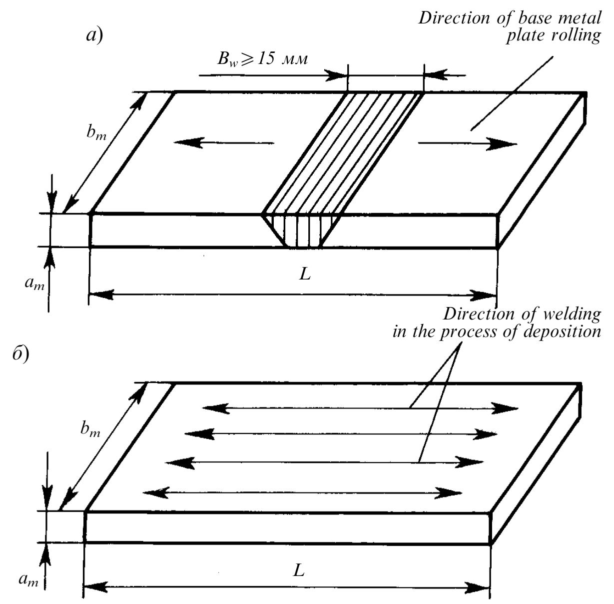


Fig. 4.8.4.3.2 Specimens for tests intended to define resistance to intercrystalline corrosion:
a — of weld metal in the welded joint;
b — of deposited metal in the cladding deposit

Table 4.8.4.3.2-1
Dimensions of specimens and diameters of mandrel rounding-off when testing weld metal for resistance to ICC

Grades of welding consumables	Specimen thickness *a*, mm	Specimen width *b*, mm	Specimen length *L*, mm	Mandrel diameter, mm
A-5, A-6, A-7, A-9sp	$6 \pm 0{,}1$	$20 \pm 0{,}5$	$\geqslant 100$	20
AF-8	$5 \pm 0{,}1$	$20 \pm 0{,}5$	$\geqslant 100$	20
F-3	$5 \pm 0{,}1$	$20 \pm 0{,}5$	$\geqslant 100$	30
AM-4, MF-2, M-1	$3 \pm 0{,}1$	$20 \pm 0{,}5$	$\geqslant 80$	20

Table 4.8.4.3.2-2
Dimensions of specimens and diameters of mandrel rounding-off when testing deposited metal for resistance to ICC

Grades of welding consumables	Specimen thickness *a*, mm	Specimen width *b*, mm	Specimen length *L*, mm	Mandrel diameter, mm
A-5, A-6, A-9sp	$4 \pm 0{,}1$	$20 \pm 0{,}5$	$\geqslant 100$	20
AF-8	$4 \pm 0{,}1$	$20 \pm 0{,}5$	$\geqslant 100$	20

this case the plane of bending load application (axis of mandrel) shall coincide with the weld axial line.

N o t e . Bending with application of the load within the heat affected zone is employed for testing of corrosion-resistant steels and for approval of technological welding processes.

The resistance of cladding layer metal to ICC is evaluated on the basis of test results obtained from four specimens cut out in accordance with the directions of Fig. 4.8.3.6.2; of these specimens:

two specimens are tested by tensioning the top surface *A* (top surface) of the deposit;

two specimens are tested by tensioning the top surface *B* (bottom surface) of the deposit.

4.8.4.3.3 The bent specimens shall be inspected using a magnifying glass with 8-12X magnification. Absence of cracks in the specimen, apart from longitudinal cracks and cracks directly on the edges, is a proof of resistance to ICC.

In questionable cases the resistance to ICC is additionally estimated by a metallographic method. In this case from a non-bent portion of the specimen after corrosion testing a wafer is cut to obtain a microsection; the plane of the cut shall be normal to the weld and contain the weld metal and heat affected zone. The presence and depth of intercrystalline corrosion is established on etched sections using 200X magnification. The maximum depth of corrosive attack is revealed in six fields of vision, which shall include portions with largest depth of ICC. The specimen is considered corrosion (ICC) — resistant, if the decay at grain boundaries has the maximum depth not exceeding 30 micron.

4.8.4.3.4 The result of the test for resistance to ICC is considered satisfactory, if the ICC is not detected on any of the tested specimens. If one of the tested specimens yields unsatisfactory results, the tests shall be repeated, as required by national or international standards.

If at the initial tests more than one specimen proved to be unsatisfactory, or if the repeated tests produced negative results, the weld or deposited metal is considered as having failed the tests for resistance to ICC.

N o t e . In ambiguous cases for materials susceptible to cracking it is recommended to carry out, as a reference check, bending tests for specimens, similar to ICC-tested, but not subjected to boiling in aqueous solution of sulphuric acid and copper sulphate.

4.8.4.4 Check of α-phase (ferrite component).

Inspection of α-phase (ferrite component) in the weld metal and cladding layer is determined in welding consumables of Grades A-5, A-6, AF-8 and A-9sp using the following methods of measurement:

.1 local non-destructive method, where the α-phase content is estimated as the mean value of at least 10 measurements for butt-welded joint assemblies, also for assemblies with cladding deposits, as specified in 4.8.3.5 and 4.8.3.6;

.2 if the above measurement method produced inadequate results, or in accordance with a special requirement of the Register, a check analysis is performed by the volumetric magnetic method with the use of ferritemeters, which make measurements with error not exceeding ±10 per cent of the measured value.

The analysis for determination of α-phase content with the aid of volumetric magnetic method requires a seven-layer deposition with welding consumables analyzed to a corrosion-resistant steel plate, which in its grade and chemical composition corresponds to the above consumables. From the two top layers of deposited material pilot cylindrical specimens are cut having a length of (60±1) mm and diameter of (5±0,1) mm, as shown in Fig. 4.8.4.4).

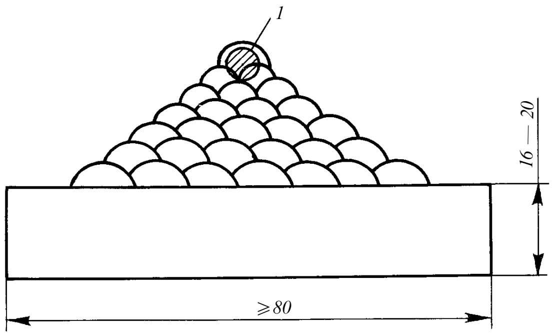


Fig. 4.8.4.4 Arrangements for cutting out specimens intended to determine α-phase content by volumetric magnetic method:
1 — place for cutting out check specimens

The controlled values of α-phase content shall meet the requirement of technical documentation approved by the Register or specified by respective national standards for particular welding consumables.

The results of check measurements of α-phase content in the weld metal and/or cladding layer shall be recorded in the Test Report.

4.8.4.5 Determination of chemical composition of deposited metal.

The test assemblies for determination of chemical composition of deposited metal shall be taken from metal of two top layers; these are:

test assembly of deposited metal;

test assembly of multilayer deposit taken in accordance with Fig. 4.8.3.6.2 (for compositions "strip-flux" the samples for determination of chemical composition are taken from deposited metal only).

The results of determination of deposited metal chemical composition shall comply with tolerances claimed by the manufacturer and shall be recorded in the Test Report.

4.8.5 Tests for confirmation of Certificate of Approval for Welding Consumables.

The program of annual re-approval test of welding consumables for corrosion-resistant steels welding and deposition shall include:

.1 manufacture of deposited metal assembly and testing of specimens, static tensile and impact bend as well as checking chemical analysis of the deposited metal;

.2 determination of resistance of weld metal or deposited metal to ICC, if this is required for a particular brand of welding consumable.

If required by the Register, the scope of annual tests may be extended and supplemented by other types of testing or preparation of additional test assemblies.

5 APPROVAL TEST FOR WELDERS

5.1 GENERAL

5.1.1 The requirements of the Section set down the general conditions of the approval test for welders (operators) who shall weld structures listed under 1.1.1.

5.1.2 The approval test for welders is a compulsory procedure used by the Register for confirmation of the qualification of welders engaged in manufacture of objects and structures to be surveyed by the Register.

5.1.3 Upon compliance with the requirements of this Section, a Welder Approval Test Certificate will be issued by the Register to testify approval of the welder for welding, under conditions stipulated therein (material, welding procedure, welding position, etc.), structures subject to survey by the Register.

5.1.4 Successful passing by a welder of theoretical and practical examinations is the grounds for issue of a Welder Approval Test Certificate.

5.1.5 The procedure for welders' tests and for issue of the Welder Approval Test Certificates shall meet the requirements of international standards (EN 287-1, EN 287-2, ISO/DIS 9606-3) recognized by the Register, with due regard to the provisions given below.

5.2 REQUIREMENTS FOR PROCEDURE FOR CARRYING OUT AND ORGANIZATION OF WELDERS' CERTIFICATION

5.2.1 Approval testing of welders shall be conducted in a centralized order by the request of works-employers in certifying centers, which competence has been verified by the Register.

5.2.2 Certifying centres may be established at works, educational institutions, specialized organizations and institutions where qualified welding specialists and the training and testing base for welders are available.

5.2.3 Structure of a certifying centre shall provide the following key components ensuring the center functioning:

management;

certifying commission;

service personnel to ensure carrying out of all the tests and equipment functioning;

main and auxiliary production equipment for carrying out practical tests;

equipment, tools and instrumentation for carrying out practical and theoretical tests of welded joints;

spaces for carrying out practical and theoretical tests of welders.

5.2.4 The working body of the certifying center directly carrying out welders' certification is a standing certifying commission.

The Surveyor to the Register carrying out the survey during tests is the member of the certifying commission and to be present during the performance of all kinds of tests, which results he surveys.

5.2.5 Where the certifying center is organized on the base of industrial facilities performing the welding of structures under the Register technical supervision, and its activity is limited by the certification of its own welders, the procedure for compulsory center recognition by the Register with issue of the relevant documents may be unnecessary.

5.2.6 All the certifying centers engaged in training and/or certification of welders from outside organizations on a commercial basis irrespective of their entity are subject to the compulsory recognition by the Register.

5.2.7 Welders' certification is classified as initial, additional, periodical and occasional.

To initial certification are subject the welders aged 18 years and over who did not previously pass an approval test for the welding of objects and equipment to be surveyed by the Register, have a welder's qualification certificate and the relevant welding experience of at least 12 months, as well as the special theoretical and practical training according to the programs individually compiled for each type of works and each welding process with due regard to the specific nature of the works, for which the welder shall be certified.

Additional certification of welders who underwent the initial certification is carried out prior to approval for the works not specified in a Welder Approval Test Certificate, as well as after the break in performance of the relevant welding works for over 6 months.

All welders are subject to periodical certification to confirm the level of their professional qualification and to extend the validity of the Welder Approval Test Certificate according to the provisions of 5.6. The periodical certification is conducted at least once in two years.

To occasional certification are subject welders prior to approval for welding works performance after their temporary removal from working for poor quality and non-observance of a welding procedure. The time period for preparation to the occasional certification (for additional training) is at least one month since the date of the removal from working.

The scope of special theoretical and practical training for the additional, periodical and occasional certification is established by a certifying commission and subject to the Register individual approval.

5.2.8 In order that the Register could carry out activities on the approval test for welders, the works administration shall send to the Register Branch Office, surveying the welding at this works, the request specifying:

name and address of a certifying centre where welders will be certifying;

list of welders to be certified with their (for each person) full names, year and place of birth, place of work, speciality and skill category, experience of work to be certified;

copies of documents confirming the professional qualification of workers for the type of works to be certified;

welding process, welding positions and other information necessary for certification and filling in the form of a Welder Approval Test Certificate;

guarantee of payment for the Register services according to the current tariffs.

Note. Request for the Register performance of works on the approval test for welders may be also submitted by certifying centers operating on behalf of the works administration.

5.3 DEFINITIONS, TERMS AND SYMBOLS USED IN APPROVAL TEST FOR WELDERS

5.3.1 Definitions and terms.

Certifying commission is the group of specialists of the certifying center who are responsible for the organization and validity of the results of welders' certification activities.

Certifying centre is a competent organization authorized by the Register to conduct tests on welders' certification in compliance with the requirements of the Register Rules.

Certification means the set of activities on determination of a welder's qualification level to ascertain the possibility of welder's approval for performance of the specific kind of welding works.

Approval means a special procedure to determine the welder's qualification through his certification and issuance of an official document, i. e. a Welder Approval Test Certificate, which verifies the permission to carry out welding works on the objects to be surveyed by the Register within the range of approval established by the Certificate.

Range of approval is the extent of a welder's qualification recognized by the Register proceeding from tests during certification.

Specimen is the part of a test assembly used for testing by destructive methods.

Test assembly is a welded piece used in practical tests on welders' certification.

Welder means a person welding metals. It is a collective term used for both a manual welder and a welding operator of equipment for semi-automatic and automatic welding.

Welder Approval Test Certificate is a Register document verifying that the welder has successfully passed the certification tests within the scope of the requirements of the Register Rules and is approved for welding on the structures to be surveyed by the Register, within the range of approval specified in the Certificate.

5.3.2 Symbols of welding processes shall comply with the provisions of ISO 4063 (refer to Table 6.2.2.1).

5.3.3 Welders' certification is conducted separately for each of the following welding processes, which vary by the degree the welder's labour is mechanized:

MW = manual welding wherein the filler wire feed and welding gun movement along and across the weld are carried out by a welder manually;

SA = semi-automatic welding wherein the welding wire feed is mechanized, but a welding gun is moved manually along and across the weld by a welder;

A = automatic welding wherein the process of the welding wire feed and welding gun movement mani-pulation are automated and carried out without direct participation of a welder.

5.3.4 To determine the range of approval as per the results of welders' practical tests, covered metal electrodes are classified by their covering into the types according to ISO 2560 and EN 499:

A = acid (oxidizing) covering;
B = basic covering;
C = cellulosic covering;
R = rutile covering;
RA (AR) = rutile-acid covering;
RB = rutile-basic covering;
RC = rutile-cellulosic covering;
RR = rutile thick covering;
S = other (special) types of coverings.

5.3.5 For designation of the composition of a shielding gas applied in welders' practical tests, alpha-numeric indices consistent with EN 439 are used.

5.3.6 For designation of the type and composition of a flux applied in welders' practical tests, letter indices consistent with EN 760 are used.

5.3.7 For designation of the presence of filler metal involved in forming of a weld, the following symbols are used in welders' certification:

wm = welding with filler metal;

nm = welding without filler metal wherein a weld is formed only at the expense of the melting of base metal.

5.3.8 Symbols relating to base metal and joint type.

5.3.8.1 Welders' certification as per the results of practical tests is carried out to fit the groups of a type composition of base metal according to Table 5.3.8.1.

5.3.8.2 Welders' certification shall be conducted to fit the specific type of a welded joint coded by a group of indices according to Fig. 7.2.2.

Table 5.3.8.1

Groups of a type composition and properties of base metal

Group index	Type and characteristic of welded materials
W01	Carbon and low-alloyed steels with a guaranteed yield stress at a normal temperature, up to 360 MPa (no heating is usually needed in welding)
W02	Chromium-molybdenum and/or chromium-molybdenum-vanadium steels (as a rule, need preheating, controlled heat input and heat treatment after welding as well)
W03	Fine-grained steels normalized, quenched and tempered, as well as thermomechanically treatedsteels with a yield stress at a normal temperature, over 360 MPa, as well as similarly welded nickel steels, with a nickel content from 2 per cent to 5 per cent (as a rule, need preheating and controlled heat input)
W04	Ferritic, martensitic and martensitic-ferritic steels, with a chromium content from 12 per cent to 20 per cent
W11	High-alloyed ferritic-austenitic and austenitic chromium-nickel steels
W21	Pure aluminium and aluminium-magnesium alloys. For example: Al 99,8; Al 99,5; AlMn 1
W22	Non-thermostrengthened aluminium-magnesium alloys. For example: AlMg 1 to 5; AlMg 3 Mn; AlMg 4,5 Mn and aluminium-silicon alloys (silumins)
W23	Thermostrengthened aluminium alloys.For example: AlMgSi 0,5 to 1; AlSiMgMn; AlSiMg; AlZn 4,5 Mg 1; AlSiCu

Notes: 1. Group indices are consistent with EN 287-1 for steel and EN 287-2 for aluminium and alloys.
2. For cast aluminium alloys, the filler material shall meet requirements of the Rules for materials of a given group.

5.3.9 Symbols relating to types of test assemblies and welding positions.

5.3.9.1 For practical tests on welders' approval, unified check welded joints/test assemblies shall be used according to provisions of the relevant international standards. Geometric parameters and dimensions of test assemblies shall be specified using the following indices:

P = plate;

T = pipe;

D = outside diameter of pipe;

t = wall thickness of plate or pipe;

Z = leg length of fillet weld;

a = throat thickness;

L = length of test assembly;

b = width of test assembly.

5.3.9.2 The welding of welded joint test assemblies is carried out in unified welding positions consistent with the provisions of ISO 6947 (refer to Figs. 6.2.2.4-1 to 6.2.2.4-3).

5.4 PROCEDURE FOR APPROVAL TESTS FOR WELDERS

5.4.1 General requirements for the test performance procedure.

The procedure for welders certification includes the passing of theoretical and practical examinations by a welder to be certified.

The certification shall begin with a practical examination. If a welder fails the practical examination, he is not admitted to other examinations and is considered to have failed the certification.

In the course of passing a theoretical examination, the welder shall answer at least 15 questions covering the basic sections of common and special (by speciality) issues. The questions are selected by the certifying commission for each welding process.

An examination is conducted by the certifying commission using one of the following methods or their combination:

knowledge verification in writing;

oral questioning;

knowledge verification with a computer;

written description with the follow-up demonstration on the equipment.

The examination results are assessed by a certifying commission according to a system: passed/not passed. The note "passed" means correct answers of a welder for at least 80 per cent of questions asked. The welder is considered to be certified if he has successfully passed practical and theoretical examinations.

If a welder has passed a practical examination and failed a theoretical one, he is allowed to resit it by an additional request within half a year since the day of the first examination, but nor earlier than in two weeks after the initial date of the theoretical examination. With the repeated negative result of the theoretical examination, the welder is considered to have failed the certification.

5.4.2 Requirements for the practical test performance procedure.

5.4.2.1 The practical tests of welders are conducted by means of welding of check welded joints, which are consistent with the requirements of the relevant international standards.

The performance of test assemblies welding shall be witnessed by at least three members of a certifying commission:

one certified welding engineer;

one representative of a technical control service whose qualification level allows him making a conclusion on the results of an external examination and measurements;

one representative of the Register.

5.4.2.2 The test assemblies of welded joints shall be marked with the identification number entered in the testing protocol before welding starts.

Assembly of joint parts for welding is carried out by a welder to be certified. The permit for test assembly welding is given by the member of a certifying commission after the acceptance of quality of assembly for welding.

The certifying commission may abort a practical examination if welding conditions and procedure are not observed or, if it is obvious that the welder is unable to perform the welding of a test assembly in compliance with the requirements of a specification and the Register Rules.

5.4.2.3 The test assemblies welding during practical qualification tests on welders' approval shall be performed proceeding from a Welding Procedure Specification of an established pattern, which is executed in accordance with actual conditions of welding performance in production. In so doing, the following requirements shall be met:

the welding of test assemblies shall be carried out with welding processes to be used in production;

filler material shall be compatible for the particular welding process and positions;

the structural components of edge preparation for welded joints of test assemblies for testing (a groove angle, root face value, joint gap) shall be used in production;

the dimensions of test assemblies shall be given in a Specification and to meet the requirements of the Rules;

the welding equipment shall be similar to that used in production;

the welding of test assemblies shall be carried out in the positions and for angles of pipes connection corresponding to those normally used in production;

welding conditions and welding sequence in the groove shall comply with those used in production;

the combination of base, filler and auxiliary materials shall correspond to the normal conditions in production;

the time spent by a welder for test assembly welding shall correspond to normal standards set in production;

the test assembly shall have at least one stop and one re-start in the root run and in the top capping run and to be identified in the inspection length to be examined; this requirement is compulsory for manual and semi-automatic welding;

where in production, specific welded joints (combinations of base material and welding consumables) need preheating, controlled heat input, or the requirement for a minimum/maximum interpass temperature is specified, than these conditions of the process shall be ensured in welding of test assemblies for welders' approval;

where in production, post-weld heat treatment for specific welded joints is stipulated, the execution of this operation is mandatory in welding if test program provides for the bend test of specimens. For other cases, the post-weld heat treatment of welded joint test assemblies may be omitted if agreed by the Register;

test assemblies shall be unambiguously identified;

if approved by the Surveyor to the Register, it is allowed to remove minor surface defects of the beads of inner layers of the weld by mechanical dressing or any other method used in production. Elimination of defects on the surface layer of a weld, as well as the continuous dressing or gouging of a root run on the side of reinforcement are not allowed.

5.4.2.4 The thickness of metal of test assemblies to be welded, their diameter for pipelines welding testing shall be specified with due regard to the actual range of these characteristics values in compliance with the request of the works, and for the range of the Register approval according to provisions of 5.5.9.

The assembly and welding of butt joints of plates shall ensure the absence of an angular deformation of the welded joint (its flatness).

Where T-joints of plates and pipes are joined by a single-sided single-pass fillet weld, designed fillet weld thichness a shall be within the following range depending on the effective throat thickness of a base metal t:

$0{,}5t \leqslant a \leqslant t$ at $t < 6$ mm;

$\leqslant 0{,}5t$ at $t \geqslant 6$ mm.

5.4.3 The number of check welded test assemblies for practical tests, their dimensions and structural components shall be specified by a certifying commission depending on the range of works set in the application, for which a welder shall be certified.

5.4.4 After welding, each welded test assembly shall be examined visually and measured. The scope of tests by other methods is specified according to the requirements of international standards in use.

Prior to mechanical testing, backing strips, where used, shall be removed. For further checks, the test assembly can be sectioned by thermal or mechanical cutting, depending on the type of used material, discarding the first and last 25 mm of the test assembly at the end of the plates.

5.4.5 Criteria for test results assessment.

5.4.5.1 Assessment of welded joints quality by visual examination and measurements.

5.4.5.1.1 General requirements.

The inspection by visual examination and measurements is applicable directly to the weld surface and the adjacent base metal zone spaced for at least 20 mm from a fusion line along the entire welded joint.

The visual examination shall be usually carried out without use of special optical instruments. In doubtful cases, magnifying glasses with not more than 10X magnification may be used.

Where cracks or their indications are detected during the visual inspection of a welded joint, it is recommended to continue testing for defects:

magnetic powder or dye penetrant inspection;

grinding of the surface followed by chemical cleaning with the reagent used for revealing a macro-structure.

Undercuts depth, pimpling and scaling height shall be checked by comparison with weld standards using special templates or by making a mould. The latter is cut so that the dimension to be checked is in the plane of a notch. In this case, drops between beads and between the weld and base metal shall be measured on a base of 12 mm, the pimpling and scaling are measured between the tops of pimples and scales.

The measurements of welded joints shall be carried out at points where deviations from specified dimensions are suspected after a visual examination. At least three measurements of geometric parameters of the welded joint shall be made on the length of the check test assembly. Universal or special templates (fit/unfit) approved by the Surveyor to the Register shall be used for measurements.

5.4.5.1.2 Criteria for defects assessment.

The following external defects of check welded joints are considered as impermissible:

cracks in the weld and adjacent zone, poor fusion, burns, blowholes, rolls, aggregates of inclusions and pores, surfaced unfilled craters and stains of short circuits on the surface of the completed weld and base metal;

non-conformity of the weld form and dimensions in excess of that allowed by the relevant national standards;

separate pores sized over 0,1 the minimum thickness of welded components for thickness up to 20 mm and pores sized over 2,0 mm for component thickness 20 mm and over, as well as the pores of this and lesser size if their number exceeds 3 pieces per any 100 mm of the weld or 6 pieces per any 300 mm of the weld;

undercuts of the base metal over 0,3 mm deep for metal thickness up to 20 mm inclusive and over 0,5 mm deep for metal thickness over 20 mm. The maximum length of the single undercut shall not be more than 0,5 the thickness of welded metal, while the total extent of undercuts shall not exceed 10 per cent of a weld length;

shrinkage in the root of a single-sided weld over 0,1 the thickness of welded metal for edge thicknesses up to 10 mm inclusive and 1 mm, over 10 mm;

drops between beads, as well as between the weld and base metal (non-smoothness of weld transition to base metal) exceeding 1,5 mm.

Tolerances for weld dimensions shall be within the requirements of a Welding Procedure Specification and in any case shall meet the requirements of the national standards.

5.4.5.2 Assessment of welded joints quality during radiographic examination.

The assessment of welded joints quality proceeding from the results of radiographic examination shall be carried out according to the requirements of 3.3 for steel welded joints and of 3.4 for welded joints of aluminium alloys while specifying permissible dimensions of defects corresponding to Marks III and III Al respectively.

5.4.5.3 Assessment of welded joints quality based on ultrasonic examination results.

Ultrasonic examination shall be carried out according to the national standards recognized by the Register or approved techniques.

The criteria for assessment of the examination results are subject to individual approval by the Register.

5.4.5.4 Assessment of welded joints quality based on bend test results.

During testing of welded joint specimens for bending, the requirements of Table 5.4.5.4 shall be followed. After specimen bending for the specified angle, no defects over 3 mm long in any direction shall be brought about on the specimen surface. Any defects up to 3 mm long formed on the specimen edges are ignored and omitted in a test protocol.

Table 5.4.5.4

Requirements for performance and assessment of bend test results

Group of base metal type composition		Ratio D/a	Bend angle prior to emergence of the first crack, degrees, min
W01, W11		3	120
W02, W03	$320 < R_{p0,2} \leqslant 490$ MPa	3	120
W04	$490 < R_{p0,2} \leqslant 690$ MPa	4	120
	$R_{p0,2} > 690$ MPa	5	120
W21 and W22 with a content of Mg⩽3,5 %		3	180
W22 with a content of 3,5 % Mg⩽6,0 %		6	180
W23		7	180

Note. The procedure for performance and assessment of test results for miscellaneous welded joints is, in each case, subject to special consideration by the Register.

5.4.5.5 Assessment of welded joints quality based on fracture test results.

5.4.5.5.1 After fracture testing of butt-welded joints, the fracture surface shall be visually examined and measured. Weld defects on the fracture surface shall be considered as impermissible if their type, number and dimensions do not meet the criteria set for internal defects of a weld in radiographic examination.

5.4.5.5.2 During fracture testing of T-welded joints made by a single-pass fillet weld, the absence of impermissible internal defects including poor penetration of the root part of the weld shall be confirmed. Minor defects like small pores and slags may be ignored if their relative area does not exceed six per cent of the cross section in question.

N o t e . Pores and slags are considered as minor if their largest linear dimension in the plane of destruction does not exceed 0,2*Z*, but not more than 2 mm (where Z = leg of a fillet weld).

5.4.5.6 Check of macrosections.

Macrosections shall be made so that their working surface covers the entire weld area and the part of base metal at least 15 mm wide adjacent to the fusion line. The reagent used for etching shall allow to clearly identify the boundaries of the weld and separate beads, the fusion line, affected zone, as well as the adjacent part of base metal. In the examination of macrosections, the following shall be checked:

shape and geometric dimensions of the weld;

shape and size of base metal penetration;

presence of base metal undercuts and shrinkage in the root of a single-sided weld;

presence of inadmissible internal defects in the weld and adjacent zone at a distance of 10 mm from the boundary of the affected zone.

The macrosections may have defects, which type and dimensions are not beyond the scope of the requirements in 5.4.5.1 and 5.4.5.2. In this case, the sum of all defects (external and internal) projections in the direction of a design thickness shall not exceed 0,15*t* or 0,15*a*, but shall not be more than 4,0 mm for all steel and aluminium alloy groups.

5.4.6 Procedure for retests performance.

5.4.6.1 In cases when a certifying commission has reliably ascertained that the unsatisfactory result of initial practical tests is due to causes not associated with the welder's qualification (e.g. malfunctions of welding equipment, defects of the welding electrode covering, etc.), the welder may be approved for retests on the same number of test assemblies. In this case, the quality of base material and welding consumables, as well as serviceability of welding equipment shall be thoroughly checked by certifying commission members.

5.4.6.2 Where ascertained that the unsatisfactory result of initial tests is attributed to the welder's inadequate qualification and had been caused by the unsatisfactory results of testing on more than one test assembly, the welder may be approved for the repeated certification after additional training for at least during a week.

5.4.6.3 Where the testing results for one of the specimens tested do not meet the requirements set for the given type of tests, the doubled number of the same specimens shall be fabricated and tested. The specimens for additional tests may be selected among stored test assemblies or a new test assembly shall be fabricated under similar conditions.

5.4.6.4 If two additional specimens fabricated according to 5.4.6.3 have demonstrated the satisfactory results, the tests are considered as completed with the satisfactory result.

With the unsatisfactory results of retesting of even one of additional specimens, the welder is recognized to have failed the practical tests and shall undergo retesting in the established order.

5.4.6.5 With additional tests of bend specimens, as well as of microsections fabricated from fixed butt pipe joints (positions PF, PG and H-L045, J-L045), the point of test assembly sampling, which corresponds to the position of a welding sector, for which unsatisfactory results in initial tests were obtained, shall be retained.

5.4.6.6 In case, when the extent of initial tests provided for the fabrication of several test assemblies (one type for various welding positions or of the different type) and the unsatisfactory results were obtained only for one of these test assemblies, the retesting as per 5.4.6.2 may be performed only to fit the test assembly the negative result was attributed to. In addition, the Register may double the extent of retesting as compared with the initial one.

5.4.6.7 The welder is considered to have failed the certification if the results of the practical retesting are unsatisfactory. The procedure for welder's approval for the new certification is established by the certifying commission individually with due regard to professional shortcomings revealed. In any case, the time period between certifications for training and gaining pertinent practical skills shall be at least one month.

5.5 RANGE OF APPROVAL

5.5.1 Defining the range of approval for a Welder Approval Test Certificate, the following parameters of the technological welding procedure shall be taken into account:

welding process and procedure;

type of structure (plate/pipe) and welded joint;

class/group of base metal;

type of filler metal;

composition of shielding gas and/or the type of flux;

type of electrode covering;

structural dimensions of a welded joint (metal thickness, pipe diameter);

welding positions and accessibility of a welded joint zone for technological operation performance.

5.5.2 Each practical test is usually limited by the range of approval for one welding process/procedure.

The change of welding process in production is accompanied by new testing for welders' approval.

Where the welding of a specific joint under production conditions is performed by one welder with the use of a combination of two welding processes, practical tests for approval may be conducted by the following ways:

.1 the fabrication of a test assembly during testing is carried out with the use of a combination of two welding processes as in production (e.g. the root run is welded by single-sided tungsten inert-gas arc welding without backing, the groove is filled by manual welding with covered electrodes);

.2 in approval tests, two test assemblies are welded for the welder's separate certification for each welding process.

5.5.3 The range of approval of a Welder Approval Test Certificate by unified welding positions depending on the conditions of performance of check practical tests shall be consistent with the provisions of Table 5.5.3.

5.5.4 Specifying the range of approval according to the technological details of welding, the provisions of Table 5.5.4 regarding the recommendations below shall be followed:

on the discretion of the Surveyor to the Register, the validity of a Welder Approval Test Certificate for the welding of butt joints of plates by a single-sided weld in all welding positions may include the welding of pipes of at least 500 mm in diameter provided that other restrictions for the range of approval are observed;

on the discretion of the Surveyor to the Register, the validity of a Welder Approval Test Certificate for the welding of butt joints of plates by a single-sided weld in the welding positions PA and PC may include the welding of pipe joints with an outside diameter at least 150 mm in similar welding positions (PA and PC), provided that other restrictions for the range of approval are observed.

Table 5.5.3

Range of approval of Welder Approval Test Certificate according to unified welding positions

Welding positions in welding of test assemblies during tests					Range of approval																		
					Plates										Pipes								
					Butt welds					Fillet welds					Butt welds					Fillet welds			
															0°			90°	45°		0°		90°
					PA	PC	PG	PF	PE	PA	PB	PG	PF	PD	PA	PG	PF	PC	H-L045	PB[1]	PB	PG	PD
Plates	Butt welds			PA	*	—	—	—	—	×	×	—	—	—	×	—	—	—	—	×	—	—	—
				PC	×	*	—	—	—	×	×	—	—	—	×	—	—	×	—	×	—	—	—
				PG	—	—	*	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
				PF	×	—	—	*	—	×	×	—	×	—	×	—	—	—	—	×	—	—	—
				PE	×	—	—	—	*	×	—	—	—	×	—	—	—	—	—	×	—	—	—
				PF + PE	×	×	—	*	*	×	×	—	×	×	—	—	—	—	—	×	—	—	—
	Fillet welds			PA	—	—	—	—	—	*	—	—	—	—	—	—	—	—	—	—	—	—	—
				PB	—	—	—	—	—	×	*	—	—	—	—	—	—	—	—	×	—	—	—
				PG	—	—	—	—	—	—	—	*	—	—	—	—	—	—	—	—	—	—	—
				PF	—	—	—	—	—	×	×	—	*	—	—	—	—	—	—	—	—	—	—
				PD	—	—	—	—	—	×	×	—	—	*	—	—	—	—	—	—	—	—	—
				PF + PD	—	—	—	—	—	×	×	—	*	*	—	—	—	—	—	—	—	—	—
Pipes	Butt weldsfor pipe axis angles to horizon	0°	Rotating	PA	×	—	—	—	—	×	×	—	—	—	*	—	—	—	—	×	—	—	—
			Fixed	PG	—	—	×	—	—	—	—	×	—	—	—	*	—	—	—	—	×	—	—
				PF	×	—	—	×	×	×	—	—	×	×	×	—	*	—	—	×	—	×	×
		90°		PC	×	×	—	—	—	×	×	—	—	—	×	—	—	*	—	×	—	—	—
		45°		H-L045	×	×	—	×	×	×	×	—	×	×	×	—	×	×	*	×	—	×	×
		90° + 0°		PC + PF	×	×	—	×	×	×	×	—	×	×	×	—	*	*	—	×	—	×	×
		45°		J-L045	—	—	×	—	—	—	—	×	—	—	—	×	—	—	—	—	×	—	—
	Fillet welds	0°	Fixed	PB[1]	—	—	—	—	—	×	×	—	—	—	—	—	—	—	—	*	—	—	—
				PG	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	*	—	—
				PF	—	—	—	—	—	×	×	—	×	×	—	—	—	—	—	×	—	*	×
		90°		PD	—	—	—	—	—	×	×	—	—	×	—	—	—	—	—	×	—	—	*

Symbols:
* indicates welding positions, for which the welder is approved directly according to the test results;
× — indicates welding positions covered by the range of approval;
— — indicates welding positions, for which the welder is not approved according to the practical test results.

[1] The welding position PB for corner joints of pipes may be realised in two versions: PB rotating (pipe axis is in the horizontal plane) and PB fixed (pipe axis is in the vertical plane) according to the diagram in Fig. 6.2.2.4-3.

Table 5.5.4

Technological details of making welds in tests			Range of approval of a Welder Approval Test Certificate according to technological details of welded joints fabrication					
			Butt joints of plates				Butt joints of pipes	
			Welded from one side (ss)		Welded from both sides (bs)		Welded from one side (ss)	
			with backing (mb)	no backing (nb)	with gouging (gg)	no gouging (ng)	with backing (mb)	no backing (nb)
Butt joints of plates	Welded from one side (ss)	with backing (mb)	*	—	×	—	With due regard for restrictions of 5.5.4	—
		no backing (nb)	×	*	×	×	Ditto	With due regard to restrictions of 5.5.4
	Welded from both sides (bs)	with gouging (gg)	×	—	*	—	Ditto	—
		no gouging (ng)	×[1]	—	×	*	Ditto	—
Butt joints of pipes	Welded from one side (ss)	with backing (mb)	×	—	×[1]	—	*	—
		no backing (nb)	×	×	×	×	×	*
T-, Y- and K[2]-joints of pipes	Welded from one side (ss)	no backing (nb)	×	×	×	×	×	T-, Y- and K-joints of pipes with full penetration

Symbols:
* — indicates technological details of making welds, for which the welder is approved directly according to the test results;
× — indicates technological details of making welds covered by the range of approval;
— — indicates technological details of making welds, for which the welder is not approved according to the practical test results.

[1] For the given technological details of making welds, the range of approval is subject to special consideration by the Register.
[2] Approval for welding of pipe joints allows for the presence of welder's approval for single-sided butt welds in pipes without backing.

5.5.5 As a rule, the range of approval of a Welder Approval Test Certificate for the welding of butt joints may include the welding of corner and T-joints. The performance of the separate type of tests on welding of T-joint test assembly is needed in the following cases:

according to the manufacturer's application, the welder is certified for the welding of these types of joints only;

according to the separate requirement of the Register when the essential part of the welder's work in production is the making of fillet welds.

Note. This requirement does not cover the welding by a fillet weld with partial or full penetration when edge preparation for welding is provided. The condition of approval for making such welds is, as a rule, the extension of the range of approval to the welding of butt welds under similar conditions.

5.5.6 The practical tests conducted with the use of base metal of a specific trade mark from one of the groups of a type composition according to 5.3.3.1, are valid for the approval test for the welding of any other steels of the given group.

The range of approval of a Welder Approval Test Certificate for welding according to the groups of base metal is given in Table 5.5.6-1 for similar welded joints, and in Table 5.5.6-2, for dissimilar welded joints. The ranges of approval in Tables 5.5.6-1 and 5.5.6-2 are valid, provided the groups of base and filler materials for practical tests are the same (i.e. filler and base metals have a similar chemical composition, and a weld and the base metal have similar properties).

5.5.7 Specifying the range of approval for a Welder Approval Test Certificate, the type of covering for electrodes used for the welding of test assemblies in performance of practical tests shall be taken into account. Unified code symbols for electrode covering types according to EN 499 are given in 5.3.4, and the relevant ranges of approval of a Welder Approval Test Certificate, in Table 5.5.7.

5.5.8 Practical tests carried out with use of specific compositions or marks of shielding gas and flux are valid for welder's approval for welding performance with use of other similar materials. In this case, the range of approval of a Welder Approval Test Certificate shall be defined with due regard to the following requirements:

alteration of a gas composition within the range of approval shall not result in the change of the

Table 5.5.6-1

Range of approval of a Welder Approval Test Certificate for welding according to base metal groups

Group of steel used in tests	Range of approval				
	W01	W02	W03	W04	W11
W01	*	—	—	—	—
W02	×	*	—	—	—
W03	×	6	*	—	—
W04	×	6	—	*	—
W11	×[1]	×[1]	×[1]	×[1]	*
Aluminium and its alloys	W21	W22	W23		
W21	*	6	—		
W22	×	*	—		
W23	×	6	*		

Symbols:

* — indicates a material group for the welding, for which the welder is approved directly according to the test results;

× — indicates a material group for the welding, for which the welder is approved proceeding from the range of approval of a Welder Approval Test Certificate;

— — indicates a material group for the welding, for which the welder is not approved.

[1] The range of approval is valid provided austenitic welding consumables intended for welding of group W11 steels are used.

Table 5.5.6-2

Range of approval of a Welder Approval Test Certificate for welding according to base metal groups for dissimilar welded joints

Group of base metal of check test assembly for practical tests	Range of approval
W02	– W02 + W01[1]
W03	– W02 + W01[1] – W03 + W01[1] – W03 + W02[1]
W04	– W02 + W01[1] – W04 + W01[1] – W04 + W02[1]
W11	– W11 + W01[2] – W11 + W02[2] – W11 + W03[2] – W11 + W04[2]
W21	– W21 + W22[1]
W22	– W22 + W21[1]
W23	– W22 + W21[1] – W23 + W21[1] – W23 + W22[1]

[1] Filler material used for dissimilar welded joints shall be consistent with the group of one of base materials to be joined.

[2] The range of approval is valid, provided that austenitic welding consumables corresponding to the group W11 of base material are used.

Table 5.5.7

Range of approval of a Welder Approval Test Certificate for welding according to electrode covering types

Type of covering of electrodes used for test assemblies welding in practical tests	Range of approval				
	A, RA	R, RB, RC, RR	B	C	S
A, RA	*	—	—	—	—
R, RB, RC, RR	×	*	—	—	—
B	×	×	*	—	—
C	—	—	—	*	—
S[1]	—	—	—	—	*

Symbols:

* — indicates the types of electrode coverings, for which the welder is approved directly according to the test results;

× — indicates the types of electrode coverings covered by the range of approval of a Welder Approval Test Certificate;

— — indicates the types of electrode coverings not covered by the welder's approval test.

[1] Approval includes only that special type of electrode covering (a trade mark), which was used in approval testing.

nature of metal transfer in an arc gap and/or to impact the shape of base metal fusion penetration;

alteration of a flux composition within the range of approval shall not result in the substantial change of welding and technological properties in the welding using the combination «wire — flux»;

extension of the range of approval beyond the limits of unified groups of welded steels and, accordingly, of the use of welding consumables, which are unlike those used in practical tests, is subject, in each case, to special consideration by the Register;

in individual cases, the Register may restrict the range of approval within more narrow limits regarding the details of welding and technological properties of fluxes and/or shielding gases actually used in tests.

5.5.9 The range of approval of a Welder Approval Test Certificate shall be specified regarding the following structural dimensions of welds:

base metal thickness;

outside diameter of welded pipes;

design thickness of a fillet weld.

Every practical test shall have the range of approval in accordance with the provisions of Tables 5.5.9-1, 5.5.9-2 and 5.5.9-3.

Table 5.5.9-1

Material	Thickness t of test assembly metal in tests, mm	Range of approval by base metal thicknesses, mm
Steels	$t \leqslant 3$	from t to $2t$[1]
	$3 < t \leqslant 12$	from 3 to $2t$[2]
	$t > 12$	from 5 and overfrom
Aluminium and its alloys	$t \leqslant 6$	$0{,}7t$ to $2{,}5t$
	$6 < t \leqslant 15$	$6 < t \leqslant 40$[3]

[1] For gas (oxy-acetylene) welding from t to $1{,}5t$.
[2] For gas (oxy-acetylene) welding from 3 mm to $1{,}5t$.
[3] For parts thickness over 40 mm, the separate certification noted in a Welder Approval Test Certificate and in a test protocol, is required.

Table 5.5.9-2

Material	Outside diameter D of pipes in tests, mm	Range of approval by welded pipes diameter, mm
Steels	$D \leqslant 25$	from D to $2D$
	$25 < D \leqslant 150$	from $0{,}5D$ to $2D$ but not less than 25
	$D > 150$	from 0,5 and over
Aluminium and its alloys	$D \leqslant 125$	from $0{,}5D$ to $2D$
	$D > 125$	from $0{,}5D$ and over

Note. For hollow building structures having a box section, a dimension D is determined as to the dimension of the smallest side.

Table 5.5.9-3

Design thickness a of a fillet weld in welding of test assemblies, mm	Range of approval by design thicknesses of fillet welds, mm
$a < 10$	from $0{,}75a$ to $1{,}5a$[1]
$a \geqslant 10$	from 10 to $1{,}5a$[1]

[1] For a downward welding procedure (position PG), the upper limit of the range of approval is limited by a value of $1{,}1a$.

5.6 EXECUTION, CONDITIONS OF VALIDITY AND PROLONGATION OF WELDER APPROVAL TEST CERTIFICATE

5.6.1 Proceeding from the results of welders' practical and theoretical tests, the certifying commission executes a protocol.

Attached to the protocol are:

the copy of a certificate on assignment of a welder's qualification and the reference of the personnel department of a works on the welder's professional experience (during the initial certification) or the copy of a welder's certificate with other types of certification;

the copy of a welder's certificate with other types of certification;

the copy of a document of an educational institution on welder's special training;

copies of certificates for base material and welding consumables;

reports, conclusions and other documents on the results of quality control for test assemblies of welded joints.

Note. It is allowed to execute one protocol for a group of welders made as a table with all pertinent information and data entered.

5.6.2 The protocol of welder's certification is drawn up in two copies. One copy is kept in an examination centre and another is sent to the Register Location supervising test performance.

5.6.3 Based on the protocol of welders' certification and provided that all the above requirements are met, the Register draws up and issues a Welder Approval Test Certificate of a standard pattern.

5.6.4 The period of validity of the Welder Approval Test Certificate is limited by two years. In addition, the works-employer at six month intervals shall make a note in appropriate columns of the Certificate on its prolongation, which evidences the observance of the Register requirements for a welder's qualification listed below:

the welder shall be continuously engaged on welding work within the current period of approval; breaks in work for over six months are not permitted;

welding works performed by the welder under work conditions shall be consistent with complexity of the range of approval specified in the Welder Approval Test Certificate;

there shall be no specific reason to question the welder's skill and knowledge during the working process.

If any of these conditions is not met, the Register cancels the Welder Approval Test Certificate, and its renewal or the issuance of the new Certificate is done individually in each case.

Note. In accordance with the practice adopted by the national legislation, the welder shall pass periodical medical examination and to have the conclusion of a medical commission on professional competence.

5.6.5 The validity of the Welder Approval Test Certificate may be extended by the Register for the following period of up to two years without the performance of new practical tests and without the change of the range of approval provided that the conditions listed in 5.6.4 were observed, as well as the observance of the following requirements has been ensured:

the quality of production welds made by the welder meets the requirements of Section 3;

the works-employer may documentarily confirm to the Surveyor to the Register the compliance of a welder's qualification with the level specified in the Welder Approval Test Certificate.

The documents submitted to the Surveyor to the Register shall include the data on the non-destructive testing results with the conclusion of the authorized person of the works-employer.

5.6.6 The performance of monitoring over the welder's production activity rests with the work-employer, which shall designate a responsible person/performer who is in charge of this work.

A file for each certified welder shall contain:

copy of a document on education;

copy of a document on special training;

reference on uninterrupted service in welding;

protocols on passing the examinations with indication of certifying commission members, marks received, the date of the examination performance, the results of a practical examination;

conclusion of the commission on the examination results;

copies of protocols for tests of welded joints made by the welder over an accountable period with the conclusion of the responsible person of a works-employer on the possibility to extend the Welder Approval Test Certificate for the next six months.

Any of the above documents shall be submitted to the Surveyor to the Register as soon as demanded.

5.6.7 On agreement with the Register, for works-employers having the system of products quality assurance approved by the Register, the extension of the period of validity for the Welder Approval Test Certificate may be effected within the framework of the special survey of a works quality system in whole.

5.6.8 Where the welder shall be approved for works beyond the limits of the initial range of approval, the new tests for welder's approval in accordance with the above requirements are needed.

If the welder's qualification or knowledge is questioned in any way (refer to 5.6.4 to 5.6.6), the Surveyor to the Register may cancel the valid Welder Approval Test Certificate and/or demand the performance of unscheduled approval tests.

5.6.9 The extension of the period of validity for the Welder Approval Test Certificate according to the provisions of 5.6.5 for the next two-year period may be effected not more than two times in sequence. The welder's periodical certification in full extent shall be conducted on the expiry of three two-year periods of the Certificate validity.

6 APPROVAL OF WELDING PROCEDURES FOR WELDING OF STEEL STRUCTURES AND ITEMS

6.1 GENERAL

6.1.1 The welding procedures adopted for the manufacture of structures subject to survey by the Register, which are mentioned in 1.1.1, shall be approved by the Register and shall comply with the requirements listed below.

6.1.2 Welding procedures may be approved by the Register after consideration of relevant documentation proceeding from the results of testing conducted in accordance with a program agreed with the Register. The documentation and program shall be attached to the application of the manufacturer seeking the Register approval.

6.1.3 Documentation submitted to the Register shall contain the following information:

.1 principal materials used for the manufacture of structures (brand, grade, condition of supply, type of semi-finished product, dimensions, etc.);

.2 types of structures, their purpose and conditions of service, sequence of assembly;

.3 welding process (including welding techniques);

.4 equipment (brief description, examination periods, etc.);

.5 welding consumables (type, brand, grade, conditions of supply and storage);

.6 welding positions and, where necessary, welding directions, types of joints, preparatory work required, presence of primer, order of beads deposition, polarity of current, etc.;

.7 information on required backings and other fixtures, tacking techniques;

.8 conditions of welding operations (temperature, protection from weather, preheating, post-weld heat treatment, etc.).

6.1.4 Besides the information given in 6.1.3, the documentation shall contain information on the quality control system applied to the welding procedure in question by the works. Requirements for control of materials and operations shall be stated, as well as the sources of quality assessment criteria.

6.1.5 The documentation containing technical requirements for welding operations, methods and criteria of assessment shall have relevant and unique identification (number) and shall be approved by the Register.

6.1.6 For welding of structures subject to survey by the Register may only be used welding processes and techniques ensuring highly stale possibility of obtaining the guaranteed quality of welds, which may be confirmed by the manufacturer of welded structures by approval testing or other techniques in accordance with the requirements of the rules or by a special agreement with the Register.

6.1.7 The principal type of welding procedure approval is conduction of approval testing. The approval tests may either be standard, the requirements to which are given in the present Section, or the approval may be done by a pre-production welding test. Types of sampling and procedures for conduction of the latter are established for each particular case and are subject to special consideration by the Register. The above pre-production welding test shall be conducted taking into account the following main requirements:

.1 welding of test assemblies shall be carried out under conditions close, as far as possible, to welding of actual structures, simulating the combined effect of factors influencing the quality of welded joint;

.2 in welding of test assemblies one shall use jigs, fixtures, devices, manipulators, etc. similar to those employed in actual production;

.3 the tack welds, whenever necessary, shall be tested together with completed welded joint;

.4 the scope of test assemblies' checking includes visual examination and measurements, control of surface cracks (magnetic particle or liquid penetrant examinations), determination of hardness, macro examination, as well as some types of destructive tests, as agreed by the Register;

.5 the scope of approval in relation to base metal thickness is limited, as a rule, to thickness of particular weld assembly, for which the tests are performed.

The pre-production welding test shall be employed in cases, when standard test assemblies cannot provide the possibility to simulate welding of actual structures. Used as test assemblies may be parts of actual structures or technological imitator-assemblies. The preliminary tests prior to production (pre-production tests) serve, as a rule, as the main method for approval of welding processes and processes of metal deposition to ship machinery items.

6.1.8 In some individual cases the Register may require additional production test. This type of testing is resorted to when there are some doubts about stability of the product quality, or some changes in the production process parameters, or when the standard or preliminary (pre-production) tests are insufficient, in the Register opinion, for a particular welding process. Such welding procedure with higher probability of deviations in quality of welded joints includes:

vertical downward welding;

one-side welding with free back-formation of the weld by coated electrodes or flux-cored wire;

welding techniques with high level of heat input (electro gas arc welding, electro slag welding, etc.);

welding techniques highly susceptible to the quality of parts assembling and edge preparation, e. g. electron beam and laser welding.

6.1.9 When the manufacturer of welded structures uses welding procedure approval schemes not involving conduction of tests meeting the requirements of the present Section, these are subject to special consideration by the Register. The use of the following approval schemes may be considered:

based on the standard welding procedure, as specified by EN 288-7;

based on previous welding experience in execution of jobs connected with manufacture of similar articles and structured in accordance with the requirements of EN 288-6.

6.1.10 Approval of welding procedure by use of standard welding procedure, as specified by EN 288-7 means application of fully identical Welding Procedure Specifications by several manufacturers of welded structures. In this case, after testing for certification and approval by the Register by one of the manufacturers the particular Welding Procedure Specification (WPS) is classified as standard. Application of this approval scheme is possible under the following conditions:

the limitations concerning the range of approval and utilization of the technology, as specified by EN 288-7, are actually observed;

the stability of welding procedure shall be confirmed by documents certifying completion of the so-called production tests.

6.1.11 Approval of welding procedure on the basis of previous welding experience shall be performed meeting all the requirements of EN 288-6. Application of this scheme is not recommended for welding processes for structures made of higher strength steels D32-D40 and is inadmissible for structures made of steel Grades E, E32-E40, also for high-strength steels of all grades. For ship machinery items limitations for application of the approval scheme based on previous experience shall be observed taking into account in each particular case all the relevant circumstances. When the manufacturer submits full information on quality of welded joints in accordance with EN 288-6, the Register may consider it as the basis for reduction of the scope of tests conducted to satisfy the requirements of the present Section.

6.2 DEFINITIONS, TERMS AND SYMBOLS

6.2.1 Definitions and terms.

In the present Section the following definitions have been adopted.

Production tests mean the tests, including destructive tests, which are based on welding of specimens obtained directly in the course of product manufacture and subjected to the same treatment, as the actual products. Besides, depending on particular conditions and possibilities, the specimens may be cut out of extra lengths (allowances) of structures or be manufactured in conditions identical with those of product manufacture and using the same WPS.

W e l d i n g p r o c e d u r e t e s t s mean the tests conducted under technical supervision and within the scope of the Register requirements to confirm the capability of the manufacturer to carry out welding of particular structures; the tests closely simulate actual working conditions and are performed in accordance with the WPS requirements.

R e p o r t i n g a b o u t a p p r o v a l o f w e l d - i n g p r o c e d u r e s means the Register documents containing complete information on testing for approval of welding procedure. The documents include the Details of Weld Test Form and Test Results Form.

P r e - p r o d u c t i o n w e l d i n g t e s t s mean the tests for approval of welding procedure based on the use of non-standard specimens and test assemblies and simulating welding in actual industrial conditions.

W e l d i n g P r o c e d u r e A p p r o v a l T e s t C e r t i f i c a t e means a Register document certifying that the welding procedure applied at the shipyard or plant manufacturing welding structures has passed the tests and is approved by the Register for application.

W e l d i n g P r o c e d u r e S p e c i f i c a t i o n (W P S) means a document compiled by the Manufacturer of welded structures and containing all the necessary information on welding of a particular joint, including specifications for materials, welding method, edge preparation data and all process parameters.

N o t e . WPS based on the previous welding experience and recommendations of welding consumables and base metal manufacturers, but having no confirmation and approval, is called "preliminary WPS" (pWPS). Welding of specimens for approval of welding procedure is carried out in accordance with the preliminary WPS.

S t a n d a r d w e l d i n g p r o c e d u r e means the welding procedure that has passed all the tests provided by the requirements of this Section and was approved by the Register for use at the specific manufacturer of welded structures. The term "standard welding procedure" there with is applied to the welding procedure approved by the Register if the last is used at other manufacturers' of welded structures, which shall be totally identical to those in the WPS approved by the Register (without test performance or with tests of much-reduced scope).

6.2.2 Designations.

6.2.2.1 The designations for welding techniques according to ISO 4063 shall correspond to those given in Table 6.2.2.1.

6.2.2.2 Approval of welding procedures and assigning of the range of approval on the basis of test results is done with reference to base metal groups of typical composition, as specified in Table 6.2.2.2 harmonised with EN 288-3.

6.2.2.3 When executing the documentation related to the approval of welding procedures, it is recommended to use coding of welded joint types as indicated in Fig. 7.2.2.

6.2.2.4 Welding of joint check samples and range of approval of welding procedures shall be assigned with reference to unified spatial welding positions, the designations for which are shown in Figs. 6.2.2.4-1 to 6.2.2.4-3 in accordance with the requirements of ISO 6947.

6.3 TYPES OF WELDED JOINT TEST ASSEMBLIES AND REQUIREMENTS TO THEIR MANUFACTURE

6.3.1 Classification of test assemblies, their purpose and dimensions.

6.3.1.1 The test assembly of butt-welded joint between plates shall comply with Fig. 6.3.1.1-1, and the plan for cutting out specimens shall comply with Fig. 6.3.1.1-2.

N o t e s : 1. When testing automatic one-side welding procedures at specialized assembling and welding stands provided with clamping devices, the test assembly length shall not be less than 3000 m.

2. When testing automatic vertical welding procedures, including forced weld formation, the test assembly length shall correspond to technical capabilities of the equipment applied in production.

The metal thickness shall be within limits of the nominal thickness range of the base metal, as specified by the WPS to be approved, and satisfy the WPS requirements concerning the range of approval. At the same time, it shall be taken into account, that:

for certification of welding procedures with close limits with respect to the range of approval (refer to Footnotes 1 to 3 to Table 6.6.2.2.2) welding of several test assemblies may be required;

it would be incompetent to specify the test assembly thickness, which is beyond the actual range of thicknesses, but within the range of approval according to 6.6.2.2.1 (for instance, in accordance with the WPS thicknesses of 20 to 28 mm are welded, but in accordance with the range of approval welding of a 14 mm thick sample may be sufficient).

Design components of edge preparation and weld elements shall meet the requirements of WPS to be approved.

Strips for butt-weld assemblies from rolled plates shall be manufactured taking into account the last rolling direction and axial orientation of specimens for

Table 6.2.2.1

Code designations of welding and cutting techniques in accordance with ISO 4063

Code (numerical) designation of welding technique	Abbreviated alphabetical designation of welding technique	Name of welding or cutting technique
111	MMAW (SMAW:USA)	Manual metal arc welding with coated electrodes
112	—	Gravity welding with coated electrodes
114	—	Self-shielded tubular-cored arc welding
12	SAW	Submerged arc welding, including:
121	—	one wire electrode;
122	—	strip electrode;
123	—	multiple wire electrode;
124	—	metal powder addition;
125	—	tubular-cored electrode
131	MIG (GMAW:USA)	Metal inert gas welding
135	MAG (GMAW:USA)	Metal active gas welding
136	FCAW(USA)	Tubular-cored metal arc welding with active gas shield
137	FCAW(USA)	Tubular-cored metal arc welding with inert gas shield
141	TIG (GTAW:USA)	Tungsten inert gas welding
15	—	Plasma-arc welding, including:
151	—	MIG welding;
152	—	powder welding
31	OGW (USA)	Oxy-fuel gas welding, including:
311	—	oxy-acetylene welding;
312	—	oxy-propane welding;
313	—	oxy-hydrogen welding
511	—	Electron-beam welding in vacuum
52	LBW (USA)	Laser-beam welding
72	—	Electroslag welding
73	—	Electrogas arc welding
8	—	Cutting and gouging, including:
81	—	oxygen cutting;
82	—	arc cutting;
821	—	air carbon-arc cutting;
822	—	oxygen-arc cutting;
83	—	plasma-arc cutting;
84	—	laser cutting;
86	—	flame gouging;
87	—	arc gouging;
871	—	air-arc gouging;
872	—	oxygen-arc gouging;
88	—	plasma gouging

Table 6.2.2.2

Groups of steel according to EN 288-3

Steel group by EN 288-3	Type of steel
1	Steels with minimum yield strength $R_e \leqslant 355$ N/mm^2 or ultimate strength $R_m \leqslant 520$ N/mm^2 and chemical composition, %: $C \leqslant 0{,}24$ $Si \leqslant 0{,}55$ $Mn \leqslant 1{,}60$ $Mo \leqslant 0{,}65$ $S \leqslant 0{,}045$ $P \leqslant 0{,}045$
2	Any other alloying element $\leqslant 0{,}3$ %; all other element in total $\leqslant 0{,}8$ %.
3	Fine-grained structural steels with yield strength $R_e > 355$ N/mm^2 supplied in N and TM (TMCP) condition
4	High-stength steels with yield strength $R_e > 500$ N/mm^2 supplied in Q + T condition
5	Heat-resistant steels with $Cr \leqslant 0{,}6$ %, $Mo \leqslant 0{,}5$ %, $V \leqslant 0{,}25$ %[1]
6	Steels with $Cr \leqslant 9$ %, $Mo \leqslant 1{,}2$ %[1]
7	Steels with $Cr \leqslant 12$ %, $Mo \leqslant 1$%, $V \leqslant 0{,}5$ %[1]
8	Steels with $Ni \leqslant 9$ %[1]
9	Ferritic or martensitic stainless steels with Cr content from 12 to 20 %[1] Austenitic stainless steels

[1] For groups 4 to 8 content of alloying elements is given with reference to ladle sample.

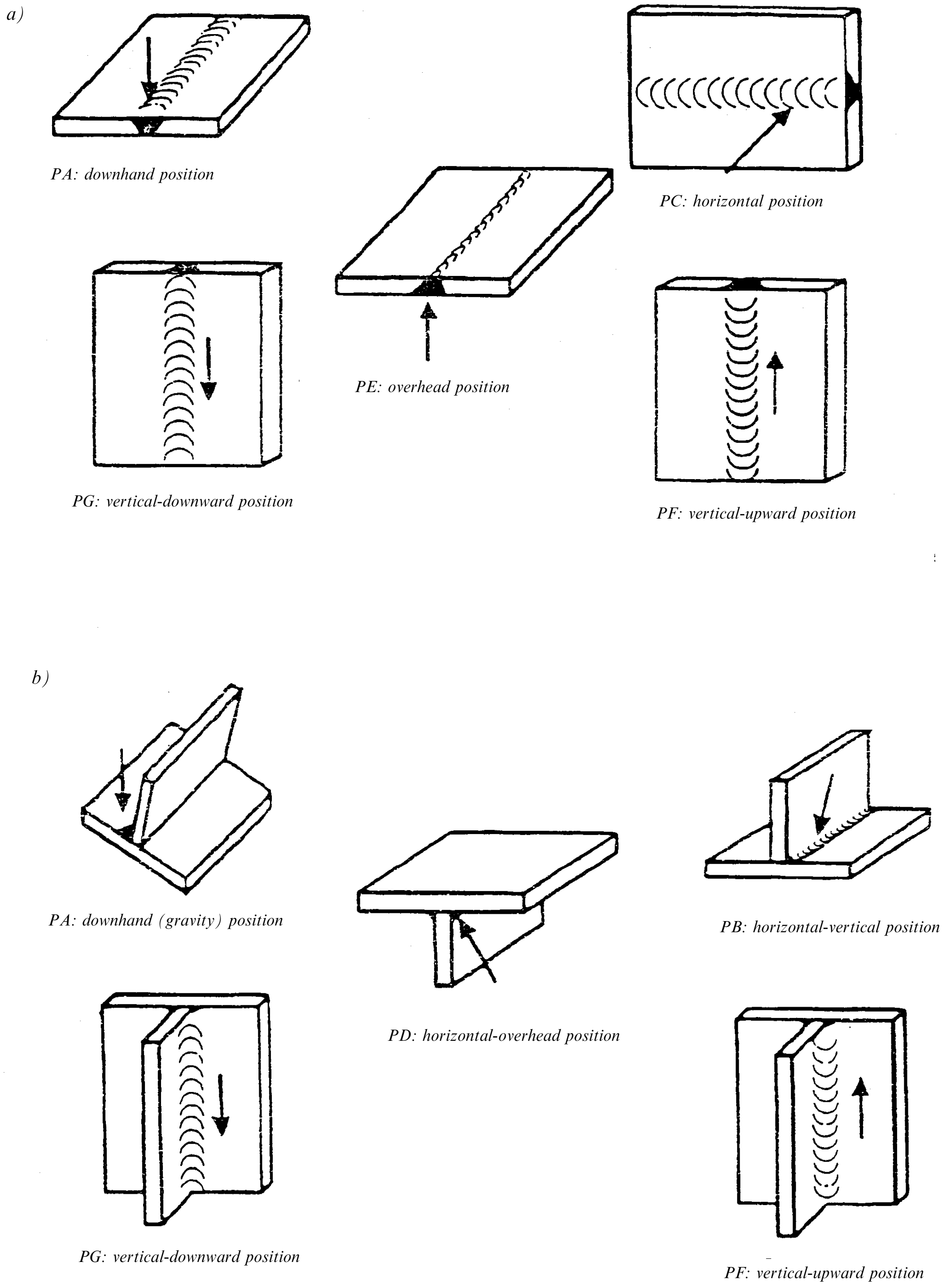
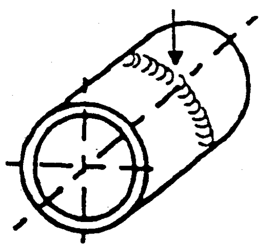
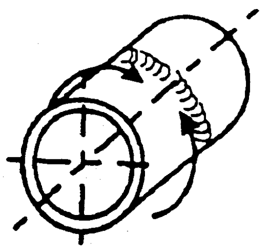


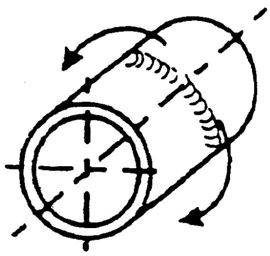
Fig. 6.2.2.4-1 Unified positions in welding of plates:
a — butt welds, *b* — fillet welds



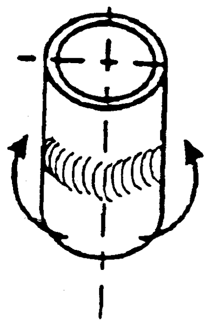
PA: downhand position.
Pipe: rotating;
axis: horizontal



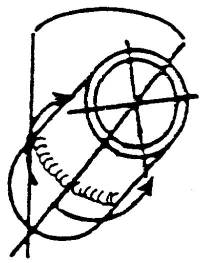
PF - vertical-upward position.
Pipe: stationary (fixed);
axis: horizontal



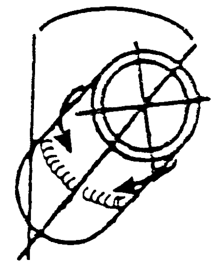
PG - vertical-downward position.
Pipe: stationary, axis:
horizontal



PC - horizontal position.
Pipe: stationary;
axis: vertical

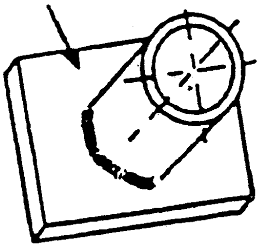


H-L045 - inclined-upward position.
Pipe: stationary;
axis: inclined

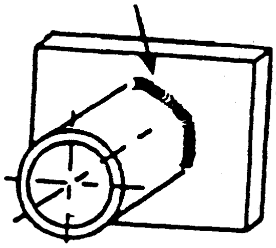


J-L045 - inclined-downward position.
Pipe: stationary;
axis: inclined

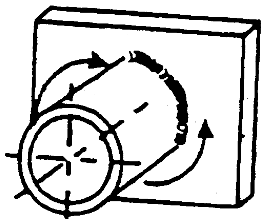
Fig. 6.2.2.4-2 Unified positions in welding of pipes (butt welds)



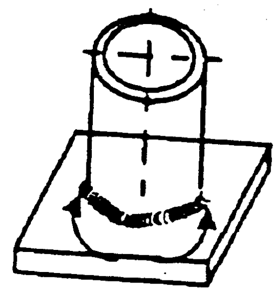
*PA: downhand "corner" position.
Pipe: rotating;
axis: inclined*



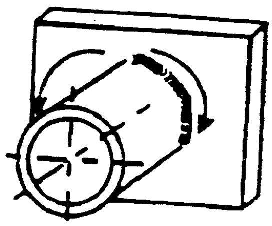
*PB: horizontal-vertical position.
Pipe: rotating;
axis: horizontal*



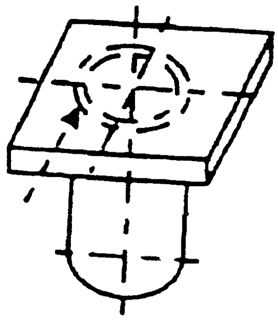
*PF: vertical upward position.
Pipe: stationary;
axis: horizontal*



*PB: horizontal-vertical position.
Pipe: stationary;
axis: vertical*



*PG: vertical-downward position.
Pipe: stationary;
axis: horizontal*



*PD: horizontal-overhead position.
Pipe: stationary;
axis: vertical*

Fig. 6.2.2.4-3 Unified positions in welding of pipes (fillet welds)

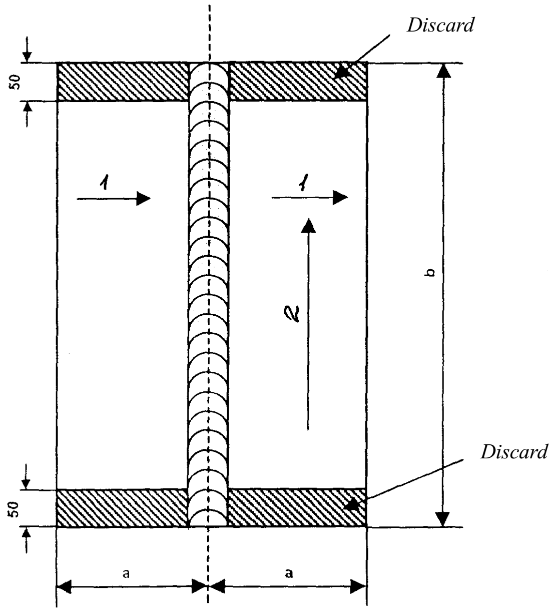


Fig. 6.3.1.1-1 The test assembly of butt-welded joint:

1 — orientation of rolled products for plates with normalization of impact energy on longitudinal specimens *KVL*;
2 — orientation of rolled products for plates with normalization of impact energy on transverse specimens *KVT*;
a and *b* — sample sizes adopted depending on the welding technique:
$a \geqslant 150$ mm, but not less than $3t$ and $b \geqslant 350$ mm, but not less than $6t$ for manual and semi-automatic welding;
$a \geqslant 200$ mm and $b \geqslant 1000$ mm
($\geqslant 3000$ mm for cases indicated in Note to 6.3.1.1)
for automatic welding

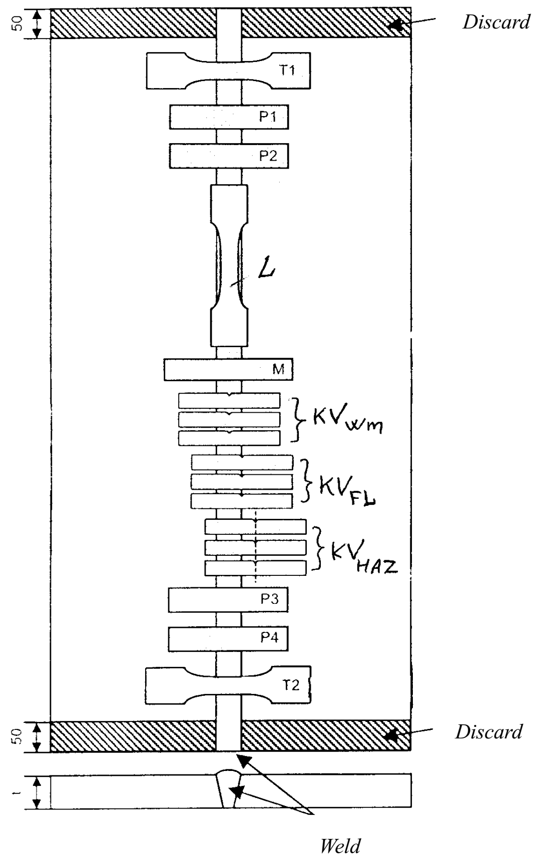


Fig. 6.3.1.1-2

Fig. 6.3.1.1-2 The plan for cutting out specimens from the test assembly of butt-welded joint:
T_1 and T_2 — transverse flat specimens for tensile test;
P_1 and P_3 — specimens for bend test with weld top tensioning or two specimens for side bend test;
P_2 and P_4 — specimens for bend test with weld root tensioning or two specimens for side bend test;
L — longitudinal cylinder specimen for tensile test, if required;
KV_{WM} — specimens for impact test with notch in weld center;
KV_{FL} — specimens for impact test with notch on fusion line;
KV_{HAZ} — specimens for impact test with notch in heat affected zone;
M — transverse macrosection for macrosection examination and determination of hardness

impact test, the test results for which are given in accompanying documents for the base material. For impact tests of rolled products with the use of longitudinal speciments, KV_L (as a rule, for all hull structural steels of normal and higher strength) the test assemblies are welded in such a way, that the weld is perpendicular to the direction of last rolling. In impact tests of rolled products using transverse speciments, KV_T the weld shall be parallel to the direction of last rolling (e.g., for steels of improved weldability).

6.3.1.2 Test assemblies for tee-joints in plates (tee-joint test assembly) shall be designed, as shown in Fig. 6.3.1.2.

Note. In cases of certification of technological procedures for automatic welding-on of framing at specialized assembling and welding stands provided with clamping devices and ensuring simultaneous welding from two sides (with two fillet welds), the test assembly length shall not be less than 3000 mm.

In accordance with WPS, the test assembly for tee-joints on plates may be prepared in two versions:

without edge preparation (fillet/weld joint);

with edge preparation (tee-butt joint).

Use of tee-joint test assembly for plates is limited due to the following conditions and requirements:

absence of the Register requirement for mandatory application of cruciform (double-tee) test assemblies for the above type of joint;

impossibility to approve the technological procedure with respect to the scope of approval taking into account the directions given below;

for manual and semi-automatic welding, unless there is no other limitations, the approval of the welding procedure for tee-joints with edge preparation is permitted within the range of approval only on the basis of the test results obtained on similar butt joints;

for automatic welding the approval of welding procedure for tee-joints with edge preparation shall be done on the basis of tee-joint assembly testing;

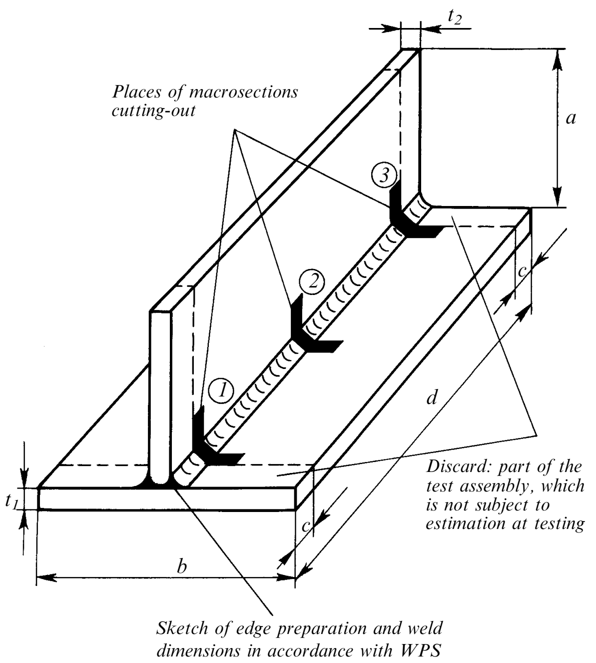


Fig. 6.3.1.2 Test assembly of tee-welded joint and plan for cutting out specimens:
for manual and semi-automatic welding, with dimensions:
$a \geqslant 150$ mm, but not less than $6t$, for joints without edge preparation;
$b \geqslant 350$ mm, but not less than $6t_1$ for joints with edge preparation;
$c \approx 25$ mm;
$a \geqslant 3t_2$, but not less than 150 mm;
$d \geqslant 350$ mm, but not less than $6t_1$;
cutting of macrosections in Zones *1* and *2* (operation "stop-start");
for automatic welding, with dimensions:
$a \geqslant 150$ mm, but not less than $3t_2$;
$b \geqslant 350$ mm, but not less than $6t_1$;
$d \geqslant 1000$ mm ($d \geqslant 3000$ mm in cases indicated in Note 1 to 3.1.2);
$c \approx 50$ mm;
cutting of macrosections in Zones *1*, *2*, *3*

approval of welding procedure for single-run fillet join without edge preparation shall be done on the basis of tee-joint assembly testing;

mechanical properties of weld metal, which were not specified in welding of the tee-joint test assembly, shall be confirmed in welding of respective butt joints providing similar proportion of the base metal in the weld metal.

Thickness of the base metal, as well as design thickness of the fillet weld shall be within the limits of the rated ranges of values for the above parameters in accordance with WPS to be approved and at the same time to meet the requirements with respect to the range of approval (refer also to 6.3.1.1).

Design components of edge preparation and elements of the weld shall meet the requirements of WPS to be approved.

6.3.1.3 Test assemblies for cruciform joints in plates (double-tee test assembly) shall be designed, as shown in Fig. 6.3.1.3.

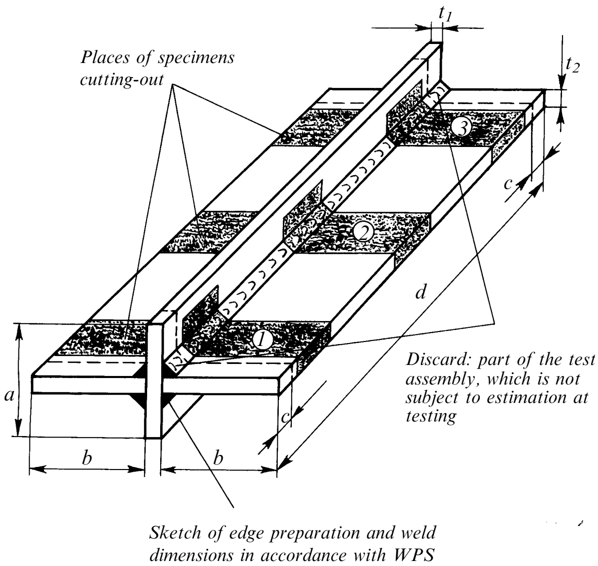


Fig. 6.3.1.3 Test assembly of cruciform welded joint (double-tee) and plan for cutting out specimens:
for manual and semi-automatic welding, with dimensions:
$a \geqslant 100$ mm, but not less than $4t_1$;
$b \geqslant 150$ mm, but not less than $3t_2$;
$c \approx 25$ mm;
$d \geqslant 350$ mm, but not less than $6t_2$;
the specimens for testing are cut out in Zone *2*;
for automatic welding, with dimensions:
$a \geqslant 150$ mm, but not less than $4t_2$;
$b \geqslant 150$ mm, but not less than $3t_2$;
$c \approx 50$ mm;
$d \geqslant 1000$ mm ($d \geqslant 3000$ mm in cases indicated in Note to 3.1.3);
the specimens for testing are cut out in Zones *1* and *3*

N o t e s: 1. In cases of certification of automatic welding procedures at specialized assembling and welding stands ensuring fillet welding from two sides simultaneously, the test assembly length shall be not less than 3000 mm.

2. In cases of certification of automatic vertical welding procedures of double-tee joints in framing with four welds simultaneously, the cruciform test assembly length shall correspond to the maximum height of welds obtained in production conditions with the use of the given type of equipment.

In accordance with the Welding Procedure Specification, the cruciform test assembly may be designed in two versions:

without edge preparation (fillet/joint);

with edge preparation (double tee-butt joint).

Application of cruciform test assembly is mandatory for the approval of:

.1 welding procedures for high-strength steels with yield strength above 460 N/mm^2, clad steels and nonferrous alloys;

.2 vertical-downward welding procedures;

.3 welded joints on higher and high strength steels, with design thickness of fillet welds considerably smaller than that of the components to be welded. This requirement is valid at fillet weld design thickness value of

$$a_{\min} \leqslant 0{,}7\sqrt{t_1 + t_2}$$

where t_1 is lower thickness of welded-to element;
t_2 is larger thickness of the main plate;

.4 welding procedures, which are applied in manufacture of cruciform test assemblies with the middle plate, the properties of which in the through-thickness direction are not specified;

.5 if the structure requires ultrasonic control of cruciform welded joints in through-thickness direction in order to detect laminar fractures;

.6 welding procedures carried out at sub-zero ambient temperatures. This requirement is put forward by a special instruction of the Register for steels of higher and high strength, when the manufacturer cannot guarantee the absence of trend in welded joints to hot, cold and underbid cracking.

The base metal thickness, as well as design thickness of fillet weld, shall be within the limits of rated ranges for values of the above parameters in accordance with WPS to be approved, and at the same time meet the requirements concerning the range of approval (refer also to 6.3.1.1).

The design components of edge preparation and elements of the weld shall meet the requirements of WPS to be approved.

6.3.1.4 Approval of welding procedures for pipe butt joints is issued on the basis of tests using the test assembly, as shown in Fig. 6.3.1.4. The outer diameter of the test assembly and thickness of the pipe wall shall be within the limits of rated ranges for values of the above parameters in accordance with WPS to be approved, and the same time meet the requirements concerning the range of approval in accordance with 6.6.2.2 (refer also to 6.3.1.1).

For pipes with outer diameter exceeding 500 m the approval of manual and semi-automatic welding procedures may be obtained by the results of testing the butt joints in plates carried out in identical conditions (refer to requirements to spatial positions listed in Table 6.6.3.2 and to other parameters of the range of approval in accordance with 6.3.2.1.1, 6.6.2, 6.6.3 and 6.6.4).

Orientation of the welded joint test assembly axis and design features of welded joints shall be in compliance with the WPS requirements for actual structures.

N o t e . The manufacturer by agreement with the Surveyor to the Register is entitled to change the arrangement of the test assembly to suit the particular features of actual welded joints. For instance, a box-shaped test assembly may be used instead of the pipe, etc.

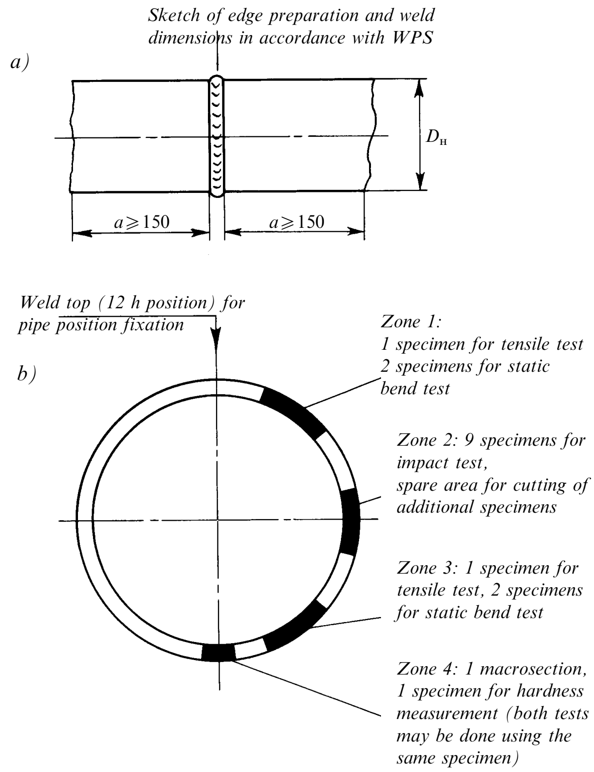


Fig. 6.3.1.4 Pipe butt joint test assembly:
a — dimensions of the test assembly;
b — plan for cutting out specimens for testing

6.3.1.5 Approval of welding procedures for pipe fillet joints, also for pipe branching nodes, shall be granted on the basis of testing the assembly, as shown in Fig. 6.3.1.5.

The outer diameter of pipes, their wall thickness and the angle between the pipe axis shall be within the limits of rated ranges for values of the above parameters in accordance with WPS to be approved, and at the same time meet the requirements concerning the range of approval (refer also to 6.3.1.1).

In accordance with particular features of edge preparation in joint to be welded and wall thickness of the pipe to be welded on, the test assembly, as shown in Fig. 6.3.1.5, may be designed in two versions:

without edge preparation — for certification of fillet welding procedures;

with edge preparation — for certification of welding procedures for pipe branching node, with full penetration.

6.3.1.5.1 When conducting tests for approval of welding procedures for pipe branching nodes (with edge preparation), one shall take into account the following directions:

.1 for manual and semi-automatic welding the axis of the main pipe shall be orientated vertically, which is sufficient for approval of all other positions of pipe axis orientation in production practice;

.2 for automatic welding, also for welding with the use of robotic units, the orientation of the main

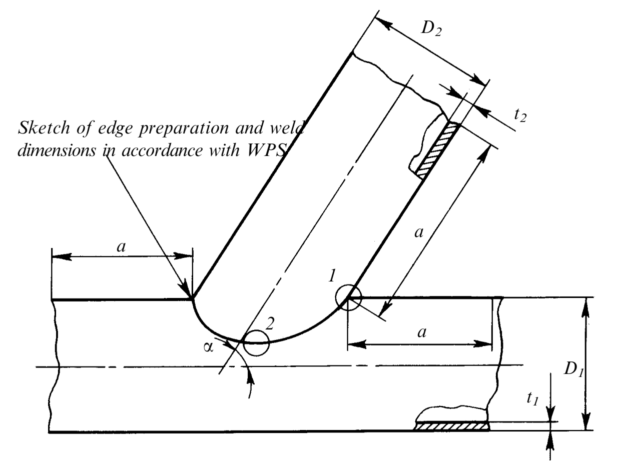


Fig. 6.3.1.5 Assembly simulating pipe branching/pipe joining node and plan for specimens cutting out.
1 and *2* are places for cutting of macrosections

pipe axis shall correspond to actual conditions of industrial welding. The range of approval with respect to main pipe axis orientation is limited by angles of $\pm 30°$ from the nominal position for certification tests;

.3 testing with the use of this type of test assembly is mandatory for:

certification of manual and semi-automatic welding procedures for welded-on pipe diameter range $150 \leqslant D_2 < 500$ mm and wall thickness $t_2 \geqslant 12$ mm, also for angels between axis of pipes to be joined $\alpha \leqslant 70°$;

certification of automatic welding procedures and also welding procedures with the use of robotic units;

.4 for other cases (not covered by 6.3.1.5.3) the Surveyor to the Register, on his own reasons, may permit an approval procedure without additional tests of the above test assembly (refer to Fig. 6.3.1.5) by expanding the range of approval of test results on pipe butt-welded joints (if the latter were conducted).

6.3.1.5.2 When conducting tests for approval of welding procedures for joining of pipes by fillet welds without edge preparation, one shall be guided with the following directions:

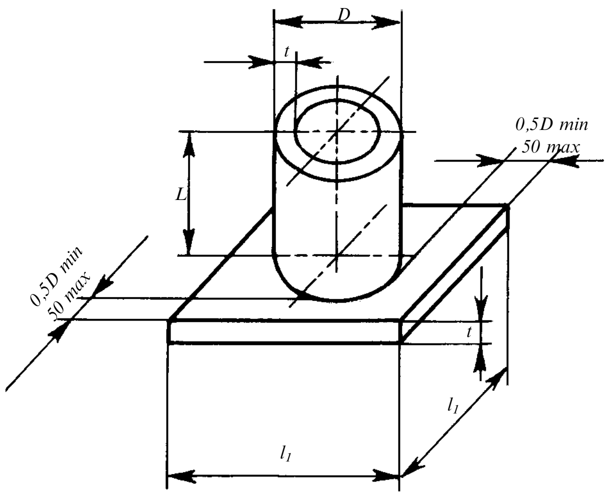
.1 for manual and semi-automatic welding procedures use of the test assembly simulating a branching node is necessary, as a rule, in cases when the technological procedures in question cannot be approved without additional tests on the basis of requirements for the range of approval by the results of testing of butt-welded pipe joints (such tests either were not conducted, or the results do not fully comply with all the requirements for range of approval for certification of fillet welding procedures);

.2 use of the test assembly is mandatory for approval of automatic welding procedures with the use of robotic units;

.3 use of the test assembly is necessary in case of application of welding procedures ensuring complete root penetration, which is taken into account in the design thickness of the fillet weld;

.4 use of the test assembly is mandatory for certification of welding procedures suitable for welding in downward direction (for pipes — in direction from 12 h to 6 h).

N o t e . By agreement with the Surveyor to the Register, it is permissible to carry out certification of pipe fillet welding procedures without edge preparation using simplified test assemblies, such as shown in Fig. 6.3.1.5.2.4, if the latter correspond in configuration to the actual welded joints. The dimensions of the test assemblies shall be agreed upon additionally with the Surveyor to the Register.



Welding procedure	Test assembly dimensions, mm	
	D	*L*
MW, SA, A[1]	⩽25 25 < *D* ⩽ 150 > 150	⩾75 ⩾125 ⩾150

[1] The size of test assembly shall be sufficient for stable operation of the equipment.

Fig. 6.3.1.5.2.4 Test assembly simulating pipe joining with fillet weld

6.3.2 Requirements to manufacture of welded joint test assemblies.

6.3.2.1 General requirements to program and scope of testing.

6.3.2.1.1 The program of testing for approval of welding procedures shall include forms, filled by the manufacturer, of WPS for all technological processes to be approved by the Register. When drafting the scope of testing, one shall be guided by the directives listed below.

6.3.2.1.2 Each welding procedure to be approved by the Register shall be subjected to tests for each welding positions, in which it shall be used in production conditions. The required positions for welding of test assemblies, depending on the positions approved for welding of actual structures, are given in Table 6.6.3.2.

It is allowed to overlap positions of PA and PE welding of a single test assembly as of actual structure.

6.3.2.1.3 For joints of the same type welded by the same method in identical spatial positions the tests for technological welding procedure approval shall cover the whole range of thicknesses of the base metal and/or design thicknesses of fillet welds applied in manufacture of welded structures, taking account of the range of approval, as mentioned in 6.6.2.2.

6.3.2.1.4 For approval of manual welding procedures using coated electrodes, certification tests shall be carried out for each grade of welding consumables.

6.3.2.1.5 For approval of mechanized welding procedures with the use of welding consumables of the same strength group, but of different grades, it is permitted, by agreement with the Register, to conduct admittance tests only for materials of highest grade, allowing lower temperatures in impact tests.

6.3.2.1.6 For approval of mechanized welding procedures (excluding electrogas arc welding, electroslag welding and similar methods with high heat input), where welding consumables with identical level of requirements are employed in relation to temperature of impact tests, but of different strength groups, it is permitted, by agreement with the Register, to conduct the tests only for materials of highest strength group/grade.

6.3.2.1.7 In addition to WPS, for materials of limited weldability, the manufacturer shall submit a document to the Register confirming the validity of his choice of technological parameters and quality control measures allowing to prevent cracking of various types. In absence of such confirmation the Register may require introduction of respective technological test assemblies into the program for testing of welding procedures.

6.3.2.1.8 The test scope shall fully comply with the range of approval of welding procedures defined by particular conditions of the welded structures manufacture.

6.3.2.1.9 When defining the scope of testing for test assemblies of welded joints, one shall be guided by the directions of Table 6.4.1.1. Besides, if necessary, the Register may require expansion of the test scope (increase in the number of specimens or addition of tests of other types).

6.3.2.2 Requirements to welding technology and preparation of test assemblies.

6.3.2.2.1 Preheating is only used if it is specified in WPS for the given material. But even if the preheating is not used, the Surveyor to the Register has the right to require welding of joint test assemblies to be done with simulation of temperature conditions corresponding to the minimum ambient air temperature, at which welding jobs are permitted in accordance with the WPS.

6.3.2.2.2 One shall meet the WPS requirements, if any, with respect to interbead (interrun) temperature. If WPS does not specify measures in control of this parameter, the temperature in welding of test assemblies shall be kept within limits normally observed in practice. The actual data of interrun temperature measurements are entered into the specification of welded joint tests.

N o t e. In case of deviation of the test assembly dimensions from values required by 6.3.1 one shall take into account the change in heat removal conditions to meet the requirements with respect to interrun temperature, as stated above.

6.3.2.2.3 The welding conditions parameters shall comply with the WPS requirements. Besides, the welding of test assemblies shall be carried out in the most unfavourable environment, at maximum values of welding current and heat input (in cases, when it is necessary to meet the requirements concerning the impact energy). Non-observance of this test condition requires additional validation and, if this is not available or not correct, the Register has the right to require from the manufacturer of welded structures limitation of weld conditions in WPS down to values actually observed in the tests and corresponding to the range of approval.

6.3.2.2.4 In welding of test assemblies it is necessary to consider all diameters of electrodes and welding wire covered by WPS; as for welding techniques 111 and 114 one shall be guided by the directions in 6.6.4.1.

6.3.2.2.5 Heat treatment of welded joints shall be performed only, if it is specified by WPS. In this case the actual conditions of the welded joint test assembly heat treatment shall be selected aiming at the most unfavourable version from the point of view of obtaining the required properties of the welded joint (refer also to requirement 6.6.3.10 concerning the range of approval).

6.3.2.2.6 Welding of test assemblies shall be performed, as far as possible, with the use of production equipment and in workshop conditions.

6.3.2.2.7 The design components of edge preparation, weld dimensions and special technological features of welding shall comply with WPS for the welding procedure to be approved with due attention to the range of approval. In the course of testing it is necessary to check the most unfavourable versions of edge preparation and weld preparation from the point of view of ensuring proper quality of welded joints.

N o t e. To observe this requirement, the Register may require expansion of the test program (for instance, welding of two assemblies instead of one for the lower and upper tolerance limit with respect to fit-up gap, wall thickness difference, root face value, etc.).

6.3.2.2.8 When testing manual and semi-automatic welding processes on tee-joint test assemblies, some additional checks are required for operations of arc-striking and rewelding of arc crater ("stop"-"start"). In this case on the effective length of the test assembly a "stop-start" operation is carried out. The place of the latter is marked, and the test assembly after completion of the welding is checked and tested in the usual manner.

6.4 REQUIREMENTS FOR TEST ASSEMBLIES, EXAMINATION TEST SPECIMENS AND TEST RESULTS ASSESMENT CRITERIA

6.4.1 General requirements for inspection.

6.4.1.1 Each test assembly after welding shall be subjected to testing in the scope of the requirements indicated in Table 6.4.1.1. In the course of welded joints' inspection, manufacture of specimens and

Table 6.4.1.1

Scope of testing for approval of welding procedures

Sec. No.	Type of welded test assembly	Type of test	Scope of test
1	Butt joint of plates and pipes — refer to Figs. 6.3.1.1 and 6.3.1.4.	Visual examination and measurements Radiographic or ultrasonic examination Examination intended to reveal surface cracking[1] Testing of transverse flat static tensile failure specimen Testing of transverse specimens for static bend[2] Testing of impact specimens[3] Determination of hardness[4] Macrosection examination	100 % of weld length 100 % of weld length 100 % of weld length 2 specimens 4 specimens 3 series of 3 specimens each; notches in weld centre, on fusion line, in heat affected zone at 2 mm distance from fusion line Required 1 transverse macrosection
2	Tee-joints on plates with edge preparation (with complete penetration), refer to Fig. 6.3.1.2. Pipe branching node with edge preparation on branch to be welded on (double tee-butt joint), refer to Fig. 6.3.1.5.	Visual examination and measurements Examination intended to reveal surface cracking[1] Ultrasonic examination [5, 6] Determination of hardness[4] Macrosection examination Additional tests[7]	100 % of weld length 100 % of weld length 100 % of weld length Required 2 transverse macrosections Refer to 6.4.1.3
3	Tee-joints on plates without edge preparation (fillet/joint), refer to Fig. 6.3.1.2. Pipe branching node without edge preparation on branch to be welded (without penetration), refer to Fig. 6.3.1.5 and 6.3.1.5.2.4.	Visual examination and measurements Examination intended to reveal surface cracking[1] Macrosection examination Determination of hardness[4] Additional tests[7]	100 % of weld length 100 % of weld length 2 transverse macrosections (3 for test assembly of ⩾1000 mm length) Required 2 — for manual and semi-automatic welding, 6 — for automatic welding Refer to 6.4.1.3
4	Cruciform joint on plates with edge preparation and without preparation, refer to Fig. 6.3.1.3.	Visual examination and measurements Examination intended to reveal surface cracking[1] Ultrasonic inspection (only for joints with edge preparation)[5, 8] Testing of transverse specimens for static tension Macrosection examination Determination of hardness[4] Additional tests[7]	100 % of weld length 100 % of weld length 100 % of welded joint length 3 specimens for test assembly ⩾350 mm length 6 specimens for test assembly ⩾1000 mm length 2 transverse macrosections Required Refer to 6.4.1.3

[1] For magnetic materials magnetic particle examination or dye penetrant examination is used, for non-magnetic materials — dye penetrant examination only.

[2] At base metal thicknesses $t < 12$ mm subjected to testing are two specimens for weld root tensioning and two specimens for weld top tensioning. At thicknesses $t \geqslant 12$ mm four specimens are tested for side-bending.

[3] The impact tests are necessary when this is required by the Register rules or by specifications for base metal approved by the Register. The tests are not carried out for at welded assembly metal thicknesses $t < 6$ mm, as they do not allow to produce specimens of standard size. All other requirements — according to 6.4.5.

[4] Determination of hardness is not required:
for hull structural steels of normal strength, also for other steels of group 1 with $R_m \leqslant 420$ N/mm^2 and $R_e \leqslant 275$ N/mm^2;
for austenitic stainless steels of group 9.

[5] Ultrasonic examination is used only for steels of groups 1, 2, 3 and 4 (refer to Table 6.2.2.2) at wall thicknesses of welded-on pipe $t \geqslant 12$ mm.

[6] Pipe with outer diameter ⩽50 mm do not require ultrasonic examination. If there is no technical possibility for ultrasonic examination of pipes with outer diameter >50 mm, radiographic examination on the maximum length of the weld shall be conducted instead.

[7] In cases when the welding process according to WPS is not subjected to approval testing by other methods, additional tests to check the mechanical properties (mechanical tests) shall be conducted on a butt-welded joint test assembly with identical edge preparation.

[8] If welded joints' inspection in production conditions requires ultrasonic examination of base metal in through-thickness direction to reveal possible laminar ruptures, the same requirement applies to inspection of cruciform test assemblies.

estimation of test results, one shall be guided with the directives given below.

6.4.1.2 The results of non-destructive testing of welded test assembly quality in all methods shall meet the relevant requirements of technical documentation approved by the Register for acceptance of a particular type of product, for which the approval of technological procedure is requested. In this case general requirements listed in Section 3 shall be observed concerning conduction of tests and estimation of test results.

6.4.1.3 If the tee-joint test assembly welding is the only type of testing conducted for certification of the given welding procedures, some additional tests shall be carried out (refer also to Table 6.4.1.1) in the following scope:

determination of deposited metal properties at certification of welding processes for tee joints without edge preparation using fillet welds. This type of test is mandatory in cases when the welding consumables employed have no Certificate of Approval for Welding Consumables issued by the Register (in other cases conduction of such tests may be specified by a special requirement of the Register);

determination of butt-welded joint properties at certification of welding procedures for tee joints with edge preparation and proper penetration. Welding of the butt joint shall be carried out under conditions as close as possible in the range of approval to welding of the tee-joint test assembly: in spatial position, welding conditions, groove angle, etc.

6.4.1.4 If for welding of butt joint assemblies welding consumables were used, which have no Certificate of Approval for Welding Consumables, some tensile test specimens shall be additionally tested in accordance with 6.4.2.2.

6.4.2 Tensile testing of specimens.

6.4.2.1 Manufactured from plate and pipe butt joint test assemblies and tested accordingly shall be two each flat transverse tensile test specimens meeting the requirements of 4.2.3.2.2 and/or 2.2.2.3, Part XIII "Materials". The value of ultimate tensile strength at these tests shall not be lower than the values specified in Table 4.2.1.2-2 for steels of normal and higher strength or in Table 4.6.2 for high-strength steels. In other cases the value of ultimate tensile strength at testing shall not be lower than the minimum values specified in Part XIII "Materials" and recognized by the Register, as national standards for respective base metals, taking into account the metal thickness.

6.4.2.2 If for welding of test assemblies welding consumables were used, which have no Certificate of Approval for Welding Consumables, one or two longitudinal cylindrical tensile test specimens with 10 mm diameter of effective part shall be additionally manufactured and tested in accordance with 2.2.2.3, Part XIII "Materials". By agreement with the Register the following version of specimens preparation for testing are acceptable:

cutting from butt-joint test assemblies, if the dimensions of the specimen effective part are fit for weld cross-section;

cutting from an additionally manufactured deposited metal test assembly meeting the requirements of Section 4 for relevant welding consumables and welding techniques.

N o t e. When the specimens are cut from the butt-welded joint test assembly, proportional cylindrical specimens with 6 mm diameter of effective part may be used, if the effective part of 10 mm diameter does not fit the weld cross-section.

6.4.2.3 Cut from the cruciform joint test assembly and then tested shall be 3 or 6 (depending on the welding technique) transverse flat fracture specimens for tensile tests. The dimensions and plan of specimens cutting-out shall be in conformity with Fig. 6.4.2.3.

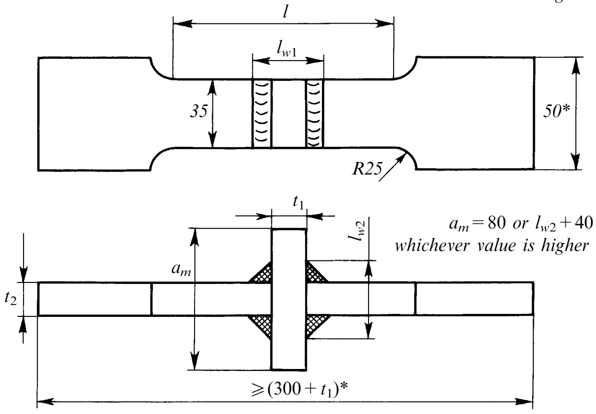


Fig. 6.4.2.3 Transverse specimen for tensile test cut out from the cruciform test assembly

N o t e. Dimensions marked with symbol * may change depending on the clamp size of the test machine.

The tensile tests of transverse specimens are carried out to define the following parameters of welded joint:

actual value of strength index Z_s of weld metal in a joint without edge preparation;

equality of strength of weld metal and base metal in a joint with edge preparation.

6.4.2.3.1 Estimation of test results for joints without edge preparation.

Index of shear strength of fillet weld metal is calculated using the formula

$$Z_s = F_p / S_B b \quad (6.4.2.3.1)$$

where F_p is breaking load, N;
$S_B = S_{1/2}$ or $S_{3/4}$ (where $S_{1/2} = a_1 + a_2$, $S_{3/4} = a_3 + a_4$, refer to Fig. 6.4.7.2) shalltal thickness of fillet welds in the place of welded joint fracture (along welds 1 and 2, or 3 and 4), mm;
b is length of weld corresponding to the width of specimen, mm.

The test results are considered satisfactory, if:

$Z_s \geqslant 0{,}88 R_m$ for rolled steel products

$Z_s \geqslant 0{,}60 R_m$ for rolled aluminium alloy products,

where R_m is the minimum value of ultimate tensile strength of deposited metal for welding consumables employed in welding in conformity with the requirements of the rules or of technical documentation approved by the Register, N/mm^2.

6.4.2.3.2 Estimation of test results for joints with edge preparation.

The test results are considered satisfactory, if the weld fracture occurred within the base metal. In this case the actual value of ultimate tensile strength shall not be lower than the minimum value established for the base metal of the test assembly by the requirements of Part XIII "Materials" or by technical documentation approved by the Register.

6.4.3 Testing of static bend specimens.

The specimens for static bend tests shall be manufactured in accordance with Fig. 2.2.5.1, Part XIII "Materials". The top and bottom surfaces of the weld shall be finished by dressing or machining to make them flush with the surface of base metal. The specimen edges on the tension side may be rounded off to a radius not exceeding 2 mm.

When the testing procedure consists in twisting the specimen over the mandrel, the length of the specimen may exceed $11a_m$.

When testing transverse specimens for bending with weld surface and weld root in tension, the specimen dimensions shall be:

$a_m = t$, i.e. thickness of metal plates of the butt-welded test assembly;

$b_m = 30$ mm.

If the test assembly plate thickness exceeds 25 mm, it is permitted to reduce specimen thickness a_m to 25 mm by machining on the side of compression zone (surface).

When testing transverse specimens for side bending, the specimen dimensions shall be:

$a_m = 10$ mm;

$b_m = t$, i.e. thickness of metal plates of the butt-welded test assembly.

In the last case, when plate thickness $t \geqslant 40$ mm, the specimen may be divided into two parts of width $b_m \geqslant 20$ mm.

Ratio of the mandrel diameter to the specimen thickness (D/t) at testing shall be increased by 1,0 relative to the values, prescribed in Section 4 for approval of the respective welding consumables. Tests shall be carried out up to reaching the bending angle of 180°. The specimen surface after tests shall be free from defects of a size more than 3 mm in any direction. Defects of the larger size at the specimen edges shall be investigated and assessed individually.

When testing dissimilar welded joints, the tests of transverse bending specimens are replaced, by agreement with the Register, by testing longitudinal specimens in the same quantity and with tension zone orientation (weld root and weld top). In this case the dimensions of specimens and test procedure shall be agreed additionally with the Register.

6.4.4 Testing of static fracture specimens.

The continuity of weld metal in tee-joints executed with single-pass fillet welding shall be checked by testing for static fracture with extension of the weld root from two (for manual and semi-automatic techniques) to six specimens (for automatic welding).

Used for testing are specimens of 100 to 120 mm length with preliminarily removed fillet weld on one side of the tee-joint. To have the fillet weld fractured in the critical cross-section, a longitudinal notch may be done on the weld surface, or scores of about 5 mm depth on the butt face surfaces of the specimen.

The specimen fracture surface shall be inspected for presence of impermissible interned defects; the value of fusion in the weld root shall also be checked. Some minor internal defects, like pores or slag inclusions, on the fracture surface are permissible, if their size does not exceed 0,2 Z or 2,0 mm, whichever is lower (where Z is the fillet weld leg), and their relative area does not exceed 1 per cent of the inspected weld fracture cross-section (in places of local clusters of defects their total area may be increased to 3 per cent, provided, their linear dimensions are limited to $\leqslant 0{,}008Z$).

6.4.5 Testing of impact specimens.

6.4.5.1 The dimensions of specimens, as well as test procedure and estimation of results shall comply with the requirements of 2.2.3, Part XIII "Materials".

The number of series consisting of three specimens each, as well as location of notches on specimens of each series shall comply with Table 6.4.1.1, Fig. 6.4.5.1-1 or Fig. 6.4.5.1-2 depending on the thickness of the sample metal and heat input with due consideration of the additional requirements mentioned below.

6.4.5.2 For welded joints of the normal and higher strength steels, for which designation of the consumable quality grades corresponds to the instructions stated in Table 2.2.4, the requirements to the impact test results shall comply with the requirements of Table 6.4.5.2.

For the joints between steels of different grades, the test specimens shall be selected from the joint side of the steel with the lower category/steel grade per the impact strength. Temperature and the results of the impact test shall comply with the requirements to this lower category/grade of steel.

In case, when for welding of samples is used more than one welding technique or welding consumable, impact specimens shall be selected from each zone of

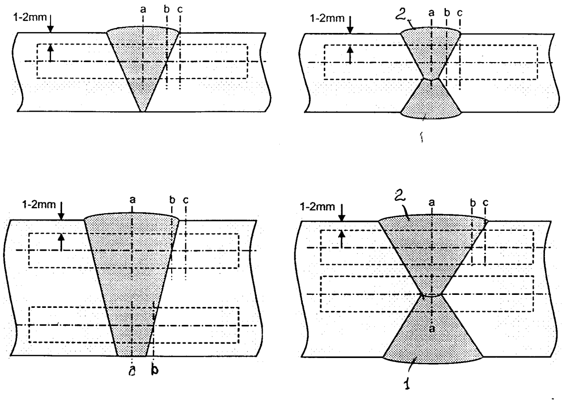


Fig. 6.4.5.1-1 The plan for cutting out and notching of specimens for impact tests at approval of the welding procedure with a heat input up to 50 kJ/cm inclusive:
1 — weld side welded the first;
2 — weld side welded the last;
a — notch in the weld center (WM);
b — notch on fusion line (FL);
c — notch in heat affected zone (Z) at 2 mm distance from fusion line

N o t e . At approval of single run one-side welding from the samples with thickness more than 20 mm the additional set of specimens from the root part of the weld shall be prepared with a notch in the weld center *a*.

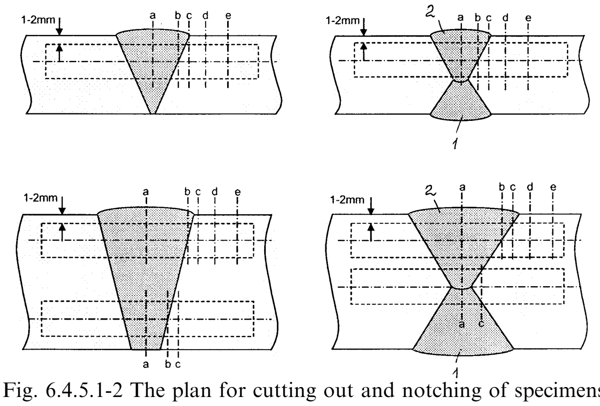


Fig. 6.4.5.1-2 The plan for cutting out and notching of specimens for impact tests at approval of the welding procedure with a heat input more than 50 kJ/m:
1 — weld side welded the first;
2 — weld side welded the last;
a — notch in the weld center (WM);
b — notch on fusion line (FL);
c — notch in heat affected zone (Z) at 2 mm distance from fusion line;
d — notch in heat affected zone (Z) at 5 mm distance from fusion line;
e — notch in heat affected zone (Z) at 10 mm distance from fusion line

N o t e . At approval of single run one-side welding from the samples with thickness more than 20 mm the additional three sets of specimens from the root part of the weld shall be prepared with a notch on the lines *a*, *b* and *c*.

T a b l e 6.4.5.2

Requirements to the impact tests for butt welded joints of the normal and higher strength steels ($t \leqslant 50$ mm)[1,2]

Welded steel grade	Tests temperature, °C	Impact energy *KV*, J, min		
		Electrodes and combinations for semi-automatic welding		Combinations for automatic welding
		Lower horizontal and overhead position	Vertical position	
(3) (3), D E A32, A36 D32, D36 E32, E36 F32, F36	20 0 –20 20 0 –20 –40	47	34	34
A40 D40 E40 F40	20 0 –20 –40		39	39

N o t e s : 1. In case the thickness of the rolled product is more than 50 mm, the requirements to the impact tests are assigned taking into account Table 3.2.3, Table 3.5.2.3 of Part XIII "Materials" and are subject to additional agreement with the Register.

2. The requirements of the Table are applicable to the samples with weld perpendicular to the direction of the rolled product (i.e. values of *KVL* are determined for metal of fusion line and 3TB).

3. For rolled steel of normal strength of grades A and B average value of impact energy for metal of fusion line and 3TB shall not be less than 27 J.

welding joint, in which the above welding technique or welding consumables have been used. The said requirement is not applicable for welding technique or welding consumables exclusively used for the first run or the root run of the weld.

Test on partial size specimens shall be carried out in compliance with the instructions of 2.2.3.1, Part XIII "Materials". In special cases, when designation of the consumables quality grade does not comply with the instructions of Table 2.2.4 (for example, for MODU and FOP structures), the results and temperature of the specimen impact tests shall comply with the requirements of Section 4 for respective consumable quality grade, relative to the weld metal and fusion line, while for the metal of heat affected zone it shall comply with the requirements 3.2 and 3.5, Part XIII "Materials" for steel of respective grade considering the direction of rolled product (refer to 6.3.1.1) at specimen welding. At that, for steel welded joints of grade F, the Register may demand test of the additional specimen series, having notch located on the heat affected zone at a distance of 5 mm from the fusion line, regardless of the heat input of welding.

6.4.5.3 For the welded joints of high strength steels, complying with the requirements of 3.13, Part XIII "Materials", the results and temperature of impact tests shall correspond to the requirements of Table 4.6.1 for the respective consumable quality grade with regard to the weld metal and fusion line, and for the metal of heat affected zone shall comply with the requirements of Table 3.13.3-1, Part XIII "Materials" for steel of respective grade, considering a direction of the rolled product (refer to 6.3.1.1) at specimen welding.

At that, the Register may demand tests of additional specimen series:

with a notch on at a distance of 5 mm from the fusion line regardless of heat input of welding;

selected from the thickness center in the same quantities as from the surface with a thickness of rolled product more than 40 mm.

6.4.5.4 For steel castings and forgings the impact tests for the fusion line and heat affected zone shall be carried our in compliance with the requirements to the base metal of Sections 3.7 and 3.8, Part XIII "Materials". Tests for the weld metal are conducted relative to the consumable quality grade, prescribed in the documentation, approved by the Register for a particular item or a structure.

6.4.5.5 For corrosion resistant steels, impact tests at approval of welding processes shall be conducted on agreement with Register, in case this type of testing is provided for the base metal by the Rules or the documentation approved by the Register for a particular product (for example, for propeller castings of corrosion resistant steels in compliance with the requirements of 3.12, Part XIII "Materials"). If not agreed with the Register otherwise, the temperature and evaluation criteria for the impact test results comply with the values specified for the base metal.

6.4.6 Requirements concerning hardness measurements.

Determination of welded joint metal hardness (*HV*5 or *HV*10) shall be carried out on transverse macrosections in conformity with indications of Figs. 6.4.6-1 to 6.4.6-5. In so doing, the hardness of each welded joint zone (weld, heat affected zone, base metal) shall be determined on the basis of at least three measurements taken on both sides of the weld axial line. In the heat affected zone the first measurement point shall be located as close as possible to the fusion line. In individual cases the Register may require the hardness measurement

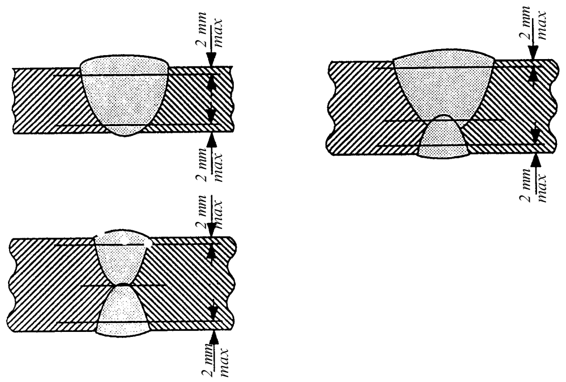


Fig. 6.4.6-1 Arrangement of measurement lines in butt joints

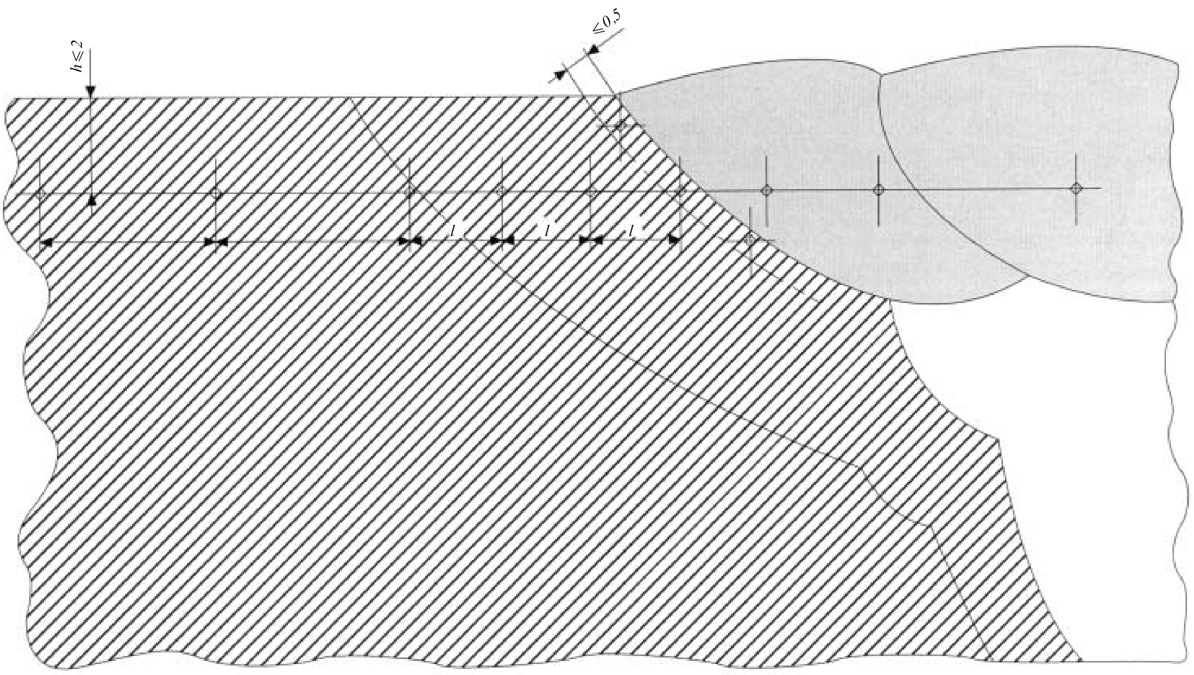


Fig. 6.4.6-2 Arrangement of measurement points for determination of hardness in the near-weld joint and butt-welded joint: l = 0,7 mm for *HV*5; t = 1,0 mm for *HV*10.

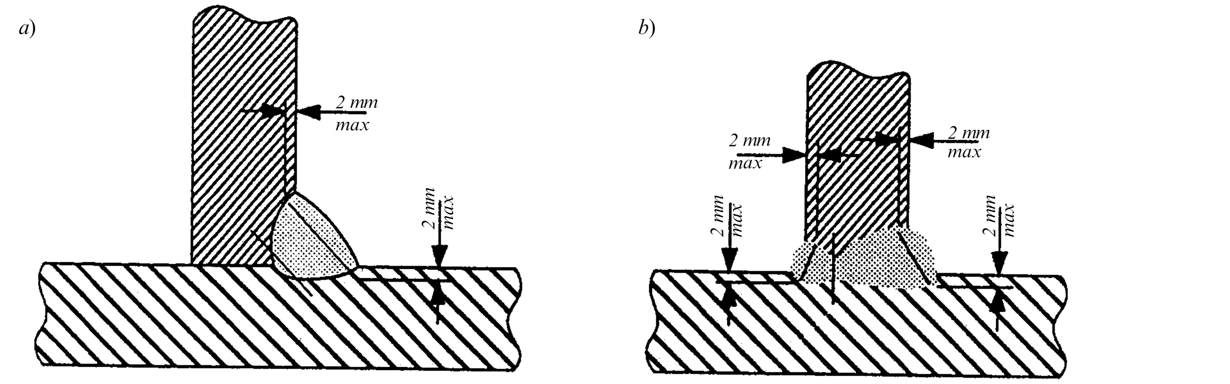


Fig. 6.4.6-3 Arrangement of hardness measurement lines for tee-joint test assemblies:
a — test assembly welded with single-run fillet weld without edge preparation; *b* — test assembly of the joint welded with full penetration.

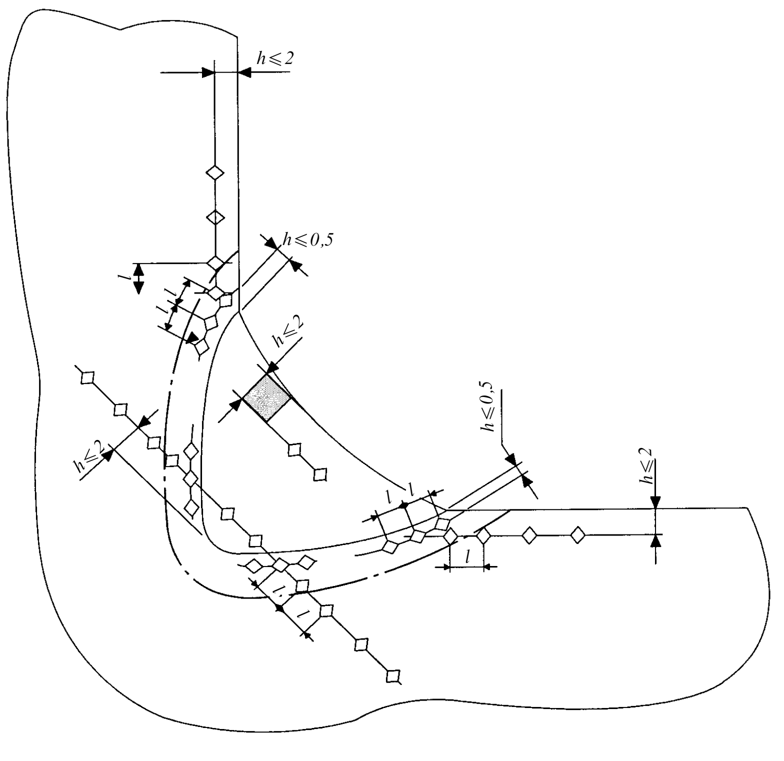


Fig. 6.4.6-4 Arrangement of hardness measurement points in the near-weld zone and in the weld of tee-joints welded with single-run fillet weld without edge preparation (limitations in *l* in accordance with Fig. 6.4.6-2)

points in the heat affected zone to be located parallel to the fusion line (in cases, when the number of points of hardness measurement does not meet the requirement stated above). The distance between hardness measurement points shall be at least 0,7 mm for scale *HV*5 and 1,0 mm for scale *HV*10.

Determination of hardness is a mandatory test type for certification of welding procedures on hull structural steels with a yield stress $R_{eH} \geqslant 355$ P, as well as high- strength steels of all the grades.

The requirements for determination of hardness shall be fulfilled in the following cases:

for welded joints of piping made of steels with $C_{eq} \geqslant 0,41$ %;

for welded joints of forgings and castings of steels of group 1 (refer to Table 6.2.2.2) with the carbon content $C \geqslant 0,18$ % and thickness of welded elements $t > 40$ mm;

for welded joints of steels of groups 2, 3, 4, 5, 6, 7 and 8 (refer to Table 6.2.2.2).

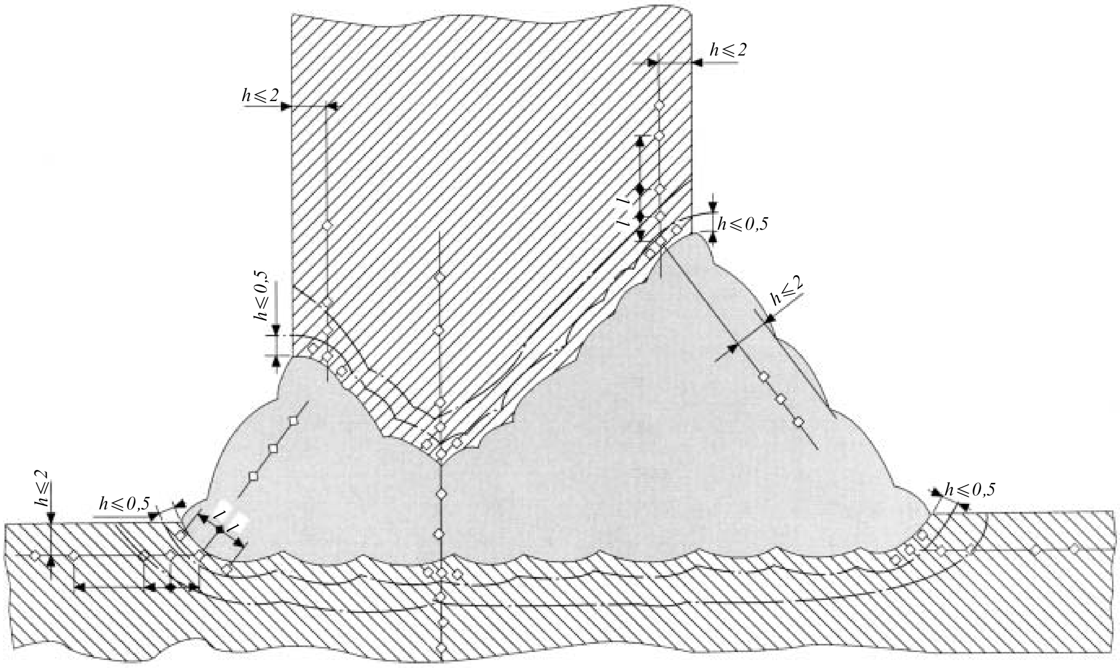


Fig. 6.4.6-5 Arrangement of hardness measurement points in the near-weld zone and in the weld of tee-joints welded with full penetration of weld root (limitations in *l* in accordance with Fig. 6.4.6-2)

Results of determination of hardness shall meet the following requirements:

for hull structures of higher and high strength with a yield stress $R_{eH} \leqslant 420$ P the maximum hardness values shall not exceed 350V10;

for high-strength steels with a yield stress $420 \text{ P} < R_{eH} \leqslant 690$ P complying with the requirements of 3.13, Part XIII "Materials", maximum hardness values shall not exceed 420V10;

in other cases it is recommended to follow the directives of Table 6.4.6.

6.4.7 Requirements for preparation and examination of macrosections.

6.4.7.1 Macrosections taken from test assembly of butt-joined plates and pipes.

The tested transverse macrosections cut out from butt-welded joints shall be ground and etched on one side in such a way, that the weld and heat affected zone are clearly distinguished. The macrosections shall not contain impermissible defects, meaning the defects in weld area including 10 mm of base metal outside the heat affected zones.

Analysis of welded joint microstructure is carried out by a special direction of the Register, and the requirements to test procedure and estimation of results are subject to agreement in each individual case.

6.4.7.2 Macrosections taken from tee-joint and cruciform joint test assemblies.

Cut and prepared from a tee-joint test assembly shall be two or three macrosections in accordance with the directions of 6.4.7.1. For manual and semi-automatic welding one macrosection shall be taken in a spot marked in accordance with the "stop-start" operation on the checked length of the test assembly.

Table 6.4.6

Limitations on maximum values of welded joints hardness *HV*10

Group of steels	Single-run butt and fillet welds		Multi-run butt and fillet welds	
	without heat treatment	with heat treatment	without heat treatment	with heat treatment
1[1]	380	320	350	320
2	400	350	370	350
3[2]	450	Subject to special consideration by the Register	420	Subject to special consideration by the Register
4, 5	Subject to special consideration by the Register	320	Subject to special consideration by the Register	320
6	Ditto	350		350
7 with Ni ≤ 4 %	" — "	300	Ditto	300
7 with Ni > 4 %	" — "	Subject to special consideration by the Register	320 400	Subject to special consideration by the Register

[1] If determination of hardness is required.
[2] Values for steels with $R_e^{min} \geqslant (885$ N/mm^2 shall be agreed upon separately.

The macrosections shall be examined for inspection of the shape and geometrical dimensions of the weld, degree of penetration, absence of impermissible undercuts, also to reveal impermissible internal defects in the weld and near weld zone.

At that, under consideration are the defects in the weld area, including 10 mm of the base metal outside the heat affected zone.

Inspection of transverse macrosections taken from a cruciform (double-tee) joint is carried out in the same way, as with butt-joint test assembly. Subject to measurement in sections are thicknesses of fillet welds, as shown in Fig. 6.4.7.2.

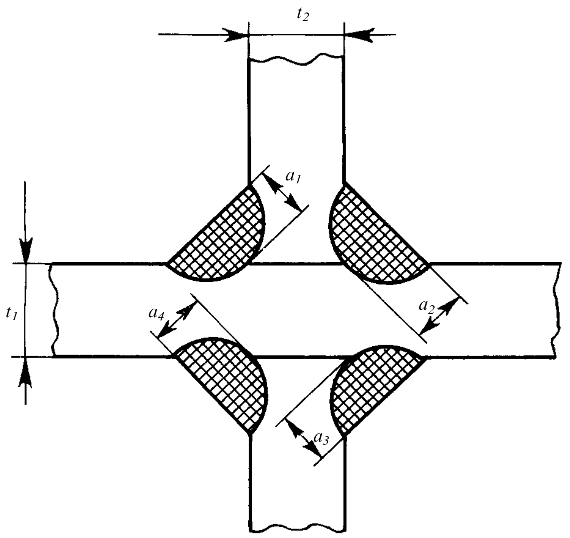


Fig. 6.4.7.2 Arrangement of measurements of fillet weld design thickness on macrosections taken from cruciform test assemblies

6.5 REQUIREMENTS TO REPEATED TESTS

6.5.1 If the results of visual examination or of non-destructive testing are not satisfactory, an additional test assembly shall be manufactured for repeated testing. If the additional test assembly is rejected on the same grounds, as the first one, the technological procedure to be certified is considered unsuitable for application in the industry, unless changes are made permitting to ensure the required quality of welded joints.

6.5.2 If the results of testing of tensile or bend specimens do not meet the requirements by reasons not connected with any welding defects in the specimens, it is necessary to carry out a repeated test with double quantity of specimens. The specimens for repeated testing are taken from the same test assembly, if a sufficient reserve of metal is available, or from a new, additionally prepared test assembly.

6.5.3 If the results of testing of impact specimens do not meet the requirements by reasons not connected with any defects in the specimens, it is necessary to carry out repeated testing of one additional series consisting of three specimens with the results assessment according to 4.2.3.3.4. The specimens for additional tests are taken in accordance with the requirements of 6.5.2.

6.5.4 If the test assembly is rejected on the basis of hardness determination results, the repeated test shall be carried out with double quantity of specimens. The specimens for additional tests are taken in accordance with the requirements of 6.5.2.

6.5.5 If the specimen fails to pass the test only due to unsatisfactory weld geometry or presence of surface defects, including crater cracks, each rejected specimen shall be replaced for additional testing with two newly prepared specimens. The specimens for additional tests shall be taken in accordance with the requirements of 6.5.2.

6.5.6 If the specimen fails to pass the test due to presence of slag or gas inclusions, an additional specimen shall be prepared for repeated testing. The specimen is cut out, as specified in 6.5.2.

6.5.7 The results of repeated tests are considered final and in case of unsatisfactory results in these tests, if only on a single specimen, the welding procedure, in conformity with the requirements of 6.5.2 to 6.5.6, is considered unsuitable for application, unless changes are made permitting to ensure the required quality of welded joint metal.

6.6 RANGE OF APPROVAL OF WELDING PROCEDURE DEFINED BY RESULTS OF TESTS

6.6.1 General.

When assigning the range of approval for the welding procedure all the requirements listed below shall be observed. Modifications introduced into WPS by the manufacturer and reaching beyond the limits of the range of approval require conduction of new tests.

The approval of welding procedure by the Register received by the shipyard or manufacturer of welded structures is valid for welding operations in all shops of the above shipyard/works, provided the WPS requirements concerning this technological procedure are properly observed.

6.6.2 Requirements to range of approval related to base metal.

6.6.2.1 Properties and chemical composition of base metal.

6.6.2.1.1 Hull structural steels of normal and higher strength.

When assigning the range of approval of the welding procedure with a heat input not more than 50 kJ/cm, one shall be guided by the following provisions:

.1 for every strength level of the base metal, the range of approval of the welding procedure is applied to steel with the same or lower grade properties on impact energy;

.2 for every grade of the base metal on impact energy, the range of approval of the welding procedure is applied to steel with the same or two strength levels lower.

For welding procedures with a heat input more than 50 kJ/cm (e.g., two-run technique, electrogas arc and electroslug welding) the range of approval per the results of tests is extended to cover the steels with the same grade on impact energy and with the same and lower strength level.

In case, when for the manufacture of structures steel is used with condition of supply another than for the steel used at the approval tests, the Register may demand to conduct additional tests.

6.6.2.1.2 High-strength steels.

When assigning the range of approval of the welding procedure for the high-strength steels complying with the requirements 3.13, Part XIII "Materials", one shall be guided by the following provisions:

.1 for every level of the base metal strength the range of approval of the welding procedure is applied to steel with the same or lower grade properties on impact energy;

.2 for every grade of the base metal on impact energy the range of approval of the welding procedure is applied to steel with the same or one strength level lower;

.3 tests for approval, conducted with reference to the steel supplied in thermally improved condition, (tempering with stress relief) are not extended to cover the steel in a condition after thermal mechanical treatment and vice versa.

6.6.2.1.3 Steel forgings.

The range of approval of the welding procedure per the test results of the hull structural steel forgings of carbon and carbon manganese steel, complying with the appropriate requirements of 3.7, Part XIII "Materials", shall be assigned in compliance with the following requirements:

.1 range of approval is extended to cover the forgings with similar or lower strength level;

.2 range of approval per the test results, conducted with reference to the forgings supplied in a condition after temper hardening, shall not be extended to cover the forgings in another condition of supply and vice versa.

6.6.2.1.4 Steel castings.

The range of approval of welding procedure per the test results of hull structural steel castings of carbon and carbon manganese steel, complying with respective requirements of 3.8, Part XIII "Materials", shall be assigned in compliance with the following requirements:

.1 range of approval is extended to cover the castings with similar or lower strength level;

.2 range of approval per the test results, conducted with reference to the forgings supplied in a condition after temper hardening, shall not be extended to cover the castings in another condition of supply and vice versa.

6.6.2.1.5 In other cases one shall be guided by the directives given below, which are identical with the recommendations of EN 288-3.

Depending on chemical composition, properties and type of heat treatment, for unification of requirements to the range of approval for welding procedures the steels, in accordance with EN 288-3, are subdivided into groups listed in Table 6.2.2.2. The tests carried out with the use of a certain brand belonging to one of these groups in accordance with Table 6.2.2.2 obtain the range of approval of the given welding procedure:

for other steels of the same group having lower content of alloying elements;

for other steels of the same group with lower guaranteed strength properties.

At the same time the range of approval of the welding procedure shall be additionally limited by the range of approval/application of a particular welding consumable used in the test for welding of steels of other brands within the same group (or a lower group).

6.6.2.1.6 As a rule, the range of approval of welding procedure for steels of group 2 is extended to cover also steels of group 1.

6.6.2.1.7 A separate approval procedure is required for each brand of steel or for their combinations not covered by classification system according to Table 6.2.2.2.

6.6.2.1.8 If a particular brand of steel may be so classified that it belongs to two groups, it shall be included into the lower group.

6.6.2.1.9 For dissimilar welded joints the range of approval of welding procedures is established in accordance with the requirements of Table 6.6.2.1.9.

Table 6.6.2.1.9

Range of approval for dissimilar welded joints

Groups of base metal (for designations refer to Table 6.3.2.2)	
When conducting tests	Range of approval
2	Welded to group 1
3	Welded to group 1 or 2
8 (welded to group 2)	Welded to group 1 or 2
8 (welded to group 3)	Welded to group 1, or 2, or 3
9 (welded to group 2 or 3)	Welded to group 1, or 2, or 3

If the dissimilar joint does not fit the classification system of Table 6.6.2.1.6, the range of approval and test program in each case shall be subject of a special consideration by the Register.

6.6.2.2 Thickness of base metal and diameter of pipes.

6.6.2.2.1 Determination of base metal nominal thickness for various types of welded joints shall be performed in conformity with the directives of Table 6.6.2.2.1.

6.6.2.2.2 The range of approval with respect to base metal thickness shall be assigned in the course of welding procedure approval depending on thickness t of test assembly metal at certification testing and depending on welding technique, as specified in Table 6.6.2.2.2.

6.6.2.2.3 Approval of welding procedure for the tee and fillet joints prepared by the single-run fillet weld without edge preparation is extended to cover the welded joints with measured thickness of fillet welds *a* (refer to 1.7.5.1, Part II "Hull") from 0,75*a* to 1,5*a*, inclusive, provided the limitation on the measured thickness of fillet welds at the sample welding is effective for $a < 10$ mm. For welded assemblies with $a \geqslant 10$ mm, range of approval of the welding procedure is extended to cover the welded joints with measured thickness of fillet welds from 10 mm up to 1,5*a*, inclusive.

For vertical-downward single-run fillet welds, the range of approval is limited by the measured thickness of fillet welds from 0,75*a* to 1,0*a*, inclusive.

For the multi-run fillet welds, the limitations to the range of approval for value *a* are adopted similar to the requirements to the range of approval on the thickness of base metal *t* for butt joints prepared according to the multi-run technique.

Along with normalizing the range of approval per value *a* for fillet welds, there are also effective limitations on the range of approval for the thickness *t* of base metal and outer diameter of pipes *D* (refer to 6.6.2.2.4).

6.6.2.2.4 The range of approval for outer diameter of pipes or pipe branches in the branching nodes shall be assigned depending on the pipe outer diameter at certification tests in accordance with directions of Table 6.6.2.2.4.

6.6.2.2.5 When certifying technological procedures involved in welding of pipe branches in branching nodes, the range of approval in relation to angle α_1 between the axes of pipes to be joined shall be assigned depending an angle α at certification, proceeding from relationship $\alpha \leqslant \alpha_1 \leqslant 90°$.

6.6.3 General requirements to range of approval concerning welding technology.

6.6.3.1 Welding procedure and technique.

Approval of welding procedure is only valid for the welding technique and procedure employed in the certification tests.

Range of approval for a multi-run technique shall not extend to cover the single-run technique.

When the welding procedure is a combination of several techniques/procedures (for instance, automatic submerged arc welding for filling of the groove and manual welding with coated electrodes to form the weld root: 12 + 111 only for root), the range of approval is also limited by this combination of techniques, which was used in the certification testing.

N o t e. The test procedure for approval of a combination of different techniques/procedures can be arranged for either individual (for each technique), or combined testing, as it is done in approval tests for welders. For each welding technique the respective range of approval concerning the welded metal thickness shall be indicated.

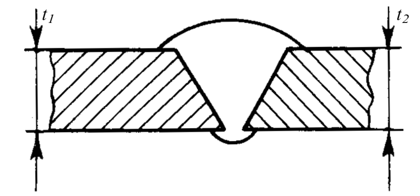
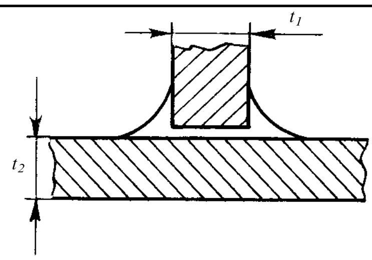
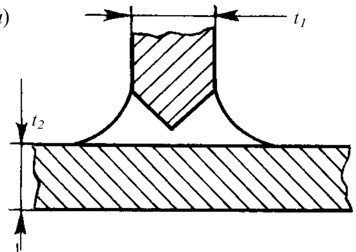
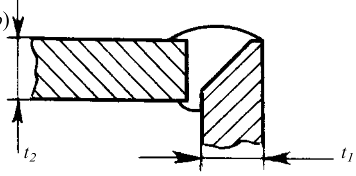
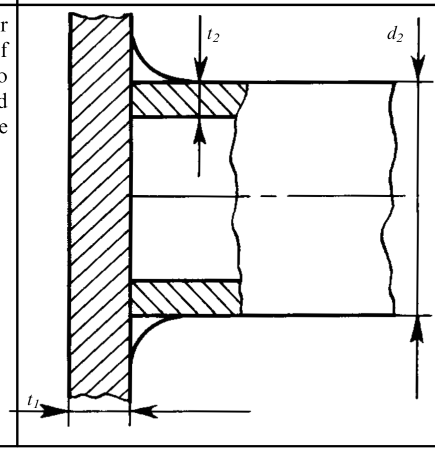
6.6.3.2 Welding positions.

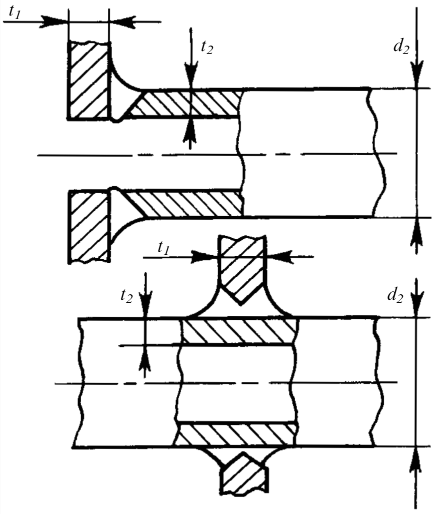
The requirements to range of approval in relation to welding spatial positions are formulated in Table 6.6.3.2. In case of certification of several spatial positions for reduction of the scope of testing it is permitted:

to perform welding of assemblies of the welded joints only in the positions of welding corresponding to the maximum and minimum values of the heat

Table 6.6.2.2.1

Determination of base metal nominal thickness

Type of joint		Nominal thickness of base metal t_p
Name	Sketch[1]	
1. Butt-weld plates and pipes		The thickness is equal to thickness of base metal of parts to be jointed, which for joints of unequal thickness corresponds to the size of the thinner part $t_p = t_1 = t_2$ at $t_1 = t_2$ $t_p = \min\{t_1 \text{ and } t_2\}$ at $t_1 =/= t_2$
2. Fillet weld/plates without edge preparation		The thicker of the parts to be joined defines the base metal nominal thickness. Beside the range of approval for thickness of parts to be joined (refer to Table 6.6.2.2.2) one shall consider the limitation in design thickness of fillet weld a in accordance with the requirements of 6.6.2.2.3: $t_p = t_1 = t_2$ at $t_1 = t_2$ $t_p = \max\{t_1 \text{ and } t_2\}$ at $t_1 =/= t_2$
3. Fillet weld/plates with edge preparation (with penetration)	*a)*  *b)* 	*a)* in tee-joints the thickness of part with edge preparation is considered the nominal thickness of base metal: $t_p = t_1$; *b)* in fillet joints (one or two parts may have edges prepared) the thickness of thinner part is considered the nominal thickness: $t_p = \min\{t_1 \text{ and } t_2\}$
4. Fillet weld for "blind" joining of pipe to pipe or to plate (with and without edge preparation)		The wall thickness of pipe to be welded on is considered the nominal thickness of base metal: $t_p = t_2$

Type of joint: Name	Type of joint: Sketch[1]	Nominal thickness of base metal t_p
5. Fillet weld for pipe-to-pipe or pipe-to plate or joint with through hole or open passage (with or without edge preparation)		The wall thickness of the main pipe or plate is considered the nominal thickness of base metal: $t_p = t_1$

[1] The shape of edge preparation is given here as an illustration, the actual edge preparation shall correspond to WPS.

Table 6.6.2.2.2

Requirements for range of approval with respect to base metal thicknesses

Name of welding procedure (welding technique)	Assembly thickness t at tests, mm[4, 5]	Range of approval with respect to thickness, mm [1,2,3,4]	Additional directions
1. Manual metal arc welding with coated electrodes:			
with basic coating	$t \leqslant 3$	from t to $2t$	
	$3 < t \leqslant 12$	from *3* to $2t$	For additional limitations refer to 2.2.4.7 and 2.2.4.3
	$12 < t \leqslant 100$	from *0,5t* to $2t$ (max 110)	
	$t > 100$	from *0,5t* to 1,5t	
with rutile coating	$t \leqslant 3$	from t to 1,5t	
	$3 < t \leqslant 12$	from *3* to 1,5t	
	$12 < t \leqslant 30$	from *0,5t* to 1,5t (max 30)	
high capacity welding	$t \leqslant 3$	from t to 1,5t	
	$3 < t \leqslant 12$	from *3* to 1,5t	
	$12 < t \leqslant 100$	from *0,5t* to 1,5t (max 110)	
2. Gas-shield welding with wire of solid cross-section:			
welding of steel	$t \leqslant 3$	from t to 1,5t	
	$3 < t \leqslant 12$	from *3* to 1,5t	
	$12 < t \leqslant 100$	from *0,5t* to 1,5t (max 110)	For aluminum and its alloys refer to Section 7
	$t > 100$	from *0,5t* to 1,2t	
welding of non-ferrous metals	$t \leqslant 3$	from t to $2t$	
	$3 < t \leqslant 12$	from *3* to $2t$	
	$12 < t \leqslant 100$	from *0,5t* to $2t$ (max 110)	
3. Flux-cored wire welding with additional gas shield:			
of basic type and fluxless	$t \leqslant 3$	from t to $2t$	
	$3 < t \leqslant 12$	from *3* to $2t$	
	$12 < t \leqslant 100$	from *0,5t* to $2t$ (max 110)	For welding with wire having non-controlled content of diffusible hydrogen and wire classified as "H" the range of approval is limited by maximum testing thickness $t > 12$ mm
	$t > 100$	from *0,5t* to 1,5t	
of rutile type	$t \leqslant 3$	from t to 1,5t	
	$3 < t \leqslant 12$	from *3* to 1,5t	
	$12 < t \leqslant 100$	from *0,5t* to 1,5t (max 110)	

Table 6.6.2.2.2 - continued

Name of welding procedure (welding technique)	Assembly thickness t at tests, mm[4, 5]	Range of approval with respect to thickness, mm [1,2,3,4]	Additional directions
4. Self-shield flux-cored wire welding without additional gas shield	$t \leqslant 3$ $3 < t \leqslant 12$ $12 < t < 30$	from t to $1{,}5t$ from 3 to $1{,}25t$ from $0{,}5t$ to $1{,}25t$ (max 30)	For metal with $t > 30$ mm the range of approval in each case is the subject of special consideration by the Register
5. Automatic submerged welding	$3 < t \leqslant 12$ $12 < t \leqslant 100$ $t > 100$	from 3 to $2t$ from $0{,}5t$ to $2t$ (max 110) from $0{,}5t$ to $1{,}5t$	—
6. Tungsten inert-gas welding: of steel of non-ferrous metals	 $t \leqslant 3$ $3 < t \leqslant 12$ $12 < t \leqslant 100$ $t > 100$ $t \leqslant 3$ $3 < t \leqslant 12$ $12 < t \leqslant 100$	 from t to $1{,}5t$ from 3 to $1{,}5t$ from $0{,}5t$ to $1{,}5t$ (max 110) from $0{,}5t$ to $1{,}2t$ from t to $2t$ from 3 to $2t$ from $0{,}5t$ to $2t$ (max 110)	For aluminum and its alloys see Section 7
7. Vertical welding with forced weld formation (electroslag and electrogas arc welding)	$10 < t \leqslant 100$	In accordance with actual thickness of assemblies: 0,9 to $1{,}1t$	Some test assemblies shall be welded with metal of minimum and maximum thickness.
8. Gas welding	$t \leqslant 8$	Up to 8, inclusive, in accordance with actual thickness of test assemblies within 0,9 to $1{,}1t$	Ditto

[1] The range of approval for assemblies prepared with the use of single-run one-side technique, as well as single-run double-side technique, is limited with thicknesses from $0{,}7t$ up to $1{,}1t$, inclusive.
[2] The range of approval for assemblies prepared vertically-downward is limited with the thicknesses from $0{,}5t$ up to $1{,}0t$, inclusive, for multi-run welds and from $0{,}7t$ up to $1{,}0t$ for single or double-run welding technique.
[3] Requirement to the range of approval for vertical-downward welding with the forced weld formation is applicable for the other welding technique with the heat input more than 50 kJ/cm.
[4] In any case, the range of approval per the maximum thickness of the base metal for any welding technique shall be limited with the thickness of the test sample t, if the measured values of hardness for any three points in the heat affected zone were within the limits of 25HV from the maximum values prescribed by the requirements of 6.4.6.
[5] The thickness of the base metal shall be determined in compliance with the directives of Table 6.6.2.2.1.

Table 6.6.2.2.4

Range of approval for outer diameter of welded pipes

Diameter D at test assemblies, mm[1,2]	Range of approval by diameters of welded pipes, mm
$D < 25$	From D to $2D$ inclusive
$25 \leqslant D < 150$	From $0{,}5D$ to $2D$, but not less than 25 mm
$150 \leqslant D < 500$	From $0{,}5D$ to $2D$, but not less than 150 mm
$D \geqslant 500$	By agreement with the Register

[1] D is as measured on the pipe outside diameter.
[2] Approval for welding of plates may also be extended to welding of pipes with $D \geqslant 500$ mm, provided the other requirements concerning the range of approval are duly met (refer to 6.3.2.1.1, 6.3.1.4, 6.6.2 and 6.6.4).

input. At that, every assembly after welding shall be checked and tested in a full scope of the requirements, according to 6.4.1.1.

6.6.3.3 Type (design particulars) of welded joint.

The range of approval by types of welded joints depending on the tests employed in the certification process shall comply with the requirements of Table 6.6.3.3.

6.6.3.4 Classes of welding consumables.

Range of approval of the welding procedures with a heat input of up to 50 kJ/cm, inclusive, based on the testing of a particular grade of the welding consumable approved by the Register, complying with 4.2 or 4.6, shall be extended also on the other grades of the welding consumables, approved by the Register, which have the same class as the tested ones, including all the additional indices, according to 4.2.1.4 and 4.2.1.8. Substitution by the shipyard or manufacturer of welded structure of one grade of the welding consumable by the other material, having the same class, requires conducting of additional tests in the following cases:

for welding procedures with a heat input exceeding 50 kJ/cm;

for welding consumables with class identification per the temperature tests for impact test 5 (−60 °C), as well as per the separate requirement of the Register 4 (−40 °C).

At that, if during the specimen welding in course of additional tests the WPS requirements are fully observed, then the extent of testing at substitution of one grade of welding consumables for another one with similar class may be, if agreed with the Register, limited by determi-nation of the impact energy for the weld metal and fusion line.

Table 6.6.3.2

Range of approval of welding procedures in relation to spatial positions for different types of welded joints

Type of weld in welding of test assembly	Weld position[1] in welding of test assembly	Spatial welding positions and types of joints to be approved					
		Plates			Pipes		
		Butt weld	Fillet weld		Butt weld	Fillet weld	
			with edge preparation[2]	without edge preparation		with edge preparation	without edge preparation
Butt weld/ plates[4] Test assembly as shown in Fig. 6.3.1.1 (without edge preparation)	PA	PA	PA, PB	—	PA[3]	PB fixed[3,5]	—
	PC	PC	PB	—	PC[3]	PB fixed, PB turning[3,5]	—
	PG	PG	PG	—		—	—
	PF	PF	PF	—		—	—
	PE	PE	PD	—		—	—
Fillet weld/ plates[4]. Test assembly as shown in Fig. 6.3.1.2 — without edge preparation	PA	—	—	PA	—	—	—
	PB	—	—	PB	—	—	PB[5]
	PG	—	—	PG	—	—	—
	PF	—	—	PF	—	—	—
	PD	—	—	PD	—	—	—
Fillet weld/ plates[4]. Test assembly as shown in Fig. 6.3.1.2 — with edge preparation	PA	—	PA	—	—	PB turning[3,5]	—
	PB	—	PB	—	—	PB fixed, PB turning[3,5]	—
	PG	—	PG	—	—	—	—
	PF	—	PF	—	—	—	—
	PD	—	PD	—	—	—	—
Butt weld, pipes[4]. Test assembly as shown in Fig. 6.3.1.4.	PA	PA	—	—	PA	PB turning[3,5]	PB turning[3,5]
	PC	PC	—	—	PC	PB fixed, PB turning[3,5]	PB fixed, PB turning[3,5]
	PG	PG	—	—	PG	PG[5]	PG[5]
	PF	PA, PF, PD	—	—	PA, PF	PB, PF, PD[5]	PB, PF, PD[5]
	H-L045	PA, PC, PF, PD	—	—	All except PG	All except PG[5]	All except PG[5]
Fillet weld/ pipes. T-, Y-, K-joints of pipes without edge preparation. Test assembly as shown in Figs. 6.3.1.5 and 6.3.1.5.2.4.	Welding procedures MW and SA, pipe axis vertical	—	—	All except PG	—	—	All except PG
	Welding procedures A, pipe axis acc. to WPS	—	—	—	—	—	Pipes axis orientation ±30° from angle at tests
Fillet weld/ pipes. T-, Y-, K-joints with edge preparation. Test assembly as shown in Fig. 6.3.1.5	Welding procedures MW and SA, pipe axis vertical	—	All except PG	—	—	All except PG	—
	Welding procedures A, pipe axis acc. to WPS	—	—	—	—	Pipes axis orientation ±30° from angle at tests	—

[1] Designations of weld spatial positions at tests comply with ISO 6947 and are shown in Figs. 6.2.2.4-1 to 6.2.2.4-3.
[2] Taking into account additional limitations established by requirements 6.3.1.2, 6.3.1.3.
[3] The approval is valid only for pipes with outer diameter over 500 mm.
[4] In case of certification of a technological procedure for several spatial positions the total scope of testing maybe reduced in accordance with the directions of 6.6.3.2.
[5] Taking into account the additional limitations introduced by 6.3.1.5.

Table 6.6.3.3

Range of approval by types of welded joints

Type of welded test assembly in tests for approval			Range of approval									
			Plates (P)							Pipes (T)		
			Butt welds (BW)				Tee-joints (BW)		Fillet bead welds without edge preparation (FW)	Butt welds (BW)		Fillet joints (FW)
			One-side welding		Two-side welding		One-side welding (ss)	Two-side welding (bs)		One-side welding		
			with backings (mb)	without backings (nb)	with gouging (gg)	without gouging (ng)				with backings (mb)	without backings (nb)	
Butt weld of plates (BW)	One-side welding (ss)	with backings (mb)	*	—	×	×	—	×	×	×	—	×
		without backings (nb)	×	*	×	×	×	×	×	×	—	×
	Two-side welding (bs)	with gouging (gg)	—	—	*	×	×	×	×	×	—	×
		without gouging (ng)	—	—	—	*	—	×	×	×	—	×
Butt weld of pipes (BW)	One-side welding (SS)	with backings (mb)	×	—	×	×	—	×	×	×	—	×
		without backings (nb)	×	×	×	×	×	×	×	×	*	×
Tee-joint of plates with edge preparation (BW)	One-side welding (ss)		—	—	—	—	*	×	×	×	—	×
	Two-side welding (bs)		—	—	—	—	—	*	×	×	—	×
Fillet (gauge) weld (FW)	Plates (P)		—	—	—	—	—	—	*	*	—	×
	Pipes (T)		—	—	—	—	—	—	×	×	—	*

Designations:
* — types of welded joints, for which WPS is approved directly by test results;
× — types of welded joints, for which WPS can be approved by the scope of approval (without additional tests);
— — types of welded joints, for which WPS cannot be approved.
Note. Symbols in brackets correspond to Fig. 7.2.2.

Range of approval of the welding procedures relative to the testing of a particular grade of the welding consumable, designated for welding/deposit of the corrosion-resistant steel and complying with the requirements of 4.8, shall be extended also to cover the other grades of the welding consumables of a similar class, approved by the Register, including the identification of typical chemical composition of deposited metal according to 4.8.1.3.

6.6.3.5 The requirements to the range of approval of the welding procedures, based on the welding consumables classification per the national standards, is used for filler materials and welding techniques do not covered by the Register approval by the grades stipulated by the requirements of 4.2, 4.5, 4.6 and 4.8.

Range of approval of the welding procedures, based on tests of the particular grade of the filler material, according to its classification per the national/international standards, may be extended to cover the other grades of the filler materials within the following limitations:

for materials, which by classification refer to the similar strength group of the hard-faced metal, if the requirements of testing on the impact work determination are not applied. At that, alternation of the electrodes coating type or flux cored electrode as well as type of welding flux is not allowed, demanding new testing;

or for materials, which by classification meet the requirement to identity of the nominal chemical composition of welding wire (combinations "wire-gas", "wire-flux") or deposited metal (electrodes, flux-cored wire).

6.6.3.6 Type and polarity of current.

The approval of the welding procedure is only valid for the type and polarity of current used during certification tests.

6.6.3.7 Heat input.

When assigning a range of approval of the welding procedures according to the value of the heat input, the following provisions shall be taken into consideration:

.1 if the requirement to determination of the impact energy of the weld metal and welded joint is mandatory, then the range of approval of the welding procedure per the maximum value of the heat input may be more than the nominal value on 15 per cent, which occurred at the assembly welding in course of certification but not more than 50 kJ/cm. In other cases, the range of approval of the welding procedure per the maximum value of the heat input may be extended on 25 per cent with reference to the nominal value at the assembly welding but not more than 55 kJ/cm;

.2 if the requirement to determination of the strength of the weld metal and welded joint is mandatory, then the range of approval of the welding procedure per the minimum value of the heat input may be less than the nominal value on 15 per cent, which occurred at the assembly welding in course of certification. In other cases, the range of approval of the welding procedure per the minimum value of the heat input may be extended on 25 per cent with reference to the nominal value at the assembly welding.

6.6.3.8 Preheating.

The minimum temperature of preheating for the range of approval for the welding procedure shall correspond to the nominal temperature of preheating prior to the test assembly welding at certification.

6.6.3.9 Interrun temperature.

The maximum interrun temperature for the range of approval for the welding procedure shall correspond to the nominal interrun temperature in the course of the test assembly welding at certification.

6.6.3.10 Post-weld heat treatment.

Deviation of heat treatment parameters (both upwards and downwards) from those employed in certification testing for the welding procedure approval is not permitted.

The range of approval shall be limited by the temperature range applied in the certification tests.

If a respective provision is made in WPS, the range of approval shall also cover such aspects, as speed of heating and cooling, as well as the time of welded joint exposure at control temperature. At that, the time of exposure may be expressed in form of a function of thickness.

6.6.4 Special requirements to range of approval related to welding techniques.

When establishing the range of approval for welding procedures, the classification and designations of welding technique in conformity with ISO 4063 are applied; they are indicated in 6.2.2.1.

6.6.4.1 Manual metal arc welding with coated electrodes and self-shielded tubular-cored arc welding (welding techniques 111 and 114).

The range of approval for welding procedure with respect to diameters of filler materials applied shall be limited with an interval of plus/minus one standard size from the nominal diameter used for each run in welding of the test assembly in certification tests.

This requirement is not applicable for one-side welding with root runs of butt welds without backings (using materials permitting reverse formation of weld in unsupported welding): with the use of this method the range of approval is limited by that diameter only, which was used in the tests.

6.6.4.2 Submerged arc welding (welding technique 12).

The range of approval is limited with filler wire feed system (single/multi-electrode welding, including multi-arc welding), which was used in certification of the procedure.

The range of approval is limited by a particular brand and classification of welding flux, which were employed in tests for welding procedure certification.

6.6.4.3 Intert-gas metal-arc welding (welding techniques 131, 135, 136).

The range of approval for the welding procedure shall be limited with:

composition of shielding gas identical with that used in the certification tests;

electrode (welding wire) feed system identical with that used in certification tests (single/multi-electrode welding).

6.6.4.4 Tungsten inert-gas welding (welding technique 141).

The range of approval for the welding procedure shall be limited with shielding gas composition identical with that used in the certification tests.

6.6.4.5 Plasma-arc welding (welding technique 15)

The range of approval shall be limited with:

composition of plasma-generating gas identical with that used in the certification tests;

composition of shielding gas identical with that used in the certification tests.

6.7 ISSUE AND CONDITIONS OF VALIDITY OF WELDING PROCEDURE APPROVAL TEST CERTIFICATE

6.7.1 Issue of the Certificate.

6.7.1.1 When all the requirements contained in the present Section are satisfied, the Register will draw up and issue the Welding Procedure Approval Test Certificate.

Note. The work on approval of welding procedures, as well as certification of welders, as a rule, shall precede starting of the Register survey of welded structures during their manufacture at the works.

6.7.1.2 The Welding Procedure Approval Test Certificate is drawn up and issued by a territorial division of the Register carrying out the survey during construction of a ship or manufacture of welded structures, for which welding the technological procedures approved by the Register are applied.

6.7.2 Drawing up of attachments to the Certificate.

6.7.2.1 Detalis of Weld Test (DWT).

The Detalis of Weld Test form is prepared by the Surveyor to the Register directly carrying out the technical supervision over the conduction of tests for approval of welding procedures at the works of welded structures manufacturer.

N o t e. The responsibility of authenticity and accuracy of technical information contained in DWT lies with a welding specialist appointed by the works administration to be in charge of testing for approval of the welding procedure. He is also responsible for preparation of necessary attachments to make DWT a complete set, after which he makes an appropriate entry in DWT, indicating his rank, putting down his name and initials.

The DWT form shall be supplemented by the attachments required for proper assignment and control of the range of approval of the Welding Procedure Approval Test Certificate, including:

copy of the certificate for base material used for welding of test assemblies;

copy of the certificate for welding consumable used for welding of test assemblies (electrodes, welding wire or rods);

copy of the certificate for welding flux or shielding gas (the availability of the latter is necessary, when preparing mixtures of shielding gases supplied by specialized companies);

copy of the certificate for backing material (e.g., ceramic straps).

6.7.2.2 Test Results form.

The Test Results form is issued by the Surveyor to the Register directly carrying out the technical supervision over conduction of tests for approval of welding procedures at the works manufacturing welded structures.

N o t e. The responsibility for authenticity and accuracy of technical information in the Test Results form rests with:

welding specialist appointed by the works administration to be in charge of testing for approval of welding procedure, or

official from the works' test center directly conducting non-destructive and mechanical testing of assemblies and having the right to sign reports.

The Test Results form may be supplemented with attachments elaborating the arrangements for cutting out specimens and test procedures and including:

copies of test results records;

copies of non-destructive inspection charts for test assemblies of complicated design, etc.

6.7.2.3 Welding Procedure Specification (WPS).

This document is compiled by the manufacturer of welded structures in accordance with the requirements of EN 288-2 and directions of Table 6.7.2.3.

6.7.3 Conditions and terms of validity of the Welding Procedure Approval Test Certificate.

6.7.3.1 The Welding Procedure Approval Test Certificate, as a rule, is not directly limited in its validity, provided all the requirements listed below are satisfied.

6.7.3.2 The manufacturer of welded structures shall observe the requirements of the Register concerning the range of approval for each welding procedure, If this condition is not fulfilled, the Welding Procedure Approval Test Certificate loses its validity and new tests for approval shall be undertaken.

New tests become necessary, if the following changes have occurred in the welding procedure:

essential, in the Register opinion, change in composition and properties of the base metal (within one group or grade), which may affect the weldability and mechanical characteristics of the welded joint;

change in the thickness of base metal exceeding the range of approval limits;

use of weld types or design modifications requiring, in the Register opinion, new certification of the welding procedure;

change in design features of the welded joint exceeding the range of approval limits (such as replacement of two-side welding with weld root dressing by one-side welding);

change in the shape of edge preparation, size of the shoulder and/or fit-up gap, which may produce significant effect on the depth of penetration, quality of fusion zone and may change the proportion of the base metal in the weld metal;

change in trademark and/or indices of welding consumables' classification;

changes in welding position, current type and polarity exceeding the range of approval limits;

use of welding conditions exceeding the limits of ± 15 per cent in current and voltage and ± 10 per cent in welding speed in relation to rated values agreed upon by the Register and in conformity with the Details of Weld Test;

deviation of preheating or interrun temperature by more than 25 °C from the values accepted as nominal in the Details of Weld Test;

change in parameters of post-weld heat treatment specified by the Certificate of Approval and stated in the Details of Weld Test.

6.7.3.3 During the period of validity of the Welding Procedure Approval Test Certificate the welding operations at the works shall be performed all the time under the technical supervision of the Register with the use of approved welding procedures. If in the work under the technical supervision of the Register there are intervals with duration of more than a year. The Welding Procedure Approval Test Certificate becomes invalid.

Note. When there is an interval in the work under supervision of the Register exceeding one year, but not more than two years, it is permitted, by agreement with the Register, to renew/re-approve the Welding Procedure Approval Test Certificate without execution of new tests, if the other conditions of the Certificate utilization are properly observed.

6.7.3.4 During the term of validity of the Welding Procedure Approval Test Certificate no problems shall arise in connection with the quality of welded joints manufactured with the use of the procedure approved by the Register. The manufacturer of welded structures shall maintain systematical control and analysis of the quality of welded joints, also with subdivision by particular welding procedures. The results of such analysis shall be made available to the Surveyor to the Register, dealing with the procedure of confirmation of the Welding Procedure Approval Test Certificate in accordance with the directions of 6.7.3.5.

In case of permanently high level of imperfection of welds, the validity of the Welding Procedure Approval Test Certificate may be ceased by the Register, and the welding procedure shall be revised and subjected to new tests for approval.

6.7.3.5 The Welding Procedure Approval Test Certificate shall be confirmed by the Register once every two years.

Confirmation of the Certificate is performed by the Surveyor to the Register on the basis of the request of the manufacturer and does not require new or additional tests, if all the conditions stated above are properly observed.

Table 6.7.2.3

Requirements to filling-in the WPS form

Ser. No.	Name of form positions	Requirements to form filling
1	Manufacturer	Name of manufacturer of welded structures, author of WPS
2	WPS No.	Designation of WPS in accordance with the coding system adopted by the Manufacturer
3	Supporting WPQR No.	Specification Designation of specifications of welded joint tests and Test Results, on the basis of which the particular welding procedure is approved by the Register.
4	Base metal: grade and trade mark; thickness range; pipe's outside diameter range	Grade of the base metal in accordance with the Register rules and/or its designation according to national standards; designation of the standard. Minimum and maximum thicknesses of metal to be welded. Minimum and maximum outside diameters of pipes to be welded
5	Welding procedure	Designation of welding procedure in accordance with ISO 4063
6	Welding process	Designations: MW — manual welding, SA — semi-automatic welding, A — automatic welding
7	Edge preparation	Sketch of edge preparation of parts to be welded with indication of shape and dimensions, also designation of normative document/standard.
8	Elements of weld and welding technique	Sketch of completed welded joint with indication of size in accordance with requirements of documentation for product/structure. Also designation of normative document/standard
9	Method of edge preparation	Method of edge preparation for welding shall be indicated and, if necessary, technological particulars of assembling for welding: welding fixture or stand, mounting clamps, assembling with tacking
10	Requirements for edge dressing	Requirements for edge dressing and method of dressing shall be indicated
11	Backing	Indicated here is the necessity for the use of backings or means of weld root protection; designations: nb — welding without backings, mb — welding with the use of backings, gb — welding with supply of shielding gas
12	Backing material	Type of backings, material and dimensions. When the weld root is protected by gas supply, the gas composition and consumption shall be indicated
DETAILS ON WELDING CONSUMABLES		
13	Filler products	Indicate: trademark and name of manufacturer (given in column "Other information"); grade in accordance with the Register rules, if it is assigned by the rules for the given material: classification in accordance with the national standards (group of indices and designation of standard); diameter of electrode/wire or width of strip electrode; for welding technique 111 requirements shall be stated in relation to calcination/drying of electrodes before use (if required) and limitations in time and conditions of storage; designations of normative documents specifying these parameters (if any) shall be indicated.

Table 6.7.2.3 — continued

14	Auxiliary materials	Indicate: for welding technique 12 — data on flux employed, including its classification (designation and standard), name of Manufacturer and its trademark, also requirements for flux calcination; for welding techniques 131, 135, 136, 137, 141 and 15 — data on actual composition and consumption of shielding gas, including designation of normative documents specifying gas composition. For gas mixtures supplied by the specialized manufacturers, trademark of the mixture may be indicated; for welding technique 141 — designation of tungsten electrode brand, with reference to standard, and diameter
DETAILS ON WELDING TECHNIQUE		
15	Welding position and direction	Designations - according to ISO 6947 (refer to Figs. 6.2.2.4-1 to 6.2.2.4-3)
16	String/weaving bead	Use of weaving movements, if any, and: maximum width of beads in manual and semi-automatic welding; amplitude of lateral oscillations of electrode in automatic welding
17	Back gouging	Indicate, if this operation is employed, its method and requirements for use (R_{min}): gg — welding with gouging, ng — welding without gouging
18	Single- and multiple-electrode welding	Indicate the quantity of welding electrodes, also (in column "Other parameters" for welding technique 12 — shape of wire electrode and arrangement for their connection to the power source
19	Single- and multi-run welding	Designations: sr — single-run, mr — multi-run welding
20	Orifice/gas cup size	For welding techniques 131, 135, 136, 137, 141 and 15 torch nozzle diameter shall be indicated
21	Contact tube to work distance	For welding techniques 12, 131, 135, 136, 137, 15 indicate the distance from the current lead tip of welding torch to the surface of the workpiece
22	Preheating	Indicate: minimum temperature of preheating, if it is planned; minimum temperature ambient air, at which welding operations are allowed, if the preheating is not used; other conditions, at which preheating is required (low ambient temperature, higher than normal hydrogen content in deposited metal, etc.)
23	Interrun temperature	Indicate limitations for interrun temperature: minimum value for welding process with concurrent heating (including automatic heating); maximum value for welding process, which does not require concurrent heating
24	Post-weld heat treament (PWHT)	Indicate, if heat treatment or ageing (age hardening) is required after welding, also give its parameters (in respective columns). If necessary, a separate specification for heat treatment is attached to WPS
WELDING CONDITIONS		
25	Type of current and polarity	Designations: DC+ — direct current of reverse polarity, DC– — direct current of forward polarity, D+ — direct current of reverse and forward polarity; AC — alternating current; PAW — pulsed arc welding
26	Run number	Indicate welding conditions for individual runs, if some changes are stipulated in them in the course of the technological process (e.g., different conditions for root and filler runs)
27	Electrode diameter	Indicate welding conditions for each diameter of electrode (item 13 of the Table) and for each welding position (item 15 of the Table), as specified in WPS
28	Current, voltage	Indicate ranges of welding current and voltage: rated value ±7,5 per cent
29	Welding speed	Indicate the range welding speed values for process A within the rated value ±5,5 per cent
30	Welding wire feed rate	For welding process SA and A indicate the range of welding wire feed rate values
31	Heat input	Indicated in cases, when for obtaining the required properties of welded joint it is necessary to limit the maximum amount of heat input
32	Additional information	Indicate in this column: for welding technique 111 — nominal length of weld completed with one electrode; if the equipment does not permit to control welding conditions (refer to items 28, 29, 30 of the Table), indicate settings for adjustment of the equipment corresponding to specified welding conditions; for pulsed arc welding indicate its characteristics (pulse time, pulse current, pulse frequency, voltage and current of pilot arc, pulse shape, etc.)

7 APPROVAL OF WELDING PROCEDURES FOR ALUMINIUM ALLOYS

7.1 GENERAL

7.1.1 Welding procedures used for the fabrication of aluminium alloy structures being subject to survey by the Register shall be approved by the Register and to meet the requirements given below.

7.1.2 The document verifying that the welding procedure used at the shipyard or welded structures Manufacturer has passed tests and approved by the Register is the Welding Procedure Approval Test Certificate (form 7.1.33).

7.1.3 The requirements of the Section cover the approval procedure for the welding of aluminium alloys through testing of type test assemblies by weld test. The use of other schemes of approval for the welding procedures of aluminium alloys is, in each case, subject to the special consideration by the Register. The issue of approval scheme change therewith may be taken by the Register for consideration in the following cases:

if the peculiarities of structures welding under working conditions can not be reproduced on type test assemblies specified by the requirements of 7.3, and the qualification tests prior to the manufacture beginning with the simulation of an actual welding procedure are needed;

if the welded structures manufacturer can submit to the Register the convincing grounds for the possible application of the approval scheme using so-called "standard welding procedure";

if the welding procedures have already passed testing and were previously approved by the competent bodies/classification societies as applied to the specific welding fabrication and the test program used therewith was on a par with the requirements of this Section.

7.1.4 Welding procedures approval tests may be supplemented with tests in the course of a manufacturing process on the separate demand of the Register.

Tests in the manufacturing process are used for monitoring the stability of the welding procedures with the increased degree of defects formation risk (for example, for the procedure of a single-sided welding with free back forming of a weld root) and also in the event of the application of welding methods not provided for in the Section.

7.2 DEFINITIONS, TERMS AND SYMBOLS

7.2.1 Definitions and explanations.

Definitions and explanations used in the present Chapter are given in 6.2.1.

7.2.2 Symbols used in welding procedure approval.

Welding procedure approval for aluminium alloys according to the requirements of the Section is carried out for the following methods of welding (the symbols comply with ISO 4063):

131 = metal-arc inert gas welding;

141 = tungsten inert gas welding;

15 = plasma arc welding.

In so doing, depending on the use of labour-saving devices by welders, welding processes are divided into the following groups:

MW = manual welding wherein the feed of filler wire and the advance of a welding torch along and across a weld are carried out by a welder (manually);

SA = semiautomatic welding where in the feed of welding wire is mechanized, but the advance of a welding torch along and across a weld are carried out by a welder;

A = automatic welding wherein the processes of welding wire feed and of welding torch movement manipulation are automated and carried out without the direct participation of a welder.

The welding fillers used for the welding of shipbuilding aluminium alloys are classified by categories according to Tables 4.7.1.2-1 and 4.7.1.2-2.

Shielding gases used for welding depending on their composition are divided into groups designated with indices in accordance with Table 4.7.1.4.

Shipbuilding aluminium alloys, to which the requirements of the Section apply, are classified by grades in accordance with Tables 5.1.2, 5.1.3-1, 5.1.3-2 and 5.1.3-3, Part XIII "Materials". In this case, in the approval of welding procedures, aluminium alloys are additionally grouped according to Table 7.2.2.

In the approval of welding procedures, the symbols of welding positions comply with ISO 6947.

The symbols relating to the type of a welded joint and to the technological peculiarities of its making are shown in Fig. 7.2.2.

7.3 TEST ASSEMBLIES TYPES AND TEST METHODS

7.3.1 General requirements for test assemblies' preparation.

7.3.1.1 The structural elements of edge preparation, weld dimensions and the technological features of welding operation shall comply with pWPS for the welding process to be approved regarding the range of approval. In testing, the most adverse versions of edge preparation and fit-up to ensure the quality of welded joints shall be checked.

Table 7.2.2

Classification of aluminium and its alloys by type composition groups

Group designation	Type and description of alloys to be welded	Designation of shipbuilding aluminium alloy grade	
		International alloys	National alloys
21	Pure aluminium. Aluminium and alloys with alloying elements and admixtures content not more than 1,5 per cent	—	—
22a	Non-hardenable by heat treatment aluminium-magnesium alloys with Mg content not more than 3,5 per cent	RA/WA:5754	R1/W1:1530
22b	Non-hardenable by heat treatment aluminium-magnesium alloys with Mg content from 4 to 6 per cent	RB/WB:5086 RC/WC:5083, 5383, 5456, 5059	R2/W2:1550 R3/W3:1561 R4/W4:1575
23	Hardenable by heat treatment alloys of alloying system Al-g-Si and l-Zn-g	RD/WD:6005A, 6061, 6082	R5/W5: (AlSi1MgMn)

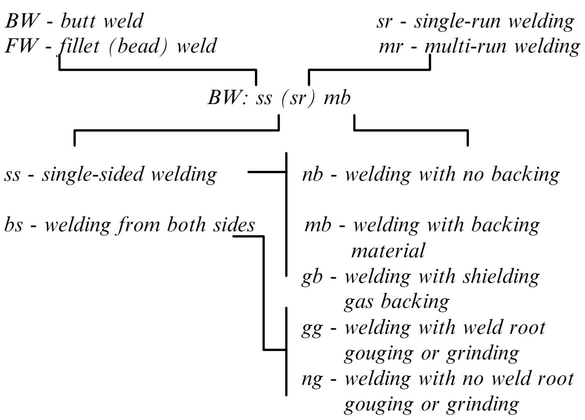


Fig. 7.2.2
Coding diagram for weld type and conditions of joints welding

Note. In order to fulfil this requirement, the Register may demand the extension of a test program (for example, the welding of two test assemblies instead of one for the lower and upper boundaries of the allowance for a root gap, variation in thickness, root faces, etc.).

7.3.1.2 The welding of test assemblies during tests shall be made with the use of equipment similar to that used in production conditions.

7.3.1.3 The cleaning of components before welding and their fit-up shall be carried out like the procedure used in the product manufacture and specified in pWPS.

7.3.1.4 Where assembly tack welds are the part of structure welds, they shall be included into the test assembly part to be tested.

7.3.1.5 The procedure parameters and welding conditions shall meet the pWPS requirements. In this case, the requirements for the heating temperature, interrun temperature and for the parameters of welded joints heat treatment/ageing, if any, shall be followed.

7.3.1.6 The dimensions of test assemblies shall assure the obtaining of reliable data on the stability of a welding procedure, and also to take into account the conditions of heat distribution during welding in an actual structure.

7.3.1.7 The thickness of the base metal, the external diameter of pipes joined and also the design thickness of a fillet weld shall be within the range of nominal values of these parameters during welded structures manufacturing, and also to meet the requirements for the range of approval.

7.3.1.8 For the welding of test assemblies, the welding wire (sticks) of the maximum diameter specified in pWPS or, by an agreement with the Register, by one standard size less, shall be used.

7.3.2 Test assemblies' types and test methods.

7.3.2.1 For the approval of welding procedures for butt joints of sheets and other types of semi-finished products, the butt joint test assembly, which complies with the directions of Fig. 7.3.2.1 with regard to the requirements of 7.3.1.7, shall be used.

After welding, the test assembly shall be tested in the scope of the Table 7.3.2.1 requirements. The diagram of test specimens' cutting-out from the test assembly of the butt joint of sheets for conducting mechanical tests shall comply with Fig. 7.3.2.1.

7.3.2.2 For the approval of welding procedures for the butt joints of pipes made of aluminium alloys, the test assembly dimensioned according to Fig. 7.3.2.2 (*a*), with regard to the requirements of 7.3.1.7 shall be applied. After welding, the test assembly shall be tested in the scope of the Table 7.3.2.1 requirements.

The diagram of test specimens cutting-out from the test assembly of butt pipe joint for mechanical tests performance shall comply with Fig. 7.3.2.2 (*b*). Where the test assembly dimensions are inadequate to machine the quantity of test specimens needed, two or more test assemblies shall be welded and tested.

7.3.2.3 For the approval of welding procedures for corner and tee-joints of sheets and semi-finished products, the tee-test assembly dimensioned according to Fig. 7.3.2.3 with regard to the requirements of 7.3.1.7 may be used.

In accordance with pWPS, the tee-joint test assembly may be fabricated:

without beveling (fillet welding),

or with beveling (with a full or partial joint penetration).

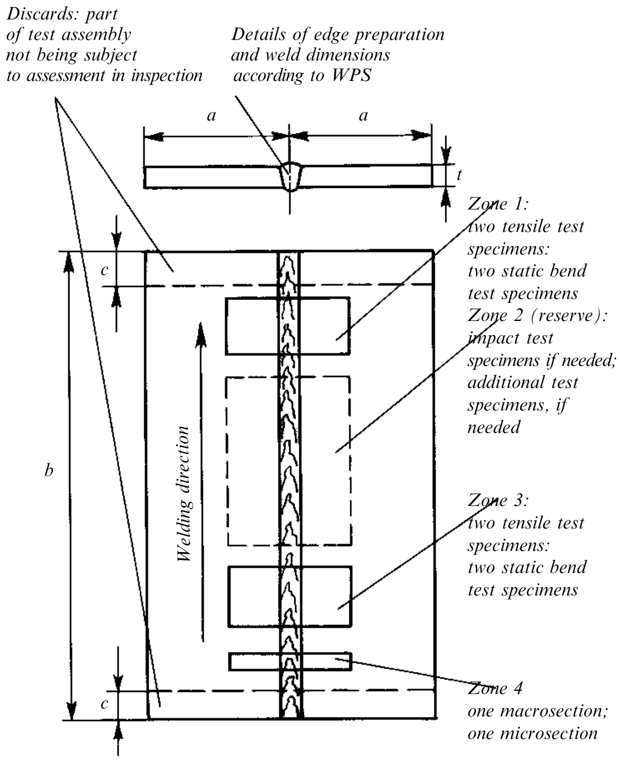


Fig. 7.3.2.1
Test assembly of welded butt joint and the diagram of test specimens' cutting-out:
for manual and semiautomatic welding with dimensions:
$a \geqslant 150$ mm, but not less than $3t$; $b \geqslant 350$ mm,
but not less than $6t$;
$c \approx 25$ mm;
for automatic welding with dimensions:
$a \geqslant 200$ mm; $b \geqslant 1000$ mm and $c \approx 50$ mm

Table 7.3.2.1

Examination and test type	Examination and testing extent	Notes
Visual and measuring examination	100 % weld length	—
Radiographic or ultrasonic examination	100 % weld length	For welded joints having thickness t < 12 mm, the radiographic examination shall be used, and for $t \geqslant 12$ mm it is allowed, by an agreement with the Register, to change the radiographic examination for the ultrasonic one
Dye-penetrant examination	100 % weld length	—
Transverse tensile test of flat test specimens	4 test specimens	Tests are conducted on two tensile test specimens with weld reinforcement removed and on two test specimens with the reinforcement complying with the national standard requirements
Transverse static bend test of test specimens	4 test specimens	For welded joints having thickness t < 12 mm, two test specimens each with weld root and surface tension shall be tested, and for $t \geqslant 12$ mm the test for side bend is conducted on dour test specimens
Macrosection examination	1 transverse macrosection	—
Microsection examination	1 transverse microsection	—

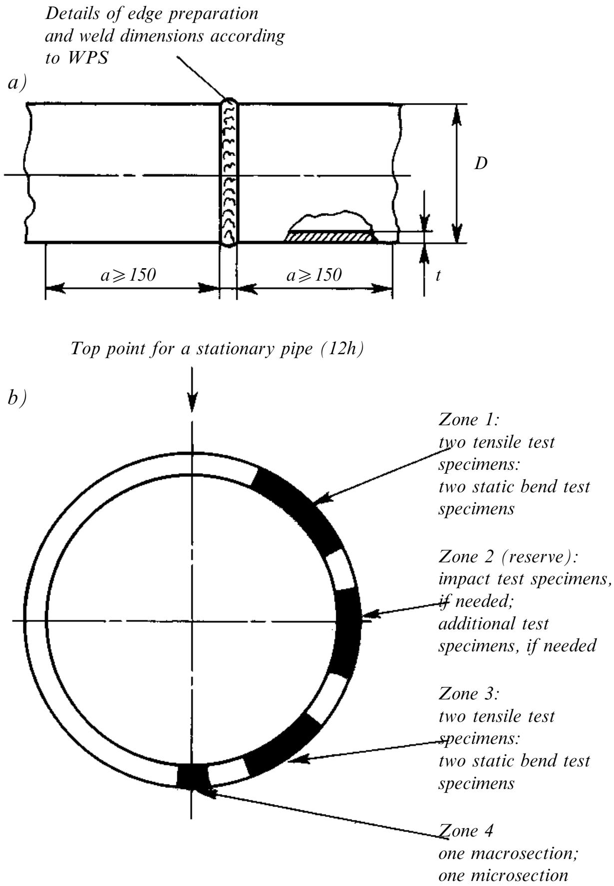


Fig. 7.3.2.2
Test assembly of butt pipe joint:
a — test assembly dimensions;
b — diagram of test specimens cutting-out

The application of tee-joint test assembly for sheets is mandatory in the following cases:

for the approval of an automatic welding of beveled tee-joints;

for the approval of a welding procedure with a single-run fillet weld without beveling.

In other cases, the welding procedure approval for the corner and tee-joints of sheets and semi-finished products may be carried out within the range of approval according to the directions of Table 7.5.3.3.

After welding, the tee-test assembly shall be tested according to the requirements of Table 7.3.2.3. The diagram of test specimens' cutting-out from the tee-joint test assembly shall comply with Fig. 7.3.2.3. In so doing, when the tests for the approval of welding procedures for a manual and semiautomatic welding are conducted, at least one operation "stop/restart" shall be made on the test length of a test assembly. The position of that operation shall be marked and subject to a thorough inspection using non-destructive examination techniques with the follow-up machining and inspection of one macro-section.

Table 7.3.2.3

Examination and test type	Examination and testing extent	Notes
Visual and measuring examination	100 % weld length	—
Radiographic or ultrasonic examination	100 % weld length	Radiographic and ultrasonic examination techniques are used for welded joints with full penetration only
Dye-penetrant examination	100 % weld length	—
Macrosection examination	2 (3) test specimens	One macrosection for a manual and semiautomatic welding shall be machined in the place, which is appropriate for the "stop-restart" operation. Three macrosections are machined from the test assemblies fabricated with an automatic welding
Microsection examination	1 test specimen	—
Fracture test	2 test specimens (⩾120 mm)	Fracture test is used only for joints without beveling made with a single-run fillet weld

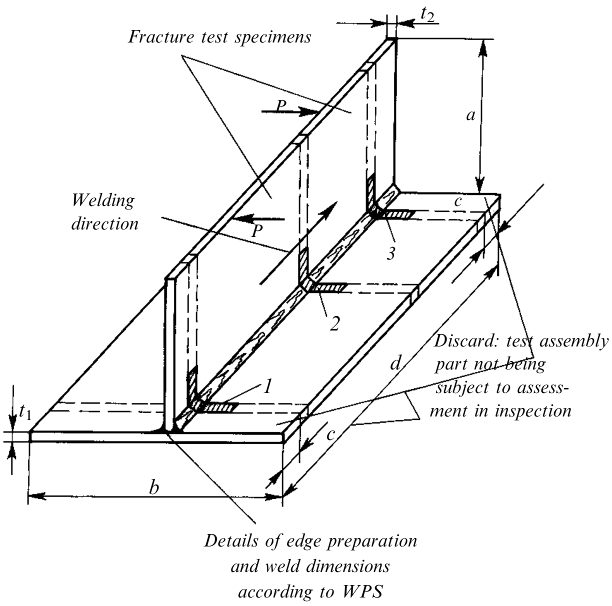


Fig. 7.3.2.3
Test assembly of tee-welded joint and the diagram of test specimens' cutting-out:
for manual and semiautomatic welding with dimensions:
$b \geqslant 150$ mm, but not less than $6t$, for joints without beveling;
$b \geqslant 350$ mm, but not less than $6t$, for joints with beveling;
$c \approx 25$ mm; $a \geqslant 150$ mm, but not less than $3t_2$;
$d \geqslant 350$ mm, but not less than $6t_1$ (macrosection sampling is made in Zones *2* and *3*, microsection sampling — in Zone *3*);
for automatic welding with dimensions:
$a \geqslant 150$ mm, but not less than $3t_2$;
$b \geqslant 350$ mm, but not less than $6t_1$;
$d \geqslant 1000$ mm;
$c \approx 50$ mm (macrosection sampling is made in Zones *1, 2* and *3*, microsection sampling — in Zone *3*)

7.3.2.4 Pipe joint test assembly.

7.3.2.4.1 The approval of welding procedures for pipe joints with a fillet weld and also for pipes joint assemblies shall be carried out on the basis of the tests of the test assembly corresponding to Fig. 7.3.2.4.1 with regard to the requirements of 7.3.1.7. The angle α between pipes axes shall comply with the minimum value accepted in manufacturing practice.

In accordance with the details of edge preparation for welding and with the thickness of a pipe to be welded on, the test assembly complying with Fig. 7.3.2.4.1 may be fabricated:

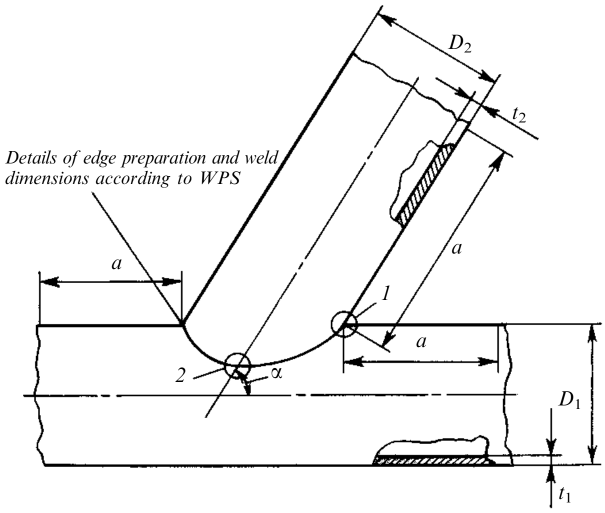


Fig. 7.3.2.4.1
Test assembly of pipes joint made with a fillet weld and the diagram of test specimens cutting-out:
1 and *2* — places of macrosections sampling;
1 — place of microsection sampling;
$a \geqslant 150$ mm

without beveling in the qualification of welding procedures for fillet welding, or

with beveling ensuring the full or partial penetration.

Depending upon the actual manufacturing practice specified in pWPS, the pipes joint test assembly may be fabricated in the following structural modifications:

as a welded-on element (not communicating with a main pipe);

as a through welded-on element (communicating with a main pipe);

as a straightway welded-on element (through a main pipe).

7.3.2.4.2 The use of a pipes joint test assembly with beveling is mandatory while conducting tests for the approval of:

welding procedures for a manual and semiautomatic welding within the range of the diameter $168{,}3 \leqslant D_2 \leqslant 500$ mm of a pipe to be welded on, with its wall thickness $t_2 \geqslant 12$ mm (refer to Fig. 7.3.2.4.1);

welding procedures for an automatic welding including robotized systems.

In this case, the following instructions shall be followed:

for a manual and semiautomatic welding, the main pipe axis shall be oriented vertically what is sufficient for the approval of all other pipe axis positions in manufacturing practice;

for an automatic welding and robotized systems, the orientation of the main pipe axis shall comply with the actual conditions of welded joints fabrication; the range of approval for the main pipe axis orientation is limited by the angles of $\pm 30°$ from the nominal axis position.

In all the other cases, applying the approval of the results of butt joint welding tests (if any), the welding procedures for pipes joint assemblies or for welding pipes in a plane bulkhead with beveling of joined components may be approved.

7.3.2.4.3 The use of a pipes joint test assembly without beveling is mandatory while conducting tests for the approval of:

welding procedures for an automatic welding including robotized systems;

welding procedures ensuring the deep weld root penetration, which is taken into account in the effective throat thickness of a fillet weld;

welding procedures providing for welding by the "vertical-downward" method i.e. in the PG or J-LO 45 position.

The requirements for the main pipe axis orientation during tests are similar to the requirements of 7.3.2.4.2.

In all the other cases, on the basis of tests (if any) of butt pipe joint test assemblies according to 7.5.3.3, the approval procedure for fillet welding procedures for pipe joints without beveling is permitted.

7.3.2.4.4 After welding, a pipe joint test assembly shall be checked according to Table 7.3.2.4.4.

The diagram for the cutting-out of test specimens for tests from a test assembly shall comply with Fig. 7.3.2.4.1.

Table 7.3.2.4.4

Examination type	Examination and testing extent	Notes
Visual and measuring examination	100 % weld length	—
Ultrasonic examination	100 % weld length	Used for welded joints with full penetration only
Dye-penetrant examination	100 % weld length	—
Macrosection examination	2 transverse macrosections	—
Microsection examination	1 transverse microsection	—

7.4 REQUIREMENTS FOR TEST ASSEMBLIES EXAMINATION, TEST SPECIMENS MACHINING AND TEST RESULTS ASSESSMENT CRITERIA

7.4.1 General provisions for examination and tests performance.

7.4.1.1 After welding each test assembly shall be tested in the scope of the 7.3 requirements. In this case, during welded joints examination, test specimens machining, tests performance and also in the assessment of the results obtained, the requirements given below shall be followed.

7.4.1.2 All the non-destructive testing and the examination of welded joints test assemblies shall be carried out after heat treatment (if specified in pWPS), and the test assemblies from hardenable by heat treatment alloys of the group 23 (refer to Table 7.2.2) shall be subjected to natural or artificial ageing prior to cutting out test specimens for tests.

7.4.1.3 The results of non-destructive testing of welded test assemblies quality for all welding processes shall meet the Register-approved technical documentation for the specific product type as applied to which the approval of a welding procedure is carried out. In this case, the general requirements set in Section 3, as to the performance of examination and its results assessment shall be observed.

7.4.1.4 The examination and tests of welded joints test assemblies shall be performed in the following sequence:

.1 visual examination and measurements;

.2 liquid penetrant examination (dye-penetrant examination is preferable);

.3 radiographic or ultrasonic examination if specified for the joint type concerned;

.4 marking-out of test assemblies and sampling for destructive tests. In doing so, the sampling is permitted from the welded joint zones, in which no defects were identified according to the non-destructive testing results;

.5 test specimens machining and non-destructive testing performance, and sections examination as well;

.6 assessment of the obtained results in terms of the provisions in 7.4.1.5 to 7.4.1.10.

7.4.1.5 Where the results of the welded test assembly visual or non-destructive testing are unsatisfactory, one additional test assembly for retesting shall be welded. If the additional test assembly is rejected due to the same reasons as the first one, the given welding procedure is considered to be unfit for use in production without the modifications ensuring the appropriate quality of welded joints.

7.4.1.6 If the results of tensile or bend test specimens testing fail to comply with the set requirements on reasons not caused by the presence of welding imperfections in the test specimens, the retest on the doubled number of test specimens shall be conducted. The test specimens for re-testing are taken from the same test assembly, if there is sufficient metal, or from a new test assembly additionally welded.

7.4.1.7 If the results of impact test specimens testing fail to comply with the set requirements on reasons not caused by the presence of imperfections in the test specimens, the re-test of one additional set of three test specimens shall be conducted. Sampling for additional tests is carried out similarly to the requirements of 7.4.1.6.

7.4.1.8 If any test specimen has not satisfied a test only due to an improper weld profile or to the presence of surface defects, crater cracks inclusive, two additional test specimens for each one that failed shall be machined for re-testing. Sampling for re-testing is carried out similarly to the requirements of 7.4.1.6.

7.4.1.9 If any test specimen has not satisfied a test due to the presence of permissible slag, gas or non-metallic inclusions, one additional test specimen shall be machined for re-testing. Sampling is carried out similarly to the requirements of 7.4.1.6.

7.4.1.10 The results of re-testing are accepted as final. Where the results obtained in re-testing are unsatisfactory if only on one test specimen, the welding procedure, in accordance with the requirements of 7.4.1.6 to 7.4.1.9, is considered to be unfit for use until the modifications ensuring the appropriate quality of welded joints metal are made.

7.4.2 Requirements for test assemblies examination, test specimens machining and test results assessment criteria for butt joints.

7.4.2.1 In order to determine the properties of welded butt joints, the following test specimens shall be used:

tensile test specimens according to Fig. 4.2.3.2.2 with the reinforcement relieved or with the weld reinforcement according to the requirements of national standards;

specimens for the static bend test of the weld surface and root according to Fig. 2.2.5.1, Part XIII "Materials" and the provisions of 4.2.3.2.3 of the present Part;

specimens for the static bend test of the weld side surface according to Fig. 2.2.5.1, Part XIII "Materials" and the provisions of 4.2.3.2.3 of the present Part;

macrosections prepared and etched on one side to clearly reveal the base metal, fusion line, heat-affected zone and the weld including the build-up of runs;

microsection prepared and etched on one side to include the heat-affected zone, fusion line and weld metal into the work area.

7.4.2.2 The test results of tensile and static bend test specimens shall meet the requirements of Table 7.4.2.2.

The transverse macrosections shall be free from prohibitive defects. In this case the defects close to a weld including 10 mm of the base metal outside of the heat-affected zone shall be taken into account.

Table 7.4.2.2

Base metal			Properties of welded joints		
Group	Grade	Digital code	Tensile strength	Static bend	
			R_m, MPa	Mandrel diameter	Bend angle[2]
International alloys					
22a	RA/WA	5754	190	$3t$	
22b	RB/WB	5086	240	$6t$	
	RC/WC	5083 5383 5456 5059	275 290 330	$6t$ $6t$ $6t$	180
23	RD/WD	6005A 6061 6082	170 170 170	$7t$ $7t$ $7t$	
National alloys					
22a	R1/W1	1530	185[1]	$3t$	
22b	R2/W2 R3/W3 R4/W4	1550 1561 1575	275[1] 305 360	$6t$ $6t$ $6t$	180
23	R5/W5	— (AlSi1MgMn)	170	$7t$	

[1] For welded joints with a thickness of up to 12,5 mm inclusive.
[2] At assessment of the test results one shall be guided by the following:
at the surface of the specimen there shall be no singular crack of a length in any direction more than 3 mm;
cracks at the edges of the specimen may be neglected if their appearance was not caused by non-weldings.
N o t e . t = specimen thickness.

In macrosections examination, it shall also be checked the compliance of the priority and sequence of weld runs performance with the pWPS requirements.

The analysis of welded joints microstructure is carried out according to the program agreed with the Register in each particular case. In microsections examination, it shall be confirmed the absence in the welded joint metal of zones containing components or admixtures, which are potentially dangerous in terms of efficiency, and static strength of the welded joint (brittle interlayers, inclusion segregations, etc.).

7.4.3 Requirements for test assemblies examination, test specimens machining and test results assessment criteria for fillet and tee-joints.

Sampling of macro- and microsections from welded joint test assemblies complying with Figs.7.3.2.3 and 7.3.2.4.1 shall be carried out similarly to the requirements of 7.4.2.1. Static fracture test specimens from a tee-joint test assembly shall be sampled and tested according to the requirements of 4.2.5. In this case, both fillet welds of the total length of at least 200 mm on the opposite sides of the joint shall be tested.

The analysis of macrosections and welds fracture surface shall confirm the absence of prohibitive internal defects including the lack of root penetration (decrease of effective throat thickness with the irregular form of base metal fusion). Insignificant defects like pores and slag inclusions may be permitted if their relative area does not exceed one per cent of the controlled weld section.

7.5 RANGE OF APPROVAL OF WELDING PROCEDURES AS PER TEST RESULTS

7.5.1 General.

Specifying the range of welding procedure approval the requirements given below shall be followed. The changes inserted in pWPS by a manufacturer, which are beyond the scope of the range of approval, need new tests.

The approval of a welding procedure by the Register obtained by a shipyard or welded structures manufacturer is valid for welding in all workshops of the given shipyard/manufacturer subject to the WPS requirements for this welding procedure.

7.5.2 Base metal-related requirements on range of approval.

7.5.2.1 Tests carried out on the aluminium alloy of one of the groups in Table 7.2.2 qualify the welding procedure for the other alloys of the same group with equal or lower tensile strength, which are part of a welded joint, according to Table 7.4.2.2.

For shipbuilding alloys, the range of approval of a welding procedure by the grades of base metal is identical to that for welding consumables according to the requirements of Tables 4.7.1.2-1 and 4.7.1.2-2.

Approval therewith also covers all the combinations of alloy grades within the range of approval.

7.5.2.2 Tests for welding procedure approval conducted on test assemblies having the nominal thickness t are valid for the thickness range according to Table 7.5.2.2. The determination of the nominal thickness t for different joint types shall be carried out in accordance with the following requirements:

Table 7.5.2.2

Test assembly thickness in tests t, in mm	Range of approval by base metal thickness	
	Single- and two-run procedure	Multi-run procedure
$t \leqslant 3$	$0,8t$ to $1,1t$	t to $2t$
$3 < t \leqslant 12$	$0,8t$ to $1,1t$	3 mm to $2t$
$12 < t \leqslant 100$	$0,8t$ to $1,1t$	$0,5t$ to $2t$, (max 150 mm)
$t > 100$	–	$0,5t$ to $1,5t$

Note. Where WPS provides for the use of the combination of two ore more processes/procedures, the test-recorded thickness of welds made by each process/procedure may be taken as a basis for the range of approval for the individual

for butt joints, t is the thickness of the thinner material;

for fillet joints without beveling, t is the thickness of the thicker material;

for tee-joints of beveled sheets, t is the thickness of a beveled component (welded-on element);

for fillet joints with bevelling, t is the thickness of the thinner material;

for joint assemblies of pipes like the "blind" welded-on adaptors, t is the welded-on element wall thickness;

for joint assemblies of pipes in the form of a through or straight-run welded-on element, t is the thickness of a main pipe or sheet.

7.5.2.3 Depending on the fillet weld thickness a of tested assemblies (refer to 1.7.5.1, Part II "Hull"), the welding procedure approval covers welded joints with design throat thickness of fillet welds from $0,75a$ to $1,5a$ inclusive. In so doing, the tests on assemblies with the fillet weld thickness $a \geqslant 10$ mm qualify for welded joints with design throat thicknesses of fillet welds from 10 mm and over.

For the fillet welds made in a vertical downward position (position PG), the range of approval covers the fillet weld design throat thicknesses from $0,75a$ to $1,1a$ inclusive.

For fillet welds, in parallel with the standardization of the range of approval by the a value, the restrictions on the range of approval for the base metal thickness and external pipe diameter are also applied.

7.5.2.4 The range of approval as to the external dia-meter of welded pipes or branch pipes of joint assemblies shall be specified in relation to the external pipes diameter during approval tests according to Table 7.5.2.4.

Table 7.5.2.4

Diameter of test assembly in tests, D, in mm[1,2]	Range of approval
$D \leqslant 168,3$	$0,5D$ to $2,0D$
$D > 168,3$	$\geqslant 0,5D$ and sheets[3]

[1] D = external pipe diameter.
[2] Approval for sheets welding may also qualify for the welding of pipes with $D \geqslant 500$ mm subject to the other requirements for the range of approval.
[3] Refer also to 7.5.3.3.

7.5.2.5 In tests for welding procedures approval which are associated with the welding of pipe joint assemblies, the range of approval as to the angle α_1 between the axes of pipes to be joined shall be specified in relation to the angle (during the tests proceeding from the condition $\alpha \leqslant \alpha_1 \leqslant 90°$.

7.5.3 Approval range requirements relating to the welding process.

7.5.3.1 Welding process and procedure.

The approval of welding procedure is valid only for the welding process and procedure used during approval tests.

Where the welding procedure used is the combination of several processes/procedures (e.g., a consumable electrode automatic welding to fill a groove and a non-consumable electrode manual welding to make a weld root), the approval range is limited by the welding process combination used in approval tests. In this case, the test procedure may be carried out according to either the combined (as the combination on one test assembly) or separate (on separate test assemblies for each process/procedure) scheme.

7.5.3.2 Welding positions.

The range of approval for welding positions for the manual and semiautomatic welding shall meet the requirements of Table 7.5.3.2.

The welding procedure for automatic welding shall pass tests for each position to be used in the construction. Where the welding procedure of automatic welding for butt joints is approved for several welding positions at a time, in order to reduce the tests scope, it is permitted to sample and test tensile and static bend test specimens only for the position, which is the most inconvenient for welding.

7.5.3.3 The range of approval for the types of welded joints in relation to the types used in approval tests shall meet the requirements of Table 7.5.3.3.

7.5.3.4 The welding procedure approval is valid for welding consumables of that grade, which passed the tests in the course of approval. The issue of the approval range extension for the welding consumables of higher grades (which provide the higher indices of welded joint strength) is, in each case, subject to the special consideration by the Register.

7.5.3.5 The approval of a welding procedure is valid only for that type of current and polarity, which were used in tests.

7.5.3.6 If the value of linear power consumption during welding is specified in pWPS, the requirements for the approval range of this parameter within ± 15 per cent of the value shown during the approval tests shall be observed.

7.5.3.7 The minimum preheat temperature for the range of approval of a welding procedure shall be consistent with the nominal temperature of a test assembly before welding during approval tests.

If the preheat is not used in general practice, the range of approval is:

the minimum ambient temperature, at which welding is permitted, and/or

specific conditions when the preheat may be needed (low temperature, the welding of large thickness, etc.).

7.5.3.8 If a welding procedure does not provide for an additional heating, the restriction of the range of approval on a maximum interrun temperature shall comply with an actual interrun temperature during the welding of a test assembly in approval tests.

For welding procedures with an additional heating, the restriction of the range of approval on a minimum interrun temperature shall comply with an actual interrun temperature during the welding of a test assembly in approval tests.

7.5.3.9 Post-weld heat treatment or ageing.

The deviation of heat treatment parameters including heat treatable hardening (in the direction of both increase and decrease), from those set during tests for the welding procedure approval is not allowed.

The range of approval shall be limited to the temperature interval used in approval tests.

If provided in WPS, the heating and cooling rate shall be additionally specified in the range of approval, as well as the soaking time of a welded joint at the check temperature. In so doing, it is not permitted to supersede heat treatable hardening with natural ageing at the room temperature and vice versa, depending on the WPS requirements.

7.5.3.10 The range of approval for the welding procedure of metal-arc inert gas welding (131) shall be limited by:

the group of the standard composition of inert gas (refer to Table 4.7.1.4), which is identical to the group with gas composition used in qualification tests;

the system of welding wire feed, which is identical to the one used in approval tests (single- or multiple-electrode welding).

7.5.3.11 The range of approval for the welding procedure of inert-gas non-consumable (tungsten)-electrode arc welding (141) shall be limited by the group of the shielding gas standard composition (refer to Table 4.7.1.4), which is identical to that with the gas composition used in approval tests to protect a welding bath and a weld root as well (with backing gas).

7.5.3.12 The range of approval for the welding procedure of plasma arc welding (15) shall be limited by the group of the shielding gas standard composition (refer to Table 4.7.1.4), which is identical to that with the gas composition used in approval tests:

as plasma-forming;

for welding bath protection;

for weld root protection (with backing gas).

Table 7.5.3.2

Range of approval of welding procedures for different types of welded joints by welding positions

Weld type in test assembly welding	Weld position[1] in test assembly welding	Approved welding positions and joint types[4]					
		Plates			Pipes		
		Butt joint	Fillet joint		Butt joint	Fillet joint	
			with bevelling	without bevelling		with bevelling	without bevelling
Butt/plate. Test assembly according to Fig. 7.3.2.1	PA	PA	PA, PB[3]	—	PA[4]	PB fixed[4,5]	—
	PC	PA, PC	PA, PB[3]	—	PA, PC[4]	PB fixed and PB rotary[4,5]	—
	PG	PG	PG[3]	—	—	—	—
	PF	PA, PC, PF	PA, PC, PF[3]	—	—	—	—
	PE	PA, PC, PE, PF	PA, PB, PD, PF[3]	—	—	—	—
Fillet/plates without bevelling. Test assembly according to Fig. 7.3.2.3	PA	—	—	PA	—	—	—
	PB	—	—	PB	—	—	PB[4,5]
	PG	—	—	PG	—	—	—
	PF	—	—	PF	—	—	—
	PD	—	—	PD	—	—	—
Fillet/plates with bevelling. Test assembly according to Fig. 7.3.2.3	PA	—	PA	—	—	PB fixed[4,5]	—
	PB	—	PA, P	—	—	PB fixed and PB rotary[4,5]	—
	PG	—	PG	—	—	—	—
	PF	—	PA, PC, PF	—	—	—	—
	PD	—	PA, PB, PD, PF	—	—	—	—
Butt/pipes. Test assembly according to Fig. 7.3.2.2	PA	PA	—	—	PA	PB fixed[4,5]	PB fixed[5]
	PC	PA, PC	—	—	PC	PB fixed and PB rotary[4,5] PG[5]	PB fixed and PB rotary[5] PG[5]
	PG	PG	—	—	PG	PB, PF, PD[5]	PB, PF, PD[5]
	PF	PA, PC, PE, PF	—	—	PA, PF, PC		
	H-LO45	PA, PC, PE, PF	—	—	All but PG	All but PG[5]	All but PG[5]
Fillet/pipes. Tee-, Y- and K-joints of pipes without bevelling. Test assembly according to Fig. 7.3.2.4.1	Welding processes: MW and SA; vertical pipe axis	—	—	All but PG	—	—	All but PG
	Welding process: A; pipe axis according to WPS	—	—	—	—	—	Pipe axes orientation is within ±30° from the angle in tests
Fillet/pipes. Tee-, Y- and K-joints of pipes with bevelling. Test assembly according to Fig. 7.3.2.4.1	Welding processes: MW and SA; vertical pipe axis	All but PG	All but PG	—	All but PG	All but PG	—
	Welding process: A; pipe axis according to WPS	—	—	—	—	Pipe axes orientation is within ±30° from the angle in tests	—

[1] Designations of weld positions in tests complies with ISO 6947.
[2] The Table requirements are valid for the manual and semiautomatic welding. For the automatic welding process, the provisions of 7.5.3.2 shall be followed.
[3] Based on the additional limitations set by the requirements of 7.3.2.3.
[4] Approval is valid only for pipes with the external diameter over 500 mm.
[5] Based on the additional limitations set by the requirements of 7.3.2.4.2 and 7.3.4.3.

Table 7.5.3.3

Range of approval by welded joint types

Type of welded test assembly in approval tests			Range of approval									
			Plates (P)							Pipes[1] (T)		
			Butt joints				Tee-joints (BW)		Fillet joints without beveling (FW)	Butt joints		Fillet-joints (FW)
			Single-sided welding		Welding from both sides		Single-sided welding (ss)	Welding from both sides (bs)		Single-sided welding		
			with backing material (mb)	without backing (nb)	with gouging or grinding (gg)	without gouging or grinding (ng)				with backing material (mb)	without backing (nb)	
Butt joint of plates (BW)	Single-sided welding (ss)	with backing material (mb)	*	—	×	×	—	×	×	—	—	×
		without backing (nb)	×	*	×	×	×	×	×	—	—	×
	Welding from both sides (bs)	with gouging or grinding (gg)	—	—	*	×	×	×	×	—	—	×
		without gouging or grinding (ng)	—	—	—	*	—	×	×	—	—	×
Butt joint of pipes[1] (BW)	Single-sided welding (ss)	with backing material (mb)	×	—	×	×	—	×	×	*	—	×
		without backing (nb)	×	×	×	×	×	×	×	×	*	×
Tee-joint of plates with beveling (BW)	Single-sided welding (ss)		—	—	—	—	*	×	×	—	—	×
	Welding from both sides (bs)		—	—	—	—	—	*	×	—	—	×
Fillet joint (FW)	Plates (P)		—	—	—	—	—	—	*	—	—	×
	Pipes (T)		—	—	—	—	—	—	—	—	—	*

Symbols:
* — types of welded joints, for which WPS is approved directly on the basis of test results;
× — types of welded joints, for which WPSs may be approved on the basis of the range of approval (without additional tests);
— types of welded joints, for which WPSs are not subject to approval.

[1] For the pipe joint test assemblies with beveling, the range of approval by welded joint types is established similarly to butt pipe joints.
Note. Designations in brackets comply with Fig. 7.2.2.

PART XV. AUTOMATION

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of Sections 1, 2, 3, 7 apply to automation equipment subject to survey irrespective of whether the ship has an automation mark in the class notation or not.

The requirements of Sections 4, 5, 6 also apply to ships, which have one of the automation marks added to the character of classification in conformity with 2.2.6, Part I "Classification".

1.1.2 The present Part contains technical requirements for the automation equipment and ships, in which it is installed and defines the extent of remote automated control, protection, alarming and indication.

1.1.3 For ships with electric propulsion plants and ships with nuclear propulsion plants, the level of automation to grant the automation mark in the class notation is subject to special consideration by the Register in each case.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 Definitions and explanations relating to the general terminology of the Rules are given in Part I "Classification".

For the purpose of the present Part the following definitions have been adopted.

A u t o m a t e d m a c h i n e r y p l a n t is a complex of machinery and equipment fitted up with an automation system.

U n i n t e r r u p t i b l e p o w e r s u p p l y is a device supplying output power in some limited time period after loss of main and/or emergency input power with no interruption of the output power.

A c k n o w l e d g e m e n t is a confirmation of receipt of an alarm or call.

G r o u p a l a r m s u b s y s t e m is the structural part of the centralized alarm system comprising individual additional blocks (panels) wherein some alarms derived from the combining (grouping) of alarms relating to individual machinery and arrangements into one common alarm are concentrated.

The group alarm shall be named after the item to be monitored, e.g. "main engine", "electric power plant", etc.

The group alarm blocks are arranged in accommodation, service and other spaces where the responsible personnel (chief engineer, watch engineers, electrician engineer, etc.) may be present.

S t a n d b y p o w e r s o u r c e is a source of electric power independent of the ship main and emergency power sources.

A l a r m s y s t e m is equipment for signalling whenever the controlled parameters reach the preset limit values or deviations of machinery and associated systems from normal working ranges occur. Individual alarms may be grouped in common alarms.

A u t o m a t i o n s y s t e m is equipment intended for an automatic and/or automated control, regulation, monitoring, signalling and protection of machinery or systems.

R e m o t e a u t o m a t e d c o n t r o l s y s t e m is equipment intended for control of machinery from a remote control station enabling an automatic execution of intermediate operations for collection and processing of information on the object and making commands to the executive devices realizing the mode of the machinery functioning set up by the operator.

S a f e t y s y s t e m is equipment to automatically influence, in a specific way, the operation of machinery under control in order to prevent an emergency or limit its consequences.

I n d i c a t i o n s y s t e m is equipment providing information on the values of certain physical parameters and certain conditions in machinery.

A u t o m a t i o n d e v i c e is a part of automation system comprising components, which form a structural and functional unity.

A u t o m a t i o n c o m p o n e n t is a structurally independent item (e.g. sensor, relay, logic element) forming part of automation devices and systems.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions concerning classification procedure, survey of ships being designed or constructed, manufacture of equipment and items shall be found in Part I "Classification" and General Regulations for the Classification and Other Activity.

1.3.2 Subject to survey during manufacture are automation components, apparatus and control devices of the following:

.1 main machinery and propellers;
.2 electric power plants;
.3 auxiliary machinery;
.4 main and auxiliary boilers;
.5 refrigerating plants;
.6 alarm systems;
.7 protection devices;
.8 other systems as required by the Register.

1.4 TECHNICAL DOCUMENTATION

1.4.1 For the automation equipment listed under 1.3.2, the technical documentation to be submitted to the Register depending on the object of survey, is as follows:

.1 functional description including technical parameters and operating conditions;

.2 block diagram of control system;

.3 functional process diagram with indication of all instruments and control devices;

.4 general arrangement and layout;

.5 user interface description showing the physical layout, a list of all alarms, functions allocated each keyboard/screen;

.6 power supply arrangement and connection diagram;

.7 cable routing layout diagram;

.8 instrument and equipment list with indication of performance specifications;

.9 description of functions covered by software and test program for application software at manufacturer's;

.10 schematic diagrams of input and output circuits;

.11 failure mode description;

.12 test program;

.13 operation manual;

.14 installation and maintenance manual.

1.4.2 The technical documentation of equipment shall be submitted to the Register for consideration prior to ship construction in the number as stipulated in 3.2.9, Part I "Classification".

2 DESIGN OF AUTOMATION SYSTEMS, AUTOMATION COMPONENTS AND CONTROL DEVICES

2.1 GENERAL

2.1.1 Reliable operation of automation systems, automation components and control devices shall be ensured under the following ambient temperature conditions:

0 °C to +45 °C in enclosed spaces,

−25 °C to +45 °C on open deck.

Electronic components and devices to be fitted in distribution boards, control panels or enclosures shall reliably operate at ambient temperatures up to +55 °C.

No damage to automation systems, automation components and control devices shall be caused by temperatures up to +70 °C.

2.1.2 Reliable operation of automation systems shall be ensured at relative air humidity of (75±3°) per cent and temperature of (45±2) °C or at relative air humidity of (80±3) per cent and temperature of (40±2) °C, as well as at relative air humidity of (95±3) per cent and temperature of (25±2) °C.

2.1.3 Reliable operation of automation systems shall be ensured at vibrations having a frequency of 2 to 100 Hz, namely, with shift amplitude of ±1 mm where the vibration frequency is between 2 and 13,2 Hz, and with an acceleration of ±0,7 g where the vibration frequency is between 13,2 and 100 Hz.

Reliable operation of automation systems mounted upon vibration sources (diesels, compressors, etc) or installed in steering flats shall be ensured at vibration frequencies of 2 to 100 Hz, namely, with a shift amplitude of ±1,6 mm where the frequency is between 2 and 25 Hz, and with an acceleration of ±4,0 g where the frequency is between 25 and 100 Hz.

2.1.4 Reliable operation of automation systems shall be ensured at long-term heel up to 22,5° and at motions of 22,5° with a period of (8±1) s.

2.1.5 The protection of automation systems, automation components and control devices shall be chosen in accordance with 2.4, Part XI "Electrical Equipment" proceeding from their location.

2.1.6 Electrical and electronic components and devices shall operate reliably in case of deviation of the power parameters listed in Table 2.1.6 from nominal values.

Table 2.1.6

Parameter	Deviation from nominal value		
	Long-term, %	Short-term	
		%	Time, s
Voltage (A. C.) Frequency	+6...−10 ±5	±20 ±10	1,5 5
Voltage (D. C.)	±10	5 10	Cyclic deviation of ripple

Automatic equipment supplied from accumulator batteries shall operate reliably with the following voltage variations from the nominal value:

from +30 to −25 per cent for the equipment, which is not disconnected from the battery during battery charging;

from +20 to −25 per cent for the equipment, which is disconnected from the battery during battery charging.

The operability of automation systems shall not be affected by three successive power supply interruptions during 5 min with switching-off time of 30 s in each case.

2.1.7 Pneumatic and hydraulic components and devices shall be operable under variations of the working medium pressure within ±20 per cent of the nominal value.

2.1.8 Provision shall be made to ensure the electromagnetic compatibility of automation equipment as specified in 2.2, Part XI "Electrical Equipment" and to keep the radio interference from it to a permissible level.

2.1.9 Automation equipment shall operate reliably in case of harmonic distortions of the supply voltage curve as specified under 2.2.1.3, Part XI "Electrical Equipment".

2.1.10 Components and devices to be installed in locations with specific operating conditions (high or low temperature, excessive mechanical loads, etc) shall be designed and tested with regard to the conditions.

2.1.11 Automation equipment shall be made of materials resistant to marine environment or shall be reliably protected from its harmful effect.

2.1.12 Automation systems shall comprise arrangements to preclude false alarms from momentary changes of parameters due to roll of the ship, machinery switch-on and switch-off, etc.

2.1.13 Automation systems shall be based on the "fail-to-safe" principle.

2.1.14 The list of spare parts for automation equipment and systems is made up by the manufacturer.

For a particular ship, the total number of spare parts is determined on the basis of agreement between the shipbuilder and equipment manufacturer on one part and the shipowner on the other with due regard to the equipment reliability.

2.2 REQUIREMENTS TO COMPONENTS AND DEVICES

2.2.1 The components and devices of automation systems shall additionally comply with the applicable parts of the Rules.

2.2.2 Replaceable components, which require adjustment, as well as check-up points (terminals, monitoring jacks) shall be so arranged that easy access is possible at any time.

2.2.3 The devices shall be capable of being tested during normal operation.

2.2.4 Equipment shall preferably function without forced cooling. Where such cooling is indispensable, precautions shall be taken to prevent the equipment from being damaged in the event of failure of the cooling unit.

2.2.5 Setting components shall be protected against spontaneous change of setting. Such protection shall not preclude the possibility of adjustment.

2.2.6 Actuators shall be so constructed that no spontaneous change of their setting is possible.

2.2.7 Sensors used for measuring temperature of fire-hazardous, toxic liquids, vapours and gases, liquids, vapours and gases under pressure shall be isolated from the medium tested.

2.2.8 Provision shall be made for checking and calibrating of the pressure transducers at their connections to the test points, without dismantling.

2.2.9 All units, devices and test points shall be clearly and permanently marked. The marking shall be preferably placed adjacent to them.

2.2.10 Electrical and electronic equipment.

2.2.10.1 The contacting connections shall be so designed as to prevent the increase of contact resistance restricting the equipment performance.

2.2.10.2 At cable and wire inlets, especially in way of connections to movable elements and devices, provision shall be made to avoid tension effects.

2.2.10.3 Printed circuit boards shall be coated with insulating varnish.

2.2.10.4 Provision shall be made to prevent incorrect mounting of removable items (modules) having plug-and-socket connections and to ensure their efficient fixing in the working position. Where necessitated by the operating or structural features of components or devices, their position assuring proper mounting shall be clearly marked or, alternatively, they shall be so constructed that the possibility of being mounted in a wrong position is excluded.

2.2.11 Hydraulic and pneumatic equipment.

2.2.11.1 Hydraulic and pneumatic components and devices shall not be damaged by overloads due to a working medium pressure rise equal to 1,5 times the working pressure.

2.2.11.2 The fluids of hydraulic systems shall retain their physical properties under all possible operating conditions, to possess good lubricating properties and a vapour flash point not less than 60 °C, not to cause the damage to components and piping and not to be toxic.

2.2.11.3 Hydraulic automation equipment shall not be connected with other systems and shall be supplied from separate tanks. On agreement with the Register, the use of fluid from other systems may be permitted for actuating systems subject to provision of filtering arrangements.

2.2.11.4 Connections of the outlet pipes shall be located below the working fluid level in the tanks under any operating conditions of the ship.

2.2.11.5 Pneumatic automation systems shall have arrangements to ensure the required degree of cleanliness and dryness of the air.

2.2.11.6 Pneumatic automation systems of the main propulsion plants and electrical power plants shall generally have two devices for cleaning and drying the air interconnected in such a way that one of them remains operative while the other is cut off.

A single air cleaning and drying device may be permitted where automatic cleaning is provided or its design is such that a rapid replacement of filtering elements is possible without interruption of the air supply.

2.2.11.7 The feeding pipes of pneumatic automation systems shall be fitted up with safety valves set to operate when the nominal working pressure is exceeded by more than 10 per cent. Reducing valves, if any, shall be duplicated.

2.2.11.8 Where hydraulic, pneumatic and electronic or electric elements and devices are combined in desks, cabinets or cubicles, they shall be effectively separated so that eventual leaks from pipes and hoses and from their connections would not damage such elements and devices.

Desks, cabinets and cubicles accommodating equipment, which contains working fluid, shall be fitted up with appliances for collection and retrieval of the leaks.

2.3 AUTOMATED CONTROL SYSTEMS

2.3.1 Machinery and plants shall be constructed in conformity with the applicable requirements of the relevant parts of the Rules, and equipped with local control stations.

2.3.2 Automated control shall keep all controlled parameters within the limits specified by the normal operating conditions of the machinery and plants under control.

2.3.3 The automated control shall be stable over the entire control range. The margin of stability shall be sufficient to ensure that variations in the controlled parameters that may be expected under normal conditions will not cause instability.

2.3.4 Machinery and plants, which can be started automatically or remotely, shall be fitted up with devices at local control stations to switch off the automatic or remote control, respectively.

In case of automatic or remote control failure, local control is still to be possible.

2.3.5 Changeover from local control mode to automatic or remote control mode shall be possible from local control stations only. Changeover from remote to automatic control mode may be effected from remote control stations.

2.3.6 If the preset sequence of operations is disturbed, the automated control system shall stop performing the program and shall bring the machinery to a safe condition with an alarm given at all cases at the permanently attended control station.

2.3.7 The starting system of powerful consumers of electrical power, the switching on of which may result in the inadmissible loss of voltage or the main switchboard busbars failure, shall provide for the following:

preliminary automatic start of the standby generator, synchronization, load acceptance and distribution; or

interlocking device preventing the switching on of such consumers prior the standby generator switching to the main switchboard busbars, and the appropriate indication.

2.4 ALARM, PROTECTION, INDICATION AND LOGGING SYSTEMS

2.4.1 Alarm system.

2.4.1.1 The alarm system shall be independent of control systems and safety devices, i.e. it shall not be affected by malfunction or failure of such devices.

Possibility of partial integration of these systems is subject to special consideration of the Register in each case.

2.4.1.2 Provision shall be made for the self-monitoring of the alarm system; the alarm signal shall be applied in the case of at least such typical faults as short-circuits, open-circuit failure and earth fault, and the failure of the power supply.

2.4.1.3 The alarm system shall give visual and audible signals simultaneously. In this case the possibility of simultaneous indication of more than one fault shall be provided. The acknowledgement of one signal shall not prevent the entry of another. The failure of one component (device) of the system shall not cause failure of the alarm system in general. When common monitors are applied instead of individual light signalling devices, at least two such monitors shall be provided.

2.4.1.4 The alarm system with its central information panels usually arranged in the engine control room shall structurally include the group alarm subsystem, which blocks shall be located:

in machinery spaces (indicator columns);

on the navigating bridge (in the wheelhouse);

in service and public spaces of a ship;

in accommodation spaces of the responsible personnel.

The switching-off of an audible alarm signal on the group alarm blocks (e.g. on the navigating bridge or in accommodation spaces) shall not cause its switching-off in the main machinery control room.

2.4.1.5 In machinery spaces, along with the audible signal devices of the alarm system provision shall be made for visual display units (indicator columns) for the identification of the signal, for which colours and symbols shown in Table 2.4.1.5 shall be used.

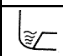
2.4.1.6 In spaces with high ambient noise levels, additional audible and visual (rotating light) signal units shall be installed.

2.4.1.7 The visual signals shall indicate the fault condition resulted in alarm operation and are generally to flash. The flashing alarm shall be illuminated for at least 50 per cent of the cycle and have a pulse frequency in the range of 0,5 and 1,5 Hz.

2.4.1.8 Alarms at workstations shall normally be acknowledged in two steps:

switch-off audible signal and additional visual signal (e.g. rotating light signals, etc) leaving the visual signal on the workstation unchanged;

Table 2.4.1.5

Signal	Colour	Symbol
Fire detection alarm in spaces other than machinery spaces	Red	
Machinery fire detection alarm	Red	
Fire-extinguishing medium release alarm	Red	CO_2 HALON AEROSOL
Machinery alarm	Yellow	
Steering gear alarm	Yellow	
Bilge alarm	Yellow	
Engineers' alarm	Yellow	
Telephone	White	
Engine-room telegraph. Command transmission	White	

acknowledgment of the visual alarm on the workstation. After being accepted, the flashing light shall change to steady condition.

Cancelling of a visual signal shall only be possible after the abnormal condition has been corrected.

2.4.1.9 Self-eliminating faults shall be indicated by the alarm system in such a way that the signal remains applied until it is accepted.

2.4.1.10 Checking of the alarm system shall be possible while machinery in operation.

2.4.1.11 Irrespective of the extent of automation and the monitoring order used for the machinery, the alarm system shall give warning signals at:

.1 parameters reaching predetermined limit values;

.2 operation of safety devices;

.3 power failure in the circuits of particular automation systems or start of emergency power sources;

.4 deviation from predetermined values of other parameters or operating conditions as regulated by the present Part.

Alarms for machinery faults shall be provided on the panels, from which the machinery is remotely controlled.

2.4.1.12 The alarm system shall be so arranged that signals not pertinent to navigation and navigational situation are in the first place relayed to the panels in machinery spaces and main machinery control room, as well as to group alarm device in the accommodation, service and public spaces, in which the members of machinery crew might be staying. Then, if the signals are not acknowledged within a specified period of time (e.g. 2 min), they shall be directed to the navigating bridge.

2.4.1.13 The engineers' alarm referred to in 7.8.1, Part XI "Electrical Equipment" shall be additionally activated automatically where an alarm for machinery plant is not acknowledged at the place of its destination within a specified period of time (e.g. 2 min).

2.4.1.14 The personnel alarm referred to in 7.9.1, Part XI "Electrical Equipment" shall be additionally activated automatically when the engineer on duty has to attend machinery space in case of a machinery alarm. Acknowledgement of the personnel alarm shall not be possible before the engineer has acknowledged the alarm in the machinery space.

2.4.1.15 Manual blocking of separate alarms shall be clearly indicated at the workstation.

2.4.1.16 Blocking of alarm and safety functions in certain operating modes of machinery (e.g. during start-up) shall be automatically disabled in other modes.

2.4.1.17 The audible signals of the alarm system shall be readily distinguishable from audible signals of other systems. The audible signals shall have a frequency from 200 up to 2500 Hz. Provision may be made for means to adjust the frequency of audible signals within the range specified above. The waveform of audible signal released by alarm system shall correspond to one of the waveforms shown in Table 2.4.1.17. The sound pressure level at a distance of 1 m from the sound source shall be not lower than 75 dB and more than by 10 dB higher than the ambient noise existing during the normal functioning of the equipment with the ship underway under moderate weather conditions. The sound pressure level in a space shall not exceed 120 dB. The sound pressure level shall be measured within the frequency band of 1/3 octave with respect to the frequency of the first harmonic of the signal. To ensure that the signal can be properly heard in large spaces and in spaces with high level of ambient noise, several audible signal units shall be installed. The audible signal of the alarm system shall be clearly heard even though one of the signal display units fails.

2.4.2 Protection devices.

2.4.2.1 The safety system shall be activated automatically at faults that could involve an emergency condition of machinery or equipment in order to:

.1 restore normal operating conditions (by starting standby units);

.2 temporarily adjust the operation of machinery to the prevailing conditions (e.g. by reducing the load upon the machinery);

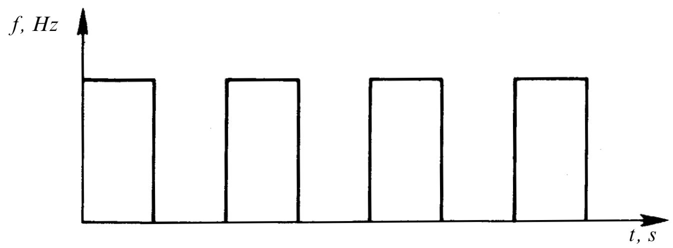
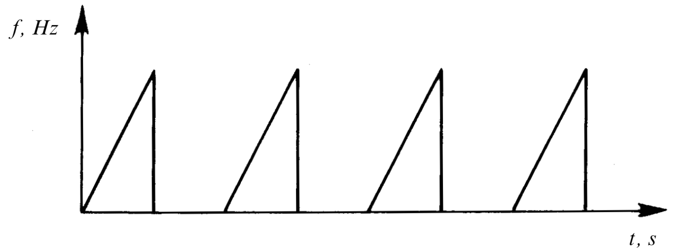
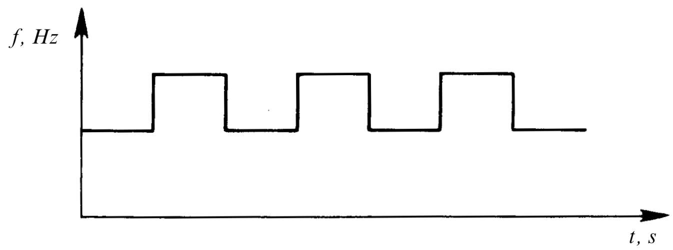
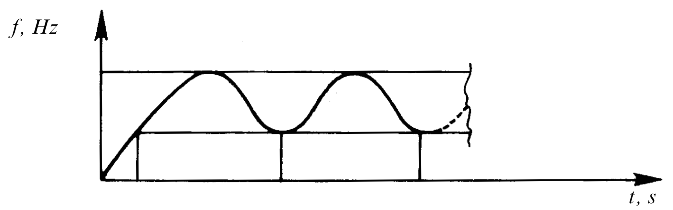
.3 protect machinery from emergency condition by stopping the machinery.

Automatic stopping of main machinery shall be executed only in cases of deviation of those parameters, which could lead to serious damage, complete breakdown or explosion.

A safety system shall include an indicator to show the parameter, for which the system was put into operation.

Table 2.4.1.17

Waveforms of audible signals of the alarm system

Nos	Waveform
1	
2	
3	
4	

2.4.2.2 The protection systems arranged to shut down the machinery shall be independent of control and alarm systems including sensors so that the faults and failures of those systems including their supply systems would not influence the safety systems.

Where arrangements for overriding the shutdown of machinery are fitted, these shall be such as to preclude inadvertent operation. Light signal shall be provided on the machinery control panel to indicate when the override has been activated.

2.4.2.3 Provision shall be made for the self-monitoring of the safety systems: at least at such faults as short-circuit, open-circuit failure and earth fault an alarm signal shall be activated.

2.4.2.4 The protection systems of particular machinery and plants shall be independent of each other so that a failure in the safety system of certain machinery or plant would not affect the operability of the safety systems of the rest of the machinery and plants.

2.4.2.5 When the protection system stops the machinery, the machinery shall not start again automatically while the emergency condition is corrected.

2.4.2.6 Provision protection be made within the automatic safety system of the main machinery (propulsion plant) for the alarm to warn of the forthcoming inevitable activation of the safety system for slowdown or shutdown propulsion so that the watchk officer has an opportunity and sufficient time to assess navigational situation and in an emergency, if necessary, to counteract the activation of the safety system except for those cases when manual intervention will result in total failure of the main machinery within a short time, for example in the case of overspeed.

2.4.3 Indication and logging systems.

2.4.3.1 Indications sufficient to allow safe operation of essential and important functions shall be installed at all control locations from where the function shall be accomplished. Alarms shall not be considered as substitutes for indications for this purpose.

2.4.3.2 Indication and logging systems shall be independent of any other systems so that their failure would not affect such other systems.

2.4.3.3 When logging systems fail, the alarm signal shall be activated.

2.4.3.4 Provision shall be made for easy reading of indicated data with regard to the illumination at the locations of indicators.

2.4.3.5 Provision shall be made for displaying the readings of indication systems in units normally used for the parameters, i.e. without recalculation.

3 POWER SUPPLY OF AUTOMATION SYSTEMS

3.1 GENERAL

3.1.1 Where automated units shall be supplied from both the main and emergency power sources, the automation systems shall also be supplied from these two power sources independent of each other.

3.1.2 The control systems of main machinery shall be supplied by two separate feeders, one of which shall take power from the main switchboard and the other may be connected to the switchboard for essential services or, by way of exception, to the nearest switchboard. The changeover from one feeder to another shall be effected automatically with appropriate signal activated at the control station.

3.1.3 Provision shall be made in the power supply for safety arrangements to allow selective disconnection of failed components.

3.1.4 Where the automation systems of particular auxiliary machinery are supplied by the same feeders as the corresponding electric drives, provision shall be made for a start of standby unit and for connection of the automation system to its feeder in case of a loss of power at the running unit.

3.1.5 Hydraulic and pneumatic automation systems shall be supplied from two sources. The second source shall be connected automatically upon pressure loss with application of an alarm signal.

The use of starting air for automation systems is permitted, provided the air receivers are filled automatically and the requirements of 2.2.11.5 and 2.2.11.6 are complied with.

3.1.6 Alarm and safety systems shall be supplied from an uninterruptible power source, with an alarm being activated upon loss of its input voltage.

The capacity of the accumulator battery of the said power source shall be sufficient for servicing the alarm and safety systems during at least 30 min.

3.1.7 The controls of generator drives shall be supplied independently of the main switchboard busbars.

4 SHIPS WITH AUT1 IN CLASS NOTATION

4.1 GENERAL

4.1.1 Self-propelled ships and floating facilities with the automation mark **AUT1** in class notation shall be equipped with machinery plant automation systems in compliance with the requirements of the Section and to the extent sufficient to ensure their manoeuvrability and safety under all operating conditions without permanent attendance of personnel in machinery spaces and engine control room.

4.1.2 Provision shall be made for an integrated alarm system to cover all the parameters and working conditions under control as mentioned in the Section.

4.1.3 Provisions concerning fire protection shall be found in 4.2.3, Part VI "Fire Protection".

4.1.4 All equipment installed in a machinery space shall be capable of operating in an unattended machinery space and engine control room. On agreement with the Register, some operations (replenishment of tanks, cleaning of filters, etc) may be performed manually, if carried out at certain intervals (not more than once every 24 h).

4.2 AUTOMATED MAIN MACHINERY AND PROPELLERS

4.2.1 Provision shall be made for remote automated control of starting and stopping, as well as of rotational frequency of the main machinery, propeller thrust value and direction within the whole permissible operating range of the propulsion system.

4.2.2 Remote automated control shall meet the following requirements:

.1 automatic attempts, which fail to produce a start, shall be limited so that after the last ineffective attempt the starting air quantity or accumulator battery capacity is sufficient to provide manually a half number of starting attempts as required in 16.1, Part VIII "Systems and Piping" or 13.7.2, Part XI "Electrical Equipment";

.2 the last command given shall be executed regardless of the order sequence and quickness;

.3 setting of the thrust value and direction may be effected by means of a single control unit;

.4 an automatic passing of the critical rotational frequency ranges irrespective of the set-operating mode;

.5 overload of the main machinery in the normal operating modes shall be prevented;

.6 remote automated control systems and engine telegraph systems shall be independent of each other (common control lever may be used);

.7 provision shall be made for signalling to indicate power loss and malfunction of the remote automated control system;

.8 impermissible operating modes of the main machinery and propellers (spontaneous increase of rotational frequency, start and reverse) in the event of failure of the remote automated control system shall be precluded;

.9 emergency manoeuvring shall be ensured within the shortest time possible, and along with that, relevant limitations and protections may be removed.

4.2.3 Where there are several control locations, the one in the engine control room shall be predominant over the one on the navigating bridge. The same is true in respect of the local control stand as compared to that in the engine control room.

4.2.4 The transfer of control from one control location to another shall be possible from a predominant location only, irrespective whether the controls at the locations are matched or not.

The transfer of control shall be accompanied with audible and visual signals at all the control locations. At the locations, provision shall be made for visual indicators showing from which location control is performed.

4.2.5 The possibility of simultaneous control from different locations shall be eliminated. Use of interconnected controls at one location (e.g. at bridge wings and spaces) may be permissible.

4.2.6 At all the control locations including disconnected ones, provision shall be made for permanent indication of commands transmitted by engine telegraph.

4.2.7 The main engine emergency stop device required by 3.2.1.6, Part VII "Machinery Installations", if electrically operated, shall be independent of the remote automated control system, alarm system and of the ship mains.

4.2.8 In case of main internal combustion engine as a propulsion plants, the temperature of the working media listed below shall be automatically adjust within the prescribed limits:

cylinder coolant;

piston coolant;

nozzle coolant;

lubricating oil;

fuel oil (if heavy oil is used and viscosity regulation is not available).

As far as main machinery of other types is concerned, the automatic regulation of working medium temperature shall be agreed with the Register.

4.2.9 With regard to geared diesel plants (two diesels and more), provision shall be made that, with one engine shut down, the others go on running without being overloaded.

4.2.10 Monitored parameters of automated main machinery and propellers, measuring points, limiting values of parameters and types of automatic protection and indication shall be found in Tables 4.2.10-1 to 4.2.10-5.

Table 4.2.10-1

Main internal combustion engines (low-speed)

Nos	Monitored parameter	Group 1: indication, alarm, automatic slowdown	Group 2: automatic start of stand-by pumps with alarm	Group 3: automatic shutdown of engine
1	**Fuel oil system**			
1.1	Fuel oil pressure after filter (at engine inlet)	●↓	■	—
1.2	Fuel oil viscosity (temperature) before fuel injection pumps	↑(↓)	—	—
1.3	Fuel oil leakage from high-pressure piping	○	—	—
1.4	Fuel oil level in daily service tank[1]	↓	—	—
2	**Lubricating oil system**			
2.1	Lubricating oil to main and thrust bearing pressure	●↓▼	■	×
2.2	Lubricating oil to crosshead bearing pressure[2]	●↓▼	■	×
2.3	Lubricating oil to camshaft pressure[2]	↓	■	×
2.4	Lubricating oil to camshaft temperature[2]	↑	—	—
2.5	Lubricating oil temperature at engine inlet	↑	—	—
2.6	Thrust bearing pads temperature or bearing outlet lubricating oil temperature	↑▼	—	×

Nos	Monitored parameter	Group 1: indication, alarm, automatic slowdown	Group 2: automatic start of stand-by pumps with alarm	Group 3: automatic shutdown of engine
2.7	Main, crank, crosshead bearing lubricating oil outlet temperature or oil mist concentration in crankcase[3]	↑▼	—	—
2.8	Flow rate of cylinder lubricating oil at outlet of each lubricator	↓▼	—	—
2.9	Lubricating oil level in sump circulation tank[4]	↓	—	—
3	**Turbocharger**			
3.1	Turbocharger lubricating oil inlet pressure	↓	—	—
3.2	Turbocharger lubricating oil temperature at outlet of each bearing	↑	—	—
3.3	Speed of turbocharger	●	—	—
4	**Piston cooling system**			
4.1	Piston coolant pressure at engine inlet[5]	↓▼	■	—
4.2	Piston coolant temperature at outlet of each piston	↑▼	—	—
4.3	Piston coolant flow at outlet of each piston[6]	↓▼	—	—
4.4	Piston coolant level in expansion tank	↓	—	—
5	**Sea water cooling system**			
5.1	Sea water pressure	↓	■	—
6	**Cylinder fresh cooling water system**			
6.1	Cylinder cooling water pressure at inlet of mains	↓▼	■	—
6.2	Cylinder cooling water temperature at outlet of each cylinder[7]	↑▼	—	—
6.3	Presence of oil in fresh cooling water[8]	○	—	—
6.4	Level of cylinder cooling water in expansion tank	↓	—	—
7	**Starting air and control air system**			
7.1	Starting air pressure before main starting valve	●↓	—	—
7.2	Control air pressure in engine control system	↓	—	—
7.3	Control air pressure in emergency engine shutdown system	↓	—	—
8	**Scavenge air system**			
8.1	Scavenge air receiver pressure	●	—	—
8.2	Temperature in scavenging and sub-piston spaces (ignition)	↑▼	—	—
8.3	Scavenge air receiver water level	↑	—	—
9	**Exhaust gas system**			
9.1	Exhaust gas temperature after each cylinder	●↑▼	—	—
9.2	Exhaust gas temperature after each cylinder outlet, deviation from average value	↑	—	—
9.3	Exhaust gas temperature before each turbocharger	●↑	—	—
9.4	Exhaust gas temperature after each turbocharger	●↑	—	—
10	**Fuel valve coolant**			
10.1	Fuel valve coolant pressure	↓	■	—
10.2	Fuel valve coolant temperature	↑	—	—
10.3	Fuel valve coolant level in expansion tank	↓	—	—
11	**Engine speed/direction of rotation**	●	—	—
12	**Engine direction of rotation opposite to that prescribed**	○	—	—
13	**Engine overspeed**	○	—	×
14	**Failure of power supply to control, safety and alarm systems**	○	—	—
15	**Gas concentration in machinery spaces**[9]	↑	—	—

Note. For Group 1 parameters a common sensor is provided for indication, alarm and safety systems (for slowdown);
for Group 2 parameters — a sensor for automatic start of stand-by pumps;
for Group 3 parameters — a sensor of safety system (engine shutdown).

Symbols:
- ● — remote indication;
- ↑ — alarm for high value;
- ↓ — alarm for low value;
- ○ — alarm signal;
- ■ — automatic start of stand-by pumps;
- ▼ — slowdown;
- × — engine shutdown.

[1] High level alarm is also required if not suitable overflow arrangement is provided.
[2] If separate lubricating oil systems are installed.
[3] For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.
[4] Where separate lubricating oil systems (for camshaft, rocker arms, etc) are installed, individual level alarms shall be provided for each system.
[5] Slowdown is not required if the coolant is oil taken from the main cooling system of the engine.
[6] Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted.
[7] Where one common cooling space without individual stop valves is employed for all cylinder jackets.
[8] Where cooling water is used in fuel and lubricating oil heat exchangers.
[9] Required where installations with dual-fuel (gas – liquid fuel) engines are used.

Table 4.2.10-2

Main internal combustion engines (medium- and high-speed)

Nos	Monitored parameter	Group1: indication, alarm, automatic slowdown	Group 2: automatic start of stand-by pumps with alarm	Group 3: automatic shutdown of engine
1	**Fuel oil system**			
1.1	Fuel oil pressure after filter (at engine inlet)	●↓	■	—
1.2	Fuel oil viscosity (temperature) before fuel injection pumps[1]	↑(↓)	—	—
1.3	Fuel oil leakage from high-pressure piping	○	—	—
1.4	Fuel oil level in daily service tank[2]	↓	—	—
2	**Lubricating oil system**			
2.1	Lubricating oil pressure to main and thrust bearings	●↓	■	×
2.2	Lubricating oil differential pressure across filter	●↑	—	—
2.3	Lubricating oil temperature at engine inlet	●↑	—	—
2.4	Oil mist concentration in crankcase[3]	↑	—	×
2.5	Flow rate of cylinder lubricating oil at outlet of each lubricator	↓▼	—	—
3	**Turbocharger**			
3.1	Lubricating oil pressure at turbocharger inlet[4]	●↓	—	—
4	**Sea water cooling system**			
4.1	Sea water pressure	●↓	■	—
5	**Cylinder fresh cooling water system**			
5.1	Cylinder cooling water pressure or flow at engine inlet	●↓▼	■	—
5.2	Cylinder cooling water temperature at outlet of each cylinder[5]	●↑▼	—	—
5.3	Level of cylinder cooling water in expansion tank	↓	—	—
6	**Starting air and control air system**			
6.1	Starting air pressure before main starting valve	●↓	—	—
6.2	Control air pressure	●↓	—	—
7	**Scavenge air system**			
7.1	Scavenge air receiver temperature	↑	—	—
8	**Exhaust gas system**			
8.1	Exhaust gas temperature after each cylinder[6]	●↑▼	—	—
8.2	Exhaust gas temperature after each cylinder outlet, deviation from average value[6]	↑	—	—
9	**Engine speed**	●	—	—
10	**Engine overspeed**	○	—	×
11	**Failure of power supply to control, safety and alarm systems**	○	—	—
12	**Gas concentration in machinery spaces**[7]	↑	—	—

Note. For Group 1 parameters a common sensor is provided for indication, alarm and safety systems (for slowdown); for Group 2 parameters — a sensor for automatic start of stand-by pumps; for Group 3 parameters — a sensor of safety system (engine shutdown).

Symbols:

● — remote indication;
↑ — alarm for high value;
↓ — alarm for low value;
○ — alarm signal;
■ — automatic start of stand-by pumps;
▼ — slowdown;
× — engine shutdown.

[1] When working on heavy fuel.
[2] High level alarm is also required if no suitable overflow arrangement is provided.
[3] Only for medium-speed engines having more than 2250 kW or a cylinder bore more than 300 mm. One oil mist detector for each engine having two independent outputs (one – to alarm system, the other – to engine shutdown) satisfy the requirements for independence between the alarm and safety systems.
[4] If without integrated self-contained lubrication oil system.
[5] Two separate sensors for the alarm system and safety system (slowdown) shall be fitted.
[6] For engines with cylinder output of more than 500 kW.
[7] Required where installations with dual-fuel (gas — liquid fuel) engines are used.

Table 4.2.10-3

Main steam turbines

Nos	Monitored parameter	Group 1: indication, alarm	Group 2: automatic start of stand-by pumps with alarm	Group 3: automatic shutdown of turbine
1	Lubricating oil pressure after oil cooler	●↓	■	×
2	Lubricating oil differential pressure across filter	◗↑	—	—
3	Lubricating oil temperature at each bearing outlet	●↑	—	—
4	Lubricating oil level in gravity tank	◗↓	—	×
5	Steam temperature before manoeuvring valves[1]	◗↑↓	—	—
6	Steam pressure before manoeuvring valves	●↑	—	—
7	Steam pressure in condenser	●↑	—	×
8	Pressure in deaerator	◗↑↓	—	—
9	Water level in deaerator	◗↑↓	—	—
10	Water level in condenser	◗↑↓	—	×
11	Water pressure after condensate pump	◗↓	■	—
12	Condensate salinity	↑	—	—
13	Turbine vibration	↑	—	×
14	Axial displacement of rotor	↑	—	×
15	Steam pressure in end glands	●↑	—	—
16	Sea water pressure at circulating pump outlet	●↓	■	—

N o t e . For Group 1 parameters a common sensor is provided for indication, alarm and safety systems (for slowdown);
for Group 2 parameters — a sensor for automatic start of stand-by pumps;
for Group 3 parameters — a sensor of safety system (turbine shutdown).

S y m b o l s :
● — remote indication (continuous);
◗ — remote indication (on call);
↑ — alarm for high value;
↓ — alarm for low value;
■ — automatic start of stand-by pumps;
× — turbine shutdown.

[1] When re-heating is used, an additional alarm is required at turbine inlet.

T a b l e 4.2.10-4

Main gas turbines

Nos	Monitored parameter	Group 1: indication, alarm	Group 2: automatic start of stand-by pumps with alarm	Group 3: automatic shutdown of gas turbine
1	Lubricating oil pressure at inlet	●↓	■	×
2	Lubricating oil temperature at inlet	◗↑	—	—
3	Bearing temperature	◗↑	—	—
4	Gas temperature at gas turbine outlet	●↑	—	×
5	Flame failure or ignition system failure or stratification of temperatures over flame tubes	◗↑	—	×
6	Automatic start system	○	—	—
7	Fuel oil pressure at gas turbine inlet	●↓	—	×[1]
8	Fuel oil pressure before burners	●↓	—	×[1]
9	Fuel oil temperature before burners[2]	◗↑↓	—	—
10	Pressure differential across air cleaner	◗↑	—	—
11	Gas turbine vibration at each support	◗↑	—	×
12	Axial displacement of rotor	↑	—	×
13	Gas turbine speed (at each rotor)	●↑	—	×[3]
14	Oil level in lubricating oil tank	◗↓	—	—
15	Automatic gas turbine shutdown	○	—	—
16	Gas pollution of machinery room	●↑	—	×[1]
17	Temperature under sheath	●↑	—	—
18	Gas temperature after gas turbine	◗↑	—	—
19	Failure of power supply to control, alarm and safety systems	○	—	—

N o t e . For Group 1 parameters a common sensor is provided for indication, alarm and safety systems (for slowdown);
for Group 2 parameters — a sensor for automatic start of stand-by pumps;
for Group 3 parameters — a sensor of safety system (turbine shutdown).

Table 4.2.10-4 - continued

Symbols:
● — remote indication (continuous);
◗ — remote indication (on call);
↑ — alarm for high value;
↓ — alarm for low value;
■ — automatic start of stand-by pumps;
× — turbine shutdown.

[1] When gas is used.
[2] When high-viscosity fuels are used.
[3] Shutdown resulted from power turbine speed.

Table 4.2.10-5

Shafting, CPP, reduction gear and couplings

Nos	Monitored parameter	Group 1: indication, automatic slowdown	Group 3: automatic shutdown of engine (turbine)
1	**Shafting**		
1.1	Temperature of thrust bearing (or lubricating oil), including those built in engine and reduction gear	↑▼	×
1.2	Temperature of shaft bearings (or lubricating oil)	↑	—
1.3	Temperature of sterntube bearing (or lubricating oil)[1]	↑	—
1.4	Lubricating oil level in sterntube lubricating tank[2]	↓	—
1.5	Water flow at sterntube inlet[3]	↓	—
2	**CPP**		
2.1	Hydraulic oil pressure at outlet of filter	↓	—
2.2	Hydraulic oil level in sterntube oil lubricating tank	↓	—
2.3	Loss of auxiliary power (power supply to controls)[4]	○	—
3	**Reduction gears and couplings**		
3.1	Lubricating oil pressure at reduction gear inlet[5]	●↓	×
3.2	Lubricating oil temperature in reduction gear	◗↑▼	—
3.3	Temperature of each sliding bearing[6]	↑	—
3.4	Hydraulic oil pressure at coupling inlet	●↓	—

Note. For Group 1 parameters a common sensor is provided for indication, alarm and safety systems (for slowdown); for Group 3 parameters — a sensor of safety system (engine (turbine) shutdown).

Symbols:
● — remote indication (continuous);
◗ — remote indication (on call);
↑ — alarm for high value;
↓ — alarm for low value;
▼ — slowdown;
○ — alarm signal;
× — turbine shutdown.

[1] Refer to 5.6.3, Part VII "Machinery Installations".
[2] With closed sterntube.
[3] When water lubrication is used.
[4] Indication at navigating bridge.
[5] Where a coupling is fitted, disengagement of coupling may be effected instead of engine shutdown.
[6] For engines having power of more than 2250 kW.

4.3 AUTOMATED BOILER PLANTS

4.3.1 The requirements of the present Chapter cover boiler plants with oil-burning installations, waste-heat boilers and composite boilers, as well as combinations of such boilers forming part of the ship's machinery plants.

4.3.2 When two or more boilers fitted on board feed a common steam main, provision shall be made for automatic control of each boiler singly operating under load, where such operation is provided by the design, keeping the standby boilers in readiness and putting the boilers under load, parallel operation of boilers and securing all steam.

Automatic transfer from one operating mode to another shall not initiate operation of the safety valves, alarms to indicate steam pressure and water level in boilers and in hot well (deaerator) of steam boiler plants, and in case of thermal fluid boilers, alarm to indicate the fluid temperature after the boilers and before the consumers, as well as the alarm to indicate the level in the expansion tank.

4.3.3 In waste-heat boilers the transfer of the evaporative mode to the water-heating mode and vice-versa shall not initiate operation of the safety valves, alarms to indicate steam pressure and water level in boilers and in hot well, as well as the necessity of the additional feed water.

4.3.4 Steam pressure and thermal fluid temperature shall be regulated automatically. Besides, the steam boilers shall be provided with automatic feed water regulators.

The waste-heat boilers may have no automatic steam pressure and thermal fluid temperature regulation, if alternative arrangements are provided to stabilize the said parameters.

4.3.5 Steam boilers shall have at least two low water level detectors independent of each other and connected to different output devices. The lower one shall be used solely for no-water protection.

The second detector may also be used for shutdown in case of low water levels, or for alarm and feed water regulating systems.

The above requirement does not apply to forced-circulation boilers, waste-heat boilers, the design of which allows operation without water, and to the secondary system headers of double-pressure boilers.

4.3.6 Provision shall be made for a remote shutdown of the burning boilers and closing of dampers in waste-heat boilers allowing no "dry" operation, from the control station where continuous watch is kept.

4.3.7 Automated oil-burning boilers shall be fitted up with interlocking devices to permit fuel oil being fed into the boiler furnace during firing-up, when the requirements listed below are complied with in addition to those of 5.3.2, Part X "Boilers, Heat Exchangers and Pressure Vessels":

.1 fuel temperature (viscosity) is such that adequate atomisation is assured;

.2 pressure of steam or air for atomisation is within the normal range.

4.3.8 Automated oil-burning boilers shall be equipped with protective devices in accordance with the requirements of 5.3.3, Part X "Boilers, Heat Exchangers and Pressure Vessels".

4.3.9 Starting of boiler plants from cold condition and after being shut down by the protection system and if the ignition of oil fuel fails shall be possible from the local control station only.

4.3.10 Boiler plants shall be provided with alarms to indicate fire outbreak in the boiler flues. Position of detectors shall be chosen depending on the design features of boilers.

4.3.11 Monitored parameters of automated boiler plants, measuring points, limited parameter values and types of automatic protection and indication shall be found in Table 4.3.11.

4.4 AUTOMATED ELECTRIC POWER PLANTS

4.4.1 Automated electric power plants shall ensure remote starting of generator sets with automatic synchronization, taking over and distribution of load.

4.4.2 Besides compliance with the requirements of 3.1.3, Part XI "Electrical Equipment", in order to ensure continuous power supply on board ships where electrical power is normally supplied from one generator, control devices shall be provided to ensure automatic starting of standby generator, automatic synchronization, taking over and distribution of load in cases where:

maximum permissible load is reached by the generator during operation;

there is malfunction of the operating unit, which enables an automatic synchronization of generators to be carried out.

4.4.3 Indicators shall be provided at relevant control stations to warn that the generator sets are ready to start immediately (automatically).

4.4.4 Provision shall be made for preliminary determination of sequence, in which the generators shall be started automatically and connected to the busbars of the main switchboard.

4.4.5 If the shaft rotational speed or the steam pressure at the exhaust-heat turbine inlet (where shaft generators or exhaust-steam electric generators are used) is lowered so that the working characteristics as stated under 2.11.3, Part IX "Machinery" and 10.6.2 and 10.7.2, Part XI "Electrical Equipment" cannot be achieved, at least one generator driven independently shall be automatically started to ensure compliance with the provisions of 4.4.2.

4.4.6 Monitored parameters of automatic electric power plants (except emergency), measuring points, limiting values of parameters and types of automatic protection and parameter indication shall be found in Tables 4.4.6-1 to 4.4.6-3.

4.5 AUTOMATED COMPRESSOR PLANTS

4.5.1 Compressed air systems shall be fitted up with ar-rangements for automatic removal (blow out) of water and oil.

4.5.2 The automated compressor plants shall be capable of operating manually from the local and remote control stations and automatically.

In automatic mode of operation, the compressors shall keep up nominal pressure of compressed air in the air receivers so that:

.1 when the air pressure drops to the preset value, for example, to 90 per cent, the preselected compressor shall be automatically started and automatically shut down once the air pressure have reached a value equal to the nominal one;

.2 in case of an intensive air consumption and further drop of air pressure, for example, to 80 per cent, a second compressor turned on automatic mode shall be automatically started, and both compressors shall keep operating until the nominal pressure is attained.

Table 4.3.11

Automated boiler plants

Nos	Monitored parameter	Indication, alarm	Automatic protection
1	**Main steam boilers and essential auxiliary steam boilers, waste-heat boilers and alternately fired boilers**		
1.1	Steam pressure in boiler drum (at super-heater outlet)[1]	●↑↓	—
1.2	Steam temperature at super-heater outlet	●↑	—
1.3	Steam temperature at steam cooler outlet	●↑	—
1.4	Water level in boiler drum	↑[2]↓	×[3]
1.5	Feed water pressure or pressure differential[4]	●↓	—
1.6	Stoppage of circulation in forced-circulation boilers	○	×
1.7	Water level in steam separator	↓	—
1.8	Water level in hot well	↓	—
2	**Automatic oil-burning installations**		
2.1	Fuel oil pressure at burner inlet[4]	↓	—
2.2	Atomization air or steam pressure	↓	—
2.3	Fuel oil temperature at burner inlet[5]	●↓	—
2.4	Air pressure before oil-burning installation[6]	↓	×
2.5	Flame failure	○	×
3	**Thermal fluid boilers and boiler plants**		
3.1	Thermal fluid temperature at boiler outlet	↑	×
3.2	Thermal fluid flow at boiler outlet	↓	×
3.4	Thermal fluid level in expansion vessel	↑↓	×[3]■[3]
3.5	Thermal fluid leakage in furnace draining arrangement	—	×
3.6	Thermal fluid leakage in draining arrangement of waste-heat boiler inlet chamber	—	■

Symbols:
● — remote indication (continuous);
↑ — alarm for high value;
↓ — alarm for low value;
○ — alarm signal;
■ — circulating pump shutdown;
× — shutdown.

[1] For auxiliary boilers, alarm may be provided in the main steam line only.
[2] Only for boilers to power machinery.
[3] Only after parameter reaches low value.
[4] For main boilers only.
[5] For heavy oil burning installations.
[6] May be dispensed with, where the forced-draft fan and fuel oil pump are directly driven by a single prime mover.

Table 4.4.6-1

Automated ship electric power plants

Nos	Monitored parameter	Indication, alarm	Automatic protection
1	**Ship mains**		
1.1	Voltage	●↓	×
1.2	Current frequency	●↓	—
1.3	Insulation resistance	↓	—
2	**Generators**		
2.1	Load (current)	●↑	▼×
2.2	Reverse power (current)	↑	×
2.3	Winding temperature[1]	↑	—

Symbols:
● — remote indication;
↑ — alarm for high value;
↓ — alarm for low value;
▼ — disconnection of non-essential consumers;
× — disconnection of generator. Effected by the protection system of the generators (refer to 8.2, Part XI "Electrical Equipment").

[1] Required only for a.c. generators having output of more than 5000 kW or axial length of active steel more than 1000 mm.

Other operation logic of the automated compressors is subject to the special consideration of the Register.

4.5.3 Monitored parameters of automated compressor plants, measuring points, limiting values of parameters and types of automatic protection and indication shall be found in Table 4.5.3.

Table 4.4.6-2

Internal combustion engines for driving generators

Nos	Monitored parameter	Alarm	Automatic shutdown of engine
1	Fuel oil leakage from high-pressure piping	○	—
2	Lubricating oil temperature	↑	—
3	Lubricating oil pressure	↓	×
4	Oil mist concentration in crankcase[1]	↑	×
5	Cooling water pressure or flow	↓	—
6	Cooling water or air temperature	↑	—
7	Cooling water level in expansion tank[2]	↓	—
8	Fuel oil level in daily tank	↓	—
9	Starting air pressure	↓	—
10	Overspeed	○	×
11	Fuel oil viscosity (temperature) at inlet of high-pressure pumps[3]	↑(↓)	—
12	Exhaust gas temperature at each cylinder outlet[4]	↑	—
13	Gas concentration in machinery spaces[5]	↑	—

Symbols:
↑ — alarm for high value;
↓ — alarm for low value;
○ — alarm signal;
× — engine shutdown.

[1] For engines having power of more than 2250 kW or a cylinder bore more than 300 mm.
[2] If separate cooling system provided.
[3] When working on heavy fuel.
[4] For engines with cylinder output more than 500 kW.
[5] Required where installations with dual-fuel (gas — liquid fuel) engines are used.

Table 4.4.6-3

Steam turbines driving generators

Nos	Monitored parameter	Indication, alarm	Automatic shutdown of turbine
1	Lubricating oil pressure at oil cooler outlet	◗↓	×
2	Lubricating oil temperature at bearing outlets	◗↑	—
3	Steam pressure in condenser	◗↑	×
4	Steam pressure before turbine	◗↓	—
5	Water level in condenser	↑	—

Symbols:
◗ — remote indication (on call);
↑ — alarm for high value;
↓ — alarm for low value;
× — turbine shutdown.

Table 4.5.3

Automated compressor plants

Nos	Monitored parameter	Indication, alarm	Automatic protection
1	Lubricating oil pressure at compressor inlet	↓	×
2	Coolant flow at compressor outlet[1]	↓	×
3	Air temperature at cooler outlet	↑	—
4	Starting air pressure at air receiver outlet	●↓	—
5	Control air pressure	↓	—

Symbols:
● — remote indication;
↑ — alarm for high value;
↓ — alarm for low value;
× — compressor shutdown.

[1] Instead of flow, maximum coolant temperature may be monitored.

4.6 AUTOMATED PUMPING UNITS

4.6.1 Automated pump control system shall ensure automatic starting of standby pumps and change-over as necessary in plants in case of pump failure or upon reaching the highest permissible deviations of parameters in essential plants. The faulty pump shall be stopped and an alarm given only after the standby pump has been started.

4.6.2 The electric circuit of pumps having equal output shall make it possible to use each of them as the main pump.

This requirement does not apply to attached pumps.

4.7 AUTOMATED BILGE PUMPING OF MACHINERY SPACES

4.7.1 Depending on the water level in the wells, the automated bilge plants shall put relevant bilge pump in operation. Indication for pump operation shall be provided.

4.7.2 If, after the bilge pumps have been started, they do not come to stop within a specified period of time, that is, the water in the bilge wells does not fall, an alarm shall be given.

4.7.3 A separate sensor shall be provided to signal the highest permissible level, which would be independent of the sensors fitted to control the bilge pumps.

4.7.4 Monitored parameters of automated bilge plants, measuring points and limiting values of parameters shall be found in Table 4.7.4.

Table 4.7.4

Automated bilge plants of machinery spaces

Nos	Monitored parameter	Alarm
1	Water level in bilge wells	↑ ↓[1]
2	Emergency water level in bilge wells and shaft passages[2]	↑

Symbols:
↑ — alarm for high value;
↓ — alarm for low value.

[1] When remotely controlled.
[2] Alarm signal is brought out to the wheelhouse.

4.8 AUTOMATED REFRIGERATING PLANTS

4.8.1 In accordance with 1.1, Part XII "Refrigerating Plants", automated refrigerating plants shall comply with the requirements of 7.2 of the same Part, as well as to provide automatic maintenance of temperature in the refrigerated spaces.

4.8.2 Provision shall be made for indication of the automated refrigerating plant operation and for alarm of its malfunction.

4.8.3 Monitored parameters of automated refrigerating plants, measuring points, limiting values of parameters and types of protection shall be found in Table 4.8.3.

4.9 EQUIPMENT ARRANGEMENT ON THE BRIDGE

4.9.1 Provision shall be made for a control station to effect-automated remote control of main machinery and/or propellers in conformity with 3.2, Part VII "Machinery Installations".

4.9.2 An alarm device shall be fitted to give group or individual signals of malfunctions of machinery installation, including those that require immediate shutdown of the main machinery and those that require reduction of the main machinery power.

4.9.3 On the bridge, provision shall be made for the following separate alarms:

"water in machinery space";

"fire in machinery space";

"alarm system failure";

as well as separate alarm "high gas concentration in machinery space", if the ship is provided with main and/or auxiliary dual-fuel (gas — liquid fuel) engines.

4.9.4 Provision shall be made for visual signalling (indication) in case of signals required by 4.9.2 and 4.9.3 being acknowledged in the machinery space.

4.10 EQUIPMENT ARRANGEMENT IN MACHINERY SPACES

4.10.1 Provision shall be made in the vicinity of the local control station for alarms and indicators of parameters as required by 4.2 to 4.8.

4.10.2 The controls of auxiliaries (pumps, separators, boiler plants, generator prime movers) are recommended to be installed in close proximity to the local control station of the main machinery.

4.10.3 Engine control room, if provided, shall be fitted up with the following:

.1 devices required by 3.2, Part VII "Machinery Installations";

.2 alarm panel;

.3 devices to indicate the operating modes of machinery and plants;

.4 disconnecting devices of the oil-burning installations of boilers, incinerators, ventilators of machinery spaces, separators fuel oil and lubricating oil pumps.

Table 4.8.3

Automated refrigerating plants

Nos	Monitored parameter	Alarm	Automatic protection
1	**Driving motors**		
1.1	Motor load (current)	↑	▼
2	**Compressors**		
2.1	Suction pressure	↓	×
2.2	Discharge pressure[1]	↑	×
2.3	Discharge temperature	↑	×
2.4	Lubricating oil pressure or flow	↓	×
2.5	Lubricating oil temperature	↑	×
2.6	Rotor displacement[2]	↑	×
2.7	Bearing temperature[2]	↑	×
3	**Pressure vessels, heat exchangers, refrigerant, secondary refrigerant, cooling water pumps**		
3.1	Refrigerant flow in pump	↓	□
3.2	Secondary refrigerant flow in evaporator	↓	×[3]
3.3	Cooling water discharge pressure or flow in discharge pipeline	↓	×
3.4	Refrigerant level in circulation receivers, liquid separators, intermediate vessels, level type evaporators[4]	↑	×
3.5	Secondary refrigerant temperature at evaporator outlet	↓	×[3]
3.6	Secondary refrigerant level in expansion tank	↑↓	—
4	**Spaces with controlled atmosphere, atmosphere control arrangements**		
4.1	Air temperature in refrigerated cargo spaces	↑↓	—
4.2	Stopping of air cooler ventilator for refrigerated cargo space[5]	○	—
4.3	Refrigerant concentration in air of spaces with equipment under refrigerant pressure[6]	↑	■
4.4	CO_2, O_2, N_2 concentration in refrigerated cargo spaces[7]	↑↓	—
4.5	Relative air humidity in refrigerated cargo spaces[7]	↑↓	—

Symbols:
● — remote indication;
↑ — alarm for high value;
↓ — alarm for low value;
○ — alarm signal;
▼ — engine shutdown;
□ — pump stop;
■ — switching-on of emergency ventilation, except emergency ventilation of refrigerated cargo spaces, for switching-on of which it is necessary previously to render the air duct shut-off devices operative;
× — compressor shutdown.

[1] In case of piston two-stage compressors, for each stage.
[2] For centrifugal compressors.
[3] Or stopping the delivery of refrigerant into evaporator.
[4] Compressor shutdown when the level is maximum. In case of liquid separators performing only protective functions, the refrigerant level indication may be dispensed with.
[5] For each ventilator.
[6] Separate alarm on the navigating bridge.
[7] Where applicable: for systems with atmosphere control, for carriage of fruits and vegetables.

4.10.4 If agreed with the Register, the engine control room may be located outside the machinery space and the list of its equipment specified in 4.10.3 may be changed.

4.10.5 Where there is an enclosed engine control room, a device shall be fitted therein to call personnel from the machinery spaces.

4.10.6 At the engine control room, the following separate signals shall be provided:

"water in machinery space";

"fire in machinery space";

as well as separate alarm “limiting gas concentration level in machinery space”, if the ship is provided with main and/or auxiliary dual-fuel (gas — liquid fuel) engines.

4.11 DEVICES IN ENGINEERS’ ACCOMMODATION

4.11.1 In engineers’ cabins, public spaces, as well as in spaces where watch is kept while in port, group alarm devices shall be fitted to warn of the malfunctions of machinery and plants, as well as signal devices in accordance with 4.9.3.

The acknowledgement of each signal from these devices shall cancel the audible signal only.

4.11.2 Where there are several cabins a switch for the devices mentioned in 4.11.1 may be provided to select the responsibility (watch keeper). The remaining cabin devices are disconnected in this case.

5 SHIPS WITH AUT2 IN CLASS NOTATION

5.1 GENERAL

5.1.1 Ships and floating facilities with the automation mark **AUT2** in class notation shall be equipped with machinery plant automation systems to the extent sufficient to ensure the manoeuvrability and safety of self-propelled ships or the safety of non-self-propelled ships under all operating conditions without permanent attendance of personnel in machinery spaces, but if watch is kept at the engine control room.

5.1.2 Unless otherwise provided hereafter, the requirements of Section 4, except for 4.11, shall be complied with.

5.1.3 Provision shall be made for automation of main machinery and propellers in accordance with the applicable requirements of 4.2.

5.1.4 An alarm system shall be provided for all applicable parameters and working conditions mentioned in Section 4.

5.1.5 All the equipment installed in the machinery space shall be adapted to unattended service. On agreement with the Register, certain operations (reple-nishment of tanks, cleaning of strainers, etc) may be performed manually if undertaken not more than once every 12 hours.

5.2 EQUIPMENT ARRANGEMENT ON THE BRIDGE

5.2.1 It is recommended to provide automated remote control of the main machinery and propellers from the bridge.

5.2.2 Where an automated remote control of the main machinery and/or propellers is effected from the bridge:

.1 equipment as required by 3.2, Part VII "Machinery Installations" shall be fitted on the bridge;

.2 provision shall be made on the bridge for alarm, which would enable to identify the reason of failure that requires slowdown and shutdown of the main machinery.

5.3 EQUIPMENT ARRANGEMENT IN MACHINERY SPACES

5.3.1 Provision shall be made for an enclosed engine control room fitted out in conformity with 4.10.3 and, additionally, with remote controls of essential auxiliaries if the latter are not automated.

5.3.2 Provision shall be made for the call and signal devices as stipulated by 4.10.5 and 4.10.6.

5.4 ELECTRIC POWER PLANTS

5.4.1 Besides compliance with the requirements of 3.1.3, Part XI "Electrical Equipment", where no provision is made for an automated electric power plant in conformity with 4.4, the following shall be available:

remote start and shutdown of generator prime movers from the engine control room;

remote synchronizing, connection and load distribution from the engine control room. These operations may be effected from the main switchboard if installed at the engine control room.

5.5 BILGE SYSTEMS OF MACHINERY SPACES

5.5.1 Where no provision is made for an automated bilge system in conformity with 4.7, bilge wells in machinery spaces shall be remotely drained from the engine control room.

5.5.2 Alarm shall be provided in conformity with 4.7.4.

6 SHIPS WITH AUT3 IN CLASS NOTATION

6.1 GENERAL

6.1.1 Ships and floating structures with the automation mark **AUT3** in class notation, the main machinery of which have the total power up to 2250 kW, shall be fitted with machinery installation automation systems to the extent, by which their manoeuvrability and safety would be ensured without permanent attendance of machinery spaces and engine control room (as far as non-self-propelled ships are concerned, the above power is the power of the prime movers of generators, which ensure that the main purpose of the ship is fulfilled).

6.1.2 Unless otherwise provided hereafter, the requirements of Section 4 shall be complied with.

6.1.3 Monitored parameters of machinery and plants, measuring points, limiting values of parameters and types of automatic protection and parameter indication shall be found in Table 6.1.3.

Table 6.1.3

Nos	Monitored parameter	Group 1: indication, alarm, automatic slowdown	Group 2: automatic start of stand-by pumps with alarm[1]	Group 3: automatic shutdown of engine
1	**Main internal combustion engines**			
1.1	Lubricating oil pressure at engine inlet	●↓	■	×
1.2	Lubricating oil temperature at engine inlet	●↑	—	—
1.3	Lubricating oil flow at lubricator outlet	↓▼[2]	—	—
1.4	Lubricating oil pressure differential across filter	◗↑	—	—
1.5	Turbocharger lubricating oil pressure at bearing inlet[3]	↓	—	—
1.6	Oil mist concentration or bearing temperature at each crank or bearing	↑▼[2, 4]	—	×[5]
1.7	Coolant pressure or flow at engine inlet	●↓▼[2]	■	—
1.8	Coolant temperature at engine outlet	◗↑▼[2]	—	—
1.9	Cooling sea water pressure or flow	●↓	■	—
1.10	Exhaust gas temperature in main line	↑	—	—
1.11	Exhaust gas temperature at each cylinder outlet[6]	◗↑▼[2]	—	—
1.12	Exhaust gas temperature. Deviation from mean value by cylinders[6]	↑	—	—
1.13	Starting air pressure before starting valve	●↓	—	—
1.14	Air pressure in engine control system	↓	—	—
1.15	Scavenging air temperature at scavenging air cooler outlet	↑	—	—
1.16	Fuel oil pressure at high-pressure pump inlets	◗↓	■	—
1.17	Fuel oil viscosity (temperature) at engine inlet[7]	↑(↓)	—	—
1.18	Fuel oil level in daily service tank	↓	—	—
1.19	Fuel oil leakage from high-pressure piping	○	—	—
1.20	Engine speed	●↑	—	×
1.21	Power supply for control, alarm and protection system	○	—	—
1.22	Gas concentration in machinery spaces[8]	↑	—	—
2	**Boilers of machinery installation[9]**			
3	**Internal combustion engines used as generator drives**			
3.1	Lubricating oil pressure at engine inlet	↓	—	×
3.2	Coolant pressure or flow at engine inlet	↓	—	—
3.3	Coolant temperature at engine outlet	↑	—	—
3.4	Fuel oil leakage from high-pressure piping	○	—	—
3.5	Engine speed	●↑	—	×
3.6	Starting air pressure (before starting valve)	↓	—	—
4	**Reduction gear**			
4.1	Lubricating oil pressure at reduction gear inlet	↓	—	×
4.2	Lubricating oil temperature in reduction gear	↑	—	—
5	**Starting air compressors**			
5.1	Lubricating oil pressure at compressor inlet	↓□	—	—
5.2	Air temperature at compressor outlet	↑	—	—
6	**Tanks**			
6.1	Lubricating oil level in daily service tanks	↓	—	—
6.2	Oil leakage level in oil leakage tank	↑	—	—
6.3	Fuel oil level in daily service tank	↓	—	—
6.4	Fuel oil level in overflow tank	↑	—	—
6.5	Coolant level in expansion tank	↓	—	—
7	**Ship mains**			
7.1	Voltage	●↑↓	—	—

Table 6.1.3 - continued

Nos	Monitored parameter	Group 1: indication, alarm, automatic slowdown	Group 2: automatic start of stand-by pumps with alarm[1]	Group 3: automatic shutdown of engine
7.2	Load (current)	●↑	—	—
7.3	Current frequency	●↓	—	—
7.4	Insulation resistance	↓	—	—

N o t e . For Group 1 parameters a common sensor is provided for indication, alarm and safety systems (for slowdown); for Group 2 parameters — a sensor for automatic start of stand-by pumps; for Group 3 parameters — a sensor of safety system (engine shutdown).

S y m b o l s :
● — remote indication (continuous);
◗ — remote indication (on call);
↑ — alarm for high value;
↓ — alarm for low value;
○ — alarm signal;
■ — automatic start of stand-by pumps;
□ — compressor shutdown;
▼ — slowdown;
× — engine shutdown.

[1] When independent stand-by pumps are available.
[2] On agreement with the Register, special visual and audible alarm may be provided instead of slowdown where the internal combustion engines are concerned.
[3] When an independent lubrication pump is available.
[4] For low-speed engines with cylinder bore over 300 mm.
[5] For medium- and high-speed engines with cylinder bore over 300 mm.
[6] For engines with cylinder output above 500 kW.
[7] When working on heavy fuel.
[8] Required, where installations with dual-fuel (gas — liquid fuel) engines are used.
[9] Refer to Table 4.3.10.

6.2 EQUIPMENT ARRANGEMENT ON THE BRIDGE

6.2.1 Provision shall be made for a remote control station for main machinery and/or propellers in conformity with 3.2, Part VII "Machinery Installations".

6.2.2 As far as applicable, provision shall be made for remote control of essential auxiliaries.

6.2.3 Provision shall be made for shutting down the oil burning installations of automated boiler plants, incinerators, machinery space fans, fuel oil pumps, if any.

6.2.4 An alarm device shall be fitted to indicate malfunction of the machinery installation in accordance with 4.9.2.

6.2.5 On the bridge, provision shall be made for the following separate alarms:

"water in machinery space";

"fire in machinery space";

"alarm system failure";

as well as separate alarm "high gas concentration in machinery space", if the ship is provided with main and/or auxiliary dual-fuel (gas — liquid fuel) engines.

6.2.6 Visual alarm shall be provided to indicate acknowledgement of alarms in machinery space as required in 6.2.4 and 6.2.5.

6.2.7 Provision shall be made for remote drainage of bilge wells in machinery spaces. The requirements of 4.7.2 to 4.7.4 shall be complied with.

6.3 EQUIPMENT ARRANGEMENT IN MACHINERY SPACES

6.3.1 In the vicinity of the main machinery local control station, if any, alarms and indicators of parameters, as stipulated by Table 6.1.3, shall be provided.

6.3.2 As far as applicable, the controls of auxiliaries shall be located in conformity with 4.10.2.

6.3.3 Where provision is made for an enclosed engine control room, the applicable requirements of 4.10.3 to 4.10.6 shall be complied with.

6.4 EQUIPMENT ARRANGEMENT IN ENGINEERS' ACCOMMODATION

6.4.1 As far as applicable, the requirements of 4.11 shall be complied with.

7 COMPUTERS AND COMPUTER-BASED SYSTEMS

7.1 APPLICATION

7.1.1 The requirements of the present Section apply to computers and computer-based systems used for monitoring and control of essential machinery and arrangements, which ensure in combination with other automation systems (requirements thereto are set forth in Sections 2 to 6) the operation of the machinery installation with unattended machinery spaces.

Ships fitted with such automation systems may be assigned, in accordance with 2.2.6, Part I "Classification", one of the following distinguishing automation marks in the class notation:

.1 AUT1-C, **AUT2-C** or **AUT3-C** — where automation of the machinery installation is based on computers or programmable logic controllers;

.2 AUT1-ICS, **AUT2-ICS** or **AUT3-ICS** — where computer-based systems are combined into a network forming a common integrated system.

7.1.2 The present requirements apply also to computers and computer-based systems used for control of non-essential machinery and devices where loss of control results in serious damage to the ship or its machinery, e.g. explosion of domestic water boilers.

7.2 DEFINITIONS AND EXPLANATIONS

7.2.1 Integrated system is a combination of computer-based systems, which are interconnected, in order to allow centralized access to sensors information and/or command/control.

Interface is a transfer point, at which information is exchanged. Examples of interface include: input/output interface used for interconnection with sensors and actuators; man-machine interface, e.g. monitors, keyboards, tracker-balls, etc. used for communication between the operator and the computer; communications interface used to enable serial communications/networking with other computers or peripherals.

Computer is a programmable electronic device for storing and processing data in the digital form, making calculations or performing control. A computer may be monoblock or may consist of several interconnected units.

Computer-based system is a system of one or more computers, associated software, peripherals and interfaces.

Programmable logic controller (PLC) is a computer device designed as a stand-alone functional unit and intended to perform functions relevant to control and monitoring of ship's machinery and processes.

Monitor is an electronic device for representing data.

Peripheral is a device performing an auxiliary action in the system, e.g. printer, data storage device, etc.

Software is programs, data and documentation associated with the operation of a computer-based system.

Node is a point of interconnection to a data communication link.

7.3 GENERAL REQUIREMENTS FOR THE DESIGN OF COMPUTER SYSTEMS USED FOR CONTROL AND MONITORING

7.3.1 Computer-based systems shall fulfil the functional requirements of the system under control for all operating conditions including emergency conditions, taking into account:

danger to persons;

environmental impact;

damage to equipment;

usability;

operability of non-computer devices and systems.

7.3.2 If process times for functions of the system are shorter than the reaction times of the operator and therefore damage cannot be prevented by manual intervention, means of automatic intervention shall be provided.

7.3.3 A computer-based system shall have sufficient capability to:

perform necessary autonomous operations;

accept operator (user) commands;

inform the operator (user) correctly under all operating conditions including emergency.

7.3.4 System capability shall provide adequate response times for all functions, taking into consideration the maximum load and maximum number of simultaneous tasks, including network communication speed, under normal and abnormal process conditions.

7.3.5 Computer-based systems shall be designed in such a way that they can be used without special previous knowledge, otherwise appropriate assistance shall be provided for the user.

7.3.6 Computer-based systems shall be protected against unintentional or unauthorized modification of programs and data.

7.4 HARDWARE REQUIREMENTS

7.4.1 Hardware shall function reliably in conditions normally encountered in ships as specified in 2.1.

7.4.2 The design of the hardware shall ensure easy access to interchangeable parts for repairs and maintenance.

7.4.3 Each replaceable part shall be simple to replace and shall be constructed for easy and safe handling. All replaceable parts shall be arranged in such a way that it is not possible to connect them incorrectly or to use incorrect replacements. Where this is not practicable, the replaceable parts shall be clearly marked.

7.5 SOFTWARE REQUIREMENTS

7.5.1 Systematic monitoring procedures shall be followed during all phases of the software life cycle (development, installation and subsequent modification).

7.5.2 System tests shall be specified, performed and documented. These tests shall include all software functions and important combinations of functions, performance, dependability and usability requirements under all modes of operation including emergency conditions and behaviour under failure conditions.

7.5.3 Any modifications of program contents and data shall be made in conformity with relevant standards and documented.

7.5.4 The software for monitoring, control and alarm computer-based systems shall not be permanently lost or altered due to short-term drops of supply voltage or due to network frequency and voltage fluctuations.

Provisions shall be made for structural means preventing the unintentional or unauthorized intervention, which may result in the alteration of control programs or limiting values of computer-based system parameters under control.

7.6 SYSTEM CONFIGURATION REQUIREMENTS

7.6.1 General.

7.6.1.1 The hardware and software shall be of modular, hierarchical design in order to maximize the fault tolerance of the system.

7.6.1.2 The selection of the computer equipment shall be consistent with safe operation of the system under control.

7.6.2 Self-test.

Computer-based systems shall have self-test capability to monitor for correct operation and alarm shall be given for an abnormal condition.

7.6.3 Power supply.

7.6.3.1 The sources of power supply shall be monitored for failure and shall give an alarm in the event of abnormal condition.

7.6.3.2 Program and data held in the system shall be protected from corruption by loss of power.

7.6.3.3 Redundant systems shall be selectively fed and separately protected against short circuits and overloads.

7.6.4 Installation.

7.6.4.1 Equipment and its associated cabling shall be installed in such a way as to minimize electromagnetic interference between the equipment concerned and other equipment on board.

7.6.4.2 Cables used for data communication shall be of adequate mechanical strength, suitably supported and also protected from mechanical damage.

7.6.5 Data communication links.

7.6.5.1 The data communication link shall be continuously self-checking, for detecting failures on the link itself and data communication failure on nodes and shall give an alarm in the event of abnormal condition.

7.6.5.2 When the same data communication link is used for two or more essential functions, this link shall be redundant. Redundant data communication links shall be routed with as much separation as practical.

7.6.5.3 Switching between redundant links shall not disturb data communication or continuous operation of functions. An automatic switching alarm signal shall be transmitted.

7.6.5.4 To ensure that data can be exchanged between various systems, standardized interfaces shall be used.

7.6.6 Fail-to-safe principle.

7.6.6.1 In the event of a failure of a computer-based system, systems under control shall automatically revert to the least hazardous condition.

7.6.6.2 The failure and restarting of computer-based systems shall not cause processes to enter undefined or critical states.

7.6.6.3 Control, alarm and safety functions shall be arranged such that a single failure will not affect more than one of these functions.

7.6.7 Integration of systems.

7.6.7.1 Operation with an integrated system shall be at least as effective as it would be with individual, stand-alone equipment. Where multifunction displays and controls are used they shall be duplicated and interchangeable.

7.6.7.2 Failure of one part (individual module, equipment or subsystem) of the integrated system shall not affect the functionality of other parts, except for those functions directly dependent upon information from the defective part.

7.6.7.3 A complete failure in connectivity between parts shall not affect their independent functionality.

7.6.7.4 An alternative means of operation, independent of the integration, shall be available for all essential functions.

7.6.7.5 When systems under control are required to be duplicated and in separate compartments this shall be also applied to computer-based systems used for control and monitoring.

7.7 USER INTERFACE

7.7.1 General.

7.7.1.1 Computer-based systems shall be designed for ease of handling and user-friendliness and shall follow ergonomic principles.

7.7.1.2 The operational status of a computer-based system (on, off, non-failed, failed, etc) shall be easily recognizable.

7.7.1.3 A user guide shall be provided. The user guide shall describe for example:

function keys;

menu displays;

computer-guided dialogue steps, etc.

7.7.1.4 An alarm shall be displayed at relevant operator stations for failure or shutdown of a subsystem.

7.7.2 Input devices.

7.7.2.1 Input devices shall have clearly definable functions, be reliable in use and operate safely under all conditions. The acknowledgement of the instruction given shall be recognizable.

7.7.2.2 Dedicated function keys shall be provided for frequently recurring commands and for commands, which shall be available for rapid execution. If multiple functions are assigned to keys, it shall be possible to recognize, which of the assigned functions is active.

7.7.2.3 Control panels on the bridge shall be provided with separate lighting. The level of lighting and the brightness of visual display units shall be controllable.

7.7.2.4 Where equipment operations or functions may be changed via keyboards access to such operations shall be provided for authorized personnel only.

7.7.2.5 If operation of a key is able to cause dangerous operating conditions, measures shall be taken to prevent the instruction in question from being executed by a single action such as:

use of a special key lock;

use of two or more keys.

7.7.2.6 Conflicting control interventions shall be prevented by means of interlocks or warnings. The active control status shall be recognizable.

7.7.2.7 The operation of input devices shall be logical and correspond to the direction of action of the controlled equipment.

7.7.3 Output devices.

7.7.3.1 The size, colour and density of text and graphic information displayed on a visual display unit shall be such that it may be easily read from the normal operator position under all operational lighting conditions. The brightness and contrast shall be capable of being adjusted to the prevailing ambient conditions in order to enable the information to be normally recognized.

7.7.3.2 Information shall be displayed in a logical priority.

7.7.3.3 If alarm messages are displayed on colour monitors, the distinctions in the alarm status shall be ensured even in the event of failure of a primary colour.

7.7.4 Graphical user interface.

7.7.4.1 Information shall be presented clearly and intelligibly according to its functional significance and association. Screen contents shall be logically structured and their representation shall be restricted to the data, which is directly relevant for the operator.

7.7.4.2 When using general purpose graphical user interfaces, only the functions necessary for the respective process shall be available.

7.7.4.3 Alarms shall be visually and audibly presented with priority over other information in every operating mode of the system; they shall be clearly distinguishable from other information.

7.7.4.4 All display and control functions in control stations operated by the same operators shall adopt a consistent user interface. Particular attention shall be paid to symbols, colours, controls, information priorities and layout.

7.8 TRAINING

7.8.1 Training shall be provided at a level required to effectively operate and maintain the system and shall cover normal, abnormal and emergency conditions. The user interface for training shall correspond with the real system.

7.8.2 Documentation shall be provided to support the training and shall be available for repeated use on board during maintenance of the computer systems.

7.8.3 Where a training mode is incorporated in a computer-based system it shall be clearly indicated when the training mode is active.

7.8.4 Whilst in the training mode the operation of the system shall not be impaired, and neither are any system alarms or indications to be inhibited.

7.9 TESTING

7.9.1 The computer-based systems shall be designed, manufactured and tested in accordance with the requirements of the Section and other requirements of the Rules. In the case of any integrated systems, evidence shall be furnished by a party responsible for the integration that the requirements applied to the integration of the subsystems have been fully satisfied.

7.9.2 In addition to the requirements of the Section, manufacturers shall ensure by means of quality control system that their products meet with their specifications.

7.9.3 Tests and inspections of a computer-based system shall be carried out with the aim of establishing the correct operation and the quality of a product.

7.9.4 Modifications of program contents and data, as well as change of version, shall be checked and tested.

8 DYNAMIC POSITIONING SYSTEMS

8.1 APPLICATION AND MARKS IN CLASS NOTATION

8.1.1 The present requirements cover the electric and electronic equipment and automated control systems of the dynamic positioning systems (DP-systems).

8.1.2 Observance of the requirements of this Section and applicable requirements of other sections of the present Part is mandatory for ships, which are assigned in conformity with 2.2.9, Part I "Classification", one of the following marks: **DYNPOS-1**, **DYNPOS-2** or **DYNPOS-3**, added to the class notation.

8.2 DEFINITIONS AND EXPLANATIONS

8.2.1 Single failure in dynamic positioning system means a failure in an active component (thruster, its local control system, power supply generator, automatic control valve) or in a passive element (pipeline, power or control cable, manually controlled valve, etc).

Redundancy of dynamic positioning system means duplication or multiple redundancy of its components, at which an installation consisting of an electric power supply system and thruster units with their individual control systems is functioning under control of a computer-based system in such a way that failure of particular control systems, particular thruster units or components of the electric power supply system does not affect the performance of the task to ensure the ship position keeping.

Dynamic positioning system (DP-system) means a complete installation intended for automatic and remote automated control of thruster units of the ship in order to dynamically maintain position the ship with prescribed accuracy under the action of disturbing environmental forces.

The installation shall comprise at least the following sub-systems:

electric power supply system;

thruster (propulsor) units to supply the DP-system with necessary thrust force and direction in order to compensate for environmental factors;

control system consisting of computer-based system with appropriate software, data displays, a system of external force and ship's position sensors, as well as set-point devices.

Thruster system means a system intended to produce and maintain at each instant of time an appropriate hydrodynamic thrust vector and force capable of compensating for the environmental factors affecting the ship.

The system shall comprise the following items:

electric machine thruster units with drive units and auxiliary systems including hydraulic piping and tanks (if any);

main propulsion plant of the ship and rudders if under the control of the DP-system;

electric and electronic equipment for individual control of the thruster units;

manual and automated devices to control jointly all the thrusters; and

associated cabling connected to all machinery and systems.

Dynamic positioning control system means an electric and electronic programmable system intended to control the thruster units of the ship and comprising the following components:

computer-based system with associated software and interfaces;

automated control systems of the thrusters with the use of a single control device (joystick) or several control devices;

system of the ship's position sensors, sensors to detect action of environmental forces and feedback sensors;

operator panel system with controls and data displays;

system to generate parameters of control effects the thrusters exert on the ship and monitoring the ship's prescribed position;

power, information and control cabling.

Electric power system means a system intended to supply the DP-system under all operating conditions including the emergency ones and comprising:

prime movers of generators with their associated auxiliaries, devices and piping;

generators;

switchboards;

cabling and cable routeing.

The electric power system may be a specialized as well as a common electric power system of the ship.

8.3 SCOPE OF SURVEYS

8.3.1 The following equipment of the DP-system is subject to survey during manufacture and in service:

electric machines and electric machine converters and transformers;

power static semi-conductor converters and transformers;

switchboards;

uninterruptable power supply arrangements;

power and control, including information, cabling, control and monitoring consoles;

switchgear and control gear and protective devices;

computer and computer-based systems with software;

ship's position sensors system;

other equipment as may required by the Register.

8.4 TECHNICAL DOCUMENTATION

8.4.1 Prior to commencement of survey of the DP-system electric and electronic equipment during manufacture thereof, the following documentation shall be submitted to the Register for consideration:

the specification with description of the operating principle and justification of the system redundancy level;

list of equipment used with indication of the devices and units used and their performance data;

layout of the thruster units and cable routeing diagram with indication of methods used for cable installation and penetration through watertight and fire-proof bulkheads;

general arrangement plans of the control consoles and panels with indication of primary and secondary control stations;

schematic and functional diagrams for electric power plant control;

functional diagrams for computerized control system with indication of the inputs and outputs with feedback,

self-check system and alarm system;

layout and diagram of the ship's position sensors and their connections with control system;

test programme for control system;

list of spare parts.

8.5 DESIGN OF THE DP-SYSTEM, CLASSES

8.5.1 The design of the dynamic positioning control systems shall conform to the general requirements set forth in Section 2.

8.5.2 Where the main machinery (propulsion plant) and rudder system of a self-propelled ship be part of the DP-system, the requirements of this Chapter shall be fully applied thereto, in addition to the requirements placed upon the propulsion machinery and rudder system.

8.5.3 The DP-systems shall be subdivided into classes based on the severity of consequences of a loss of position keeping stability.

8.5.4 Class 1 DP-system, which corresponds by its characteristics to mark **DYNPOS-1** in the class notation, is a system with minimum redundancy as indicated in 8.5.8. In this case, the loss of position of the ship may occur in the event of a single failure as stated in 8.2.1.

8.5.5 Class 2 DP-system, which corresponds by its characteristics to mark **DYNPOS-2** in the class notation, shall have such redundancy that a loss of position shall not occur in the event of a single failure in any active component of the system. Passive components of the system shall not be considered to fail where an adequate protection from mechanical damages and owing to the component properties is demonstrated confirmed by a certificate of the Register.

8.5.6 Class 3 DP-system, which corresponds by its characteristics to mark **DYNPOS-3** in the class notation, shall have such redundancy that a loss of position is not to occur in the event of a single failure in components in the following cases:

failure in any active and passive component, as indicated in 8.2.1, located in different watertight compartments, or failure in active and passive components located in any one watertight compartment, from flooding or fire, or

failure of active and passive components in any one fire sub-division, from fire or explosion.

8.5.7 For Class 2 and 3 DP-systems, the operator's error or incompetence shall be considered as a single failure and such failure shall not lead to loss of ship's position keeping stability.

8.5.8 Class 1 DP-system shall be designed with redundancy of the following components:

thrusters with their local control systems,

control systems of the installation (one manual control system and one computerized control system),

position sensors system.

8.5.9 Class 2 DP-system shall be designed with redundancy of the following components:

electric power supply system,

thrusters with their local control systems,

computerized control system of the installation,

position sensors system.

8.5.10 Class 3 DP-system shall be designed with redundancy of components as provided for Class 2 DP-system, but in addition, all the redundant components shall be separated by watertight or "A-60" class fire-resisting bulkheads.

8.5.11 The redundant components ensuring an appropriate reliability of the system shall function continuously or be switched on immediately shall the need arise. Transfer to a redundant component shall be effected either automatically or by simple action of the operator. The transfer shall not cause excessive fluctuation of the positioning conditions.

8.6 ELECTRIC POWER PLANT SYSTEM

8.6.1 The power system necessary to supply the thruster units shall have a sufficient capacity and shall respond in time to power demand changes caused by operating modes needed at the moment.

8.6.2 For Class 1 DP-systems, the power system need not be redundant.

8.6.3 For Class 2 DP-systems, the power system shall be divisible into at least two independent systems, each having a capacity sufficient to ensure all the operating modes of the thruster units. While in use, the power system may be run as a common electric power supply system.

8.6.4 For Class 3 DP-systems, the power system shall have characteristics mentioned in 8.6.3, but in addition, it shall be physically divided by "A-60" class division (bulkhead) into two independent systems. Where the electric power supply systems are located onboard below the operational waterline, they shall be divided by watertight bulkheads. During operation, such systems shall function separately, except for the cases subject to special consideration by the Register.

8.6.5 Where an automated power management system is provided, it shall be designed with redundancy.

8.6.6 The power management systems shall be supplied from both the main and the emergency source of electric power. Where one of the power sources fails, alarm shall be released at the control stations.

8.6.7 The programmable electronic systems (computer-based or microprocessor (PLC) systems) shall be supplied in such a way as to minimize voltage bumps, harmonic interference and to provide protection against erroneous connection (connection with a wrong polarity).

8.6.8 For the DP-systems designed with appropriate redundancy, depending on their class, the following arrangements shall be provided:

.1 the power system shall be equipped with an automatic changeover device to a back-up source having appropriate quality characteristics including those concerning stabilization;

.2 the change-over operations shall not interrupt or disturb procedures essential to the safety of the ship;

.3 particular attention shall be given to:

sufficiency of the accumulator battery capacity,

consistency between the charging facilities and relevant accumulators,

invertor equipment,

load monitoring systems,

protection systems,

earthing systems,

switchgear,

synchronizing devices to provide change-over to back-up energy sources or back-up power supply systems.

8.7 THRUSTER SYSTEM

8.7.1 Each electric drive of the thrusters shall be power supplied by a separate supply circuits without the use of common feeders or common protective devices and shall be provided with an independent device for emergency shutdown of electric motor actuated from the control station.

8.7.2 Each electric drive shall be provided with its own control system supplied by a separate circuit without the use of common feeders or common protective devices.

8.7.3 Propeller blade position and thrust azimuth (direction) of the rotatable thrusters in the event of electric drive failure shall remain unchanged without marked deviations.

Control of a thruster shall be restored manually.

8.7.4 To eliminate electromagnetic interaction between command signals, feedback signals of the local and electronic (computer-based) DP control systems, the mentioned control systems shall meet the requirements set forth in 2.2, Part XI "Electrical Equipment".

8.7.5 Each electric and hydraulic control system shall be provided with duplicated power supply via separate circuits without the use of common feeders or common protective devices.

8.7.6 Provision shall be made for back-up power supply circuits, which enable the power supply to be automatically changed over thereto, in the event of the main power failure, not only for the control system but also for the power circuit of the thrusters.

8.7.7 The operations to transfer the power supply of control systems from the main feeders to the back-up ones shall not result in loss of power supply to equipment and devices.

8.7.8 For the local control system of a thruster and for the computer-based control system, separate feedback sensors shall be provided. The feedback channels shall not have common elements, the failure of which will result in loss of control from both the one and the other control system. For example, two feedback channels shall have two independent sensors actuated by separate mechanical linkages, and cable lines of these sensors shall run with as much separation as practicable.

8.7.9 The feedback signals of various parameters describing condition of the ship, the information on the power consumed to maintain position of the ship and some other parameters are the most important. The DP-system shall be able to compare these signals, initiate the alarm system in the event of their faults and continue to maintain position of the ship using feedback signals from other sensors.

8.8 CONTROL STATIONS

8.8.1 The main DP-system control station shall be generally combined with the main bridge control station where the operator has a good view of the ship's exterior limits and the surrounding area.

The panels of the DP-system control consoles shall be fitted with permanent visual alarm and indication of normal operational status of the following sub-systems;

electric power supply system (number of running generators and converters, their load, availability of back-up sets),

power thruster system (number of thrusters, operating mode, load, status of local control systems),

dynamic positioning control systems (status of main and back-up power supply, values and directions of thrust produced by thrusters, with reference to the ship axes, indication of the ship's position on station, status of computer-based system and status of ship's position sensor system, other information needed to ensure safe functioning of the DP-system).

Information regarding other parameters of particular devices and machinery shall be submitted to the operator on demand.

8.8.2 The display switching system and controls shall be designed with due regard to the national ergonomic standards. The thruster control mode shall be selectable by simple actions of the operator and the mode selected shall be clearly distinguishable among the following control modes provided:

manual remote thruster control from local stations,

joystick thruster control from main control station,

automatic (computer) control.

8.8.3 For Class 2 and 3 DP-systems, the controls and electronic control logic shall be such that incompetent or unauthorized actions of the operator cannot cause disturbance of the normal positioning conditions.

8.8.4 The alarm system of the DP-system shall meet the general requirements set forth in 2.4.

8.8.5 The alarm system of the DP-system, in addition to audible and visual signals relating to the DP-system machinery and devices, shall contain textual and graphic information on typical failure of the system components and recommendations to the operator with respect of necessary arrangements to be made in order to keep the position of the ship.

8.8.6 The dynamic positioning control system shall be designed with a logic that would render fault development and transfer from one system to another impossible. The redundant system components shall interact in such a manner that if one of these components fails, it is isolated (disconnected) while the other component is activated. The displays shall represent sufficient visual and audible information on transfer to the back-up component.

8.8.7 The control system shall provide for quick transfer from the automatic to remote manual control of the thrusters using both several joysticks according to the number of thrusters) and a single common joystick. Transfer from the manual to automatic (computer-aided) control shall be effected with similar quickness.

8.9 COMPUTER-BASED CONTROL SYSTEMS

8.9.1 The redundancy requirements shall not be applicable to computer-based systems in Class 1 dynamic positioning control systems.

8.9.2 Computer-based systems in Class 2 dynamic positioning control systems shall be duplicated and independent of one another. Common facilities, such as plant interfaces, data transfer arrangements, data buses and software, including self-checking routines shall not be capable of causing the failure of both systems.

8.9.3 Computer-based systems in Class 3 dynamic positioning control systems shall be duplicated as indicated in 8.9.2, and furthermore, provision shall be made for an independent back-up dynamic positioning control system arranged in a special space separated by “A-60” class bulkhead from the main control station. During normal dynamic positioning control, the back-up system shall be in “hot back-up” state in “on” condition and shall be automatically updated by input data from the position reference system, thruster feedback, etc. Change-over of control to the back-up system shall be possible at all times and shall be effected manually from the back-up control station.

8.9.4 For equipment Classes 2 and 3, the computer-based DP-control systems shall include a software function known as "failure consequence analysis" to verify the ability of the ship to remain in position after failure of the DP-system equipment and devices, which can bring the installation into the most severe emergency conditions. This analysis shall verify that the thrusters remaining in operation after a typical failure can generate the same resultant hydrodynamic thrust vector and force as required before the failure, under current weather conditions.

8.9.5 Where the "failure consequence analysis" establishes an inability to maintain position of the ship, warning alarm shall be actuated.

8.9.6 For operations, which will take a long time to safely terminate, the "failure consequence analysis" shall include a function, which simulates the thrust and power remaining after the worst case failure, based on manual input of weather trend.

8.9.7 Redundant computer-based systems shall be arranged with automatic transfer of control after a failure in one of the computer-based systems. The automatic transfer of control from one computer-based system to another shall be smooth, without particular disturbing effects on the thrusters while in positioning mode.

8.9.8 An interruptable power supply shall be provided for each DP-computer-based system to provide a minimum of 30 minutes operation following a mains supply failure.

8.9.9 Application programs and database shall be protected against destruction or data loss due to faults in the power supply system, that is they shall be stored in the read-only memory (ROM) or in the memory with continuous independent power supply.

8.10 POSITION REFERENCE SYSTEMS

8.10.1 Position reference systems for Class 1 DP-systems shall be based on the operating requirements with due regard to the acceptable performance characteristics.

8.10.2 For Classes 2 and 3 DP-systems, provision shall be made for at least three independent position reference systems based on different principles, which shall be simultaneously and co-ordinately available to the DP-control system during operation.

8.10.3 The position reference systems shall produce data with adequate accuracy. Provision shall be made for visual and audible alarm to indicate deviations from true data or excessive degradation of the signals from the position reference systems.

8.10.4 For Class 3 DP-systems, one of the position reference systems shall be connected to the back-up control system and located in a special space separated by "A-60" class bulkhead from the spaces containing other position reference systems.

8.11 EXTERNAL FORCE SENSORS

8.11.1 For the dynamic positioning system, provision shall be made for at least the following sensors to measure effects of forces acting on the ship or the forces themselves:

heading,
magnitude of ship motions,
wind speed,
wind direction.

8.11.2 For Classes 2 and 3 DP-systems, the external force signals shall come from at least three independent systems for each parameter (e.g. for heading, three gyro compasses shall be provided).

8.11.3 For Class 3 DP-systems, one group of sensors of each type, in addition to the requirements set forth in 8.11.2, shall comply with the requirement for separation thereof by "A-60" class bulkhead from other sensors.

8.12 ALARM SYSTEM

8.12.1 In addition to the requirements set forth in 2.4, the alarm system shall be arranged with facilities to preserve and indicate the "first fault" data.

8.12.2 Monitored parameters of the alarm system shall be subdivided structurally into parameters, which to a certain degree are informative, and parameters, which when alarmed require immediate actions to be taken by the personnel. The list of parameters is given in Table 8.12.2.

8.13 CABLE ROUTEING AND PIPING OF DP-SYSTEM MACHINERY AND DEVICES

8.13.1 For Classes 1 and 2 DP-systems cable routes of electrical equipment and control systems, as well as hydraulic, fuel and lubricating oil and other piping shall be installed with due regard to the requirements set forth in 16.8.4, Part XI "Electrical Equipment" and Section 5, Part VIII "Systems and Piping".

8.13.2 For Class 3 DP-systems, cables of stand-by electric and electronic equipment and piping of stand-by support systems and control systems shall not be routed together with cables and piping systems of the main equipment through the same spaces (compartments). Such installation may be only accepted in cases when the cables of stand-by equipment run in "A-60" class fire-protective ducts. Cable connection boxes are not allowed in such ducts.

Table 8.12.2

Parameter	Alarm system	Comments
Computer-based control system	Failure[1]	Automatic change-over to back-up system
Heading	Deviation beyond permissible limit	—
Position on station	Deviation beyond permissible limit	—
Power supply system	Failure	Automatic change-over to back-up system
Position reference installation	Failure Error Customizing non-conformity	For each position reference system
Gyro compass	Error Non-conformity	Automatic change-over to stand-by compass
Position reference system	Error Non-conformity	Automatic change-over to back-up system
Wind pressure sensor	Error Non-conformity	Automatic change-over to stand-by sensor
Oil pressure in the hydraulic system "Taut wire"	Minimum	The alarm system parameters may be integrated
Oil temperature in the hydraulic system "Taut wire"	Maximum	Ditto
Oil tank level in the hydraulic system "Taut wire"	Minimum	Ditto
Deviation signal of the hydraulic system "Taut wire"	Limiting deviation	—
Total electric power consumption	Excess	Controllable within 50 — 100 %
Air temperature of the air conditioning system for computers	Maximum	—
Serviceable condition of main units (sub-systems)	Change in state	—

[1] The computer-based system shall be able to use the last information on position in case when one or more position reference systems are failured or not switched on.

9 ANCHORING POSITIONING SYSTEMS

9.1 SCOPE OF APPLICATION

9.1.1 The requirements of the present Section apply to the automated control systems of power equipment of anchoring positioning systems.

9.2 DEFINITIONS AND EXPLANATIONS

9.2.1 Anchoring positioning system means a complex of systems, machinery and equipment intended for the ship's position keeping at predetermined accuracy when exposed to external disturbing forces by means of tensile anchor lines.

9.2.2 Auxiliary propellers-assisted anchoring positioning means the use the ship's main propulsion plant and thrusters together with the anchoring positioning system.

9.3 CONTROL SYSTEMS

9.3.1 Each anchor winch shall be provided with the independent control system supplied by its own feeder with an individual protective device.

9.3.2 Each winch shall have a control station located so as to provide a good view of the anchoring operations having regard to the laying-out of the anchor by an anchor handling vessel.

9.3.3 Means shall be provided at each anchor winch control station to monitor chain cable/rope tension, the winch load (current) and the length of the chain cable/rope paid out, the chain cable/rope paying out speed.

9.3.4 A manned anchoring operations control station shall be provided with means to indicate chain cables tension, wind speed and direction. Besides, it shall be provided with means of communication between all control stations critical to anchoring operations.

9.3.5 The local and remote control stations shall be provided with the emergency anchor release arrangements that remain operable at the loss of power supply from the main source of electrical power by automatic switching to the standby source of power. The above controls need not be supplied from the independent source of power.

9.3.6 The emergency release arrangements shall actuate at a load equal to the minimum design tensile strength of the chain cable/rope, as well as at the maximum possible angles of heel and trim as regards damage stability and flooding conditions.

9.3.7 The following alarm signals shall be provided at the central and local anchoring operations control stations: on excessive chain cable/rope tension, on decrease of the chain cable/rope tension below the permissible limits.

9.3.8 Alarms shall be provided at the central anchoring operation control station on the ship's leaving the positioning point and on the ship's deviations from the set course.

The possibility shall be provided of the settings adjustment of the alarms actuation within the specified limits. Actuation settings shall be clearly identified. Measures shall be taken against inadvertent/unintended resetting.

9.4 AUXILIARY THRUSTERS FOR ANCHORING SYSTEMS

9.4.1 Where the anchoring systems are used in conjunction with auxiliary thrusters to keep the ship position, their power equipment and control systems are subject to special consideration by the Register.

9.4.2 Applicable requirements for dynamic positioning systems set forth in 8.7, 8.8 cover also auxiliary thrusters control systems including centralized microprocessor control units.

9.4.3 Input signals validity of the auxiliary propellers control system shall be provided by the signals relevant processing. All errors revealed during the validity check shall actuate alarms.

PART XVI. HULL STRUCTURE AND STRENGTH OF GLASS-REINFORCED PLASTIC SHIPS AND BOATS

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to:

.1 displacement ships of glass-reinforced plastic from 12 to 30 m in length having the speed $v \leqslant 3{,}05\sqrt{L}$ knots and the dimension ratios within the following limits:

length to depth ratio $L : D = 6...10$;

breadth to depth ratio $B : D = 2...2{,}5$;

length to breadth ratio $L : B = 3...5$.

Where the dimension ratios are beyond the specified limits, the structure and scantlings of the hull are subject to special consideration by the Register;

.2 lifeboats from 4,5 to 12 m in length.

1.1.2 The requirements of the present Part are also applicable to:

.1 displacement ships from (5)[1] up to 12 m and those over 30 m in length, the structure of ships over 30 m in length being subject to special consideration by the Register;

.2 hydrogliders, air-cushion vehicles and hydrofoil ships, the structure of such ships being subject to special consideration by the Register.

1.2 DEFINITIONS AND EXPLANATIONS

1.2.1 The definitions and explanations relating to the general terminology of the Rules are given in 1.1, Part I "Classification".

The definitions of dimensions of ships comply with the provisions of Part II "Hull".

For the purpose of the present Part the following definitions have been adopted.

Single-skin construction is a construction comprising a single-skin laminate stiffened by framing members.

Double-skin construction is a construction comprising two single-skin laminates interconnected by framing members.

Sandwich construction is a construction comprising two single-skin laminates interconnected by a core of plastic foam, honeycomb structure, etc. In this type of construction the core is load-bearing and takes up the load together with the laminates.

[1] References for ships below 12 m in length are shown in parentheses.

1.3 GENERAL

1.3.1 The requirements of the present Part apply to:

.1 hulls moulded either as a whole or in two halves (starboard and portside), which are jointed together along the keel, stem and sternframe;

.2 ships with the following connections of hull sections:

shell skin along the centre line;

deck to side;

superstructures and deckhouses to deck;

.3 ships with shell, deck and strength bulkheads of single-skin construction;

.4 ships with deckhouse and superstructure sides and ends of single-skin and sandwich construction;

.5 lifeboat hulls of single-skin, double-skin and sandwich construction.

1.3.2 The scantlings of structural members of sandwich and double-skin hull structures of ships as well as application of composite structures are in each case subject to special consideration by the Register unless special requirements are given in the present Part.

1.3.3 On drawings of glass-reinforced plastic structures the thickness of laminates, in mm, as well as the number of reinforcing material layers and the total mass of reinforcement in kg per square metre of the laminate area shall be shown.

1.3.4 The hull moulding technique is subject to approval by the Register in each case.

1.3.5 Types of structures other than those stated in the present Part may be approved by the Register, provided the requirements of 1.3.3.1, General Regulations for the Classification and Other Activity are met.

1.4 SCOPE OF SURVEYS

1.4.1 The general provisions for survey of the hull are set forth in General Regulations for the Classification and Other Activity.

1.4.2 After consideration and approval of the technical design of a ship as a whole, the following items shall undergo survey by the Register during the hull construction:

.1 basic materials for moulding hull structures;

.2 condition and microclimate of working shops;

.3 equipment to be used in moulding hull structures;

.4 moulding of shell assemblies with relevant framing;

.5 moulding of deck assemblies;

.6 moulding of bulkheads;

.7 moulding of tanks;

.8 moulding of superstructures and deckhouses;

.9 moulding of seatings for main machinery as well as for other machinery and arrangements subject to survey by the Register;

.10 moulding of coamings, companions and similar guards for openings in hull;

.11 stems and sternframes, shaft brackets.

1.4.3 Prior to manufacturing structures listed in 1.4.2, technical documentation for the hull in the scope specified in 3.1.3, Part I "Classification" shall be submitted to the Register for approval.

1.4.4 During construction the hull structures mentioned in 1.4.2 are subject to survey as regards the compliance with the requirements of Part XIII "Materials" and with the technical documentation approved.

1.4.5 The procedure and results of tests for rigidity and strength of completed structures are in each case subject to special consideration by the Register.

1.5 MATERIALS

1.5.1 In the present Part the use of glass-reinforced plastics of the types given in Appendix 1 is specified.

1.5.2 In addition to the plastics mentioned in Appendix 1, glass-reinforced plastics containing reinforcements and binders in alternative combinations as well as with alternative reinforcement schemes may be used, provided that detailed information on their mechanical properties, which is submitted, is approved by the Register.

1.6 FRAMING SYSTEM AND SPACING

1.6.1 The present Part deals with the transverse system of framing of ship's hull.

In the case of longitudinal or combined system of framing the hull structure design and scantlings are subject to special consideration by the Register.

1.6.2 For standard spacings of transverse framing, refer to Table 1.6.2.

Table 1.6.2

Length of ship, m	Spacing, mm
12(5)...15	350
$15 < L < 25$	400
25...30	450

Where the spacing adopted is different from that given in Table 1.6.2, the thicknesses and scantlings of framing members are recalculated in accordance with the requirements of 2.2, 2.3, 2.5.

1.6.3 The frame spacing in the fore peak shall not exceed:

300 mm with L from 12 (5) to 15 m;

350 mm with L over 15 and below 25 m;

400 mm with L from 25 to 30 m (inclusive).

1.6.4 The spacing of stiffeners of the watertight transverse bulkheads is assumed to be equal to the spacing of the hull framing.

For the fore peak bulkhead the spacing of stiffeners is assumed to be equal to the spacing at the fore end.

For the superstructure and deckhouse sides the spacing shall be equal to that of the single-skin construction hull.

1.7 MATTING-IN CONNECTIONS AND FASTENINGS

1.7.1 The connection of longitudinal and transverse framing members is made by means of matting-in angles (wet angles), which are formed in situ and in which glass mats are used as reinforcement. By way of exception glass fabric of satin or plain weave may be used. The use of glass roving cloth is not permitted. The surfaces to be jointed shall be thoroughly cleaned prior to laying-up the matting-in connections.

On agreement with the Register, the matting-in angles may be moulded by spraying.

1.7.2 The thickness of the matting-in angle shall be equal to half the thickness of the stiffener web in the case of tee-shaped sections and to a full thickness of the stiffener web in the case of closed box sections. The width of the matting-in angle flange and the

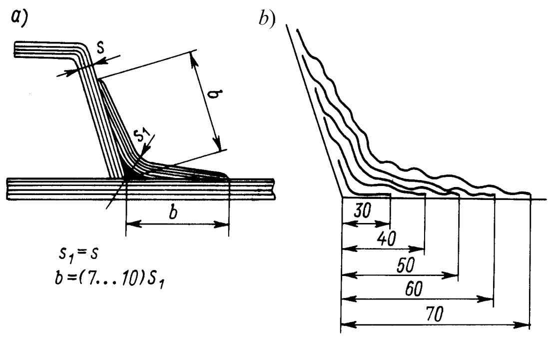


Fig. 1.7.2-1:
a — scantling of matting-in connection;
b — diagram of laying-up layers of glass mat or glass fabric strips

s_1, mm	3	4	5	6	8	10
b, mm	30	30	40	50	60	70

diagram of laying-up the reinforcement shall be in accordance with Figs. 1.7.2-1 and 1.7.2-2. In any case, the width of the matting-in angle flanges shall not be less than 30 mm for stiffeners and 50 mm for transverse watertight bulkheads.

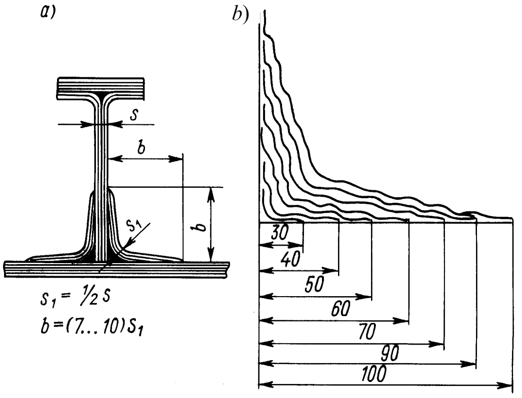


Fig. 1.7.2-2:
a — scantlings of matting-in connection; *b* — diagram of laying-up layers of glass mat or glass fabric strips

s_1, mm	3	4	5	6	8	10	12	14
b, mm	30	30	40	50	60	70	90	100

1.7.3 The thickness of matting-in angles of bulkheads, platforms, superstructures and deckhouse sides and ends shall be equal to that of the bulkhead sheathing, platform planking, superstructure or deckhouse side and end, respectively.

1.7.4 For bolted connections the following conditions shall be met:

.1 bolting shall not be less than three bolt diameters away from the edge of the laminate;

.2 the bolt diameter shall be equal to the thickness of the thickest laminate to be connected;

.3 bolts shall not be closer spaced than four diameters apart;

.4 parts of the bolted connections shall be protected with anticorrosive coating or made of corrosion-resistant materials;

.5 washers of not less than 2,5 times the bolt diameter shall be fitted under the bolt head and nut, the washer thickness being 0,1 times the bolt diameter, but not less than 1,5 mm.

1.7.5 Connections made with the use of riveting shall be specially considered by the Register.

1.7.6 Non-essential or low-stresses connections are permitted to be made by means of matting-in butts (Fig. 1.7.6). The contact surfaces shall be thoroughly cleaned prior to the laying-up of strap layers.

1.7.7 Where the hull is moulded in two (starboard and port) halves, they shall be connected along the

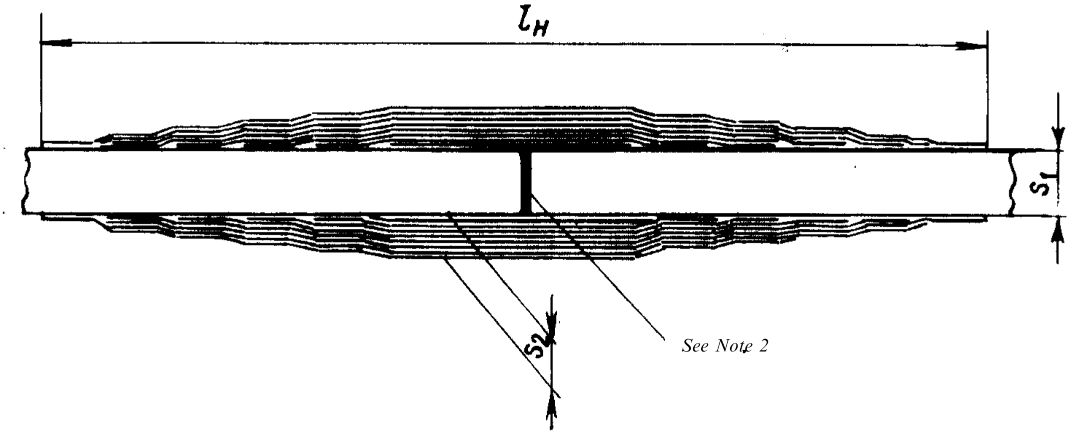


Fig. 1.7.6:
l_s — width of the matted-on strap: (l_s = 200 + 15s_1); (s_2 = 0,5s_1); s_1 — thickness of the laminates being connected; s_2 — thickness of the matted-on strap

s_1, mm	s_2, mm	Glass fabric layer numbers													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
		Width of the matted-on strap, mm													
6	3	100	150	150	200	200	250	300							
8	4	100	100	150	150	150	200	250	250	300					
10	3	100	100	150	150	200	200	250	250	300	300				
14	7	100	100	150	150	200	200	250	250	300	300	330	350	400	400

N o t e s : 1. The glass fabric warp shall be oriented perpendicularly to the butts in the laminates.
2. The space between the laminates shall be 1 to 2 mm.
3. The strap material is a laminate on the basis of glass fabric of satin or plain weave. Glass mats are not permitted.

centre line by means of matted-on straps (Fig. 1.7.7). The straps shall be moulded of glass-reinforced plastics of type III or IV for any length of the hull. The thickness s of each strap shall be 0,7 times the keel plate thickness s_k (refer to Table 2.2.1). The entire width of the matted-on straps shall not be less than 200 mm + $15s_k$.

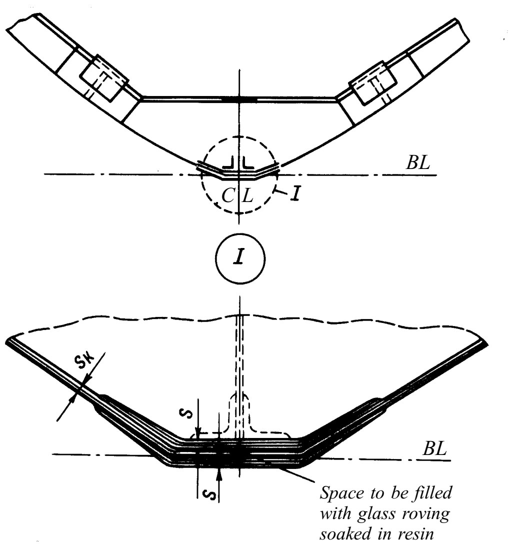


Fig. 1.7.7

1.7.8 The thickness of the matted-on straps shall reduce towards the edges down to the thickness of one layer of glass fabric. This reduction in thickness is achieved by gradual increase in the width of the laid up tapes, the first layer based on a 100 mm tape (50 mm on each side) and subsequent layers formed by tapes 140 mm, 180 mm and so on wide laid up in the number of one or from two to three at a time.

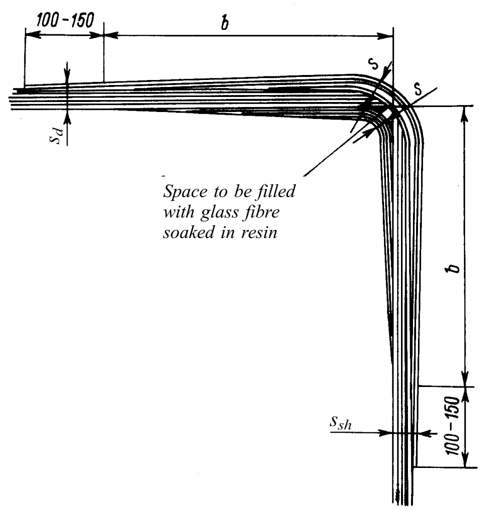


Fig. 1.7.9:
s_{sh} — sheerstrake thickness; s_d — deck laminate thickness;
s — thickness of the matting-in single angle; b — half width of flanges of the matting-in angle

N o t e . Additional layer of fabric shall be laid onto the outer surface of the deck and side shell laminate to overlap the matting-in angle for 100 to 150 mm on each side, the direction of fabric warp being along the hull.

1.7.9 Deck-to-side connection shall be made by means of inner and outer matting-in angles (straps) in accordance with Fig. 1.7.9. The angles shall be moulded of glass-reinforced plastics of type III or IV. The width of both flanges of the matting-in angles (2*b*) shall not be less than 200 mm + $15s_{sh}$ (where s_{sh} is the sheerstrake thickness). The thickness of the matting-in angle shall be taken equal to 0,7 s_{sh}.

1.7.10 The layers in the matting-in angles shall be distributed as specified in 1.7.2.

2 HULL AND SUPERSTRUCTURES OF SHIPS

2.1 GENERAL

2.1.1 The thickness of the shell and deck laminates as well as of the bulkhead and other laminates shall be determinated from Figs. 2.1.1-1, 2.1.1-2 and 2.1.1-3 depending on the permissible bending moment m_{perm} acting on a strip 1 cm wide, which is given in Table 2.2.1.

The thickness of laminates with the glass content as specified in line No.1 of Tables 1 to 6 presented in Appendix 2 shall be determined from Fig. 2.1.1-1.

The thickness of laminates with the glass content as specified in lines Nos. 2 and 3 of the above-mentioned Tables shall be determined from Figs. 2.1.1-2 and 2.1.1-3.

The reinforcement schemes given in lines Nos. 1 and 2 of Tables 1, 2, 5 and 6 of Appendix 2 are used for moulding sides and bottom shell, decks, divisions, etc.

The reinforcement scheme given in line No. 3 of Tables 3 and 6 and in line 2 of Table 1 is used for framing members, which shall be moulded and squeezed in special devices during manufacture.

2.1.2 The present Part provides for hull framing members to be made of closed box sections of glass-reinforced plastics, type I_2, and of T-shaped sections with a face plate of glass-reinforced plastics, type III_3, and the web of glass-reinforced plastics, type I_2.

2.1.3 The scantlings of framing members shall be determined from Figs. 2.1.3-1, 2.1.3-2 and 2.1.3-3

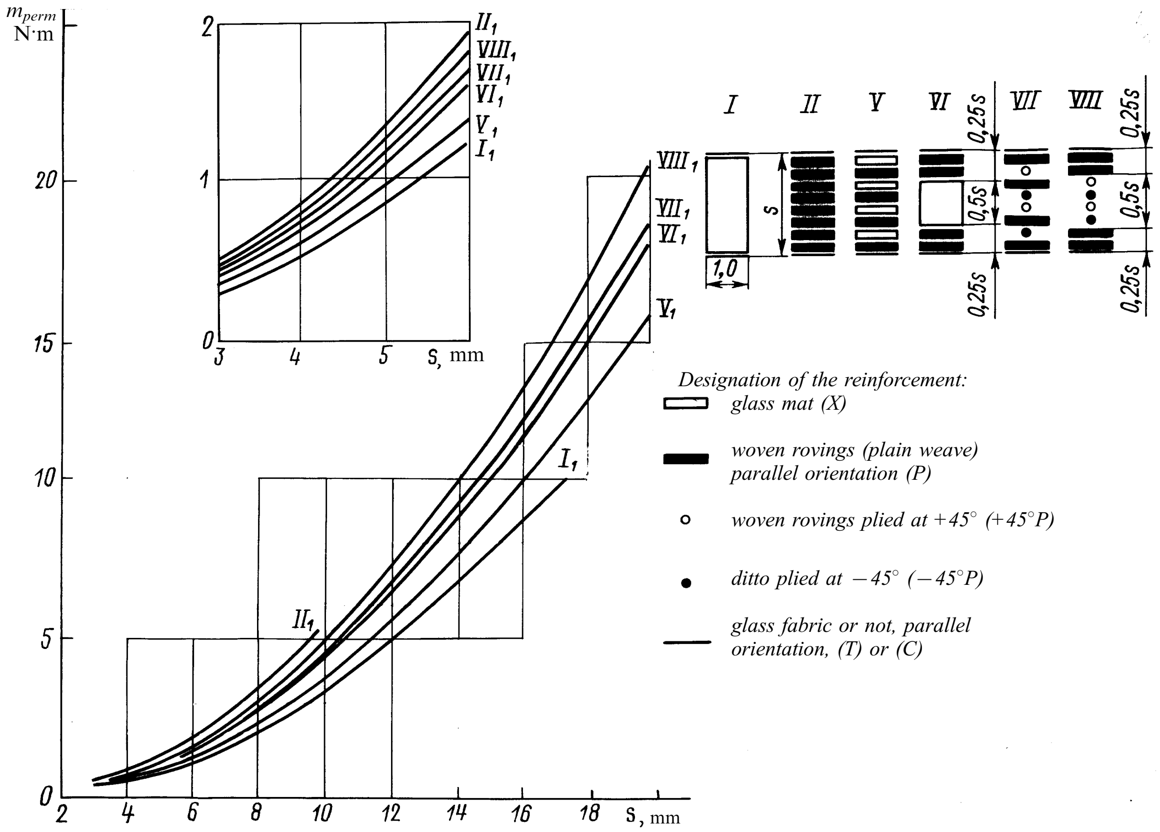


Fig. 2.1.1-1

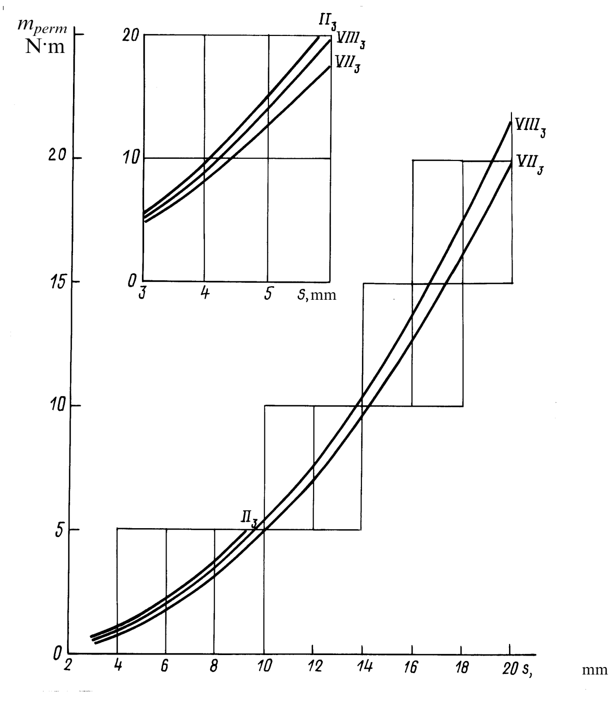


Fig. 2.1.1-2

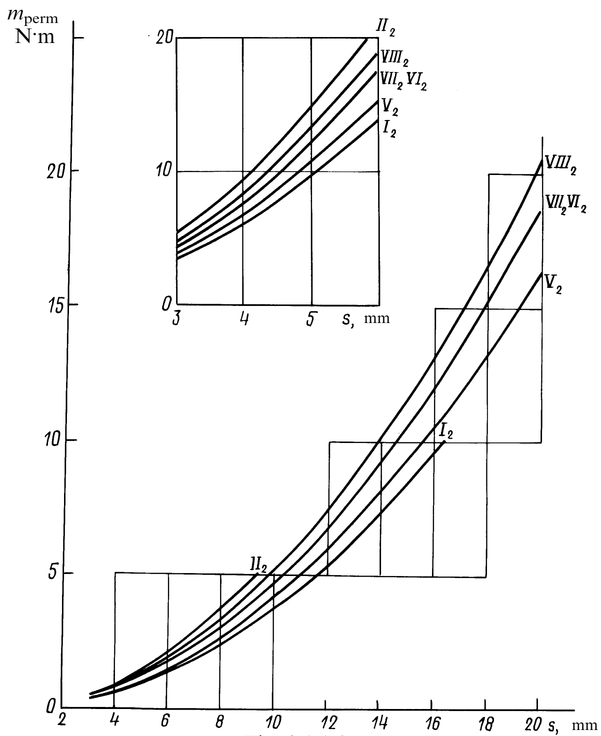


Fig. 2.1.1-3

depending on the section modulus of stiffeners with the associated face plate.

The scantlings of stiffeners of closed box section are determined from Fig. 2.1.3-1.

The scantlings of T-shaped stiffeners are determined from Figs. 2.1.3-2 and 2.1.3-3, Fig. 2.1.3-3 being the scaled-up original of Fig. 2.1.3-2.

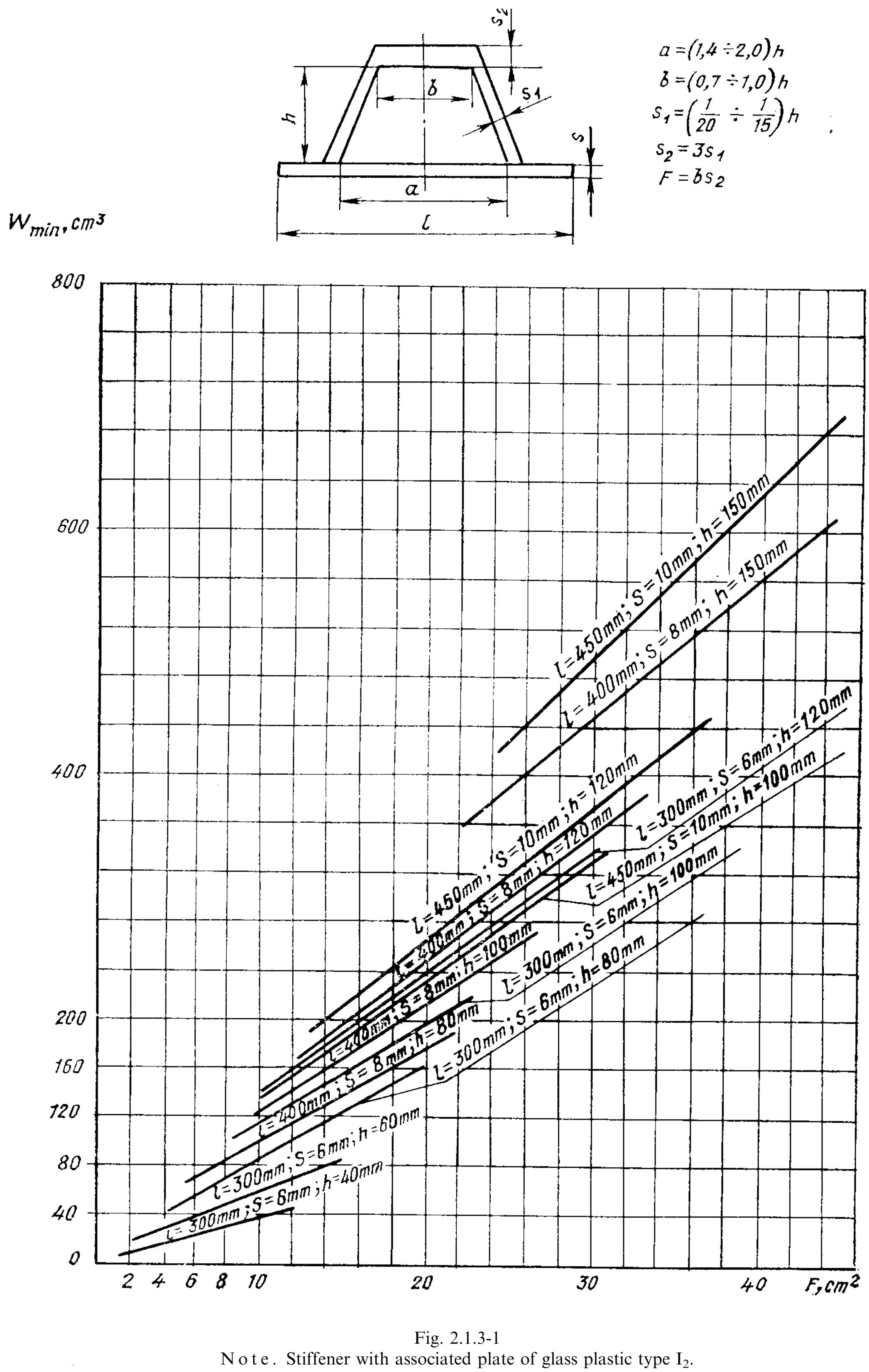


Fig. 2.1.3-1

N o t e . Stiffener with associated plate of glass plastic type I_2.

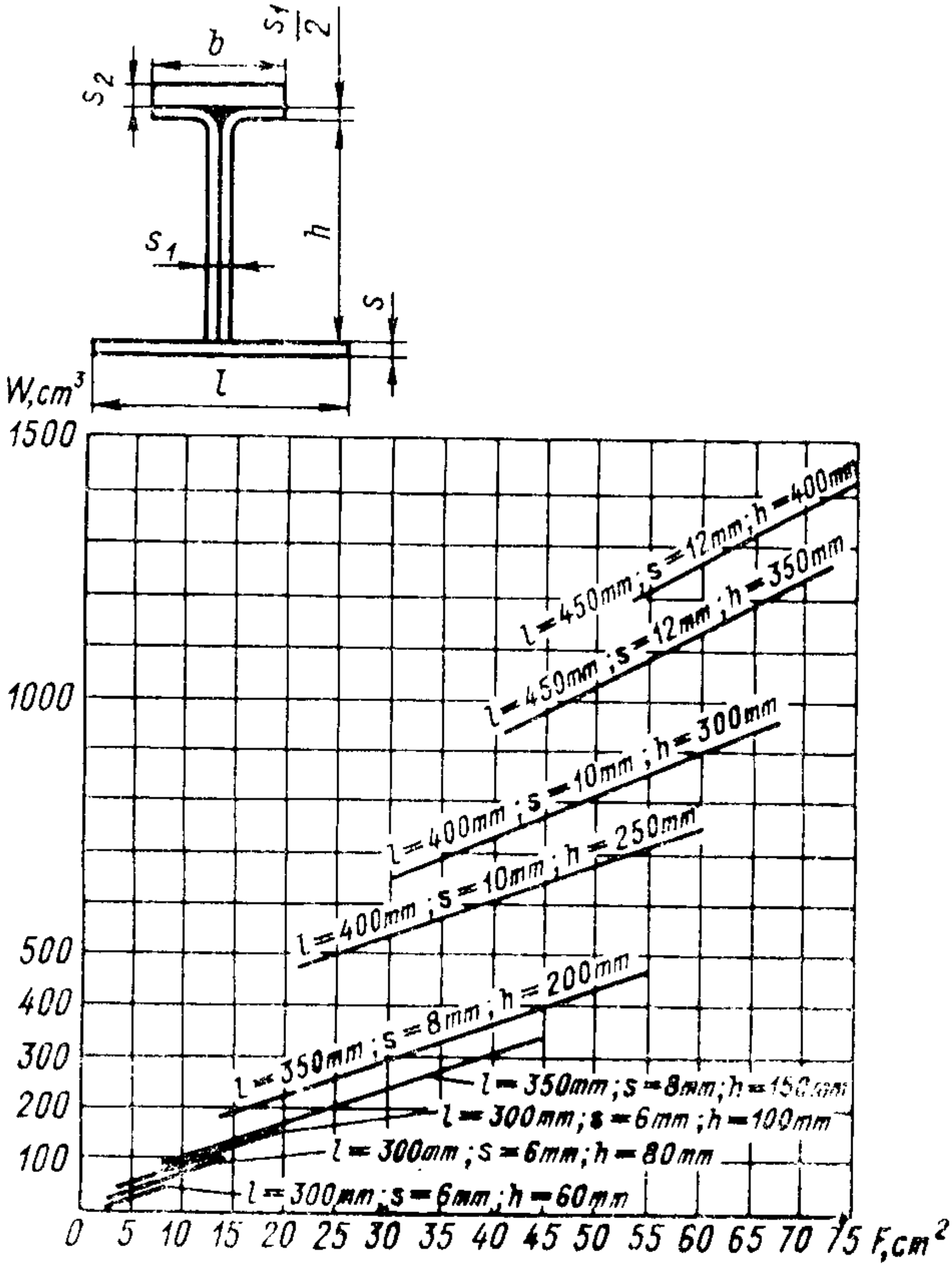


Fig. 2.1.3-2

b	s_1	s_2
$(\frac{1}{1,5} \cdots \frac{1}{1,3})h$	$(\frac{1}{10} \cdots \frac{1}{20})h$	$(2...3)s_1$
$F = b \cdot s_2$		

N o t e s : 1. Face plate of glass plastic type III_3, the associated plate of glass plastic type VII_2, with E_{VII} - $0,7E_{III}$ (where E is the modulus of elasticity).

2. Web of glass plastic type I_2.

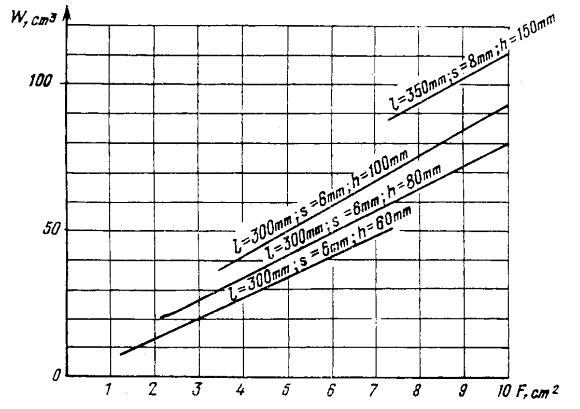


Fig. 2.1.3-3

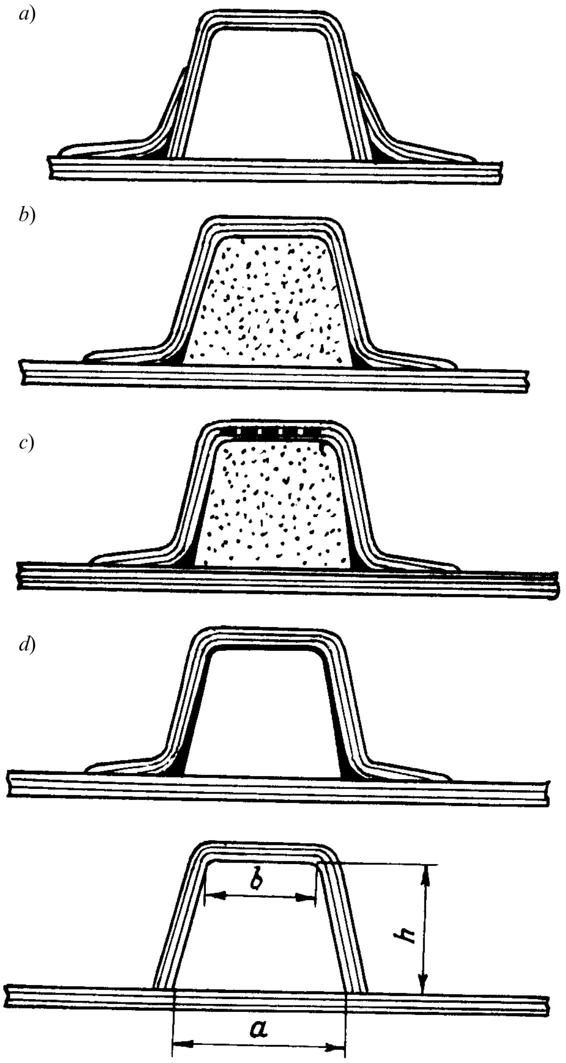


Fig. 2.1.3-4:
a — pre-moulded stiffener; *b* — stiffener moulded in situ, with core of foamed plastic; *c* — ditto, with face plate reinforced; *d* — stiffener moulded in situ over a former of sheet aluminium

Notes: 1. Reinforcement in face on the basis of glass fabric or glass rovings.

2. These sketches do not indicate the relations for longitudinal framing members.

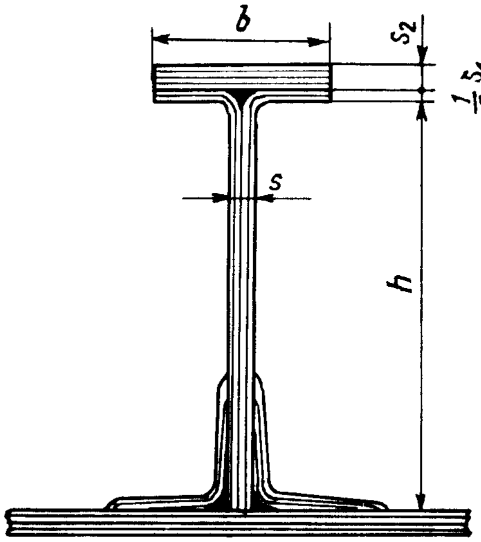


Fig. 2.1.3-5

b	s_1	s_2
$(\frac{1}{1,5} \cdots \frac{1}{3,0})h$	$(\frac{1}{10} \cdots \frac{1}{20})h$	$(2...3)s_1$

Note. The warp of glass fabric in face plate shall be directed along the stiffener.

The scantlings of bottom stiffeners (centre girder and side girders) shall be determined in accordance with 2.3.5.

The recommended structural types of closed-box and T-shaped sections are shown in Figs. 2.1.3-4 and 2.1.3-5.

2.1.4 The scantlings of the framing members are permitted to be determined according to Appendix 3.

2.1.5 The width of the associated plate is taken to be 1/6 of the stiffener span, provided that the panel is of glass-reinforced plastics, types I, V, VI, VII and VIII, or 1/10 of the stiffener span, provided that the panel is of glass-reinforced plastics, type II, but it shall not be more than the distance between adjacent parallel stiffeners.

2.2 SIDE AND BOTTOM SHELL

2.2.1 The thickness of the side and bottom shell shall be determined from Figs. 2.1.1-1 and 2.1.1-2 depending on the permissible bending moment value given in Table 2.2.1.

2.2.2 The minimum side and bottom shell thickness shall not be less than:

Table 2.2.1

Length of ship, m	Spacing, mm	m_{perm}, N·m		Width, mm	
		Bottom shel	Side shell	Plate keel	Sheer-strake
1	2	3	4	5	6
(5)	(350)	(1,4)	(0,8)	(400)	(300)
(7,5)	(350)	(2,0)	(1,3)	(475)	(400)
(10)	(350)	(3,1)	(2,0)	(550)	(475)
12	350	4,2	2,8	600	575
15	350/400	5,2/6,7	3,5/4,5	675	650
17,5	400	8,0	5,2	750	750
20	400	9,0	6,0	825	825
22,5	400	10,2	6,7	875	925
25	400/450	11,4/13,6	7,5/9,5	950	1000
27,5	450	14,8	10,3	1025	1100
30	450	16,0	11,0	1100	1200

Notes: 1. Where the design spacing differs from that given in column 2, m_{perm} shall be modified in the ratio of $\left(\frac{\text{actual spacing}}{\text{Table spacing}}\right)^2$.
2. For intermediate ship lengths m_{perm} shall be determined by interpolation.
3. The thickness of the plate keel and sheerstrake is taken equal to 1,5 times the bottom shell thickness.
4. In column 5 the entire width of the plate keel is shown.
5. Reduction in thickness shall be made across the width of 50 mm for each 5 mm difference in thickness.
6. For ships of 15 and 25 m in length shown in the numerator is the smaller spacing and in the denominator — the greater spacing.
7. The following areas are considered as bottom shell:
in ships of hard chine form — from the keel line up to the bilge;
in ships of rounded chine form — from the keel line to $1/3D$.

.1 4 mm for sides and 5 mm for bottom in case of single-skin construction with reinforcement of any type;

.2 3 mm for sides and 4 mm for bottom in case of double-skin or sandwich construction.

2.2.3 Side and bottom shell is permitted to be moulded of glass-reinforced plastics of the following types:

I — for hulls from 12(5) to 15 m in length;

II — for hulls from (5) to (10) m in length;

V — for hulls from 12(5) to 30 m in length;

VII — for hulls from 12(10) to 30 m in length.

2.2.4 In the case of shell thickness between 3 and 6 mm provision shall be made for a 40 mm overlap of butts in reinforcements. Seams are formed without overlapping.

In the case of shell thickness of 6 mm and above the butts and seams in reinforcements need not be overlapped, the number of reinforcing material layers being not less than 8.

2.2.5 The butts and seams in each adjacent layer of the reinforcing material shall be spaced not closer than 100 mm apart.

Butts and seams are permitted to be coincident in one section after 6 layers at least.

2.2.6 Woven rovings in layers of the diagonal lay-up shall not have butts.

2.2.7 The thickness and width of the plate keel and sheerstrake shall be determined in accordance with Table 2.2.1 (refer to Note 3).

2.2.8 The thickness of the stern laminates (transom included) shall not be less than that of the bottom laminates.

2.2.9 The thickness of the shell and sheerstrake laminates in way of the fore peak shall be taken equal to that of the midship portion.

2.2.10 The plate keel and sheerstrake shall be moulded by addition of reinforcing material layers, which shall be uniformly distributed between the shell basic layers and alternate with the latter.

The change in thickness shall be made in accordance with Table 2.2.1 (refer to Note 5).

2.3 BOTTOM FRAMING

2.3.1 Floors shall be fitted at each frame.

2.3.2 Floors of increased section modulus shall be fitted at all web frames. The depth of floors of increased section modulus shall be taken equal to that of the centre girder and side girders, whichever is greater.

2.3.3 The scantlings of floors are taken in accordance with 2.1.2 depending on the section modulus given in Table 2.3.3.

2.3.4 The minimum thickness of floors shall be 2 mm in the case of closed-box sections and 4 mm in the case of T-shaped sections.

2.3.5 Where the half-breadth measured along the top edge of the floor is in excess of 0,75 m, a centre girder is required to be fitted. Where this value is in excess of 2,5 m, the fitting of one side girder on each side is required in addition to the centre girder.

The scantlings of the centre girder and side girders are given in Table 2.3.5.

2.3.6 The intersection of the side girders with floor shall be effected in accordance with Figs. 2.3.6-1 and 2.3.6-2 without the floors being cut.

The intersection of side girders with floors of increased section modulus shall be made by means of an edge cross-lap joint (refer to Fig. 2.4.6).

Table 2.3.3

Length of ship, m	Design load, kPa	Section modulus for floors of closed-box section, cm^3, for 400 mm spacing, with the span, m					
		0,50	0,75	1,00	1,50	2,00	2,50
(5,0)	(20,0)	(15)	(25)	(50)	(100)	—	—
(7,5)	(30,0)	(20)	(40)	(70)	(150)	(260)	—
(10,0)	(40,0)	(30)	(50)	(90)	(200)	(350)	—
12,0	25,0	15	30	60	130	220	350
15,0	30,0	20	40	70	150	270	420
17,5	35,0	25	50	80	180	310	490
20,0	38,0	30	60	90	200	350	560
22,5	43,0	35	70	100	230	400	630
25,0	47,0	—	80	110	250	440	690
27,5	51,0	—	—	120	280	490	760
30,0	55,0	—	—	—	300	530	830

Notes: 1. The section moduli shown in the Table are given for the spacing of 400 mm, for other spacings the section modulus shall be modified in proportion to the ratio of $\frac{\text{spacing, mm}}{400}$.

2. Where T-shaped sections are used, the section modulus may be reduced by the factor of three.

3. The span is measured between the floor ends where the keel is omitted; from the keel to the floor end where the keel is fitted and the side girder is omitted; from the keel to the side girder or from the side girder to the floor end, whichever is greater.

4. For ships between (5) and (10) m in length, the design load is taken with account of water impact against the bottom likely to occur when the ship is dropped into water.

5. For ships over (10) m in length, the design load is taken equal to the maximum side depth obtained at $L : D = 6$ plus 0,5 m.

6. Where the design load differs considerably from that given in the Table, the section modulus may be reduced in proportion to the ratio of $\frac{\text{actual design load}}{\text{tabulated load}}$.

Table 2.3.5

Length of ship, m	Spacing, mm	Centre girder			Side girder		
		Height, mm	Thickness, mm	Section of face plate, mm^2	Height, mm	Thickness, mm	Section of face plate, mm^2
(5,0)	(350)	(150)	(8)	(60 × 12)	—	—	—
(7,5)	(350)	(180)	(9)	(70 × 14)	—	—	—
(10,0)	(350)	(210)	(10)	(80 × 15)	—	—	—
12,0	350	240	11	90 × 15	—	—	—
15,0	350	270	12	100 × 15	200	10	80 × 15
17,5	400	300	13	110 × 16	225	11	90 × 15
20,0	400	330	14	120 × 18	250	12	100 × 15
22,5	400	370	15	130 × 20	275	13	110 × 16
25,0	400	410	16	140 × 22	300	14	110 × 16
27,5	450	440	17	150 × 24	325	15	120 × 18
30,0	450	470	18	160 × 26	350	16	130 × 20

Notes: 1. The scantlings shown in the Table are given for a T-shaped section with the face plate of glass-reinforced plastic, type III_3, and the web of glass-reinforced plastic, types I_2, V_2, VII_2.

2. Where closed-box sections of glass-reinforced plastic, type I_2, are used, the section moduli shall be increased by the factor of three.

3. The scantlings of longitudinal framing members are given for compartments, which length amounts to 30 per cent of the ship's length for ships between 12(5) and 20 m in length, and to 20 per cent for ships between 20 and 30 m in length. In the case of compartments of greater lengths the scantlings of the longitudinal framing members shall be considered specially.

4. Where the actual spacing differs from that shown in the Table, the scantlings of the centre girder and side girders shall not be modified.

5. For intermediate ship lengths the section modulus is determined by interpolation.

2.3.7 The depths of non-continuous longitudinals shall be reduced to the floor depth within at least three spacings at each longitudinal end.

2.3.8 In floors and side girders water courses shall be provided. The recommended structural design of a water course is shown in Fig. 2.3.8.

2.3.9 The connection of the bottom framing to the side framing may be effected by means of matting-in or matting-on connections.

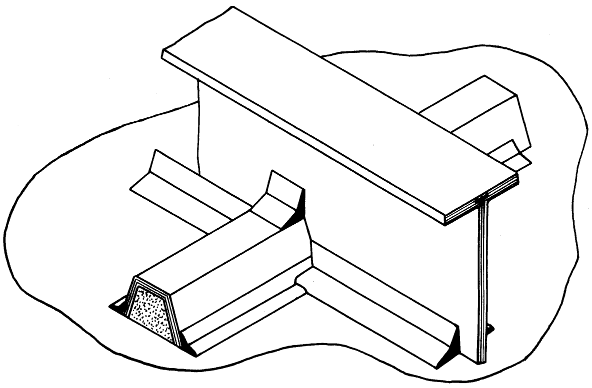


Fig. 2.3.6-1

N o t e . The framing member, which is formed the first, shall not be cut at a deep member.

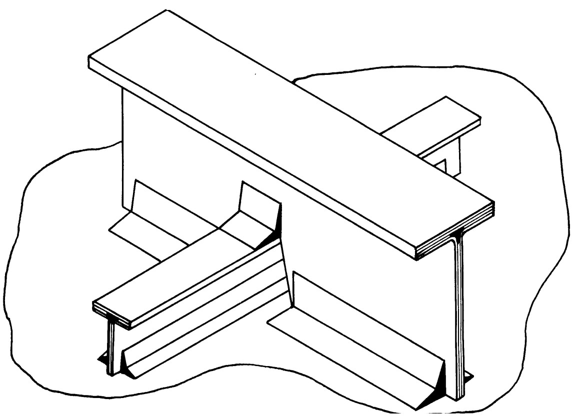


Fig. 2.3.6-2

N o t e . The framing member, which is formed the first, shall not be cut at a deep member.

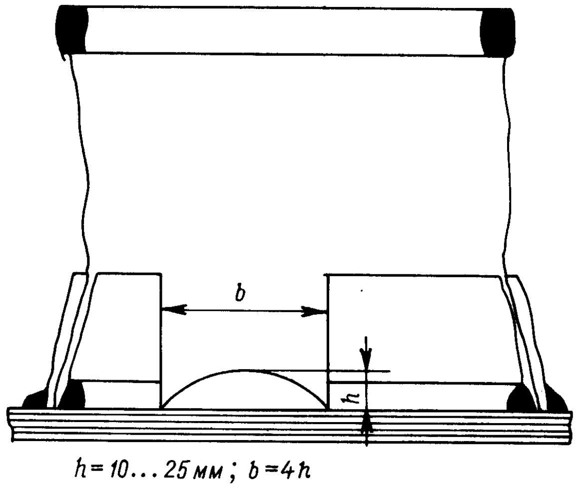


Fig. 2.3.8

N o t e s : 1. The hole is cut at 1/4 of the spacing distance from the intersection with a floor.

2. The edge of the hole shall be covered with resin.

2.4 SIDE FRAMING

2.4.1 The scantlings of frames shall be taken in accordance with 2.1.2 depending on the section modulus given in Table 2.4.1.

2.4.2 The distance between adjacent bulkheads and web frames shall not exceed 6 spacings.

2.4.3 The section modulus of a web frame shall not be less than 5 times the frame section modulus.

2.4.4 Where the frame span is in excess of 2,4 m, a side stringer shall be fitted.

2.4.5 The section modulus of a side stringer shall be equal to that of a web frame.

2.4.6 The intersection of a web frame and a side stringer shall be effected by means of an edge cross lap joint only (Fig. 2.4.6).

2.4.7 The intersection of a side stringer and a frame shall be made as shown in Figs. 2.3.6-1 and 2.3.6-2 without cutting the frame.

T a b l e 2.4.1

Span, m	Section modulus, cm^3					
	Closed-box section, with spacing, mm			T-shaped section, with spacing, mm		
	350	400	450	350	400	450
1,0	47	54	61	12	18	20
1,2	76	87	98	29	29	33
1,4	107	128	138	35	41	46
1,6	147	159	180	47	53	59
1,8	200	228	256	70	76	85
2,0	290	330	370	93	110	123
2,2	369	420	470	123	140	157
2,4	500	570	640	150	189	210

N o t e . Where a side stringer is fitted, the section modulus of the frame shall be taken equal to 1,5 times the section modulus determined from the Table for a span measured from the deck to the side stringer or from the side stringer to the floor, whichever is greater.

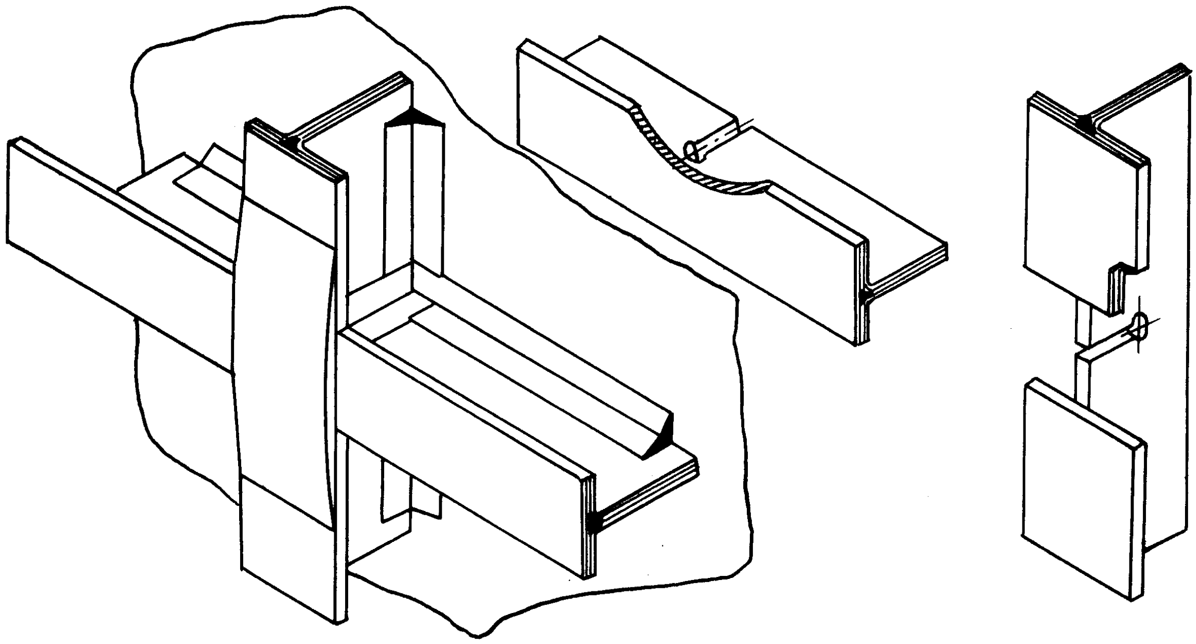


Fig. 2.4.6

N o t e s : 1. Deep members are jointed by means of an edge cross lap.

2. The length of the outer strap shall not be more than three widths of the flange of longitudinal framing member. A 20 mm overlap in adjacent layers shall be provided. The strap thickness shall be equal to that of the flange of transverse framing member.

2.5 DECKS AND DECK FRAMING

2.5.1 The upper deck laminate thickness shall be determined from Figs. 2.1.1-1 and 2.1.1-2 depending on the permissible bending moment value given in Table 2.5.1.

2.5.2 The minimum deck laminate thickness shall be 4 mm.

2.5.3 The thickness and width of a deck stringer shall be determined in accordance with Table 2.5.1.

2.5.4 The deck is permitted to be constructed of glass-reinforced plastics of the following types:

I — for hulls from 12(5) to 15 m in length;

VI — for hulls from 12(5) to 30 m in length;

VIII — for hulls from 12(10) to 30 m in length.

Decks of ships between (5) and (10) m in length may be constructed of glass-reinforced plastic of type II.

2.5.5 The reinforcing material shall be laid up in accordance with the requirements of 2.2.4 to 2.2.6.

2.5.6 Areas, which are subject to intense wear, shall be increased in thickness by means of straps not less than 3 mm thick, unless the deck in these areas has a special protective coating.

2.5.7 The scantlings of beams are taken in accordance with the requirements of 2.1.2, depending on the section modulus given in Table 2.5.7.

2.5.8 Deep beams having 5 times the bottom section modulus shall be fitted at every web frame.

T a b l e 2.5.1

Length of ship, mm	Spacing, mm	m_{perm}, N·m	Deck stringer width, mm
(5)	(350)	(0,8)	(300)
(7,5)	(350)	(1,3)	(400)
(10)	(350)	(2,0)	(475)
12	350	2,8	575
15	350/400	3,5/4,5	650
17,5	400	5,2	750
20	400	6,0	825
22,5	400	6,7	925
25	400/450	7,5/9,5	1000
27,5	450	10,3	1100
30	450	11,0	1200

N o t e s : 1 . Where the spacing differs from the Table value, m_{perm} shall be modified in proportion to the ratio of $\left(\frac{\text{actual spacing}}{\text{table spacing}}\right)^2$.

2. The deck stringer thickness is taken equal to the sheerstrake thickness (refer to Table 2.2.1).

3. For intermediate ship lengths m_{perm} shall be determined by linear interpolation.

Table 2.5.7

Span of beam, m	Section modulus, cm^3					
	Closed-box section, with spacing, mm			T-shaped section, with spacing, mm		
	350	400	450	350	400	450
1,0	16	18	20	—	—	—
1,2	24	27	30	—	—	—
1,4	33	38	43	—	—	—
1,6	43	49	55	15	17	19
1,8	52	59	66	18	20	22
2,0	65	74	83	23	25	27
2,2	80	90	100	26	30	34
2,4	98	110	124	32	37	42

Note. The design span of the beam is measured between the ends of the beam brackets, from the bracket end to the deck girder or between the deck girders, whichever is greater.

2.5.9 The scantlings of the deck girders are taken according to 2.1.2 depending on the section modulus given in Table 2.5.9.

Table 2.5.9

Span of deck girder, m	Section modulus, cm^3, at supported deck breadth, m				
	1,0	1,25	1,50	1,75	2,0
1,8	95	120	140	165	190
2,0	120	150	180	210	240
2,2	140	175	210	250	280
2,4	170	210	250	300	340
2,6	200	250	300	350	400
2,8	230	290	345	400	460

Notes: 1. The section moduli are given for a T-shaped section. Where closed-box section is used, the Table section modulus shall be increased by the factor of three.
2. Deck girder span is the greatest of the deck girder spans measured between two supports (centres of pillars, bulkheads, end hatch beams).

2.5.10 Intersection of deck framing members shall be made in accordance with Figs. 2.3.6-1, 2.3.6-2 and 2.4.6.

2.6 PILLARS

2.6.1 The present Rules provide for the fitting of tubular pillars manufactured of aluminium alloys.

Alternative materials may be used for construction of pillars on agreement with the Register.

In any case, the pillar material shall be in compliance with the requirements of Part XIII "Materials".

2.6.2 The scantlings of pillars of aluminium alloys shall be taken according to Table 2.6.2.

2.6.3 The pillars shall be connected to the framing by pillar heels made of aluminium alloys or steel and fastened to the framing by bolts.

2.7 BULKHEADS

2.7.1 The thickness of bulkhead laminates shall be determined from Figs. 2.1.1-1, 2.1.1-2 and 2.1.1-3 depending on the permissible bending moment values given in Table 2.7.1.

2.7.2 The minimum plate thickness of laminates for watertight bulkheads shall be 4 mm.

2.7.3 Bulkhead panels may be manufactured of glass-reinforced plastics type I_2, V_2 or VII_3.

2.7.4 The scantlings of bulkhead stiffeners are taken according to 2.1.2 depending on the section modulus given in Table 2.7.4.

2.7.5 The maximum span of the stiffeners shall not exceed 3 m. Where the bulkhead height exceeds 3 m, a horizontal girder with a section modulus of not less than 5 times the section modulus of the stiffener shall be fitted.

Table 2.6.2

Supported area $l \times b$, m^2	Height of pillar, m						
	1,8	2,0	2,2	2,4	2,6	2,8	3,0
1,8	85/70	85/70	85/70	85/70	85/70	85/70	95/80
2,5	85/70	85/70	85/70	85/70	95/80	95/80	105/90
3,0	85/70	95/80	95/80	95/80	95/80	105/90	105/90
4,0	85/70	95/80	95/80	105/90	105/90	110/90	110/90
5,0	95/80	95/80	105/90	105/90	110/90	110/90	120/90
6,0	95/80	105/90	105/90	105/90	110/90	120/90	120/90

Notes: 1. Shown in the nominator and denominator are the outside and inside tube diameters, in mm, respectively.
2. l is the distance between the centres of adjacent spans of a deck girder, in m; b is the breadth of deck supported by deck girder,

Table 2.7.1

Overall height of bulkhead, m	m_{perm}, N·m, with spacing, mm			
	300	350	400	450
1,25	0,9	—	—	—
1,50	1,1	1,5	—	—
1,75	1,3	1,8	2,3	—
2,00	1,5	2,0	2,7	3,4
2,25	1,7	2,3	3,0	3,8
2,50	1,9	2,6	3,3	4,2
2,75	2,1	2,8	3,7	4,6
3,00	2,2	3,1	4,0	5,1
3,25	2,4	3,3	4,3	5,5
3,50	2,6	3,6	4,7	5,9
3,75	2,8	3,8	5,0	6,3
4,00	3,0	4,1	5,3	6,8
4,25	3,2	4,3	5,7	7,2
4,50	—	4,6	6,0	7,6
4,75	—	—	6,3	8,0
5,00	—	—	—	8,4

Notes: 1. m_{perm} is given for the bottom strake of the bulkhead panels.
2. The bulkhead thickness may be reduced in height, the bulkhead thickness at the upper deck shall not be less than half the bottom strake thickness.
3. The width of each strake shall be 0,7...1,0 m.
4. For bulkheads of intermediate height m_{perm} is determined by linear interpolation.

2.7.6 Where a horizontal girder is provided, a stiffener of the same section modulus as the horizontal girder shall be fitted at the centre line.

2.7.7 The design of openings in the bulkheads shall comply with the requirements of 2.10.

2.7.8 The longitudinals shall not be cut at bulkheads. The slots in the bulkheads for the longitudinals shall be 3 to 4 mm higher and wider than the longitudinals proper and after the installation of bulkheads shall be filled with glass rovings and covered with not less than 3 layers of glass fabric.

2.7.9 The horizontal girders of bulkheads shall be fitted in one plane with side stringers and interconnected by means of brackets, which arm length shall be equal to the web depth of the side stringer.

2.7.10 The bulkhead stiffeners supported by longi-tudinal framing members shall be connected thereto by means of straps and mattings-in.

2.7.11 The bulkhead stiffeners receiving support from the bottom or deck shall be interconnected with the nearest transverse member by means of short longitudinals, which depth shall be equal to the stiffener depth. The connection of these short longitudinals to stiffeners shall be effected in accordance with 2.7.9.

2.8 TANKS

2.8.1 The thickness of the laminates for the tank boundary structures shall be determined from Figs. 2.1.1-1 to 2.1.1-3 depending on the value of permissible bending moment m_{perm} given in Table 2.7.1. In so doing, the distance up to the top of the air pipe shall be used in lieu of the full height of the bulkhead shown in Table 2.7.1 (refer also to 2.7.2).

2.8.2 The scantlings of tank framing members shall be determined in accordance with Table 2.8.2.

2.8.3 The thickness of the margin plate in way of the double bottom tanks shall be equal to the thickness of shell laminates in this area.

2.8.4 The sides and tops of tanks may be constructed of glass-reinforced plastics type I_2, II_2 or V_2.

2.8.5 Fuel tanks constructed of glass-reinforced plastics shall be provided with earthing arrangements for discharging static electricity approved by the Register.

2.8.6 The construction of tank manholes and covers shall ensure the watertightness of the tanks.

The recommended design of a manhole fitted in the crown of tank is shown in Fig. 2.8.6.

2.8.7 The framing members situated inside the tanks shall be provided with water courses and air holes.

Table 2.7.4

Span of stiffener, m	Section modulus of bulkhead stiffener, cm^3							
	Stiffener span from deck to bottom or horizontal girder, with spacing, mm				Stiffener span from horizontal girder to bottom, with spacing, mm			
	300	350	400	450	300	350	400	450
1,25	15	18	20	23	24	29	33	37
1,50	25	29	33	37	30	35	40	45
1,75	40	47	54	60	50	59	67	76
2,00	55	64	73	92	80	92	105	105
2,25	80	93	105	105	95	110	125	140
2,50	95	110	125	140	130	150	170	190
2,75	130	150	170	190	170	200	225	260
3,00	160	187	210	240	225	260	300	335

Notes: 1. The section moduli are given for stiffeners of T-shaped section.
2. For stiffeners of closed-box section with the face plate reinforced with glass mats the table section modulus shall be increased by the factor of three.

Table 2.8.2

Head of water, m	Section modulus of closed-box section, cm^3, with 400 mm spacing and span, m			
	0,50	0,75	1,00	1,25
2,00	10	25	50	70
2,50	15	30	60	85
3,00	20	40	70	100
3,50	25	45	80	120
4,00	30	50	90	140
4,50	35	55	100	160
5,00	40	65	110	175

Notes: 1. In this table scantlings for a closed-box section are given. Material used is glass-reinforced plastic on the basis of glass mats (type I_2). Where T-shaped section with a flange of glass-reinforced plastic, type III_3, is used, the section modulus may be reduced by the factor of three.

2. The section moduli in the Table are given for a 400 mm spacing. For other spacings the section modulus value shall be modified in proportion to the ratio of $\frac{\text{spacing, mm}}{400}$.

3. The design head of water is measured from the midlength of stiffener or from the crown to the air pipe top.

4. The span of stiffener is measured from the bottom to the crown. The span of beams is measured between the sides or between the side and the collision bulkhead.

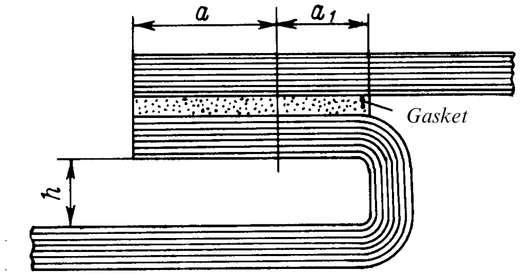


Fig. 2.8.6:
a — minimum distance from the edge to bolts;
$a \geqslant 3d$ (*d* is a diameter of bolt);
h — depth of suit bolt or nut fitting;
$a_1 \geqslant 1{,}5d$. Bolts shall be spaced not more than 4*d* apart

2.9 SUPERSTRUCTURES AND DECKHOUSES

2.9.1 The superstructure outer shell, which is the continuation of the ship's side plating, shall be integral with this plating. The laminate thickness of the superstructure shall be equal to that of the hull sides. The thickness reduction from the sheerstrake to the superstructure sides shall be in accordance with Table 2.2.1.

2.9.2 The sides of superstructures not extending to the hull sides and deckhouses may be of single-skin or sandwich construction. The material to be used for superstructure and deckhouse sides is glass-reinforced plastic on the basis of glass mats or woven rovings (type I_2 or II_2). The framing members shall be of glass-reinforced plastic, type I_2.

2.9.3 The double-skin construction of superstructures and deckhouse is subject to special consideration by the Register.

2.9.4 In sandwich constructions the thickness of the foam plastic core shall be 30 to 50 mm. The average density of the foam plastic core for superstructure sides shall not be less than 100 and more than 200 kg/m^3.

2.9.5 The laminate thicknesses for the end bulkheads of superstructures as well as for all outer ends and sides of deckhouses shall be taken according to Table 2.9.5-1 for single-skin construction and Table 2.9.5-2 for sandwich construction.

Table 2.9.5-1

Ends and sides of superstructures and deckhouses of single-skin construction, spacing 400 mm

Length of ship, m	Plate thickness, mm
(5)	(4)
(10)	(6)
15	8
20	10
25	10
30	10

Notes: 1. For other spacings the thickness shall be modified in proportion to the ratio of spacing, mm/400, but it shall not be less than 4 mm.

2. Material used is glass-reinforced plastic on the basis of glass mat (type I_2).

3. For intermediate ship lengths the thickness shall be determined by linear interpolation.

Table 2.9.5-2

Ends and sides of superstructures and deckhouses of sandwich construction with core thickness 30 to 50 mm, spacing 800 mm

Length of ship, m	Laminate thickness, mm	
	outer	inner
(5)	(3)	(2,5)
(10)	(4)	(3)
15	7	3,5
20	8	4
25	8	4
30	8	4

Note. For other spacings the outer laminate thickness shall be modified in proportion to the ratio of spacing, mm/800 but it shall not be less than 3 mm.

2.9.6 The scantlings of stiffeners of the superstructure and deckhouse ends and sides are determined from Table 2.9.6-1 for single-skin construction and Table 2.9.6-2 for sandwich construction.

2.9.7 The deck laminate thickness and the scantlings of the deck framing of superstructures and deckhouses are taken in accordance with the requirements of 2.5 and 2.6.

Table 2.9.6-1

Stiffeners in superstructures and deckhouses of single-skin construction, spacing 400 mm

Span of stiffener, mm	Modulus of closed-box section, cm^3	Span of stiffener, mm	Modulus of closed-box section, cm^3
1,0	18	1,8	53
1,2	25	2,0	74
1,4	38	2,2	90
1,6	49	2,4	105

Notes: 1. For other spacings the section modulus shall be modified in proportion to the ratio of $\frac{\text{spacing, mm}}{400}$.
2. For intermediate values of stiffener spans the section modulus shall be determined by linear interpolation.

Table 2.9.6-2

Stiffeners in superstructures and deckhouses of sandwich construction, spacing 800 mm

Span of stiffener, m	Section modulus of closed-box section, cm^3	Span of stiffener, m	Section modulus of closed-box section, cm^3
1,0	37	1,8	120
1,2	52	2,0	150
1,4	75	2,2	194
1,6	98	2,4	215

Notes: 1. For other spacings the section modulus shall be modified in proportion to the ratio of $\frac{\text{spacing, mm}}{800}$.
2. The spacing for superstructure sides shall be brought in compliance with the beam spacing of the superstructure deck.
3. For intermediate values of stiffener spans the section modulus is determined by linear interpolation.

2.10 OPENINGS IN STRUCTURES

2.10.1 Round openings cut in the shell, deck and watertight bulkheads with a diameter less than 150 mm are permitted not to be reinforced.

2.10.2 Round openings cut in the shell with a diameter of 150 mm and over shall be reinforced with glass fabric of satin weave or woven rovings in accordance with Fig. 2.10.2.

The reinforcements of openings having other shapes are subject to special consideration by the Register.

2.10.3 Round openings cut in decks with a diameter of 150 mm and over as well as rectangular openings of any diameter shall be reinforced with glass fabric of satin weave or woven rovings.

The recommended reinforcement of openings is shown in Figs. 2.10.3-1 and 2.10.3-2.

2.10.4 Lightening holes are not permitted to be made in the webs of framing members.

2.10.5 Openings cut in the framing member webs for the passage of cables, pipes, etc. and having diameters more than 1/3 of the web depth shall be strengthened with straps.

2.10.6 Dimensions of openings and the structure of closures in the outer shell and watertight bulkheads of ships, which subdivision is regulated by Part V "Subdivision", shall be specially agreed with the Register.

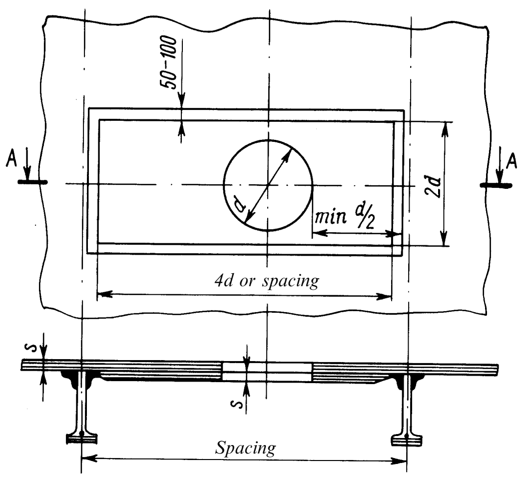


Fig. 2.10.2

Notes: 1. Reinforcing shall be made only with glass fabric whose warp is oriented along the hull.
2. The thickness of the strap shall be equal to that of the structure. If the position of the openings is specified beforehand, the strap is moulded into the basic layers of the laminate, otherwise it shall be matted onto the inner face of the laminate between the frames, within one spacing as shown in the Figure.
3. Openings are not permitted to be positioned closer than $d/2$ to the frame.

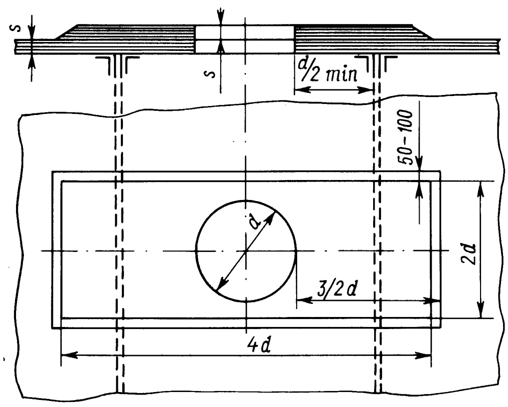


Fig. 2.10.3-1

Notes: 1. Reinforcing shall be made only with glass fabric, which warp is oriented along the hull.
2. The thickness of the strap shall be equal to that of the structure. The strap is matted into the basic layers of the laminate of the position of the openings is known beforehand or moulded onto the upper surface of the deck.

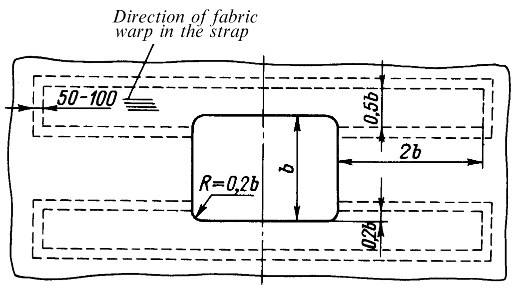


Fig. 2.10.3-2

Notes: 1. Reinforcing shall be made only with glass fabric.
2. The fabric layers forming the strap shall be laid between the reinforcement layers of the deck laminate.
3. The total thickness of the reinforcing fabric layers shall be equal to the deck laminate thickness.

2.11 BULWARK

2.11.1 The bulwark thickness shall be equal to half the thickness of the side laminate but not less than 4 mm.

2.11.2 The bulwark stays shall be fitted at alternate beams.

2.11.3 In ships over 15 m in length the bulwark laminate shall not form an integral part of the side laminate, and its sectional area shall not be taken into account when the hull section modulus is determined.

2.11.4 The structure of bulwarks in ships, which can moor at sea, shall be specially considered by the Register.

2.12 ENGINE SEATINGS

2.12.1 Side girders shall be used as far as possible as bearers of the main engine seatings. Where this is not feasible, additional bottom longitudinals shall be fitted with the web thickness equal to that of the side girder.

2.12.2 The engine seating girders shall extend forward and aft beyond the machinery space bulkheads for at least three spacings and be tapered at the end of the third spacing to floor depth.

2.12.3 The seating girders shall be reliably connected with transverse brackets fitted at every frame.

2.12.4 Seatings are permitted to be built of steel and aluminium alloys on special agreement with the Register.

2.12.5 The fastening of the engine bed flanges may be made by metal flats moulded into the flanges of the girders by fitting of metal angle sections bolted to the girder top edge or by other means approved by the Register.

2.13 STEMS, STERNFRAMES, PROPELLER SHAFT BRACKETS AND BILGE KEELS

2.13.1 Stems may be moulded of glass-reinforced plastic or may be of composite structure with the use of metal.

2.13.2 For the reinforcing of the stem laminate glass fabrics, woven rovings and glass-fibre bundless (rovings) are used.

The use of glass mats is not permitted.

2.13.3 Metal parts of the stem may be of aluminium alloys or of steel reliably protected by corrosion-resistant coating.

As a rule, they shall be moulded into the stem.

2.13.4 The stem moulded of glass-reinforced plastic shall be shaped as a rectangle with the width b and length l calculated by the formulae, in mm:

$$b = 1{,}5L + 30; \qquad (2.13.4)$$

$$l = 2{,}5b$$

where L = ship's length, m.

The thickness of the stem laminate reinforced with glass fabrics (types II, III or IV) shall be 1,5 times the sheerstrake thickness. The space inside the stem shall be filled with plastic reinforced with glass-fibre bundles, which shall be directed along the stem.

2.13.5 In the case of composite stems the width b_1 of the aluminium alloy core, length l_1 and total width b_2 of the stem are calculated by the formulae, in mm:

$$b_1 = 0{,}4L + 10;$$

$$b_2 = b_1 + 2s; \qquad (2.13.5)$$

$$l_1 = 2{,}5b_2$$

where L = ship's length, m;
s = stem laminate thickness determined as specified in 2.13.4.

2.13.6 The steel core width may be equal to 3/4 of the aluminium core width (refer to 2.13.5). The core length is calculated in accordance with 2.13.5.

2.13.7 The sternframe, if fitted, may be metal or composite (glass-reinforced plastic with metal core).

The scantlings and structure of the sternframe are subject to special consideration by the Register.

2.13.8 The shaft brackets shall be as required in 2.10.4.5, Part II "Hull". The flanges of the brackets shall be attached to the hull by means of bolting. Straps of glass-reinforced plastic having a thickness equal to twice the shell thickness and fitted on the reverse side in way of bracket attachment as well as stiffening for framing members, which shall be agreed with the Register, shall be provided in this area.

2.13.9 Bilge keels, if fitted, shall be of glass-reinforced plastic of type II. The attachment of bilge keels to the hull shall be effected by means of matting-in double angles (without using bolts), which shall be fitted on both sides of the keel laminate. The thickness of the matting-in double angles shall be equal to that of the keel laminate. The structural design of bilge keels shall be such that no damage would be caused to the shell in case of bilge keel loss.

2.14 CASINGS OF ENGINE AND BOILER ROOMS, HATCH AND FAN COAMINGS

2.14.1 The structure and scantlings of engine and boiler room casings, hatch and fan coamings are subject to special consideration by the Register.

3 STRENGTHENING IN SHIPS FOR NAVIGATION IN ICE

3.1 GENERAL

3.1.1 Ships with glass-reinforced plastic hull over 12 m in length and ice strengthening in accordance with the requirements stated below obtain the mark **Ice2** in their class notation.

The definitions of ice category marks are given in 2.2.3, Part I "Classification".

3.2 ICE STRENGTHENING IN SHIPS OF CATEGORY ICE2

3.2.1 An ice belt shall be provided on the shells, the upper edge of which shall be extended 0,5 m above the winter load waterline, while the lower edge shall be 0,5 m below the waterline in the ballast condition.

The ice belt shall extend from the stem to the transom or sternframe over the entire length of the ship.

3.2.2 The ice belt in ships from 12 to 30 m in length is formed as a strap,which is moulded of glass-reinforced plastics of types III_1, IV_1 and II_1 matted layer by layer onto the finished hull.

3.2.3 Prior to laying up the strap the shell surface in the area shall be thoroughly cleaned.

3.2.4 The thickness of the ice belt strap shall not be less than 1/3 of the shell thickness in the area. The thickness of the strap shall be tapered over a width of 100 mm upwards from the lower edge and 100 mm downwards from the upper edge of the ice belt.

3.2.5 The scheme of the strap reinforcement in way of the stem shall preclude the tear-off of the fore edge of the ice belt. To this end, a strap of glass-reinforced plastic of type II, III or IV as thick as the sheerstrake shall be fitted along the stem in way of the ice belt. The strap shall overlap the ice belt for one spacing. The strap thickness shall be tapered in the aft direction beginning from the spacing middle.

3.2.6 The use of synthetic materials for the ice belt is permitted on special agreement with the Register.

3.2.7 For ships under 12 m in length, the scantlings of the ice belt may be reduced on agreement with the Register.

3.2.8 For ships of 15 m and over in length a side stringer is required to be fitted at the level of the winter load waterline.

3.2.9 For ships of 15 m and over in length the spacing shall be reduced by 50 mm as compared to that given in 1.6. The section modulus of frames is then adopted in accordance with 2.4 without regard to the spacing reduction.

4 LIFEBOAT HULL

4.1 GENERAL

4.1.1 The determination of scantlings and selection of the required type of glass-reinforced plastic shall be made in accordance with Section 2 unless special requirements are given in the present Section.

4.1.2 The scantlings are permitted to be determined by calculation in accordance with Appendix 3.

4.2 SHELL

4.2.1 For hulls of lifeboats the following types of glass-reinforced plastics are permitted to be used:

for hulls up to 8 m in length — plastics based on glass mats or woven rovings of parallel lay-up with one or two layers of glass mat or woven rovings on the faces to preclude the passage of water into the laminate and impart necessary smoothness to the laminate surface (types I and II). The mass of 1 m^2 of glass mat and of woven roving fabric shall not exceed 0,8 kg and 0,7 kg, respectively;

for hulls over 8 m in length — plastics based on glass mats (type I) or woven rovings of parallel and diagonal lay-up with one or two protective layers of glass mats (type VII) on the faces or a combination of woven rovings of parallel lay-up (50 per cent of the laminate thickness) and glass mats (50 per cent of the laminate thickness) of type V. In any case, at least one layer of glass mats or glass fabric shall be laid on the laminate faces.

4.2.2 Seams and butts of strips of reinforcing material in members with parallel and diagonal reinforcement shall be formed as butts without overlap for any thickness exceeding 6 mm; for thicknesses between 2 and 6 mm, the overlap shall be at least 50 mm.

The butts and seams in each adjacent layer shall be spaced not closer than 100 mm apart. Butts and seams are permitted to be coincident in one section after 6 layers at least.

4.2.3 The minimum thickness of shell laminate in the case of single-skin construction shall be 4 mm, the outer and inner skins in the case of sandwich construction shall be 3 mm and 2 mm, respectively.

4.2.4 The thickness of shell laminate in the case of single-skin construction shall be determined from Figs. 2.1.1-1, 2.1.1-2 and 2.1.1-3 depending on the value of m_{perm} given in Table 4.2.4 and according to the plastic type chosen and the glass content by mass.

Table 4.2.4

Shell laminate (single-skin construction)

Length of lifeboat, m	Spacing, mm	m_{perm}, N·m	
		Bottom	Side
4,5	300	1,2	0,8
6,5	350	1,8	1,3
8,0	400	2,3	1,7
10,0	450	2,8	2,1
12,0	450	3,2	1,4

Notes: 1. For intermediate hull lengths m_{perm} is determined by linear interpolation.
2. For conversion to the spacing other than given in this Table, refer to Table 2.2.1.
3. The thickness adopted for the bottom shell shall be maintained from the keel to a level not less than 1/3 of the side

4.2.5 The laminate thickness of air cases of glass-reinforced plastic of type I or II shall be from 2 mm (for a length of 4,5 m) to 4 mm (for a length of 12 m).

For air cases serving at the same time as seats the laminate thickness shall be increased by 3 mm.

4.2.6 For double-skin and sandwich constructions, the laminate thickness of the outer skin shall be 75 per cent and the thickness of the inner skin — 50 per cent of the thickness of the single-skin construction, respectively (refer to Table 4.2.4).

4.2.7 Special care shall be given to the quality of the lifeboat shell coating with decorative polyester binder.

4.2.8 Any necessary increase in the hull laminate thickness shall be formed by additional reinforcing material layers, which shall be uniformly distributed between the basic layers and be alternate with same.

4.2.9 Connection of the hull halves along C.L. is permitted only in well-founded cases.

4.2.10 Connection of the lifeboat side to the deck or gunwale shall be effected by means of bolts or matting-in angles of glass-reinforced plastics of type III or IV, the thickness of each matting-in angle being not less than 0,7 times the side thickness, and the flange width being 80 mm + $5s_s$, where s_s is the thickness of the side shell laminate, in mm.

4.3 FRAMING

4.3.1 The section moduli of frames in a lifeboat of single-skin shell construction shall not be less than stated in Table 4.3.1.

Table 4.3.1

Length of lifeboat, m	Spacing,mm	Section modulus, cm^3
4,5	300	28
6,5	350	42
8,0	400	56
10,0	450	70
12,0	450	77

Notes: 1. The section moduli are given for closed box section frames moulded of glass-reinforced plastic, type I_2. For tee-shaped frames with flanges of glass-reinforced plastic of type II_3 and webs of glass-reinforced plastic of type I_2 the section moduli may be reduced by the factor of three.
2. Where the spacing differs from the Table value, the section modulus shall be modified in proportion to the ratio of the actual spacing to the Table spacing.

4.3.2 In the case of double-skin construction, the section modulus of the frame enclosed between the outer and inner skin in conjunction with the skin strips as wide as the spacing shall not be less than that given in Table 4.3.1.

4.3.3 In the case of sandwich construction the necessity of fitting transverse framing and the scantlings of same are subject to special consideration by the Register.

4.3.4 The scantlings of the keel girder shall be chosen in accordance with Fig. 4.3.4.

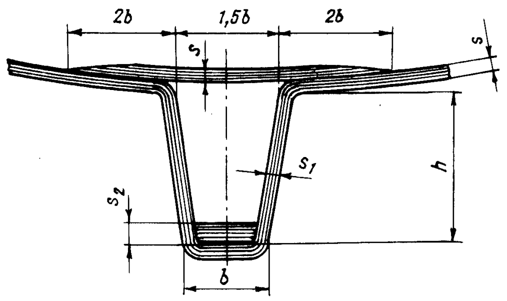
4.3.5 The recommended design of the keel is shown in Fig. 4.3.5.

4.3.6 In lifeboats between 8 and 12 m in length keelsons shall be fitted (one on each side). The section moduli of the keelsons shall be found in Table 4.3.6.

4.4 ATTACHMENT OF LIFTING GEAR AND EQUIPMENT

4.4.1 The attachment of lifting gear to the lifeboat hull shall ensure the transfer of forces to the hull during the lowering of the lifeboat sustaining possible impact overloads due to a sudden braking of the winch, ship's motion and seaways at ship's sides under any possible conditions of ambient temperature.

4.4.2 The strength of attachment of each lifting hook to the lifeboat hull shall be checked by a static load equal for each lifting hook to 0,75 times the mass of the lifeboat when loaded with full comple-



Length of lifeboat, m	Scantlings of section, mm				
	depth h	width b	s	s_1	s_2
4,5	70/90	60/80	4,5/5,0	9,0/10,0	15,0/20,0
6,5	110/140	80/100	5,5/7,0	10,0/12,0	20,0/25,0
8,0	135/180	100/120	6,0/8,0	12,0/14,0	24,0/30,0
10,0	190/240	120/140	7,0/9,0	14,0/16,0	30,0/35,0
12,0	220/260	130/150	8,0/9,0	16,0/18,0	35,0/40,0

Notes: 1. Given in the numerator are the scantlings for glass-reinforced plastics, types II, V and VII, in the denominator — those for type I.
2. The density of laying up the reinforcing glass fabric (percentage content of glass by mass) is in compliance with the second lines of Tables 1 to 6, Appendix 2.
3. Thickness s_2 is obtained by addition of rovings to be laid inside the keel.

Fig. 4.3.4

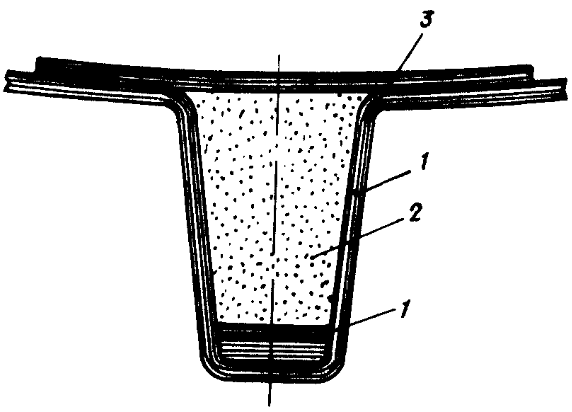


Fig. 4.3.5:

1 — glass-reinforced plastic;
2 — foam plastic;
3 — glass-reinforced plastic laid up inside the keel

Table 4.3.6

Length of lifeboat, m	Section modulus, cm^3
4,5	—
6,5	—
8,0	150
10,0	400
12,0	600

Notes: 1. The section moduli of keelsons are given for tee-shaped sections with the face plate of glass-reinforced plastic, type III_3 and the web of type I_2.
2. For closed-box sections of glass-reinforced plastic, type I_2, the section modulus shall be increased by the factor of three.
3. Keelson shall be fitted at 0,35 to 0,45 of the lifeboat half-breadth ($B/2$) from the C.L.
4. Where the lifeboat arrangement requires fitting of two keelsons on each side, the section modulus of each keelson shall not be less than 0,75 of the value given in this Table.

ment of persons and equipment, which shall be applied for at least 5 min.

4.4.3 The structure of the mounts for lifting gear parts shall preclude the creep effect of glass-reinforced plastics.

The operation of lifting gear parts for separation from the lifeboat hull is not permitted.

The recommended design of the mounts is shown in Fig. 4.4.3.

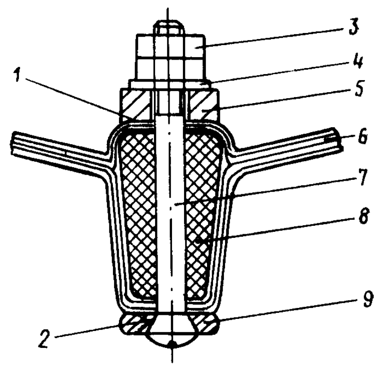


Fig. 4.4.3
1, *2* — tarpaulin gaskets; *3* — nut; *4* — washer; *5* — lifting lug; *6* — deck laminate; *7* — bolt; *8* — insert; *9* — base plate

4.4.4 The recommended design of the mounts for engine seatings, platforms and pipes is shown in Figs. 4.4.4-1, 4.4.4-2 and 4.4.4-3.

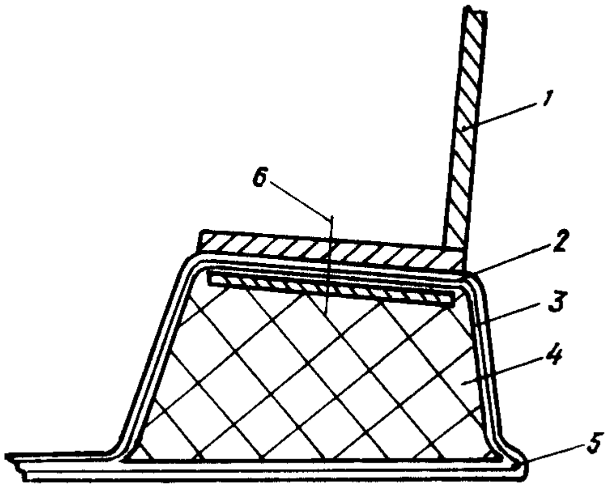


Fig. 4.4.4-1
1 — engine bearer; *2* — steel plate;
3 — girder moulded integral with the inner shell skin;
4 — core (PVC-1); *5* — inner shell skin;
6 — screw

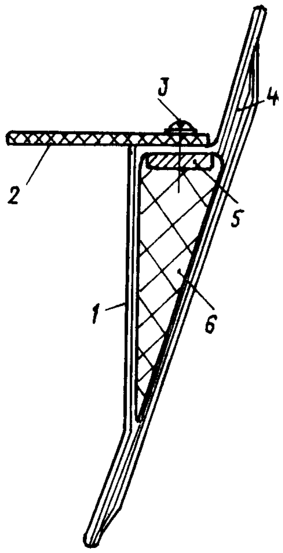


Fig. 4.4.4-2
1 — step moulded integral with the inner shell skin;
2 — platform (thwart); *3* — screw;
4 — inner shell skin; *5* — steel plate; *6* — core (PVC-1)

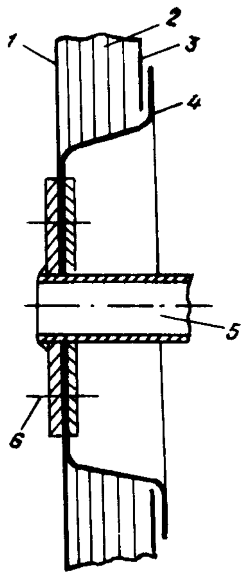


Fig. 4.4.4-3
1 — outer shell skin; 2 — core; *3* — inner shell skin;
4 — glass-reinforced plastic lined hole in the inner shell skin and core;
5 — pipeline; *6* — bolt

APPENDIX 1

RECOMMENDED TYPES OF GLASS-REINFORCED PLASTICS

1. The following eight types of glass-reinforced plastics are recommended for use in hull structures of ships and lifeboats:

.1 *type I:* plastic reinforced with glass mats, which may be coated on the outer face or on both faces with one or two layers of glass net or glass fabric to impart better surface smoothness to it (designation *X*);

.2 *type II:* plastic reinforced with woven rovings of plain weave and parallel orientation, i.e. all layers are laid with their warp in one direction (designation *P*);

.3 *type III:* plastic reinforced with glass fabric of satin weave with parallel orientation (designation *T*);

.4 *type IV:* plastic reinforced with glass fabric or glass net of plain weave with parallel orientation (designation *T* or *C*);

.5 *type V:* plastic reinforced both with glass mats and woven rovings of parallel orientation, each amounting to 50 per cent in thickness, the layers of mats and woven rovings being alternately laid through the entire thickness of the laminate;

.6 *type VI:* plastic with the same reinforcement thickness ratio as for type V, but with mats concentrated in the middle and woven rovings laid on the outer and inner faces and amounting to 1/4 of the thickness on each side;

.7 *type VII:* plastic with parallel and diagonal reinforcement of woven rovings at angles + 45° and −45°, which layers, laid parallel to the warp, shall amount to half the laminate thickness, while the diagonal parts plied at + 45° and −45° to the layers of parallel orientation shall amount to 1/4 of the laminate thickness each, the layers of parallel reinforcement being alternately laid throughout the entire thickness;

.8 *type VIII:* layers arranged diagonally shall occupy the middle portion of the laminate thickness while those of parallel reinforcement shall form the outer and inner faces of the laminate (packet arrangement).

Glass-reinforced plastics, types II, V, VI, VII and VIII shall be overlaid on both faces with one or two layers of glass fabric or glass net.

2. The schemes of reinforcement for the above plastics types are shown in Fig. 1.

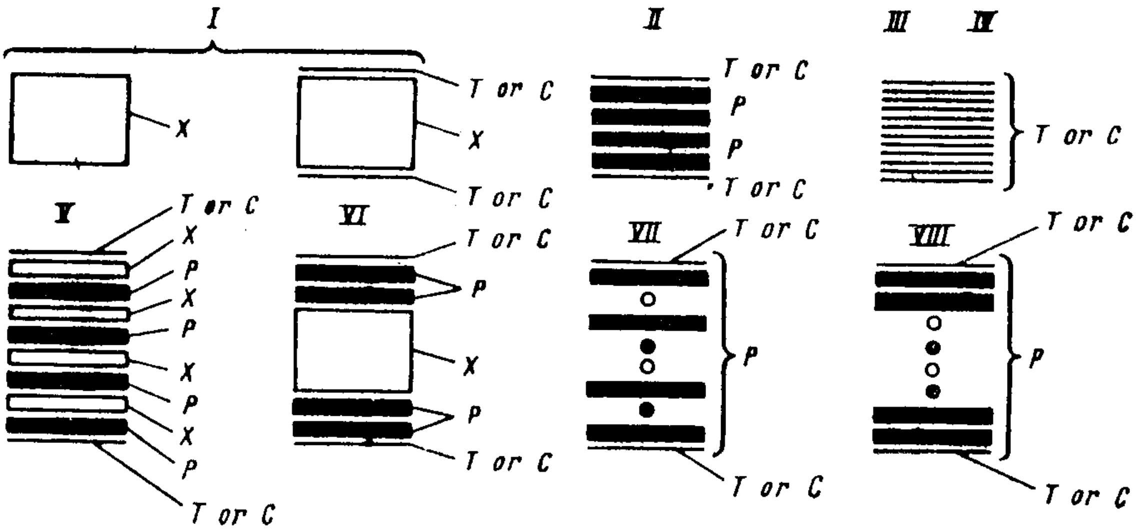


Fig. 1
Schemes of reinforcement. Reinforcing material:
X — glass mat, *P* — woven rovings (plain weave), parallel orientation of layers: woven rovings, plied at + 45° or −45°; *T* or *C* — glass fabric or glass net, parallel orientation of layers. Types of glass-reinforced plastics (shown in per cent is the fraction of thickness composed by layers of the given reinforcement): type I — *X* 100%; type II — *P* 100%; types III and IV — *T* 100% (or *C* 100%); types V and VI — *X* 50%, *P* 50%; types VII and VIII — 0° *P* 50%, + 45° *P* 25%, −45° *P* 25%

APPENDIX 2

PHYSICAL AND MECHANICAL PROPERTIES OF GLASS-REINFORCED PLASTICS

Physical and mechanical properties of glass-reinforced plastics depending on the reinforcement schemes included in Appendix 1 shall be in accordance with the values stated in Tables 1 to 6.

For each type of plastic depending on the fibre glass content in per cent by mass the tables contain respective values of physical and mechanical properties.

The values of physical and mechanical properties such as glass content by volume, average density, shear modulus, Poisson's ratio and shear strength in the laminate plane are determined only during approval tests of a particular type of plastic.

Table 1

Physical and mechanical properties of glass-reinforced plastics with glass mass as reinforcement and a polyester binder (type I). Tested in dry condition at 20 °C

Nos	Type	Glass content, per cent		Average density, kg/m^3	Young's modulus, MPa	Shear modulus in laminate plane, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate plane, MPa
		by mass	by volume							
1	I_1	25	15	1,45	$0{,}60 \cdot 10^4$	$0{,}22 \cdot 10^4$	0,35	80,0	110,0	40,0
2	I_2	30	18	1,50	$0{,}70 \cdot 10^4$	$0{,}26 \cdot 10^4$	0,35	90,0	120,0	50,0

N o t e s : 1. Glass content by volume and average density of plastics are given for the average density of glass 2550 – 2600 kg/m^3 and average density of binder as cured 1200 – 1250 kg/m^3.
2. Young's modulus is given for tension-and-compression.
3. For thicknesses of 4 mm and less the tensile strength is reduced by 20 per cent against the Table value.

Table 2

Physical and mechanical properties of glass-reinforced plastics with woven rovings of parallel orientation and a polyester binder (type II). Tested in dry condition at 20 °C

Nos	Type	Glass content, per cent		Average density, kg/m^3	Young's modulus, MPa	Shear modulus in laminate plane, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate plane, MPa
		by mass	by volume							
1	II_1	45	28	1600	$\frac{1{,}30 \cdot 10^4}{1{,}30 \cdot 10^4}$	$0{,}21 \cdot 10^4$	$\frac{0{,}12}{0{,}12}$	$\frac{170{,}0}{170{,}0}$	$\frac{105{,}0}{105{,}0}$	60,0
2	II_2	50	32	1640	$\frac{1{,}50 \cdot 10^4}{1{,}50 \cdot 10^4}$	$0{,}25 \cdot 10^4$	$\frac{012}{0{,}12}$	$\frac{200{,}0}{200{,}0}$	$\frac{110{,}0}{110{,}0}$	70,0
3	II_3	55	37	1700	$\frac{1{,}70 \cdot 10^4}{1{,}70 \cdot 10^4}$	$0{,}29 \cdot 10^4$	$\frac{0{,}12}{0{,}12}$	$\frac{230{,}0}{230{,}0}$	$\frac{115{,}0}{115{,}0}$	80,0

N o t e s : 1. Glass content by volume and average density of plastics are given for the average density of glass 2550 – 2600 kg/m^3 and average density of binder as cured 1200 – 1250 kg/m^3.
2. Young's modulus is given for tension-and-compression.
3. Shown in the numerator are the values for the warp direction, in the denominator — for the weft direction.
4. For woven rovings the ratio of breaking strength in the warp and weft direction is 1:1.

Table 3

Physical and mechanical properties of glass-reinforced plastics with glass fabric of satin weave and parallel orientation, and a polyester binder (type III). Tested in dry condition at 20 °C

Nos	Type	Glass content, per cent		Average density, kg/m^3	Young's modulus, MPa	Shear modulus in laminate plane, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate plane, MPa
		by mass	by volume							
1	III_1	45	28	1600	$\frac{1,7 \cdot 10^4}{1,1 \cdot 10^4}$	$0,28 \cdot 10^4$	$\frac{0,15}{0,10}$	$\frac{270,0}{170,0}$	$\frac{200,0}{150,0}$	80,0
2	III_2	49	31	1640	$\frac{1,8 \cdot 10^4}{1,2 \cdot 10^4}$	$0,10 \cdot 10^4$	$\frac{0,15}{0,10}$	$\frac{290,0}{180,0}$	$\frac{210,0}{160,0}$	85,0
3	III_3	52	34	1670	$\frac{1,9 \cdot 10^4}{1,3 \cdot 10^4}$	$0,32 \cdot 10^4$	$\frac{0,15}{0,10}$	$\frac{300,0}{190,0}$	$\frac{220,0}{170,0}$	90,0

Notes: 1. Glass content by volume and average density of plastics are given for the average density of glass 2550 – 2600 kg/m^3 and average density of binder as cured 1200 – 1250 kg/m^3.
2. Young's modulus is given for tension-and-compression.
3. Shown in the numerator are the values for the warp direction, in the denominator — for the weft direction.
4. For the glass fabric the ratio of the breaking strength in the warp and weft direction is 2:1.

Table 4

Physical and mechanical properties of glass-reinforced plastics with glass net or glass fabric of plain weave and parallel orientation, and a polyester binder (type IV). Tested in dry condition at 20 °C

Nos	Type	Glass content, per cent		Average density, kg/m^3	Young's modulus, MPa	Shear modulus in laminate plane, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate plane, MPa
		by mass	by volume							
1	IV_1	45	28	1600	$\frac{1,3 \cdot 10^4}{1,3 \cdot 10^4}$	$0,28 \cdot 10^4$	$\frac{0,13}{0,13}$	$\frac{220,0}{220,0}$	$\frac{160,0}{160,0}$	80,0
2	IV_2	49	31	1640	$\frac{1,4 \cdot 10^4}{1,4 \cdot 10^4}$	$0,30 \cdot 10^4$	$\frac{0,13}{0,13}$	$\frac{230,0}{230,0}$	$\frac{170,0}{170,0}$	85,0
3	IV_3	52	34	1670	$\frac{1,5 \cdot 10^4}{1,5 \cdot 10^4}$	$0,32 \cdot 10^4$	$\frac{0,13}{0,13}$	$\frac{240,0}{240,0}$	$\frac{180,0}{180,0}$	90,0

Notes: 1. Glass content by volume and average density of plastics are given for the average density of glass 2550 – 2600 kg/m^3 and average density of binder as cured 1200 – 1250 kg/m^3.
2. Young's modulus is given for tension-and-compression.
3. Shown in the numerator are the values for the warp direction, in the denominator — for the weft direction.
4. For the glass fabric the ratio of the breaking strength in the warp and weft direction is 1:1.

Table 5

Physical and mechanical properties of glass-reinforced plastics with composite reinforcement of 1/2 of the thickness by glass mats and 1/2 of thickness by woven rovings of parallel orientation on the basis of polyester binder (type V and VI). Tested in dry condition at 20 °C

Nos	Type	Glass content, per cent			Average density, kg/m³	Young's modulus, MPa	Shear modulus in laminate plane, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate plane, MPa
		Glass mats	Woven rovings	Glass							
1	V_1 VI_1	25	50	37,5	1550	$\frac{1,05 \cdot 10^4}{1,05 \cdot 10^4}$	$0,24 \cdot 10^4$	$\frac{0,21}{0,21}$	$\frac{135,0}{135,0}$	$\frac{77,0}{77,0}$	55,0
2	V_2 VI_2	30	55	42,5	1600	$\frac{1,2 \cdot 10^4}{1,2 \cdot 10^4}$	$0,28 \cdot 10^4$	$\frac{0,21}{0,21}$	$\frac{160,0}{160,0}$	$\frac{80,0}{80,0}$	65,0

Notes: 1. Average density of plastics is given for the average density of glass 2550—2600 kg/m³.
2. Young's modulus is given for tension-and-compression.
3. Shown in the numerator are the values for the warp direction, in the denominator — for the weft direction.

Table 6

Physical and mechanical properties of glass-reinforced plastics with parallel-and-diagonal reinforcement by woven rovings, one half of which is of parallel orientation and the remainder of diagonal orientation, i.e. 1/4 at +45° and 1/4 at −45° and a polyester binder (types VII and VIII). Tested in dry condition at 20 °C

Nos	Type	Glass content by mass, per cent	Average density, kg/m³	Young's modulus, MPa	Shear modulus in laminate plane, MPa	Poisson's ratio	Tensile strength, MPa	Compression strength, MPa	Shear strength in laminate plane, MPa
1	VII_1 $VIII_1$	45	1600	$\frac{1,1 \cdot 10^4}{1,1 \cdot 10^4}$	$0,37 \cdot 10^4$	$\frac{0,30}{0,30}$	$\frac{140,0}{140,0}$	$\frac{80,0}{80,0}$	56,0
2	VII_2 $VIII_2$	50	1650	$\frac{1,3 \cdot 10^4}{1,3 \cdot 10^4}$	$0,45 \cdot 10^4$	$\frac{0,30}{0,30}$	$\frac{170,0}{170,0}$	$\frac{95,0}{95,0}$	68,0
3	VII_3 $VIII_3$	55	1700	$\frac{1,5 \cdot 10^4}{1,5 \cdot 10^4}$	$0,52 \cdot 10^4$	$\frac{0,30}{0,30}$	$\frac{200,0}{200,0}$	$\frac{110,0}{110,0}$	79,0

Notes: 1. Average density of plastics is given for the average density of glass 2550—2600 kg/m³ and the average density of binder as cured 1200—1250 kg/m³.
2. Young's modulus is given for tension-and-compression.
3. Shown in the numerator are the values for the warp direction, in the denominator — for the weft direction.
4. For the glass fabric the ratio of the breaking strength in the warp and weft direction is 1:1.

APPENDIX 3

GUIDANCE FOR DETERMINATION OF HULL MEMBER SCANTLINGS OF SHIPS AND LIFEBOATS BY CALCULATION

1 SHIP'S HULL

1.1 In addition to the table method of the hull scantlings determination as given in this Part of the Rules, this may be done by a calculation method approved by the Register.

1.2 The basic data for recalculation of separate hull members as well as calculation of the longitudinal and local strength of the hull as a whole are given in Tables 1, 2 and 3.

Table 1

Ship's length, m	Maximum bending moment at general bending, kN·m
5 — 10	$1{,}66\Delta L$
15 — 30	ΔL (ΔL — is the full load displacement of the ship, m^3)

[1] For ships from 10 to 15 m in length the bending moment is determined by linear interpolation.

Table 2

Type of load	Design formula or value
Local load on bottom and side shell	$h_p = 10(h_1 + \Delta)$ kPa
Local load on the upper deck:	
forward of the fore peak bulkhead	15 kPa
elsewhere	5 kPa
Ditto for ships of restricted area of navigation III:	
forward of the fore peak bulkhead	10 kPa
elsewhere	4 kPa
Water impact against the bottom, when dropped in an emergency:	
$L = 5$ m	20 kPa
$L = 10$ m	40 kPa

Notes: 1. h_1 is the distance from the member under consideration to the upper deck: $\Delta = 0{,}5$ m for any region, with the exception of the shell in way of the fore peak; $\Delta = 1{,}5$ m for the region forward of the fore peak bulkhead.
2. For ships of intermediate length the load is determined by linear interpolation.

1.3 The permissible stress is taken as a part of design tensile, compression or shear strength. For permissible stress in the case of alternating tension-and-compression and bending, either tensile or compressive stresses shall be taken, whichever are less.

Table 3

Type of load	Permissible stress
Stresses due to general and local bending:	
at instantaneous load:	
for glass-reinforced plastic of type I	$\sigma = 0{,}25R_m$ $\tau = 0{,}25\tau_m$
for glass-reinforced plastic of types II-VIII	$\sigma = 0{,}30R_m$ $\tau = 0{,}30\tau_m$
at permanent load for all types of glass-reinforced plastics	$\sigma = 0{,}10R_m$ $\tau = 0{,}10\tau_m$
at shear in the laminate plane for all types of glass-reinforced plastics	$\tau = 0{,}30\tau_m$
at shear in matting-in connections and at interlaminar shear	$\tau = 0{,}60\tau_m$
Stresses in matting-in connections subject to pull:	
at instantaneous load	$\sigma = 2$ MPa
at permanent load	$\sigma = 1$ MPa

Symbols:
σ = permissible normal stress;
τ = permissible shear stress;
R_m, τ_m = tensile strength and shear strength obtained on dry specimens at $t = 20$ °C (refer to Appendix 2).

1.4 Design values for Young's modulus and shear modulus are taken equal to:

$$E_d = 0{,}6E \text{ and } G_d = 0{,}6G$$

where E and G — Young's modulus and shear modulus determined for dry material at 20 °C (refer to Appendix 2).

1.5 For hull structural components the factor of safety against buckling shall be taken not lower than that given in Table 4.

Table 4

Structural component to be calculated	Safety factor
Centre girder, side and deck girders	3
Plate keel, sheerstrake and deck stringer	1,5

1.6 Permissible deflection values calculated with consideration of shear are taken as follows:

1/400 of length for the hull as a whole;

1/50 of spacing for the shell;

1/100 of span for framing members.

1.7 For the shell and upper deck the reduction coefficient may be used. The moment of inertia with consideration of the reduction coefficient shall then not be less than 95 per cent of the moment of inertia calculated in the first approximation without regard to the reduction coefficient.

2 LIFEBOAT HULL

2.1 It is recommended that recalculations of scantlings of separate structures may, if necessary, be based on the following:

2.1.1 For loads used in checking the longitudinal strength of the lifeboat hull, the bending moments and shearing forces acting on the hull during the lowering of a fully loaded lifeboat suspended from two hooks shall be taken. In this case, the maximum bending moment is determined, in kN·m, by the formula

$$M = 1{,}25 \cdot 10^{-3} Ql$$

where Q = mass of fully loaded lifeboat with 50 per cent overloading, kg;
l = lifeboat length between hooks, m.

The maximum shearing force value is determined, in kN, by the formula

$$N = 0{,}005Q.$$

The equivalent static design pressures on the bottom with regard to dynamical loads due to water impact against the hull are given in Table 5 according to the lifeboat mass.

The design pressure on the side is taken to be 80 per cent of the relevant pressure on the bottom;

2.1.2 In calculating the longitudinal and local strength of the lifeboat hull the permissible normal stress is taken equal to 0,30 of the tensile or compression strength for glass-reinforced plastics of type II-VIII (whichever is less) and to 0,25 for type I plastics. The permissible shear stress is taken equal to 0,30 of the shear strength in the laminate plane (for all types of glass-reinforced plastics);

Table 5

Mass of lifeboat loaded with its full complement of persons and equipment, kg	Design pressure, MPa	Mass of lifeboat loaded with its full complement of persons and equipment, kg	Design pressure, MPa
1000	0,04	8000	0,06
2000	0,04	10000	0,07
3000	0,05	15000	0,07
5000	0,05	20000	0,08
7000	0,06		

Note. For intermediate mass values the pressure shall be determined by linear interpolation.

2.1.3 In calculating the longitudinal and local strength the permissible deflections are taken as follows:

1/333 of length for the lifeboat hull as a whole;

1/50 of spacing for shell and bulkheads;

1/100 of span for frames.

The permissible variation in the lifeboat's breadth shall be 1/333*L*.

For the design values of Young's modulus and shear modulus in calculating deflections and checking buckling strength 0,60 of the corresponding values for dry material in initial state at 20 °C shall be taken;

2.1.4 The factors of safety against buckling shall not be less than:

3 for side girders and keel;

1,5 for gunwale;

1 for shell.

In this case, the local buckling strength only shall be checked.

2.2 Testing of finished hulls of lifeboat for strength and rigidity shall be effected in accordance with the requirements of Part II "Life-Saving Appliances" of the Rules for the Equipment of Sea-Going Ships.

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