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 1999.

The Rules are based on the seventh edition taking into account additions and amendments contained in Notice No.1(1996), Notice No.2 (1997), Notice No.3 (1998) and those developed immediately before publication.

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

Rules for the Classification and Construction of Sea-Going Ships are published in two volumes. General Regulations for the Supervision, 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" - in Volume 2.

The text of the Rules in the Russian language published in 1999 should be considered as the original.

ISBN 5-89331-037-3

ЛР № 021056 от 03.06.96

"*Ivan Fiodorov*". *Printing House. 1820*

The eighth edition, as compared to the previous edition (1995), includes the following additions and amendments:

RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING SHIPS

PART VII. MACHINERY INSTALLATIONS

1. The structure of the part has been amended: the chapters of Section 1 containing the particular requirements for equipment, materials and welding, control and communication devices, machinery spaces, arrangement of machinery and equipment have been separated as independent sections.

The numeration of all the sections and chapters has been amended and regulated accordingly.

Ice category marks, where necessary, have been amended and specified in accordance with the new content of 2.2.3, Part I "Classification".

2. The requirements for cargo control rooms have been introduced to Chapters 1.2, 3.2 and 3.3.

3. The requirements for the main engines reversing duration of river-sea navigation ships have been introduced to Chapter 3.1.

4. The requirements for means of communication have been specified and extended in Chapter 3.3.

5. The requirements for chock absorbing fastenings of machinery have been introduced to Chapter 4.4.

6. Chapter 6.2 has been supplemented with the requirements for propeller high-skewed blade thickness.

7. The requirements for active means of ship's steering have been introduced to Section 7.

8. The requirements for machinery power for torsional vibration calculations have been specified in Chapter 8.1.

9. Section 9 has been revised.

10. The requirements for the lists of spare parts have been amended.

PART VIII. SYSTEMS AND PIPING

1. The structure of the part has been amended: the chapters of Section 1 containing the particular requirements for piping, fittings, pipes laying and joints have been separated as independent sections.

2. New sections and chapters concerning the application of methane as a fuel, keel coolants in cooling systems, vapor discharge systems, plastic piping, ship's hoses, heating of cargo tanks have been introduced.

3. The requirements for types of pipe joints have been revised, the requirements for the minimum wall thickness of stainless steel pipes have been regulated.

4. Ice category marks, where necessary, have been amended and specified in accordance with the new content of 2.2.3, Part I "Classification".

PART IX. MACHINERY

1. The requirements for the ambient conditions for the design power of engines determination have been amended and specified in Chapter 2.2.

2. The requirements of the International convention for the safety of life at sea,1974, for protection of high-pressure oil fuel injection piping have been introduced to Chapter 2.6.

3. The requirements for main and auxiliary engines instruments have been specified in Chapter 2.12.

4. The regulations of the IACS Unified Requirement M56 for gearing have been introduced to Chapter 4.2.

Ice category marks have been amended and specified in accordance with the new content of 2.2.3, Part I "Classification".

5. The requirements for turbochargers impellers testing have been amended in Chapter 5.3.

6. The requirements for the design of hydraulic working cylinders seals have been specified in Section 7.

7. The requirements for regulation and protection systems of gas turbines have been specified in Section 8.

8. The requirements for dual-fuel internal combustion engines have been introduced to Section 9, the regulations for free-piston gasifiers have been excluded.

PART X. BOILERS,HEAT EXCHANGERS AND PRESSURE VESSELS

1. The definition of the auxiliary boiler for essential services has been specified in Chapter 1.2.

2. The requirement for manufacturing of class I and II boilers by the manufacturers having the Recognition Certificate of the Register has been introduced to Chapter 1.3.

3. The additional requirements for the design of waist-heat boilers have been introduced to Chapter 3.2.

4. The requirements for safety valves of steam boilers and air receivers have been specified in Chapters 3.3 and 6.4.

PART XI. ELECTRICAL EQUIPMENT

1. The definitions of the main electrical power source and of non-essential services have been introduced to Chapter 1.2.

2. Chapter 2.2 has been completely revised.

3. Table 2.4.4.2 (on the minimal protection of electrical equipment) has been specified and extended in Chapter 2.4.

4. The additional requirements for electrical equipment installed in paint stores have been introduced to Chapter 2.9.

5. The requirements of the IMO Resolution MSC.57(67) regarding the main electrical power source have been introduced to Chapter 3.1.

6. The specifications in compliance with the IACS Unified Interpretation SC136 have been introduced to Chapter 3.5.

7. The requirement of the Regulation II-I/41.3 of the International convention for the safety of life at sea,1974, concerning the main switchboard and generating sets position has been introduced to Chapter 4.6.

8. The requirements for automatic pilots have been excluded from Chapter 5.5 because of introduction of these requirements to Part V "Navigational Equipment" of Rules for the Equipment of Sea-Going Ships.

The specifications in compliance with the IACS Unified Interpretation SC94 concerning the mechanical and electrical independence of steering gear electrical control systems have been introduced.

9. Chapter 5.7 has been supplemented with the requirement for electric motors of oily and sewage water transfer and discharge pumps.

10. Chapter 7.2 has been supplemented with the requirements for telephone communication between the wheel-house and cargo operations control station (in oil tankers) and fire and rescue control station (in ships with distinguishing mark of provision with means for fire fighting aboard other ships in the class notation).

11. The provisions in compliance with the IACS Unified Interpretation SC117 concerning fire detection systems with a zone address identification capability have been introduced to Chapter 7.4.

12. The requirements of the IMO Resolution MSC.57(67) and the IACS Unified Interpretation SC124 concerning the emergency source of power have been introduced to Chapter 9.1.

13. The requirement of the IMO MSC/Circ. 808 for installation of cables for command broadcast apparatus through machinery spaces of category A have been introduced to Chapter 16.8.

14. The additional requirements for electric propulsion plants with semiconductor converters have been introduced to Chapter 17.6.

15. The additional requirements for protective devices have been introduced to Chapter 17.7.

16. Chapter 19.1 has been supplemented with the requirement for electrically powered low-location lighting in compliance with the requirements of the IACS Unified Interpretation SC135, as well as the requirement for general alarm system when the number of passengers is less than 36.

17. Section 19 has been supplemented with Chapter 19.10 "Fishing vessels".

18. In Chapter 21.1 ice category mark has been amended in accordance with the new content of 2.2.3, Part I " Classification".

PART XII. REFRIGERATING PLANTS

1. Chapter 1.1 has been revised.

2. Definitions of the refrigerant and the coolant have been given in Chapter 1.2.

3. The classification of refrigerants in Table 2.2.1 has been amended.

4. The requirement for provisioning of the standby freezing equipment is excluded from Chapter 2.3.

5. The limitation for the use of air coolers with direct expansion of Group II refrigerants is excluded from this part.

6. The requirements for spaces with equipment under refrigerant pressure as well as the requirements for the ventilation of refrigerated cargo spaces have been revised in Section 3.

7. The requirements for emergency discharge of refrigerant have been revised in Section 6.

8. The requirements for the alarm system of spaces with equipment under refrigerant pressure have been specified in Section 7.

9. Section 8 has been supplemented with the requirements for the refrigerated spaces insulation.

10. The present part has been supplemented with Sections 10 and 11 concerning the atmosphere control system in refrigerated spaces and refrigerating plants designed for cooling of liquefied gases.

PART XIII. MATERIALS

1. The provisions concerning the recognition of standards by the Register have been specified in Chapter 1.1.

2. The amendments to regulations on recognition of materials, methods of their manufacture and of manufactures have been introduced to Chapter 1.3.

3. The dimensions of test specimens during testing of metals have been specified in Chapter 2.2.

4. The requirements for the carbon equivalent for higher strength steels supplied in thermo-mechanical controlled processed condition as well as the requirements for the impact energy for steels of more than 50 mm thick have been introduced to Chapter 3.2.

5. The heading of Chapter 3.6 " Steel for chains" has been amended to "Steel for welded chain cable lengths".The requirements for mooring chain cables material have been introduced to the Chapter.

6. The requirements for mechanical properties and manufacture of test specimens have been specified in Chapter 3.9.

7. The requirements for propeller castings of copper alloys have been specified and extended in Chapter 4.2.

8. The text of Chapter 5.1 has been fully revised basing on the modern international requirements for aluminium alloys.

9. Section 6 has been supplemented by Chapter 6.8 "Plastic pipes and fittings".

10. The heading of Section 7 has been amended to "Anchor and mooring chain cables". The requirements for mooring chain cables have been introduced to the Section .

PART XIV. WELDING

1. The requirements for the choice of welding consumables have been extended and specified in Chapter 2.2.

2. In Chapters 2.6 and 4.2 ,where necessary , ice category marks have been amended and specified in accordance with the new content of 2.2.3, Part I "Classification".

3. The requirements for welding consumables for hull structural steel of normal and higher strength have been revised in Chapter 4.2.

4. The additions and amendments to the requirements for welding consumables for constructions intended for low temperature service have been introduced to Chapter 4.5.

5. The requirements for welding consumables for high strength steel have been specified in Chapter 4.6.

PART XV. AUTOMATION

1. In Chapter 1.2 the definition of the remote automated control system has been specified; the new definitions of the standby power source, grouping, call, acknowledgement have been introduced.

2. The requirement for automation equipment supply from accumulator batteries has been brought to conformity with the IACS Unified Requirement E10 in Chapter 2.1.

3. The formulation of a number of paragraphs has been specified basing on the IMO Code on alarms and indicators in Chapter 2.4.

4. The heading of Chapter 4.2 has been brought to conformity with the definition stated in Part VII "Machinery Installations". Some paragraphs of the chapter have been corrected accordingly.

The new text of 4.2.7 has been given to specify the reason for the limiting of ineffective attempts of automatic starting of the main machinery.

On the basis of the IACS Unified Requirement M35 the appropriate amendments have been introduced to the table of the main machinery controlled parameters for ships with automation mark A1 or A2 in their class notation.

5. On the basis of the IACS Unified Requirement M36 the amendments to the table of the automated electric power plants controlled parameters have been introduced to Chapter 4.4.

The text of 4.4.4 concerning the indication provided to warn that automatic starting of the unit is impossible has been supplemented.

6. On the basis of the IACS Unified Requirements M35 and M36 the amendments to Table 7.1.4 (concerning the main and auxiliary machinery controlled parameters for ships with automation mark A3 in their class notation) have been introduced to Chapter 7.1.

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

Ice category mark has been amended in accordance with the new content of 2.2.3, Part I "Classification" in Chapters 3.1 and 3.2.

CONTENTS

RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING SHIPS

PART VII. MACHINERY INSTALLATIONS

1 General . . . 17
1.1 Application . . . 17
1.2 Definitions and explanations . . . 17
1.3 Scope of supervision . . . 18
2 General requirements . . . 19
2.1 Power of main machinery . . . 19
2.2 Number of main boilers . . . 20
2.3 Environmental conditions . . . 20
2.4 Materials and welding . . . 20
2.5 Indicating instruments . . . 21
3 Control devices and stations. Means of communication . . . 21
3.1 Control devices . . . 21
3.2 Control stations . . . 22
3.3 Means of communication . . . 23
4 Machinery spaces, arrangement of machinery and equipment . . . 24
4.1 General provisions . . . 24
4.2 Arrangement of machinery and equipment 24
4.3 Arrangement of oil fuel tanks . . . 24
4.4 Installation of machinery and equipment. 25
4.5 Means of escape from machinery spaces . 25
4.6 Insulation of heated surfaces . . . 26
5 Shafting . . . 26
5.1 General provisions . . . 26
5.2 Construction and diameters of shafts . . 26
5.3 Shaft couplings . . . 29
5.4 Keyless fitting of propellers and shaft couplings. . . . 29
5.5 Shaft bearings . . . 31
5.6 Braking devices . . . 31
5.7 Hydraulic tests . . . 31
6 Propellers . . . 31
6.1 General provisions . . . 31
6.2 Blade thickness. . . . 32
6.3 Propeller boss and blade fastening parts . 34
6.4 Propeller balancing. . . . 34
6.5 Controllable pitch propellers . . . 34
6.6 Hydraulic tests . . . 35
7 Active means of the ship's steering . . . 35
7.1 General provisions . . . 35
7.2 Construction requirements . . . 35
7.3 Alarms . . . 36
7.4 Hydraulic testing. . . . 36
8 Torsional vibration . . . 36
8.1 General provisions . . . 36
8.2 Permissible stresses for crankshafts. . . . 37
8.3 Permissible stresses for intermediate, thrust, propeller shafts and generator shafts . . . 37
8.4 Permissible torque in reduction gear. . . . 38
8.5 Permissible torque and temperature of flexible couplings . . . 38
8.6 Other installation components. . . . 38
8.7 Torsional vibration measurement . . . 39
8.8 Restricted speed ranges . . . 39
9 Vibration of machinery and equipment. Vibration standards . . . 40
9.1 General provisions . . . 40
9.2 Standardized vibration parameters . . . 40
9.3 Vibration standards for internal combustion engines . . . 40
9.4 Vibration standards for main geared turbines and thrust bearings. . . . 41
9.5 Vibration standards for auxiliary machinery of rotary type . . . 46
9.6 Vibration standards for piston air compressors . . . 49
9.7 Vibration standards for boilers and heat exchangers . . . 49
10 Spare parts . . . 50
10.1 General provisions . . . 50
10.2 Required minimum of spare parts . . . 51

PART VIII. SYSTEMS AND PIPING

1 General . . . 55
1.1 Application . . . 55
1.2 Definitions and explanations . . . 55
1.3 Scope of supervision. . . . 55
1.4 Protection and insulation of piping . . . 56
1.5 Welding and non-destructive examination of welds . . . 57
1.6 Machinery, apparatus and control devices. 57
2 Metal piping . . . 57
2.1 Material, manufacture and application . . 57
2.2 Radii of pipe bends, heat treatment after bending . . . 58
2.3 Pipe wall thickness . . . 59
2.4 Pipe joints. . . . 62
3 Plastic piping . . . 64
3.1 Terms and definitions . . . 64
3.2 Scope of application. General requirements 64
3.3 Requirements for piping depending on their purpose and location . . . 64
3.4 Installation requirements . . . 64
3.5 Plastic pipes joints. . . . 66

3.6 Plastic piping laying . . . 66
3.7 Inspection during the installation . . . 66
3.8 Testing of piping after installation aboard the ship . . . 66
4 Fittings . . . 67
4.1 Construction, marking, arrangement and installation of fittings . . . 67
4.2 Filters . . . 67
4.3 Sea-inlet water boxes and ice boxes. Bottom and side fittings. Openings in shell plating 67
5 Piping laying . . . 70
5.1 Piping laying through watertight and fire-resisting structures . . . 70
5.2 Piping laying in tanks . . . 71
5.3 Piping laying in cargo holds and other spaces . . . 71
5.4 Piping laying in refrigerated cargo spaces 71
5.5 Piping laying in the vicinity of electrical and radio equipment . . . 71
5.6 Piping laying in unattended machinery spaces . . . 72
5.7 Piping laying in ships with twin hulls . . 72
6 Ship's hose . . . 72
6.1 Construction of hoses . . . 72
6.2 Testing of hoses . . . 73
7 Bilge system . . . 74
7.1 Pumps . . . 74
7.2 Piping diameters . . . 75
7.3 Piping laying . . . 76
7.4 Drainage of machinery spaces . . . 77
7.5 Drainage of tunnels . . . 78
7.6 Drainage of cargo spaces . . . 78
7.7 Drainage of cargo pump spaces of oil tankers . . . 79
7.8 Drainage of refrigerated cargo spaces . . 79
7.9 Drainage of deep tanks . . . 79
7.10 Drainage of cofferdams . . . 79
7.11 Fore and aft peak drainage . . . 79
7.12 Drainage of other spaces . . . 79
7.13 Drainage of floating dock compartments. 80
7.14 Drainage of cargo spaces intended for the carriage of dangerous cargo . . . 80
8 Ballast, heel and trim systems . . . 80
8.1 Pumps . . . 80
8.2 Piping diameters . . . 81
8.3 Piping laying . . . 81
8.4 Ballast system of floating docks . . . 81
8.5 Heel and trim systems . . . 82
9 Cargo piping system of oil tankers and oil recovery ships. Oil recovery system of oil recovery ships . . . 82
9.1 Pumps and their drives . . . 82
9.2 Piping laying . . . 82
9.3 Heating of cargo tanks . . . 83
9.4 Oil recovery system of oil recovery ships . 83
9.5 Fore and aft cargo gear of oil tankers . . . 83
10 Air, venting, overflow and sounding piping . 84
10.1 Air pipes . . . 84
10.2 Venting system of oil tankers and combination carriers . . . 85
10.3 Cargo vapor discharge system . . . 87
10.4 Overflow pipes . . . 88
10.5 Overflow tanks . . . 88
10.6 Sounding arrangements . . . 89
11 Exhaust gas system . . . 90
11.1 Exhaust gas piping . . . 90
11.2 Silencers and spark arresters . . . 90
12 Ventilation system . . . 91
12.1 Ventilation ducts and ventilator heads, air inlets . . . 91
12.2 Ventilation 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 . . . 91
12.3 Ventilation of passenger ships carrying more than 36 passengers and special purpose ships carrying more than 200 special personnel . 93
12.4 Ventilation of oil tankers and combination carriers carrying crude oil and petroleum products with flash point 60°C and below . 93
12.5 Ventilation of machinery spaces and tunnels . 94
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 . . . 94
12.7 Ventilation of cargo spaces adapted for the carriage of dangerous cargoes . . . 95
12.8 Ventilation of refrigerated cargo spaces . . 95
12.9 Ventilation of foam fire-extinguishing and smothering stations . . . 95
12.10 Ventilation of accumulator battery rooms and boxes . . . 96
12.11 Ventilation of hangars for helicopters . . . 96
12.12 Ventilation of spaces in oil recovery ships . 96
12.13 Ventilation of spaces intended for inert gas equipment . . . 97
13 Oil fuel system . . . 97
13.1 Pumps . . . 97
13.2 Piping laying . . . 97
13.3 Heating arrangements of oil fuel tanks . . 98
13.4 Drainage arrangements of oil fuel tanks . . 98
13.5 Arrangements for collection of leakage fuel 98
13.6 Filling of storage tanks . . . 98
13.7 Oil fuel tanks . . . 98
13.8 Oil fuel supply to internal combustion engines . 99

13.9 Oil fuel supply to boilers . . . 100
13.10 Oil fuel supply to gas turbines . . . 100
13.11 Use of crude oil or slops as fuel for tanker boilers . . . 100
13.12 Application of natural gas (methane) as a fuel for dual-fuel internal combustion engines 102
13.13 Oil fuel system for helicopters . . . 103
14 Lubricating oil system . . . 104
14.1 Lubricating oil pumps of internal combustion engines, gears and couplings . . . 104
14.2 Lubricating oil supply to internal combustion engines and gears . . . 104
14.3 Lubricating oil pumps of steam turbines and gears . . . 104
14.4 Lubricating oil supply to steam turbines and gears . . . 105
14.5 Lubricating oil tanks . . . 105
14.6 Arrangements for collection of leakage lubricating oil . . . 105
14.7 Lubricating oil supply to gas turbines . . . 105
15 Cooling water system . . . 106
15.1 Pumps . . . 106
15.2 Piping laying . . . 106
15.3 Cooling water filters . . . 107
15.4 Cooling of internal combustion engines . 107
15.5 Cooling of gas turbine installations . . . 107
15.6 Keel cooling system . . . 107
16 Compressed air system . . . 108
16.1 Number and capacity of starting air receivers . . . 108
16.2 Compressors . . . 108
16.3 Piping laying . . . 109
17 Feed water system . . . 109
17.1 Pumps . . . 109
17.2 Piping laying . . . 110
17.3 Tanks . . . 110
18 Steam and blow-off systems . . . 110
18.1 Piping laying . . . 110
18.2 Blow-off arrangements of steam lines . . 110
18.3 Calculation of steam pipes for thermal expansion . . . 110
19 Condenser installations . . . 112
19.1 General provisions . . . 112
19.2 Pumps . . . 112
19.3 Piping laying . . . 112
19.4 Instrumentation . . . 112
20 Tests . . . 112
20.1 Hydraulic tests of fittings . . . 112
20.2 Hydraulic tests of piping . . . 113
20.3 Testing of devices to prevent the passage of flame into cargo tanks in tankers . . . 113
20.4 Testing of air pipe automatic closing devices 113
20.5 Testing of plastic pipes . . . 114
21 Thermal liquid systems . . . 114
21.1 Pumps . . . 114
21.2 Expansion tank . . . 114
21.3 Storage tank . . . 114
21.4 Piping laying . . . 114
21.5 Air pipes . . . 114
21.6 Arrangements for leakage collecting and thermal liquid discharge . . . 114
21.7 Cooling of heat-transfer agent . . . 115
21.8 Combination boilers for thermal liquids . 115
21.9 Insulation . . . 115
21.10 Heating of liquid cargoes . . . 115
21.11 Thermal liquid piping testing . . . 115

PART IX. MACHINERY

1 General . . . 116
1.1 Application . . . 116
1.2 Scope of supervision . . . 116
1.3 Hydraulic tests . . . 120
1.4 Operation tests . . . 121
1.5 General technical requirements . . . 121
1.6 Materials and welding . . . 121
2 Internal combustion engines . . . 122
2.1 General provisions . . . 122
2.2 General requirements . . . 122
2.3 Engine frame . . . 123
2.4 Crankshafts . . . 123
2.5 Scavenging and supercharging . . . 128
2.6 Fuel system . . . 129
2.7 Lubrication . . . 129
2.8 Cooling . . . 129
2.9 Starting arrangements . . . 129
2.10 Exhaust arrangements . . . 129
2.11 Control, protection and regulation . . . 130
2.12 Instruments and alarm devices . . . 131
2.13 Torsional vibration damper. Antivibrator . 131
3 Steam turbines . . . 131
3.1 General requirements . . . 131
3.2 Rotor . . . 132
3.3 Casing . . . 132
3.4 Bearings . . . 132
3.5 Suction, gland-sealing and blowing systems . . . 132
3.6 Control, protection and regulation . . . 132
3.7 Instrumentation . . . 133
4 Gears, disengaging and elastic couplings . 134
4.1 General requirements . . . 134
4.2 Gearing . . . 134
4.3 Elastic and disengaging couplings . . . 147
4.4 Turning gear . . . 147
5 Auxiliary machinery . . . 148
5.1 Power-driven air compressors . . . 148
5.2 Pumps . . . 149
5.3 Fans, blowers and turbochargers . . . 150
5.4 Centrifugal separator . . . 150
6 Deck machinery . . . 151
6.1 General requirements . . . 151

6.2 Steering gear . . . 151
6.3 Anchor machinery . . . 153
6.4 Mooring machinery . . . 155
6.5 Towing winches . . . 156
7 Hydraulic drives . . . 156
7.1 General requirements . . . 156
7.2 Strength calculation . . . 157
7.3 Safety and other arrangements . . . 157
8 Gas turbines . . . 157
8.1 General requirements . . . 157
8.2 Rotors of gas turbines . . . 159
8.3 Casing of gas turbines . . . 159
8.4 Gas turbines bearings . . . 159
8.5 Combustion chambers . . . 159
8.6 Heat exchangers . . . 159
8.7 Control, protection and regulation . . . 160
8.8 Instrumentation . . . 161
8.9 Waste-heat circuit of gas turbine . . . 161
9 Dual-fuel internal combustion engines . . . 161
9.1 General . . . 161
9.2 Conditions of operation on two kinds of fuel . . . 161
9.3 Crankcase protection. . . . 161
9.4 Protection of sub-bearing spaces of the cross-head type DF-engines . . . 162
9.5 Intake and exhaust gas systems . . . 162
9.6 Starting air piping . . . 162
9.7 Combustion control . . . 162
9.8 Gas fuel supply . . . 162
9.9 Gas fuel supply cut-off. . . . 162

PART X. BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

1 General . . . 163
1.1 Application . . . 163
1.2 Definitions and explanations . . . 163
1.3 Scope of supervision . . . 163
1.4 Materials. . . . 165
1.5 Welding . . . 166
1.6 Heat treatment. . . . 166
1.7 Tests . . . 166
1.8 Boiler rooms and spare parts. . . . 167
2 Strength calculations . . . 167
2.1 General provisions . . . 167
2.2 Cylindrical and spherical elements and tubes . . . 172
2.3 Conical elements . . . 173
2.4 Flat walls, end plates and covers . . . 175
2.5 Tube plates . . . 177
2.6 Dished ends . . . 178
2.7 Flanged end plates . . . 179
2.8 Headers of rectangular section . . . 179
2.9 Reinforcement of openings in cylindrical, spherical, conical walls and in dished ends . 180
2.10 Stays . . . 184
2.11 Top girders . . . 185
3 Boilers . . . 185
3.1 General provisions . . . 185
3.2 Construction requirements . . . 185
3.3 Fittings and gauges . . . 186
3.4 Incinerator boilers. . . . 189
3.5 Thermal fluid boilers . . . 190
4 Controls, governors, protective devices and alarms for boilers . . . 191
4.1 General provisions . . . 191
4.2 Governors and controls . . . 191
4.3 Protective devices . . . 191
4.4 Alarms . . . 191
5 Oil burning installations of boilers . . . 191
5.1 General provisions . . . 191
5.2 Burners . . . 191
5.3 Burning installations . . . 192
6 Heat exchangers and pressure vessels . . . 192
6.1 General provisions . . . 192
6.2 Construction requirements . . . 192
6.3 Fittings and gauges . . . 193
6.4 Special requirements for heat exchangers and pressure vessels . . . 193
7 Strength characteristics of boiler steel . . . 195
7.1 Lower yield stress as a function of design temperature, MPa . . . 195
7.2 Average stress to produce rupture in 100 000 hours as a function of design temperature, MPa . . . 195
Appendix. Typical examples of allowable welded joints for boilers, heat exchangers and pressure vessels . . . 196

PART XI. ELECTRICAL EQUIPMENT

1 General . . . 205
1.1 Application . . . 205
1.2 Definitions and explanations . . . 205
1.3 Scope of supervision. . . . 205
1.4 Technical documentation . . . 206
2 General requirements . . . 207
2.1 Operating conditions . . . 207
2.2 Electromagnetic compatibility . . . 208
2.3 Materials . . . 210
2.4 Structural requirements and protection of electrical equipment . . . 210
2.5 Protective earthing of metal parts which do not carry current . . . 211
2.6 Thunderstorm protection . . . 213
2.7 Arrangement of electrical equipment . . . 214
2.8 Special electrical spaces . . . 215
2.9 Safe-type electrical equipment . . . 215
3 Main electrical power source . . . 216

3.1 Composition and capacity of main electrical power source 216
3.2 Electric machine sets 217
3.3 Number and capacity of transformers . . 218
3.4 Power supply from an external source of electrical power 218
3.5 Connection of electrical power supply units 218
4 Distribution of electrical power 219
4.1 Distribution system 219
4.2 Permissible voltage 219
4.3 Power supply of essential services 219
4.4 Power supply of electrical (electronic) automation systems 221
4.5 Power supply to integrated bridge control console. 221
4.6 Switchboard and switchgear 221
5 Electric drives for shipboard mechanisms and equipment 225
5.1 General requirements 225
5.2 Interlocking of machinery operation . . . 225
5.3 Safety isolation devices. 226
5.4 Switchgear and control gear 226
5.5 Electric drives and control of steering gear. 226
5.6 Electric drives of anchor and mooring machinery 227
5.7 Electric drives of pumps 228
5.8 Electric drives of fans 228
5.9 Electric drives of boat winches 228
5.10 Electric drives of watertight and fire doors 228
6 Lighting 229
6.1 General requirements 229
6.2 Power supply of main lighting electric circuits 229
6.3 Emergency lighting. 230
6.4 Switches in lighting circuits 230
6.5 Gas discharge lamp installations 230
6.6 Socket outlets 231
6.7 Illumination 231
6.8 Navigation lights. 232
7 Internal communication and signalling . . 232
7.1 Electric engine room telegraphs 232
7.2 Internal service communication 233
7.3 General alarm system 233
7.4 Fire detection system. 234
7.5 Warning alarm of smothering system release 235
7.6 Indication of closure of watertight and fire doors 235
7.7 Sound signals in engineers' accommodation spaces. 235
8 Protective devices. 236
8.1 General requirements 236
8.2 Protection of generators 236
8.3 Protection of electric motors 237
8.4 Steering gear protection 237
8.5 Protection of transformers. 238
8.6 Protection of accumulator batteries . . . 238
8.7 Protection of pilot lamps, voltmeters, capacitors and voltage coils 238
8.8 Protection of power semiconductor units. 238
9 Emergency electrical installations 239
9.1 General requirements 239
9.2 Spaces of emergency sources of electrical power 239
9.3 Emergency sources of electrical power in cargo ships 240
9.4 Distribution of electrical power from emergency sources. 241
9.5 Starting arrangements for emergency diesel generators. 241
10 Electrical machines 242
10.1 General requirements 242
10.2 Slip rings, commutators and brushes . . 242
10.3 Bearings 242
10.4 Temperature detectors. 242
10.5 Overcurrent 243
10.6 Alternating-current generators. 243
10.7 Direct-current generators 244
10.8 Electromagnetic brakes 244
11 Transformers 244
11.1 General provisions 244
11.2 General requirements 244
11.3 Overload, voltage variation and operation in parallel 244
12 Power semiconductor units 245
12.1 General requirements 245
12.2 Permissible parameters of voltage distortion 245
12.3 Control and signalling systems 245
12.4 Measuring instruments 245
13 Accumulator batteries 246
13.1 General requirements 246
13.2 Arrangement of accumulator batteries. . 246
13.3 Heating 246
13.4 Ventilation 246
13.5 Charging of accumulator batteries. . . . 247
13.6 Installation of electrical equipment in battery compartments 247
13.7 Electrical starters for internal combustion engines 247
14 Electrical apparatus and accessories . . . 247
14.1 Electrical apparatus 247
14.2 Electrical accessories 248
15 Electrical cooking and heating appliances. 249
15.1 General requirements 249
15.2 Heating appliances 249
15.3 Oil and fuel heaters 249
16 Cables and wires. 250
16.1 General requirements 250

16.2 Cable conductors . . . 250
16.3 Insulating materials . . . 250
16.4 Cable sheathing . . . 250
16.5 Protective coverings . . . 251
16.6 Marking . . . 251
16.7 Hookup wires . . . 251
16.8 Cabling . . . 251
17 Electric propulsion plants . . . 258
17.1 General requirements . . . 258
17.2 Permissible supply voltage . . . 258
17.3 Electric machines . . . 258
17.4 Switches in main and field circuits . . . 259
17.5 Control stations of electric propulsion plant . 259
17.6 Electric propulsion plants with semi-conductor converters . . . 260
17.7 Protection of electric propulsion plants . 260
17.8 Measuring instruments and alarms . . . 261
17.9 Electric slip couplings . . . 261
18 Additional requirements for electrical equipment designed for a voltage in excess of 1000 V . . . 262
18.1 General requirements . . . 262
18.2 Distribution of electrical power . . . 262
18.3 Protective devices . . . 262
18.4 Protection earthing . . . 263
18.5 Arrangement and degree of protection of electrical equipment . . . 263
18.6 Distribution gear . . . 263
18.7 Terminal boxes . . . 264
18.8 Transformers . . . 264
18.9 Cabling . . . 264
19 Requirements for electrical equipment proceeding from ship purpose . . . 264
19.1 Passenger ships . . . 264
19.2 Oil tankers and oil recovery ships . . . 267
19.3 Ships intended for carriage of motor vehicles with fuel in their tanks, tank cars and tank wagons for flammable liquids . 270
19.4 Special purpose ships . . . 271
19.5 Container ships . . . 271
19.6 Catamarans . . . 272
19.7 Floating cranes and crane ships . . . 272
19.8 Floating docks . . . 272
19.9 Berth-connected ships . . . 276
19.10 Fishing vessels . . . 276
20 Requirements for electrical equipment of refrigerating plants . . . 277
20.1 General provisions . . . 277
20.2 Power supply and switching . . . 277
20.3 Ventilation . . . 278
20.4 Lighting . . . 278
21 Spare parts . . . 278
21.1 General requirements . . . 278
21.2 Required minimum of spare parts . . . 280

PART XII. REFRIGERATING PLANTS

1 General . . . 281
1.1 Application . . . 281
1.2 Definitions and explanations . . . 281
1.3 Scope of supervision and technical documentation . . . 281
2 General technical requirements . . . 282
2.1 General provisions . . . 282
2.2 Refrigerants and design pressure . . . 282
2.3 Composition and capacity of the refrigerating equipment . . . 282
2.4 Materials . . . 283
2.5 Electrical equipment . . . 283
3 Spaces for refrigerating plants, refrigerated cargo, process services . . . 284
3.1 Refrigerating machinery spaces . . . 284
3.2 Refrigerant storerooms . . . 284
3.3 Refrigerated cargo spaces . . . 285
3.4 Freezing and cooling apparatus . . . 285
3.5 Spaces containing process equipment . . 285
4 Machinery . . . 286
4.1 Compressors . . . 286
4.2 Pumps . . . 286
4.3 Fans . . . 286
5 Heat exchangers, pressure vessels and cooling arrangements . . . 286
5.1 Heat exchangers and pressure vessels . . 286
5.2 Air coolers . . . 287
6 Fittings and piping . . . 287
6.1 Fittings and safety valves . . . 287
6.2 Piping . . . 287
7 Indicating and measuring instruments and automatic devices . . . 288
7.1 Indicating and measuring instruments . . 288
7.2 Automatic devices . . . 288
8 Insulation . . . 289
8.1 Insulation of the refrigerated spaces . . . 289
8.2 Insulation of piping . . . 289
9 Refrigerating plants designed for cooling of cargo in thermal containers . . . 289
9.1 General provisions and technical requirements . . . 289
10 Atmosphere control system . . . 290
10.1 General provisions and technical requirements . . . 290
11 Refrigerating plants designed for cooling of liquified gas . . . 290
11.1 General provisions . . . 290
12 Tests . . . 291
12.1 Tests at maker's works . . . 291
12.2 Testing on board . . . 291
13 Spare parts . . . 291
13.1 General requirements . . . 291
13.2 Required minimum of spare parts . . . 291

PART XIII. MATERIALS

1 General . . . 293
1.1 Application . . . 293
1.2 Definitions and explanations . . . 293
1.3 Scope of supervision . . . 293
1.4 Marking . . . 295
1.5 Laboratories engaged in testing . . . 296
2 Procedures of testing . . . 296
2.1 General provisions . . . 296
2.2 Testing procedures for metals . . . 297
2.3 Procedures of testing non-metallic materials . . . 301
2.4 Weldability test . . . 307
3 Steel and cast iron . . . 307
3.1 General provisions . . . 307
3.2 Hull structural steel . . . 307
3.3 Steel for boilers, heat exchangers and pressure vessels . . . 313
3.4 Steel tubes and pipes . . . 314
3.5 Steel for structures intended for low temperature service . . . 315
3.6 Steel for welded chain cable lengths . . . 317
3.7 Steel forgings . . . 318
3.8 Steel castings . . . 324
3.9 Spheroidal or nodular graphite iron castings . . . 326
3.10 Grey iron castings . . . 328
3.11 Malleable cast iron . . . 329
3.12 Steel castings for propellers . . . 329
3.13 High strength steel for welded structures . 330
3.14 Z-steel . . . 332
3.15 Wire ropes . . . 333
4 Copper and copper-base alloys . . . 334
4.1 Semi-finished products of copper and copper-base alloys . . . 334
4.2 Propeller castings . . . 334
5 Aluminium alloys . . . 342
5.1 Wrought aluminium alloys . . . 342
5.2 Cast aluminium alloys . . . 346
6 Plastics and materials of organic origin . . 348
6.1 General provisions . . . 348
6.2 Materials for reinforced plastic structures 348
6.3 Laminated textiles . . . 349
6.4 Foam plastics . . . 350
6.5 Adhesives, polymer pastes and coats . . . 351
6.6 Ropes of natural and synthetic fibre . . . 351
6.7 Retro-reflective materials for life-saving appliances . . . 352
6.8 Plastic pipes and fittings . . . 353
7 Anchor and mooring chain cables . . . 354
7.1 Anchor chain cables and accessories . . . 354
7.2 Mooring chain cables and accessories . . 359

PART XIV. WELDING

1 General . . . 363
1.1 Application . . . 363
1.2 Definitions and explanations . . . 363
1.3 General provisions . . . 363
1.4 Scope of supervision . . . 363
1.5 Technical documentation . . . 363
2 Technological requirements for welding . . 364
2.1 General provisions . . . 364
2.2 Welding of ship hull and equipment . . . 365
2.3 Welding in ship machinery construction . 367
2.4 Welding of steam boilers and pressure vessels . . . 368
2.5 Welding of pipelines . . . 368
2.6 Welding of castings and forgings . . . 369
2.7 Welding of cast iron . . . 369
2.8 Welding of clad steels . . . 369
2.9 Brazing . . . 370
2.10 Welding of aluminium and its alloys . . 370
2.11 Welding of copper and copper alloys, heavy metals and other non-ferrous metals . . . 370
2.12 Welding of high strength steels . . . 370
3 Inspection of welded joints . . . 371
3.1 General requirements . . . 371
3.2 Scope of non-destructive testing . . . 372
3.3 Assessment of welded joint quality in hull structural steel . . . 373
3.4 Assessment of welded joint quality in aluminium alloy hull structures . . . 375
4 Welding consumables . . . 376
4.1 General provisions . . . 376
4.2 Welding consumables for hull structural steel . . . 379
4.3 Welding consumables for boiler steel . . 394
4.4 Welding consumables for welding of steel intended for machinery, arrangements, outfit, equipment and piping . . . 394
4.5 Welding consumables for hull structural steels intended for low temperature service . 394
4.6 Welding consumables for high strength steels . . . 395
4.7 Welding consumables for aluminium and aluminium alloys . . . 396
5 Approval test for welders . . . 397
5.1 General . . . 397
5.2 Welder approval test . . . 397
5.3 Certificate validity . . . 397
6 Approval of welding process . . . 404
6.1 General . . . 404
6.2 Testing . . . 404
6.3 Preparation of test assemblies and test specimens, and criteria for assessment of test results . . . 405

PART XV. AUTOMATION

1 General . . . 410
1.1 Application . . . 410
1.2 Definitions and explanations . . . 410
1.3 Scope of supervision . . . 410
1.4 Technical documentation. . . . 411
2 Design of automation systems, automation elements and control devices . . . 411
2.1 General requirements . . . 411
2.2 Elements and devices. . . . 412
2.3 Automation systems . . . 412
2.4 Alarm, protection, indication and recording systems . . . 413
3 Supply of automation systems . . . 415
3.1 General . . . 415
4 Automated machinery and units . . . 415
4.1 General . . . 415
4.2 Automated main machinery and propellers . . . 415
4.3 Automated boiler plants . . . 419
4.4 Automated electric power plants . . . 421
4.5 Automated compressor plants . . . 422
4.6 Automated pumping plants . . . 422
4.7 Automated bilge plants of machinery spaces . . . 423
4.8 Automated refrigerating plants. . . . 423
5 Requirements for ships having the automation mark A1 in their class notation . . . 424
5.1 General . . . 424
5.2 Bridge devices . . . 424
5.3 Devices in machinery spaces . . . 424
5.4 Devices in engineers' accommodation . . . 425
6 Requirements for ships having the automation mark A2 in their class notation . . . 425
6.1 General . . . 425
6.2 Devices on the bridge . . . 425
6.3 Devices in machinery spaces . . . 425
6.4 Devices in engineers' accommodation . . . 425
6.5 Electric power plants. . . . 426
6.6 Bilge systems. . . . 426
7 Requirements for ships having the automation mark A3 in their class notation . . . 426
7.1 General . . . 426
7.2 Devices on the bridge . . . 427
7.3 Devices in machinery spaces . . . 428
7.4 Devices in engineers' accommodation . . . 428
7.5 Main propulsion plants . . . 428
7.6 Electric power plants. . . . 428
7.7 Boiler plants with oil-burning installations . . . 428
8 Requirements for computers and computer systems . . . 428
8.1 Application . . . 428
8.2 Definitions and explanations . . . 428
8.3 Scope of supervision . . . 429
8.4 Technical documentation . . . 429
8.5 Requirements for computer design . . . 429
8.6 General technical requirements . . . 429
8.7 Functional tests, self-checking and malfunction signalling . . . 429
8.8 Additional requirements for computers which control and monitor ship plants . . . 430
8.9 Installation of computers and computer systems on board ships . . . 430

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

1 General . . . 431
1.1 Application . . . 431
1.2 Definitions and explanations . . . 431
1.3 General provisions . . . 431
1.4 Scope of supervision. . . . 431
1.5 Materials . . . 432
1.6 Framing system and spacing . . . 432
1.7 Matting-in connections and fastenings. . . 432
2 Hull and superstructures of ships . . . 434
2.1 General provisions . . . 434
2.2 Side and bottom shell . . . 438
2.3 Bottom framing . . . 439
2.4 Side framing. . . . 441
2.5 Decks and deck framing. . . . 442
2.6 Pillars . . . 443
2.7 Bulkheads . . . 443
2.8 Tanks . . . 444
2.9 Superstructures and deckhouses . . . 445
2.10 Openings in structures. . . . 446
2.11 Bulwark . . . 447
2.12 Engine seatings . . . 447
2.13 Stems, sternframes, propeller shaft brackets and bilge keels. . . . 447
2.14 Casings of engine and boiler rooms, hatch and fan coamings . . . 448
3 Strengthening in ships for navigation in ice . . . 448
3.1 General provisions . . . 448
3.2 Ice strengthening in ships of category **ЛУ2** . . . 448
4 Lifeboat hull . . . 449
4.1 General provisions . . . 449
4.2 Shell. . . . 449
4.3 Framing. . . . 450
4.4 Attachment of lifting gear and equipment . . . 451
Appendix 1. Recommended types of glass-reinforced plastics . . . 452
Appendix 2. Physical and mechanical properties of glass-reinforced plastics. . . . 453
Appendix 3. Guidance for determination of hull member scantlings of ships and lifeboats by calculation . . . 456

PART VII. MACHINERY INSTALLATIONS

1 GENERAL

1.1 APPLICATION

1.1.1 The present Part of the Rules applies to ship machinery installations, equipment of machinery spaces, shafting lines, propellers, 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 berth-connected ships must comply with the requirements of Sections 1 to 4, 8 and 9 of the present Part of the Rules in so much as applicable and sufficient.

1.1.2 The requirements of the present Part of the Rules are set forth proceeding from the condition that the flash point of oil fuel (see 1.2 of 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 oil fuel is stored will not rise to within 10 °C below its flash point may use oil fuel with flash point not less than 43 °C. In this case, measures should 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 is not to 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

Definitions and explanations relating to general terminology of the Rules are given in General Regulations for the Supervision.

The following definitions, as adopted in this Part of the Rules, 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 supervision of the Register.

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 ensuring propulsion and steering of a ship under all running conditions as well as steering of a ship at zero speed (with no longitudinal component of propeller thrust or tractive force).

Main machinery is the machinery intended for driving the propellers, exclusive of prime movers of the auxiliary active means of the ship's steering.

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, oil fuel units, steam and internal combustion engines, generators and other major electrical machinery, oil fuel 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

boilers, inert gas generators, incinerators that are oil-fired, and oil fuel 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 is the condition under which the main propulsion plant, auxiliaries and boilers are not in operation due to the absence of power.

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.

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 rated power.

Oil fuel unit is the equipment used for the preparation and delivery of oil fuel (heated or unheated) to an oil-fired boiler, inert gas generator, incinerator or machinery using oil fuel and includes any oil pressure pumps, separators, filters and heaters dealing with oil at a pressure of more than 0,18 MPa.

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

1.3 SCOPE OF SUPERVISION

1.3.1 General provisions covering the procedure of classification, supervision during construction and surveys as well as the requirements for technical documentation submitted for consideration and approval to the Register are stated in General Regulations for the Supervision and in Part I "Classification".

1.3.2 Supervision by the Register, including the approval of technical documentation according to 3.1.8, 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;

.3 parts indicated in Table 1.3.2.3 and the corresponding spare parts specified in 5.2.

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

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

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

3. The list of details and materials used for the parts of CP-propellers (crankpin rings, crossheads, push-pull rods, hydraulic cylinders, etc.), as well as of AMSS are subject to special consideration by the Register in each case.

1.3.3 Subject to supervision of 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 is to 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 icebreakers is to be consistent with their category according to 2.2.3, Part I "Classification".

In ships strengthened for navigation in ice of categories **ЛУ2 — ЛУ9** the power delivered to the propeller shaft P_{min}, in kW, is not to 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 controllable pitch propellers;
$f_2 = \varphi/200 + 0{,}675$, but not more than 1,1:
φ = slope of stem (see 3.10.1.2, Part II "Hull").
f_2 = 1,1 for a bulbous stem;
the product $f_1 f_2$ is to 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 (see 1.2.1, Part III "Equipment, Arrangements and Outfit"), t;
calculating P_{min} for ships strengthened for navigation in ice of **ЛУ2** and **ЛУ3** 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 is not to be less than:

10000 kW for ice category **ЛУ9**;
7200 kW for ice category **ЛУ8**;
5000 kW for ice category **ЛУ7**;
3500 kW for ice category **ЛУ6**;
2600 kW for ice category **ЛУ5**;
1000 kW for ice category **ЛУ4**;
740 kW for ice categories **ЛУ3**, **ЛУ2**.

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 **ЛУ6 — ЛУ9**, 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 The machinery installation shall provide sufficient astern power to maintain manoeuvring of the ship in all normal service conditions.

2.1.4 The machinery installation 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.

The astern power is to 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 machinery installations 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 can be brought into operation from the dead ship condition without external aid (see 16.2.3, Part VIII "Systems and Piping").

Table 2.1.1

Displacement Δ, t	Value	Ice strengthening category							
		ЛУ2	**ЛУ3**	**ЛУ4**	**ЛУ5**	**ЛУ6**	**ЛУ7**	**ЛУ8**	**ЛУ9**
$\Delta < 30000$	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	7,5
Emergency machinery and equipment	22,5[3]	22,5[3]	10,0	10,0

[1] Steady list and trim are to 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 oil tankers, gas carriers and chemical tankers emergency power sources are to remian operative when the ship is listed up to 30 deg.

2.1.7 In the event of failure of one turbocharger (see 2.5.1, Part IX "Machinery") the machinery installation with one main internal combustion engine shall provide the ship's speed at which the steerability of the ship is maintained.

2.1.8 The power of main machinery in ships of river-sea navigation is to 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), whose increased noise level makes direct local control difficult, may be approved 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 are to 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.

2.2 NUMBER OF MAIN BOILERS

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

2.3 ENVIRONMENTAL CONDITIONS

2.3.1 The machinery, equipment and systems installed in the ship are to 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 are to 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 is to 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 are to be manufactured under supervision of the Register; supervision 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 should be in compliance with 3.12 and 4.2, Part XIII "Materials". Whereas grades 3 and 4 steel is permitted for the manufacture of propellers for ships of all types, grade 5 steel 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 Grade 3 and Grade 4 are admitted for propellers in all ships, except icebreakers and ships with ice categories **ЛУ7** — **ЛУ9**; copper alloys of Grade 1 and Grade 2 may be used exclusively for propellers in ships without ice strengthening and in ships with ice strengthening of categories **ЛУ1** — **ЛУ3**.

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, are to 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 3.7.1.3, Part XIII "Materials".

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

2.4.7 Welding procedure and non-destructive testing of welded joints are to 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, are to be checked by competent bodies.

Pressure gauges fitted on boilers, heat exchangers, pressure vessels and refrigerating plants are to meet the requirements of 3.3.5 and 6.3.9, Part X "Boilers, Heat Exchangers and Pressure Vessels" and 7.1, Part XII "Refrigerating Plants", respectively.

2.5.2 The tachometer accuracy is to be within $\pm 2{,}5$ per cent. With restricted speed ranges, the accuracy is not to be below 2 per cent, and the ranges are to be marked with bright colour on the scales of tachometers or in another way.

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 are to be provided with effective means for its operation and control. All control systems essential for the propulsion, control and safety of the ship are to 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 are to 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 is to 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 are to be so designed as to eliminate the possibility of spontaneously changing the positions prescribed.

3.1.6 The control devices of main engines are to 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 should remain unchanged until control is transferred to a local station. Among other factors, the loss of power supply (electric, pneumatic or hydraulic power) is not to substantially affect the power of main engines or change the direction of propeller rotation.

3.1.9 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) is not to 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, are to be equipped with:

.1 controls for the operation of main engines and propellers. For installations comprising CP-propellers, Voith-Schneider 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 (see 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.

3.2.2 The control stations on the wings of navigating bridge should 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 are to 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 should 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.

The communication between the control stations on the wings of navigating bridge and the control station on the navigating bridge shall be effected in such a way that the control from each location is performed without transferring and from one control station only.

3.2.7 Main engines should be operated from the wheelhouse by means of a single control element per propeller with automatic performance of all modes including, where necessary, means of preventing overload and continuous running within the restricted speed ranges. 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, should be controlled automatically with the time intervals admissible for main engines. The modes assigned are to 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 list, 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 are to be located as far from the machinery spaces as practicable. Onboard the tankers the CCR are to be arranged according to 2.4.9, Part VI "Fire Protection".

Furthermore, arrangement of CCR onboard chemical tankers is to comply with the requirements of Section 3, Part II "Structure of chemical tanker" of Rules for the Classification and Construction of Chemical Tankers, and for gas carriers - the requirements of Section 9, Part VI "Systems and pipelines" of Rules for the Classification and Construction of Gas Carriers.

3.2.11 CCR are to 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 % 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 ballast tanks;

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

.4.11 parameters of inert gas system in compliance with 3.9.7.6, Part VI "Fire Protection";

.4.12 status of technical aids stipulated in 3.2.10;

.4.13 low water level in deck water seal (see 3.9.5.1, Part VI "Fire Protection").

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

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

3.3 MEANS OF COMMUNICATION

3.3.1 At least two independent means should 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 should 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 (see also 7.1, Part XI "Electrical Equipment").

Appropriate means of communication should 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 is to 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, is to 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 should 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 PROVISIONS

4.1.1 Ventilation of machinery spaces is to comply with the requirements of 12.5.1, Part VIII "Systems and Piping".

4.2 ARRANGEMENT OF MACHINERY AND EQUIPMENT

4.2.1 Engines, boilers, equipment, pipes and fittings are to be so arranged as to provide easy access for servicing and repair; the requirements stated in 4.5.1 are also to be met.

4.2.2 The arrangement of boilers should 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 13.3.4, Part VIII "Systems and Piping".

4.2.3 Where auxiliary boilers are installed in the same space with the internal combustion engines, their furnaces are to 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 are to 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 should 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 are to 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 should 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 should be subjected to test pressure before fitting.

Temperature sensing devices should be provided for the bulkhead shaft glands and bearings of pumps and also the casings of these pumps, and an alarm should be initiated in the cargo control room or the pump control station.

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

4.2.7 Oil fuel units (see 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 (see 19.2, Part XI "Electrical Equipment").

4.2.10 In oil tankers, entrance doors, air intakes and openings to the accommodation and service spaces, control stations and machinery spaces should not lead to the cargo area. They should be located on the transverse bulkhead not facing the cargo area 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 transverse bulkhead of the superstructure or deckhouse facing the cargo area.

4.3 ARRANGEMENT OF OIL FUEL TANKS

4.3.1 In general, oil fuel tanks shall be part of the ship's structure and shall be located outside machinery spaces of category A. Where oil fuel 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 oil fuel having flash point less than 60 °C. In general, the use of free standing oil fuel tanks shall be avoided.

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

4.3.2 Where the use of free standing oil fuel tanks is permitted by the Register, they should 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 Oil fuel 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 the area of accommodation, service and refrigerated cargo spaces is to comply with the requirements of 2.1.12, Part VI "Fire Protection".

4.4 INSTALLATION OF MACHINERY AND EQUIPMENT

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

4.4.2 Boilers are to 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 is to be made for efficient stops and securing for rough sea; thermal expansion of boiler structures is to be taken into account.

4.4.4 The main engines, their gears, thrust bearings of shafts are to 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 are to 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 are to be fitted with appropriate lockers against spontaneous loosening.

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

Shock absorbing fastenings of the machinery and equipment are to:

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 on plastic pads in each case is subject to special consideration by the Register. Polymeric materials used for the pads are to comply with the requirements of 6.5, Part XIII "Materials".

4.4.8 The machinery with horizontal arrangement of the shaft is to 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 is to be mounted on the same seatings as the generators.

4.5 MEANS OF ESCAPE FROM MACHINERY SPACES

4.5.1 The main and auxiliary machinery is to 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 is to comply with the requirements of 4.6.7, Part XI "Electrical Equipment".

4.5.2 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.

4.5.3 Every machinery space of category A, the shaft tunnels and pipe ducts are to have at least two means of escape which provide access to the appropriate lifeboat and liferaft embarkation decks.

The two means of escape are to be as widely separated as possible and shall comprise steel ladders leading to the exits from the space.

The protection of these ladders from fire is to comply with the requirements of 2.1.4.5, Part VI "Fire Protection".

One of the escape routes may lead through a steel door capable of being operated from either side and fitted in the lower section of the space reasonably apart from the other ladder, which provides access to a safe escape route leading from the lower section of the space to the open deck.

The escape routes from shaft tunnels and pipe ducts are to be enclosed in watertight trunks carried to above the margin line. One of these escape routes may lead in the machinery spaces.

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.

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

In the case of ships of less than 1000 gross tonnage the second means of escape may be dispensed with on agreement with the Register, due regard being paid to the disposition and dimensions of these spaces.

The lifts shall not be considered as means of escape.

4.5.4 Machinery spaces which are not covered by 4.5.3 as well as incinerator spaces may have one means of escape.

The workshops, rooms of oil fuel units, boilers, test rooms of fuel injection valves, etc. enclosed within the machinery spaces are permitted to have exits leading into these spaces.

The main machinery control room enclosure in the engine room shall have its own means of escape according to 4.5.7, in addition to the exit leading into the engine room. In case of a smaller engine room or where the exits from main machinery control room are located close to the engine room exit, the main machinery control room need not be provided with the additional means of escape if agreed to by the Register.

4.5.5 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 are to be located at the opposite sides.

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

4.5.7 Escape routes from the machinery spaces are to lead to such positions which provide ready access to the lifeboat embarkation deck.

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

The covers of skylights, which are not intended to be used for escape, shall, as a minimum, be fitted with means for closing them from outside.

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

4.6 INSULATION OF HEATED SURFACES

4.6.1 Surfaces of machinery, equipment and piping which may be heated to a temperature over 220°C are to be insulated. Precautions shall be taken to prevent damage to insulation from vibration and mechanical shocks.

4.6.2 The insulating materials and surface of insulation are to be in accordance with the requirements of 2.1.1.1, Part VI "Fire Protection".

5 SHAFTING

5.1 GENERAL PROVISIONS

5.1.1 The minimum shaft diameters without allowance for subsequent turning on lathe during service life are to 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.

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

5.1.2 In icebreakers and ships strengthened for navigation in ice, the propeller shafts are to be protected from ice effects.

5.1.3 In ships with no obstruction for the propeller shaft to slip out of the sterntube, devices should be provided which, in the event of the propeller shaft breaking, will prevent its slipping out of the stern gland; alternative arrangements are to be made to preclude flooding of the engine room, should the propeller shaft be lost.

5.1.4 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, is not to 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, is not to 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, is not to 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 value in the above formula shall not exceed 800 MPa 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 are to 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 **ЛУ1**) is, besides, to 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;
$R_{m_{bl}}$ = 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 or transverse hole, the shaft diameter is to be increased over a length of at least seven diameters of the hole. The

Table 5.2.5

Increase of shaft diameter, %

Shafts	Ships with ice categories							Icebreakers	
	ЛУ1, ЛУ2	**ЛУ3**	**ЛУ4**	**ЛУ5**	**ЛУ6**	**ЛУ7**	**ЛУ8 — ЛУ9**	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.

hole is to be located at mid-length of the bossed portion of the shaft, and its diameter is not to exceed 0,3 of the shaft design diameter. In all cases, irrespective of the hole diameter, the diameter of the shaft is to be increased by not less than 0,1 times the design diameter. The edges of the hole are to be rounded to a radius not less than 0,35 times its diameter and the inside surface is to have a smooth finish.

5.2.8 The diameter of a shaft having a longitudinal slot is to be increased by at least 0,2 of the design diameter of that shaft; the length of the slot is to be not more than 1,4 and the width of the slot not more than 0,2 of the design diameter of the shaft.

The bossed portion of the shaft is to 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 should be smooth. The ends of the slot are to 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 is to have a smooth finish.

5.2.9 The diameter of a shaft having a keyway is to 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.

5.2.10 For intermediate shafts, thrust shafts and inboard end of propeller shafts the coupling flange is to have a minimum thickness of 0,2 times the required diameter of the intermediate shaft, or the thickness of the coupling bolt diameter (see 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 is to be not 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 is to be not less than 0,125 and for other flanges of shafts — not 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 are to 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 are to be not 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 is to 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 are to be ski-shaped, while in propeller shaft cones they are to 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 ski-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 should be also rounded off. The fillet radius should be not less than specified in 5.2.12.

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

5.2.16 Propeller shaft liners are to 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, is not to 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 are to be joined by welding or by other methods approved by the Register. The butt welded joints of the liner should be arranged outside the region of bearings. In case of non-continuous liners the portion of the shaft between the liners is to 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 is to be provided.

Structural provision is to be made for hydraulic testing of the sealing.

5.2.20 The liners are to 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 are to be all fitted bolts of cylindrical section.

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

5.3.2 The coupling bolt diameter, in mm, is not to be less than:

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

where d_{int} = diameter of intermediate shaft determined by Formula (5.2.1) taking into account the ice strengthening requirements under 5.2.5, mm.
If the shaft diameter is increased to account for torsional vibration, d_{int} will be taken as the increased diameter of intermediate shaft;
R_{msh} = tensile strength of the shaft material, MPa;
R_{m_b} = tensile strength of the fitted coupling bolt material, MPa, taken:
$R_{msh} \leqslant R_{m_b} \leqslant 1{,}7R_{msh}$,
but not higher than 1000 MPa;
i = number of fitted coupling bolts;
D = pitch circle diameter of coupling bolts, mm.

The diameter of bolts 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 is not to 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 are to be secured to the shaft.

5.4.2 A keyless assembly should 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, is to 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

$$B = \frac{1}{E_y}\left(\frac{y^2+1}{y^2-1} + v_y\right) + \frac{1}{E_w}\left(\frac{1+w^2}{1-w^2} - v_w\right).$$

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;
v_y = Poisson's ratio for the boss material;
v_w = Poisson's ratio for the shaft material; for steel $v_w = 0{,}3$;
y = mean factor of outside boss diameter;
w = mean factor of shaft bore;

Table. 5.4.3-1

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

Factor y	Copper alloy boss, $v_y = 0{,}34$ with E_y, MPa							Steel boss, $v_y = 0{,}3$ 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	
	ЛУ1, ЛУ2	**ЛУ3**	**ЛУ4**	**ЛУ5**	**ЛУ6**	**ЛУ7**	**ЛУ8, ЛУ9**	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.									

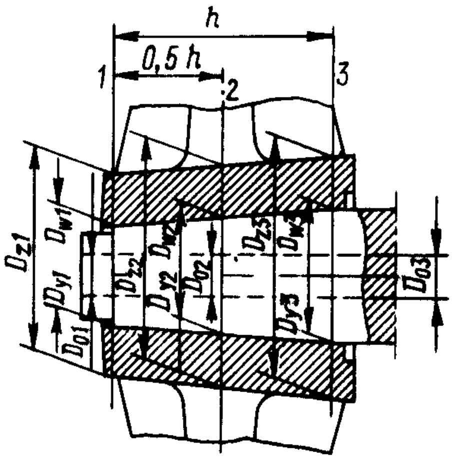


Fig. 5.4.3

D_w = mean outside shaft diameter in way of contact with the boss or intermediate sleeve (see Fig. 5.4.3):
without intermediate sleeve:

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

$D_w = D_y$;

with intermediate sleeve:

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

$D_w \neq D_y$;

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

$$w = \frac{D_{01} + D_{02} + D_{03}}{D_{w1} + D_{w2} + D_{w3}}$$ 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, kN;
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 will 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 is to 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 is to 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 is to 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.

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		

$C = \Delta h_r z$ 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.

5.5 SHAFT BEARINGS

5.5.1 The length of the bearing nearest to the propeller is to be taken according to Table 5.5.1.

Table 5.5.1

Relative length of bearing

Bearing material	l/d [1]
White metal	2 [2]
Lignum vitae	4
Rubber or other synthetic water-lubricated materials approved by the Register	4 [3]

[1] l = length of bearing; d = design shaft diameter in way of bearing.
[2] Length of the bearing may be reduced if the pressure on the bearing does not exceed 0,8 MPa. In this case, the mass of the shaft and the propeller is to be taken as the load, considering that it acts only on the aft bearing. In all cases, the length of the bearing is to be not less than 1,5 of the actual shaft diameter in way of the bearing.
[3] Length of the bearing may be reduced to two design diameters in way of the aft bearing if the results of the operational check are satisfactory.

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

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

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

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

Indication of temperature of oil or bearing bush is to be provided.

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

5.5.5 The distance between the centres of adjacent bearings of the shaftline, where there are no concentrated masses in the span, is to meet the condition:

$$5{,}5\sqrt{d} \leqslant l \leqslant \lambda\sqrt{d} \qquad (5.5.5)$$

where l = distance between the bearings, m;
d = shaft diameter between the bearings, m;
λ = factor taken: 14 for $n \leqslant 500$;
$300/\sqrt{n}$ for $n > 500$;
(n = rated speed of the shaft, rpm).

5.6 BRAKING DEVICES

5.6.1 The shaftline is to 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.

5.7 HYDRAULIC TESTS

5.7.1 Propeller shaft liners and cast sterntubes are to 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.

5.7.2 After assembling, the sealing glands of the sterntube are to be tested for tightness by a pressure head up to the working level of liquid in gravity tanks. In general, the test should be carried out while the propeller shaft is turning.

6 PROPELLERS

6.1 GENERAL PROVISIONS

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 should meet the requirements of the present Section of the Rules.

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 is not to be less than:

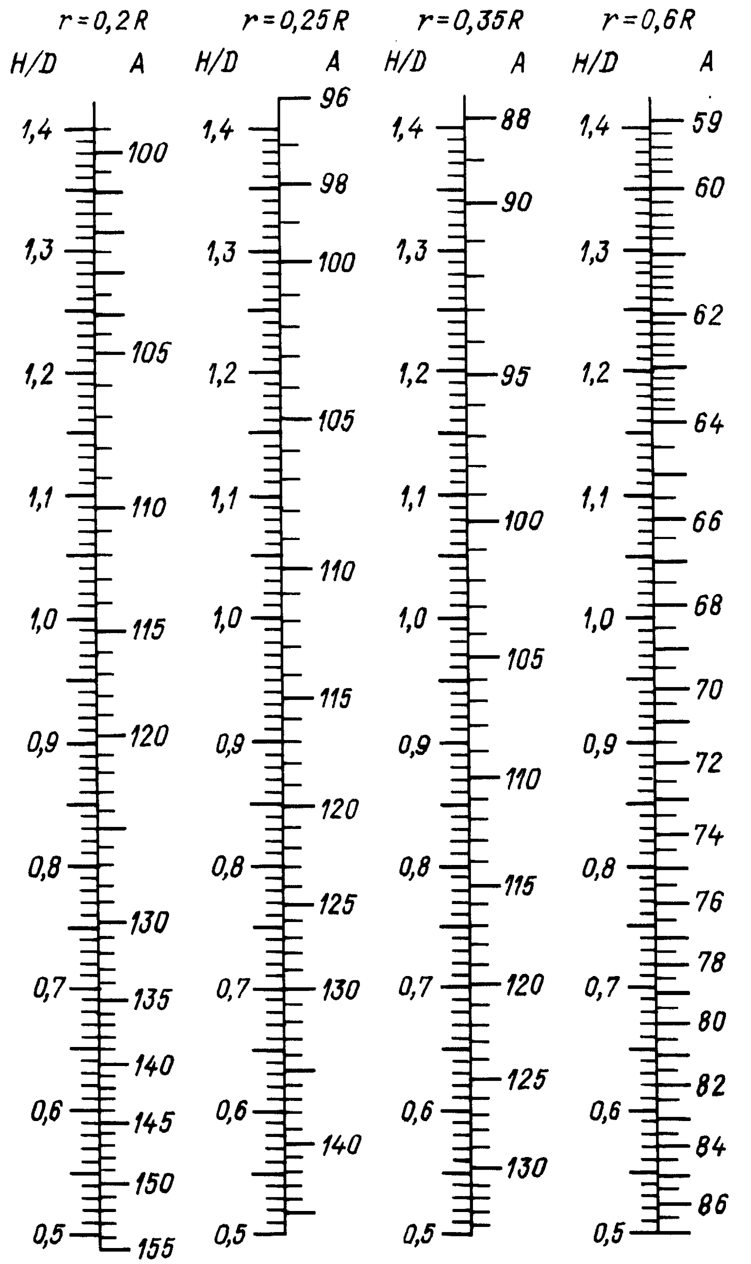


Fig. 6.2.1

Table 6.2.1-1

Coefficient k

Ships without ice strengthening	Ships with ice strengthening categories							Icebreakers	
	ЛУ1, ЛУ2	**ЛУ3**	**ЛУ4**	**ЛУ5**	**ЛУ6**	**ЛУ7**	**ЛУ8, ЛУ9**	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.
Notes: 1. If reciprocating engines with less than four cylinders are installed in the ship, k should 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 **ЛУ1** and **ЛУ2**, k may be reduced by 7 per cent.

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

where A = coefficient to be determined from the nomograph in Fig. 6.2.1 depending on the assumed radius r/R of design section and the pitch ratio H/D at this radius (for a CP-propeller, take the pitch ratio of the basic design operating condition);
k = coefficient obtained from Table 6.2.1-1;
P = shaft power at the rated output of the main propulsion engine, kW;
z = number of blades;
b = width of the expanded cylindrical section of the blade on the design radius, m;
$\sigma=0{,}6R_{m_{bl}}+175$ 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.

Table 6.2.1-2

Coefficient c

r/R	c
0,20	0,50
0,25	0,45
0,35	0,30
0,60	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 II and III may be reduced by 5 per cent.

6.2.2 The blade tip thickness at the radius $D/2$ is not to be less than provided in Table 6.2.2. The leading and trailing blade edge thickness measured at 0,05 of the cross-sectional breadth from the edges should not be less than 50% of blade tip thickness.

Table 6.2.2

Ships without ice strengthening	Ships with ice strengthening categories				Icebreakers
	ЛУ1—ЛУ5	**ЛУ6**	**ЛУ7**	**ЛУ8, ЛУ9**	
0,0035D*	0,005D	0,0055D	0,006D	**	0,008D

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

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 is to be checked in compliance with the requirements of 6.2.1. Besides, the blade thickness at the radius 0.6R at a distance of 0.8 of the width of section b is to be not less than determined from the following formula:

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

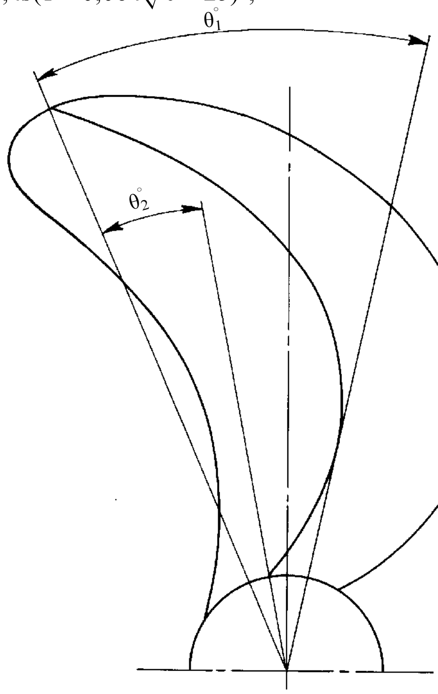


Fig 6.2.4:
θ_1° = angle between the radius drawn through the blade tip and the radius tangent to the mid-chord;
θ_2° = angle between radii drawn through the blade tip and root section centre of the blade

where
s = to be determined from Formula (6.2.1) at the radius 0.6R;
θ = angle, in degrees, equal to angle θ_1 or θ_2, whichever is the greater (see Fig. 6.2.4).

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

6.2.5 In icebreakers and ships provided with ice strengthening, the stresses in most loaded parts of pitch control gear are not to 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 turning 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 are to be not less than 0,04D on the suction side of the blade and not less than 0,03D on the thrust side.

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

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

6.3.2 The propeller boss is to be provided with holes through which the empty spaces between the boss and shaft cone are filled with non-corrosive mass; the latter is also to 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, is not to be less than that determined by the following formula:

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

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 = maximum actual thickness of the blade at design root section (see 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 are to be recessed in the blade flange.

6.4 PROPELLER BALANCING

6.4.1 The completely finished propeller is to be statically balanced.

The extent of balancing is to 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 is not to be more than:

$$m \leqslant km_p/R\ , \qquad (6.4.1)$$

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

Where the propeller mass exceeds 10 tons, the coefficient k is not to 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 is to be designed so as to enable turning the blades into ahead speed position, should the hydraulic power system fail.

In multi-screw ships, except icebreakers and ships with ice strengthening of categories **ЛУ5 — ЛУ9**, 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 is to be constructed according to the requirements of Section 7, Part IX "Machinery", and the pipes are to be tested according to Section 20, 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 is not to 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) are to 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 are to 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 is to be made during blade adjustment.

7 ACTIVE MEANS OF THE SHIP'S STEERING

7.1 GENERAL PROVISIONS

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 should be provided.

Provision in this case should be made for control stations equipped with necessary devices and means of communication as indicated in Chapters 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 should meet the requirements of relevant parts and sections of the Rules.

Moreover, the main AMSS should 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 should 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 should 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 should be taken as for the main AMSS.

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

20000 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 should be equipped with appropriate ventilating, fire extinguishing, drainage, heating and lighting arrangements.

7.2 CONSTRUCTION REQUIREMENTS

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

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

7.2.3 Sealing boxes of a type approved by the Register are to 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 should contain at least two separate, closely effective sealing elements.

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

7.2.5 In case of failure of the prime mover it is to be possible to stop the propeller by means of a braking arrangement independent of the remote control system".

7.3 ALARMS

7.3.1 The AMSS should 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 compartments.

7.3.2 Individual indication units should 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 TESTING

7.4.1 Once assembled, the internal parts of the units should 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 should 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 nondestructive inspection 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 PROVISIONS

8.1.1 The present Section applies to machinery installations 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 are to 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 Voith-Schneider propellers;

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

.3 reverse-reduction gear engagement;

.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).

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

No calculations are to 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.

8.1.3 Torsional vibration calculations should 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.

8.2 PERMISSIBLE STRESSES FOR CRANKSHAFTS

8.2.1 For main engine crankshafts of icebreakers and of ships with ice categories **ЛУ4 — ЛУ9** 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 are not to exceed the values determined by the following formulas:

when calculating a crankshaft in accordance with 2.4.5, Part IX "Machinery",

$$\tau_1 = \pm\tau_N ; \qquad (8.2.1\text{-}1)$$

when calculating a crankshaft by another method,

$$\tau_1 = \pm 0{,}76\,\frac{R_m + 160}{18}\,C_d ; \qquad (8.2.1\text{-}2)$$

within speed ranges lower than indicated

$$\tau_1 = \pm\frac{\tau_N[3 — 2(n/n_r)^2]}{1{,}38} ; \qquad (8.2.1\text{-}3)$$

or

$$\tau_1 = \pm 0{,}55\,\frac{R_m + 160}{18}\,C_d[3 — 2(n/n_r)^2] , \qquad (8.2.1\text{-}4)$$

where τ_1 = permissible stresses, MPa;
τ_N = 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 should be adopted for calculation purposes;
n = speed under consideration, rpm. For tugs, trawlers and other ships whose main engines run continuously under conditions of maximum torque at speeds below the rated speed throughout the speed range, $n = n_r$ should be adopted and Formulas (8.2.1-1) and (8.2.1-2) should be used. For the main diesel generators of ships with electric propulsion plants, all the specified values of n_r should, 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) should be used for partial loads;
n_r = rated speed, rpm;
C_d = $0{,}35 + 0{,}93d^{-0{,}2}$ — scale factor;
d = shaft diameter, mm.

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

for the crankshafts of main engines

$$\tau_2 = 2\tau_1; \qquad (8.2.2\text{-}1)$$

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

$$\tau_2 = 5\tau_1 , \qquad (8.2.2\text{-}2)$$

where τ_2 = permissible stresses for speed ranges to be rapidly passed through, MPa;
τ_1 = permissible stresses determined by one of Formulas (8.2.1-1) to (8.2.1-4).

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

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

for the shafts of icebreakers and ships with ice categories **ЛУ4 — ЛУ9** within the speed range (0,7 — 1,05)n_r, and for the shafts of all other ships and generator shafts within the speed range (0,9 — 1,05)n_r

$$\tau_1 = \pm 1{,}38 \frac{R_m + 160}{18} C_k C_d ; \qquad (8.3.1\text{-}1)$$

within speed ranges lower than indicated

$$\tau_1 = \pm \frac{R_m + 160}{18} C_k C_d [3 - 2(n/n_r)^2] , \qquad (8.3.1\text{-}2)$$

where R_m = tensile strength of the shaft material, MPa. Where the intermediate and thrust shaft materials having the tensile strength above 800 MPa, or propeller shaft materials having the tensile strength above 600 MPa are used, R_m = 800 MPa and R_m = 600 MPa should be adopted for calculation purposes respectively;
C_k = factor obtained from Table 8.3.1;
for C_d , see 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 or transverse hole (see 5.2.7)	0,70
	with a keyway (see 5.2.9)	0,60
	with a longitudinal slot having the length $L \leqslant 1{,}4d$ and the breadth $b \leqslant 0{,}2d$ where d is the design shaft diameter, mm (see 5.2.8)	$0{,}70 - 0{,}25 \times L/d$
Thrust shaft in way of the collar or the roller thrust bearing (see 5.2.2)		0,85
Propeller shaft	forward sections (k = 1,15, see 5.2.3)	0,72
	sections in way of the aft stern-tube bearing and propeller (k = 1,22, k = 1,26, see 5.2.3)	0,55

8.3.2 The total stresses due to torsional vibration within speed ranges prohibited for conti-nuous running, but which may only be rapidly passed through are not to exceed:

for intermediate, thrust, propeller shafts and shafts of generators driven by the main engine

$$\tau_2 = \frac{1{,}7\tau_1}{\sqrt{C_k}} ; \qquad (8.3.2)$$

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

8.4 PERMISSIBLE TORQUE IN REDUCTION GEAR

8.4.1 For the case of continuous running or rapid passage, the alternating torques in any reduction gear step are not to 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 is to 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 **ЛУ4 — ЛУ9**, 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 are not to 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 are to 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) is not to 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 is not to 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 are to be confirmed by measurements. The measurements should cover all the variants and operation conditions of the installation for which calculations were made in accordance with 8.1.2.

Measurements in accordance with 8.1.2.6 and 8.1.2.7 may be omitted provided the results for the other variants of operation of the installation agree with the calculated values.

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 should not differ from the design values by more than 5 per cent. Otherwise, the calculation is to be corrected accordingly.

8.7.4 The stresses should 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 should 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:

$n \geqslant 0{,}7 n_r$ with respect to icebreakers and ships with ice categories **ЛУ4 — ЛУ9**;

$n \geqslant 0{,}9 n_r$ 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 should alternately be adopted for n_r.

In icebreakers and ships with ice categories **ЛУ7 — ЛУ9** fitted with a FPP, blade frequency resonance should be avoided within the range $(0{,}5 — 0{,}8) n_r$.

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 is to 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 **ЛУ4 — ЛУ9** 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 permis-sible values increased by 0,02 of n_{res} on both sides.

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

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

where n_{res} = resonance speed, rpm.

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

Information on restricted speed ranges and their borders should 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 3.2.6 should be complied with.

9 VIBRATION OF MACHINERY AND EQUIPMENT. VIBRATION STANDARDS

9.1 GENERAL PROVISIONS

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 *A* and *B* categories.

9.1.2 Vibration measurements of machinery and equipment are to be taken during construction of the ship according to the program approved by the Register. Technical documentation as per the measurement results is to be submitted according to the requirements of 1.5.4, Part II "Hull".

Vibration measurements of machinery and equipment are to be performed in compliance with the instructions of 17.7, Part 4 "Supervision during construction of ships" of Guidelines on Technical Supervision During Construction of Ships and Manufacture of Materials and Products.

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 are to be compared with the permissible vibration levels.

Where vibration exceeds the standards, measures are to 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 9.7 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 are to 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 should 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.

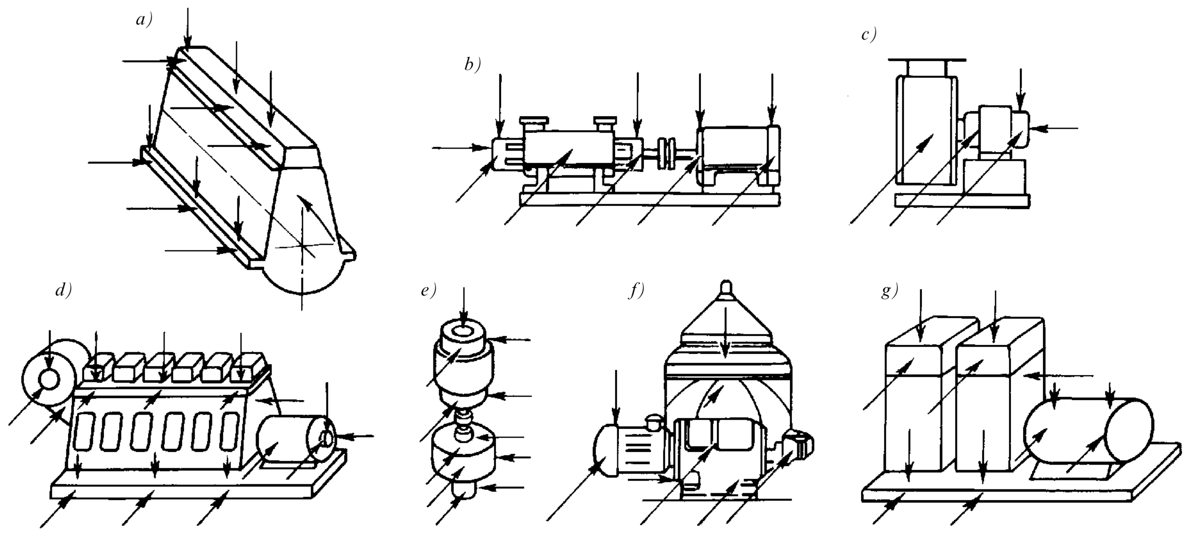


Fig. 9.2.5 Points of vibration measuring:
a) internal combustion engine; b) horizontal pump; c) fan; d) diesel-generator;
e) vertical pump; f) separator; g) piston compressor.
The points and directions of vibration measurement are shown by arrows

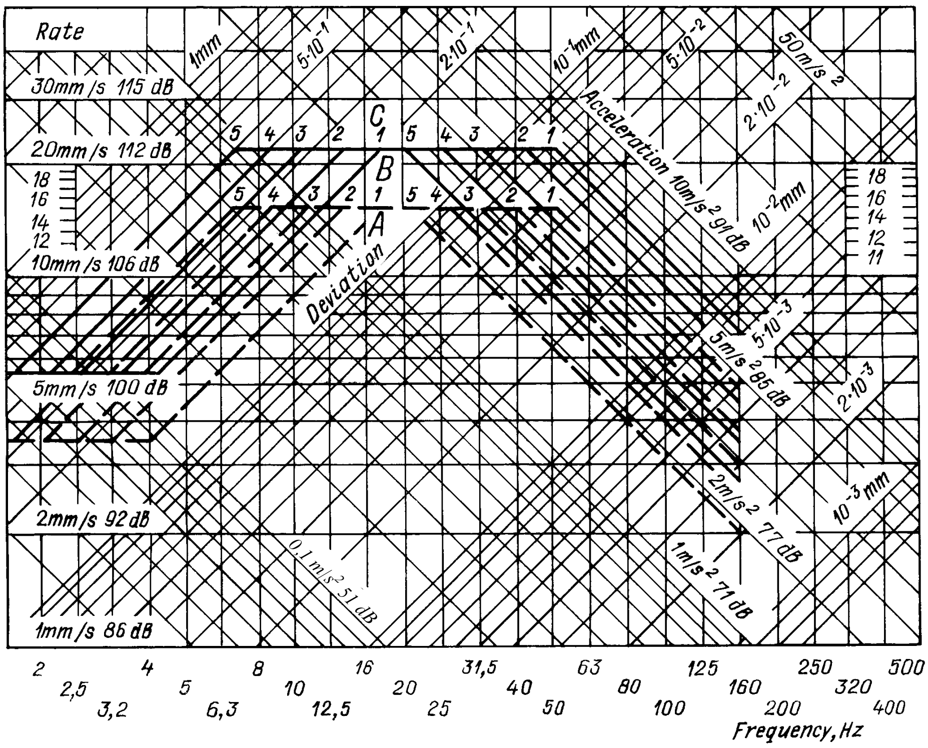


Fig. 9.3.2 Vibration standards for internal combustion engines with a piston stroke:
1- under 30 cm; *2* - 30 to 70 cm; *3* - 71 to 140 cm; *4* - 141 to 240 cm; *5* - over 240 cm.
_ _ _ _ Upper limit of Category *A*; ________ Upper limit of Category *B*

9.4 VIBRATION STANDARDS FOR MAIN GEARED TURBINES AND THRUST BEARINGS

9.4.1 The running vibration of 15000 - 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 should 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

T a b l e 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				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

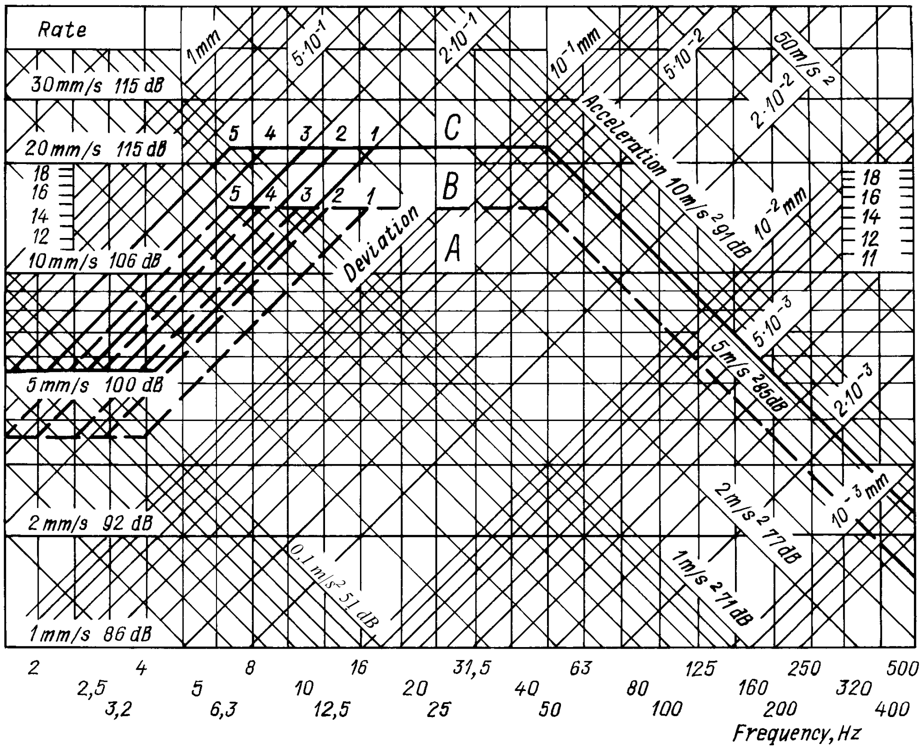


Fig. 9.3.4 Vibration standards for turbo-compressors of internal combustion engines: for *1, 2, 3, 4* and *5* - see Fig. 9.3.2;

— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

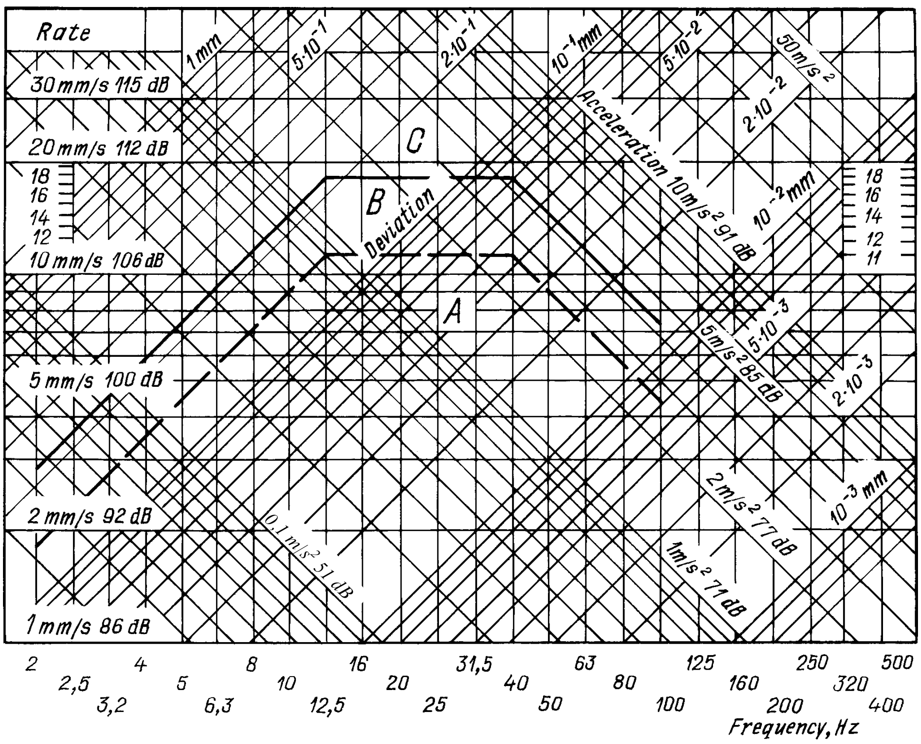


Fig. 9.4.1 Vibration standards for main steam geared turbines of 15000 - 30000 kW capacity and thrust bearings:

— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

9.5 VIBRATION STANDARDS FOR AUXILIARY MACHINERY OF ROTARY TYPE

9.5.1 Vibration of vertical pumps with the capacity of 15 - 75 kW, including their electric drive, is assumed permissible for the 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 - 15 kW the vibration standards for the categories *A* and *B* are assumed being 3 dB lower compared with the vibration standards for the pumps hewing the capacity of 15 - 75 kW, and for the pumps with the capacity of 75 - 300 kW such standards are to 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 the 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 the 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 - 2000 kW, measured on the bearing housings, is assumed permissible for the 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 the 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 - 75 kW				Centrifugal separators				Fans			
	Permissible values of vibration rate											
	Category *A*		Category *B*		Category *A*		Category *B*		Category *A*		Category *B*	
	mm/c	dB	mm/c	dB	mm/c	dB	mm/c	dB	mm/c	dB	mm/c	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

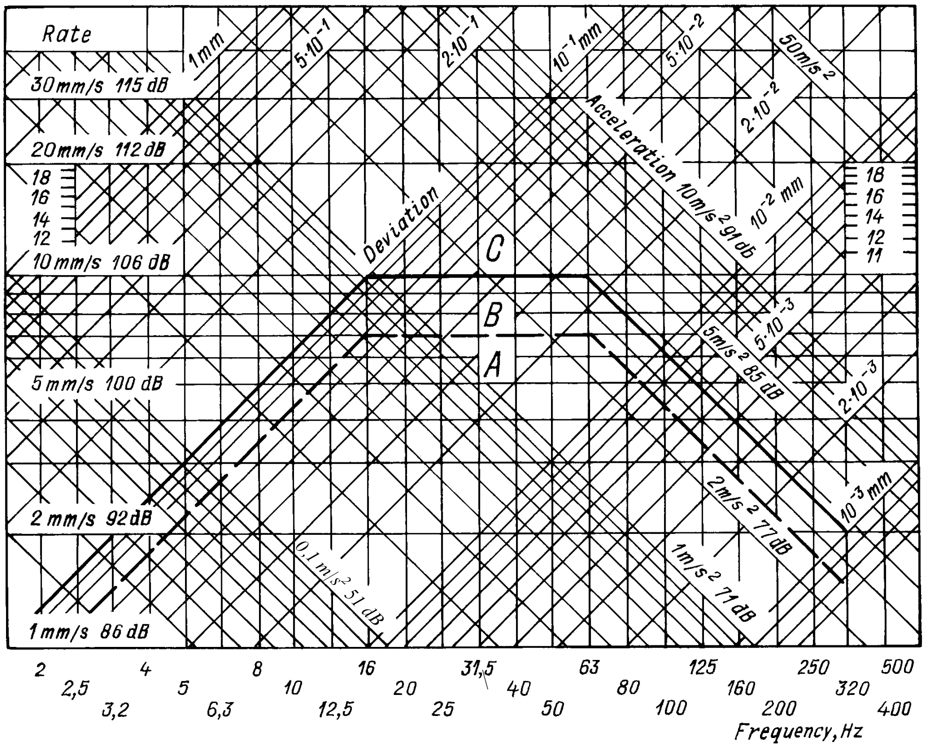


Fig. 9.5.1 Vibration standards for pumps with the capacity of 15 — 75 kW:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

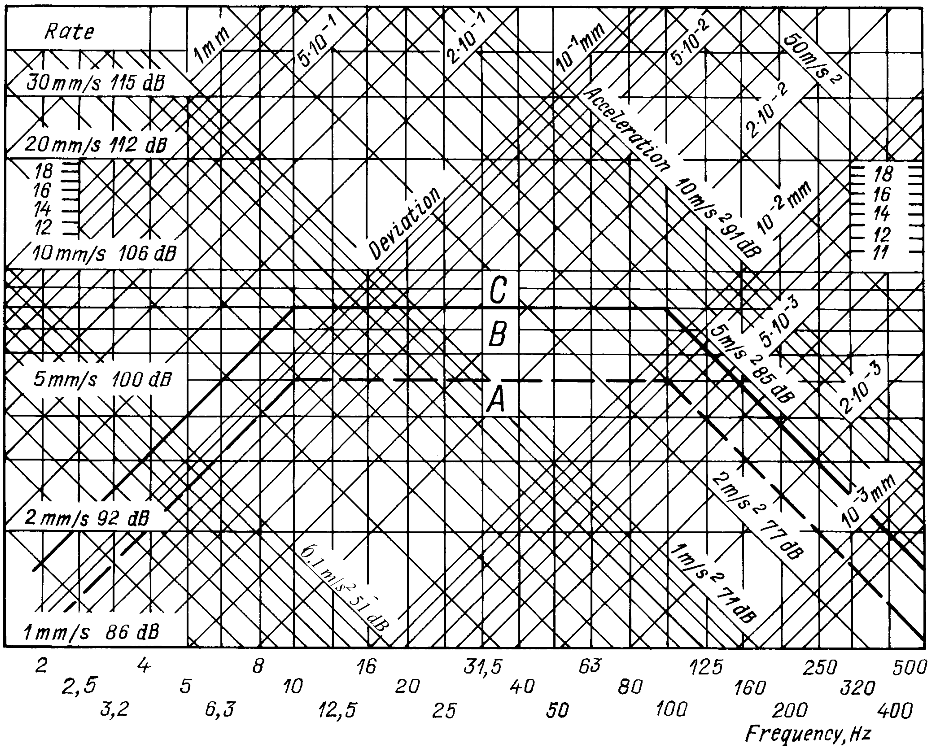


Fig. 9.5.2 Vibration standards for centrifugal separators:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

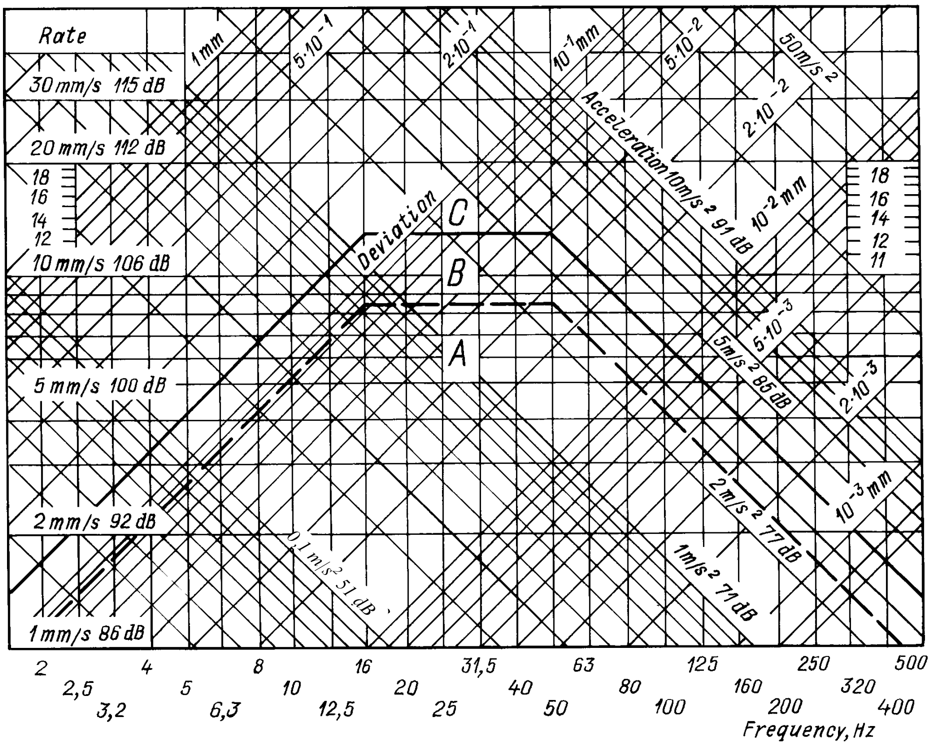


Fig. 9.5.3 Vibration standards for fans:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

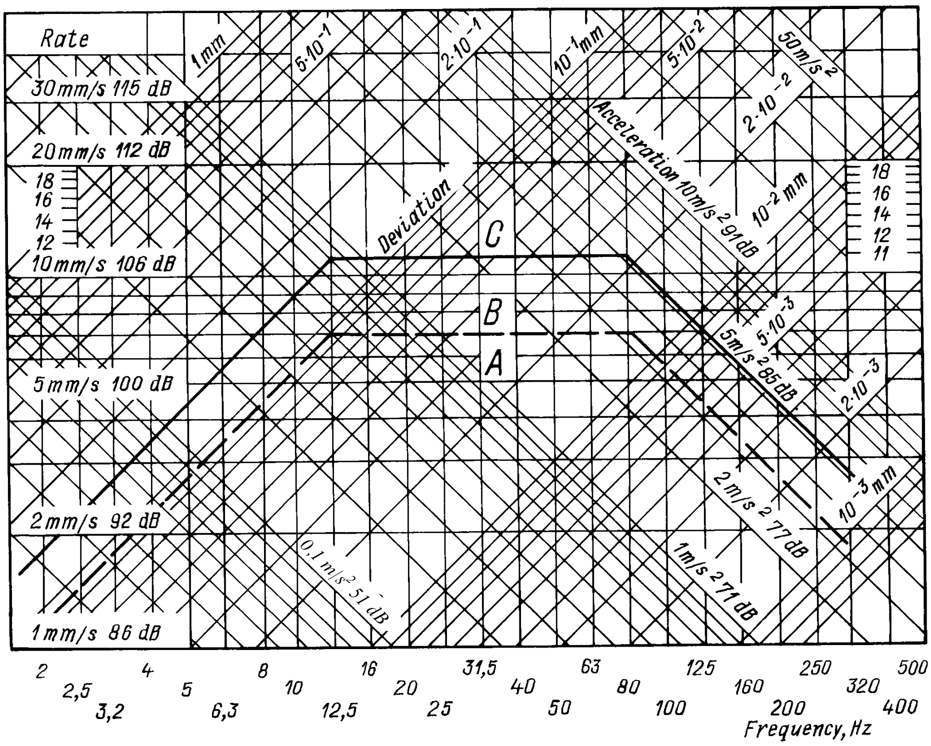


Fig. 9.5.4 Vibration standards for ICE-driven generators, shaft-generators, turbo-drives and turbo-generators of 1000 - 2000 kW capacity:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

9.6 VIBRATION STANDARDS FOR PISTON AIR COMPRESSORS

9.6.1 Vibration of piston air compressors is assumed permissible for the 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 are to 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 the 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, are to be chosen based on 9.7.1.

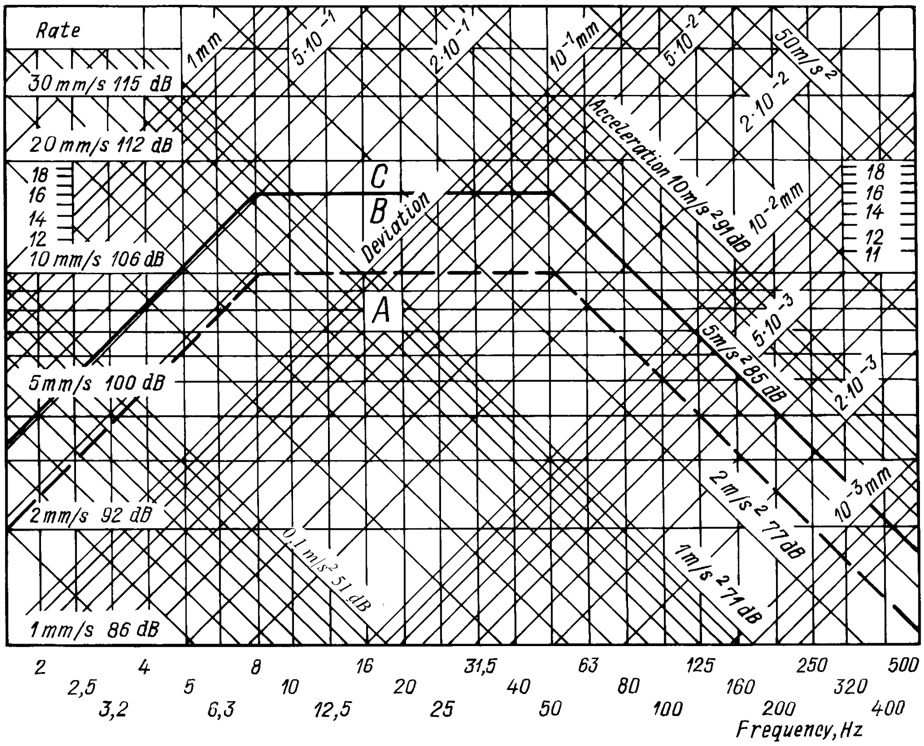


Fig. 9.6.1 Vibration standards for piston compressors:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

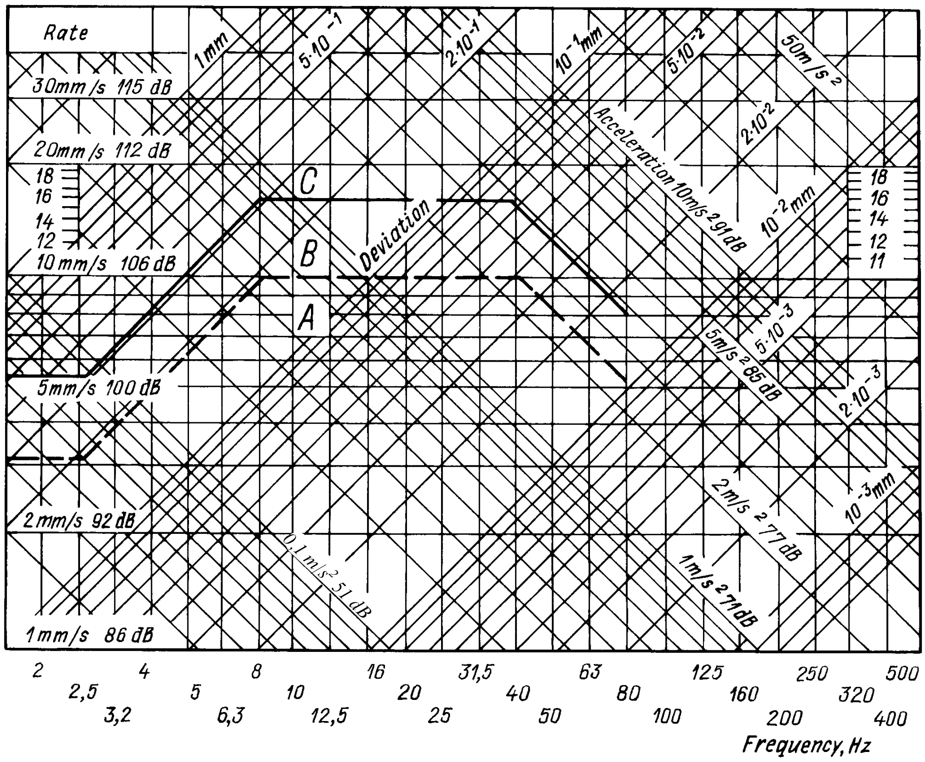


Fig. 9.7.1 Vibration standards for boilers, auxiliary machinery and equipment:
— — — — Upper limit of Category *A*; ———— Upper limit of Category *B*

10 SPARE PARTS

10.1 GENERAL PROVISIONS

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.

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 are to be properly secured in easily accessible places, marked and efficiently protected against corrosion.

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 is to be taken.

10.1.7 For ships assigned to restricted navigation areas II, III, II СП, III СП and for floating docks, the required minimum of spare parts is not regulated.

For the definitions of restricted areas of navigation, see 2.2.5.1 of Part I "Classification

10.2 REQUIRED MINIMUM OF SPARE PARTS

Table 10.2-1

Internal combustion engines

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 I		unrestricted	restricted I	
1	Main bearings or shells of each type and size fitted, complete with shims, studs (bolts) and nuts	1		O	—		—
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. For engines without covers, respective valves	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	2 sets	1 set	P	2 sets	1 set	P
4.2	Air inlet valves, complete with casings, seats, springs and other fittings, per cylinder	1 set		P	—		—
4.3	Starting air valve, complete with casing, seats, springs and other fittings	1	1	O	1	—	P
4.4	Overpressure sentinel valve, complete	1	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	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

Table 10.2-1 - continued

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 I		unrestricted	restricted I	
10.2	High pressure fuel pipe of each size and shape fitted, complete with unions	1	—	O	1	—	P
11[6]	Scavenge blowers including turbo-chargers						
11.1	Rotors, rotor shafts, bearings, gear wheels, nozzle devices, seal parts, suction and discharge valves (proceeding from the type of supercharger)	1 set	—	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 should be determined by the shipowner with regard for 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 should be provided for the case of turbocharger being damaged.

Table 10.2-2

Steam turbines (main and auxiliary) [1,2]

Nos	Spare parts	Number of spare parts on board depending on the navigation area		Supply of spare parts
		unrestricted	restricted I	
1	Main bearings bushes of each size and type, per turbine	1 set per bearing		O
2[3]	Pads of each size for one face of thrust block with liners, or adjusting rings of each size fitted, with assorted liners, per turbine	1 set		O
3	Roller type bearings of each type and size, if fitted	1		O
4	Carbon sealing rings for each type and size of gland	1 set		O
5	Strainer baskets, inserts and other detachable parts for oil filters of special design, each type and size	1 set for filter		O

[1] For installations comprising several turbines of the same type, spare parts are required for one turbine only.
By turbines of the same type, turbines are meant the identical parts of which are interchangeable.
[2] Where the number of auxiliary turbines of adequate capacity exceeds the number required by the Rules, no spare parts are necessary for auxiliary turbines.
[3] When the pads of one face differ from those of the other, one set is required for each face.

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 I	
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		Supply of spare parts
		unrestricted	restricted I	
	Shafting			
1	Thrust block of shaftline			
1.1	Pads for ahead face of Mitchel type thrust block, where used	1 set		O
1.2	Inner and outer race with rollers where roller thrust bearings are used	Ditto		O
2	Coupling bolts with nuts for flanges and shaft couplings, each type and size fitted	1 coupling set		P
	Propellers			
3[1]	Detachable propeller blades complete with securing items (for icebreakers and ships with ice categories **ЛУ4 — ЛУ9** only)	2 per propeller	—	O
4[1]	CP-propeller blades complete with securing items (for icebreakers and ships with ice categories **ЛУ4 — ЛУ9** only)	Ditto	—	O
5	Spare parts for arrangements of CP-propellers, propulsion units, Voith-Schneider 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		Supply of spare parts
		unrestricted	restricted I	
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		Supply of spare parts
		unrestricted	restricted I	
	Hydraulic steering gears			
1	Plunger seals 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 I	
	Steam boilers (main and auxiliary for essential services), thermal fluid boilers			
1	Springs of safety valves	1 per boiler		O
2	Water gauge glasses, complete	Ditto		O
3[1]	Oil fuel burners, complete, each type and size fitted	- " -		O
4[1]	Fuel atomizers complete with washers	- " -		O
5	Tube plugs of each diameter fitted, including superheater plugs	For 4% of tubes (but not more than 20 pcs)		O
6	Boiler pressure gauge of each type and size fitted	1 set of boiler unit		O
7	Metal gaskets of special type for superheater and economizer fittings	1 set for 1 boiler		P
8	Gaskets for manholes and other openings, each type and size fitted	1 set		P
	Pressure vessels and heat exchangers			
9	Level gauge glasses of each type and size fitted	1		P
10	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
11	Plugs for heat exchanger tubes	For 5% 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	Number of spare parts on board depending on the navigation area		Supply of spare parts
		unrestricted	restricted I	
	Turbines and compressors			
1	Bearing bushes of each type and size fitted	1 set per engine		O
2	Ball or roller bearings of each type and size fitted	1		O
3	Thrust bearing pads of each type and size fitted	1 set per engine		O
4	Bolts and nuts for split casing of main turbines of each type and size fitted	5 %	—	P
5	Bolts (studs) and nuts for main turbine bearings of each type and size fitted	1	—	P
6	Seal components complete with springs of each type and size fitted	1 set per engine		P
	Combustion chambers			
7	Flame tubes	1 set per combustion chamber		O
8	Main burners	Ditto		O
9	Auxiliary burners	- " -		O
10	Ignition arrangements, complete	1 set per engine		O
11	Ignition plugs	1 set per combustion chamber		O
12	Atomizers of main burners	1 per burner		O
13	Atomizers of auxiliary burners	Ditto		O

SYMBOLS FOR TABLES 10.2-1 — 10.2-8:

O — required;
P — recommended.

PART VIII. SYSTEMS AND PIPING

1 GENERAL

1.1 APPLICATION

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

.1 bilge and drain;
.2 ballast, heel and trim;
.3 cargo oil;
.4 liquefied gas;
.5 toxic media;
.6 steam and blow-down systems of boilers;
.7 feed water and condensate;
.8 fuel oil;
.9 lubricating oil;
.10 cooling water;
.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 must comply with the requirements of the present Part of the Rules insomuch as applicable and sufficient unless expressly provided otherwise below.

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

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

1.2 DEFINITIONS AND EXPLANATIONS

In the present Part of the Rules the following definitions are accepted:

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.

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 SUPERVISION

1.3.1 General provisions relating to classification procedure, construction supervision and surveys, as well as requirements for technical documentation submitted to the Register for consideration and

Table 1.3.2

Piping system for	Class I	Class II	Class III
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, liquefied gases[3]	Without special safeguards[1]	With special safeguards[1]	—
Steam and thermal oil[4]	$p > 1{,}6$ or $t > 300$	$p \leqslant 1{,}6$ and $t \leqslant 300$	$p \leqslant 0{,}7$ and $t \leqslant 170$
Fuel oil, lubricating oil and hydraulic oil	$p > 1{,}6$ or $t > 150$	$p \leqslant 1{,}6$ and $t \leqslant 150$	$p \leqslant 0{,}7$ and $t \leqslant 60$
Other media[5,6]	$p > 4{,}0$ or $t > 300$	$p \leqslant 4{,}0$ and $t \leqslant 300$	$p \leqslant 1{,}6$ 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, as defined in 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.

approval, are set forth in General Regulations for the Supervision and in Part I "Classification".

1.3.2 For the purpose of testing, the type of joint to be adopted, heat treatment and welding procedure, pipes are subdivided into three classes as indicated in Table 1.3.2.

1.3.3 Class I, Class II and Class III pipes, Class I and Class II pipelines fittings, as well as 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 supervision of the Register during manufacture.

Class III pipelines fittings shall have Type Approval Certificate of the Register.

1.4 PROTECTION AND INSULATION OF PIPING

1.4.1 Insulation of piping.

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

1.4.2 Protection against corrosion.

1.4.2.1 Steel pipes of sea water, as well as air, sounding and overflow pipes of water tanks and of tanks for alternative carriage of water ballast and fuel oil, cargo tanks vents and air pipes of cofferdams in oil tankers, shall be protected against corrosion upon completion of bending and welding work by a method approved by the Register.

Zinc coating may be used as such protection. In this case zinc coating of pipes shall be applied by a hot method upon completion of pipe bending and all the welding. The minimum thickness of zinc coating layer shall be not less than 50 micron. Depending on the purpose of piping the Register may require the increasing of the coating thickness. Aluminium coatings of pipelines are allowed in ballast tanks, in cargo inerted tanks, as well as in dangerous areas on the open deck, provided their protection of the accidental impacts. Application of zinc coating does not relieve of measures for protection of pipelines against contact corrosion.

1.4.2.2 During the design and installation of the ship's sea water piping the constructional measures for reduction of corrosion-erosion wear of pipelines shall be provided.

1.4.2.2.1 A number of detachable joints shall be minimum. Detachable joints shall be located in the places accessible for inspection, maintenance and repair.

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

1.4.2.2.3 Pipelines shall be made with the minimum number of bends. The radii of pipe bends shall be at least 2,5 of their external diameter.

Where the use of bends with less radii is required, the special fittings shall be applied.

For pipes with the nominal diameter less than 200 mm the use of welded bends made of segments is not allowed. A number of segments for 90° bend shall be not less than three.

The use of bent or welded fittings for the manufacturing of side and kingston valve branch pipes is not permitted.

1.4.2.2.4 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.

1.4.2.2.5 Flow velocity determined according to the Formula (1.4.2.2.5) for the pipelines sections, including welded fittings (tee-pipes, welded-on pieces, etc.), throttle membranes, as well as side and kingston branch pipes, shall not exceed the values stated in Table 1.4.2.2.5.

The compliance of the design flow velocity in the above mentioned sections of pipelines as well as kingston connecting channels with the present requirements shall be verified by the calculation according to the formula:

$$V_{mean} = 354Q/d^2, \quad (1.4.2.2.5)$$

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

Table 1.4.2.2.5

Material of the pipeline	Allowable flow velocity, m/s
Steel, including galvanized	2,5
Copper	0,9
Copper-nickel alloys	
Cu Ni 5 Fe	2,0
Cu Ni 10 Fe	2,5
Cu Ni 30 Fe	3,5
Aluminium brass	2,0
Notes: 1. For pipelines with fittings having the rounding radii in the places of conjunction with the main being equal to 0,15 diameter of the latter and more, bent branch pipes with the bending radius in excess of 2,5 external diameters, without welded turns and throttle membranes, the flow velocity may be 30 % higher than the values stated in the table. 2. In low-activity systems - flooding, water seal, sprinkling, ballast, heel, trim systems - the allowable values of flow velocity, regardless of the design-technological version of the applied piping components, may be 30 % higher than the values stated in the table.	

1.4.2.3 Where bottom and side fittings of nonferrous metal alloys, provision shall be made for cathodic protection of the ship's shell and all components coming into contact with those fittings against contact corrosion. Cathodic protection of filling and overboard welded branch pipes with fittings against contact corrosion shall be made with the use of standard ring end or ring flange protectors to be mounted on branch pipes flanges. The use of electric insulating joints of the mating components made in accordance with the approved standards is allowed; in this case, bottom and side fittings shall be insulated on both sides with the obligatory measuring of the joint insulation resistance upon completion of installation.

1.4.2.4 Where galvanized pipes of sea water systems are connected to fittings, pumps casings, machinery units and heat exchangers of copper alloys, precautions shall be taken against contact corrosion.

1.4.3 Protection against excessive pressure.

1.4.3.1 The pipelines in which pressure in excess of the design pressure are possible, shall be fitted with arrangements which will prevent the pressure rising above the design pressure of the piping.

Open escape of fuel and lubricating oil from relief valves is not permitted.

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

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

1.5 WELDING AND NON-DESTRUCTIVE EXAMINATION OF WELDS

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

1.6 MACHINERY, APPARATUS AND CONTROL DEVICES

1.6.1 Pumps, fans, compressors and the electric drives used in systems described in this Part are to comply also with requirements of Part IX "Machinery" and Part XI "Electrical Equipment".

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

1.6.3 Heat exchangers and pressure vessels used in ships systems are to comply with 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 requirements of Part XIII "Materials".

The materials for pipes, fittings and drives, intended for especially corrosive media, will be considered by the Register in each case. The fuel and lubricating oil pipes, fittings and their couplings are to be manufactured of steel or other materials which comply with the requirements of the Register as far as their strength and fire-resistance are concerned.

2.1.2 In general, pipes and fittings of carbon steel and carbon-manganese steel are to 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 are to be manufactured of alloy steel. Exhaust gas pipes are excluded from this requirement.

2.1.3 Copper and copper alloy pipes are to 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 are generally to be used for media having temperature not in excess of 200° C, and those of copper-nickel alloys, for temperature not over 300° C (see Table 2.3.5.3). Bronze fittings may be admitted for media having temperatures up to 260° C.

2.1.4 Spheroidal or nodular graphite cast iron may be admitted for pipes and fittings of bilge, ballast and liquid cargo piping within double bottom or cargo tanks.

The use of such pipes and fittings in other locations, as well as for other service in Classes II and III, will be specially considered by the Register.

Spheroidal graphite cast iron fittings may be admitted for media with temperature not over 350° C.

Ship side fittings and branches, the bottom fittings, as well as the valves and fittings referred to in 4.3.2.4, 4.3.2.6 — 4.3.2.8, 4.3.2.10 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".

2.1.5 Grey cast iron piping may be used for cargo lines inside cargo and slop tanks.

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 of tankers, except for the end fittings of cargo piping for connection to the loading/discharge hoses.

The use of grey cast iron for pipes and fittings for other services in Class III will be specially considered by the Register. However, it 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 connected to the shell plating;

.4 sea valves fitted on ship sides and collision bulkhead;

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

.6 fittings of systems containing thermal liquids.

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

2.1.7 Application of plastic pipes shall be performed in compliance with Table 3.3.1.2.

2.1.8 Flexible joints (hoses).

2.1.8.1 The type and design of flexible joints used for systems listed in 1.1.1 shall be approved by the Register. The material of flexible joints shall be selected with regard to the applicable media to be conveyed, pressures, temperature values and environmental conditions. Disruptive pressure of flexible joints (except ventilation systems) shall be at least 4 times higher than the design pressure.

2.1.8.2 In the pipelines conveying fuel oil, oil and other flammable liquids, as well as in pipes connected with the drives of watertight doors or openings in shell plating only fire-resistant flexible joints supplied as fabricated inserts with connecting items (flanges or screwed nipple unions) are permitted for use. Where such flexible joints are installed in engine rooms of A category the possibility of their disconnection in case of damage shall be provided. Shut-off valves shall be located in readily accessible positions in the vicinity of flexible joints so that any flexible joint can be replaced without stopping other machinery.

2.1.8.3 A joint is considered fire-resistant if, being connected to a pipe in which water is circulating at a temperature not less than 80°C at the maximum working pressure, it withstands fire for 30 min at a temperature of 800°C and its integrity is preserved during and after a proof pressure test. An alternative to this test are the above-mentioned fire tests with circulating water pressure equal to 0,5 MPa with further hydraulic test for double design pressure.

2.1.8.4 When a flexible joint is made of steel or another equivalent material complying the requirements of the Register in respect of fire-resistance, fire-resistance test is not required.

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

2.1.10 The self-closing fittings of sounding pipes of the oil fuel tanks in double bottom shall be corrosion-resistant and shall not initiate sparks.

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

2.2 RADII OF PIPE BENDS, HEAT TREATMENT AFTER BENDING

2.2.1 Radii of pipe bends.

The inner radius of bend of the boiler blow off pipes is to be at least 3,5 d_1 (d = 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, is to be at least 2,5 d (d = pipe outside diameter).

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

2.2.2 Hot bending of stell pipes is to be generally carried out in the temperature range 1000 — 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 — 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 —

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 $r \leqslant 4\,d$, 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 — 640°C, 1 Cr — 0,5 Mo steel with a wall thickness >8 mm at 620 — 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 — 720°C.

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

2.2.6 Preheating before welding and postweld heat treatment should be effected in accordance with 2.5.5, 2.5.6 and 2.5.7, Part XIV "Welding".

2.3 PIPE WALL THICKNESS

2.3.1 The wall thickness of metal pipes (except cast iron pipes) operating under the internal pressure shall not be less than determined by the formula (see also 2.3.8):

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

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 accor dance with 2.3.5 - 2.3.7, MPa;
c = allowance for corrosion taken in accordance with Table 2.3.1-1 for steel pipes and Table 2.3.1-2 for pipes of nonferrous metals, mm;
a = negative manufacturing tolerance for pipe wall thickness, % (when pipes without negative allowance are used, $a = 0$).

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. If pipes are fitted with efficient protection, then, at the iscretion of the Register the allowance for corrosion may be reduced by the value up to 50 %.
2. Where pipes of special steel alloys 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 ⩾ 10%)	0,5

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

2.3.2 The design pressure on the basis of which the calculations of pipelines strength are made shall be assumed equal to the maximum pressure of the safety valves opening. 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 fuel oil heated above 60°C the design pressure shall be taken not less than 1,4 MPa.

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 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 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, 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;

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

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

The design temperature t for determining permissible stresses is taken as the maximum temperature of the medium inside the pipes. 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 $R_{0.2/t}/1{,}8$; $R^{100\ 000}_{m/t}/1{,}8$; $R^{100\ 000}_{p1/t}/1{,}0$.

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:

$$R_{m/20}/4{,}0;\ R_{0.2/t}/1{,}6;\ R^{100\ 000}_{m/t}/1{,}6.$$

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

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

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

2.3.7 The wall thickness of cast iron pipes are subject to special consideration by the Register in each case.

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

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 95/5 and 90/10	Ditto	270	69	69	68	66	64	62	59	56	52 5,3	48	44
Copper-nickel 70/30	Ditto	360	81	79	77	76	74	72	70	68	66	64	62

Notes: 1. Intermediate values should 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 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 (see also 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 national and international standard values are acceptable 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 diameters greater than those stated in the Table, the minimum thicknesses will be subject to special consideration by the Register in each case.

4. The minimum internal diameters of drain, sounding, air and overflow pipes shall be accepted in compliance with 7.2.3, 10.5.7 and 10.1.13 accordingly.

5. If the pipes are efficiently protected against corrosion, then, at discretion of the Register, the wall thicknesses of pipes, stated in colns 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 colns 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 deep 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. During the installation and operation of titanium pipes systems the accidental overloading or impacts shall be avoided because light-wall pipes are used.

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 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 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 60,3 mm except the pipelines conveying toxic or corrosive media and for operation under heavy fatigue loads, excessive corrosion and erosion.

2.4.3 Flange connections.

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

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

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.

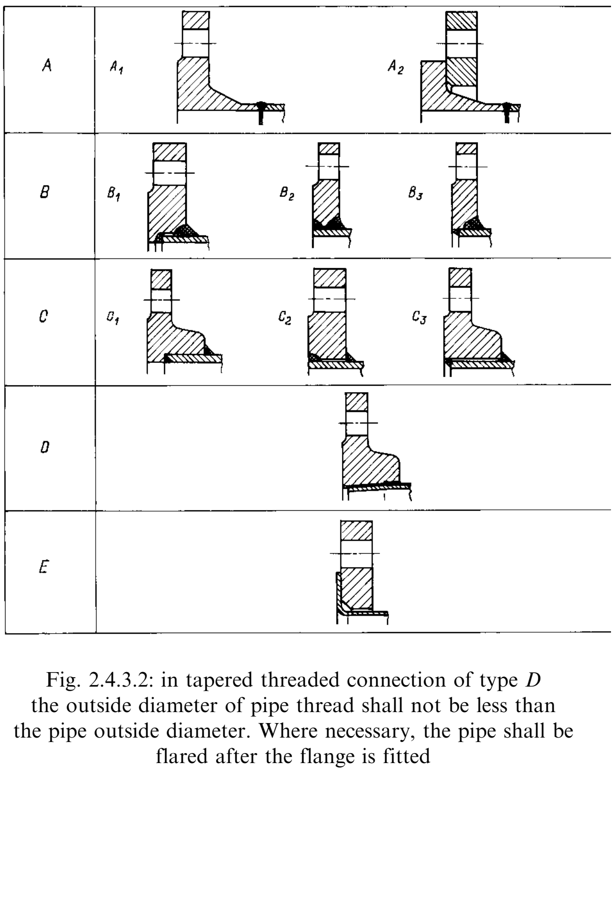


Fig. 2.4.3.2: in tapered threaded connection of type *D* the outside diameter of pipe thread shall not be less than the pipe outside diameter. Where necessary, the pipe shall be flared after the flange is fitted

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] Only type *A* when design temperature exceeds 400°C.
[3] Only type *A* when design pressure is over 1 MPa.
[4] Types C_3, *D* and *E* (see Fig. 2.4.3.2) are not to be used when design temperature exceeds 250°C.
[5] Type *B* - for pipelines with outside diameter of 154,4 mm and lower.
[6] Type *E* - the flanging technology shall be approved by the Register.

2.4.4 Tapered threaded connections.

2.4.4.1 Threaded slip-on sleeve connections with buttress screw thread may be applied in Class I pipelines with the diameter up to 33,7 mm and Class II pipelines with the outside diameter up to 60,3 mm, except systems containing toxic and flammable media and for operational conditions with heavy fatigue loads, excessive corrosion and erosion.

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 Mechanical joints are pipelines joints different from welded, flange or threaded connections described in 2.4.2 — 2.4.4.

The present requirements are applicable both to various screwed nipple unions ensuring rigid fixing of pipe ends, and slip-on sleeve connections which allow shifting of pipe ends in axial and/or radial directions.

The used types of mechanical joints shall be approved by the Register.

2.4.5.2 Design of mechanical joints is to exclude the possibility of their spontaneous opening under the influence of pipeline vibration, change of pressure and temperature, as well as other influences, connected with operational conditions on board the ship.

2.4.5.3 In case application of the joint results in thinning of pipe wall, this shall be taken into consideration while determining the permissible pipe wall thickness for threaded connections (see Note 7 to Table 2.3.8).

2.4.5.4 Materials of mechanical joints shall be compatible with pipe materials resistant to the media conveyed.

2.4.5.5 Mechanical joints shall resist pressure 4 times exceeding the design pressure.

When design pressure is 20 MPa and above, the test pressure value may be decreased upon the agreement with the Register.

2.4.5.6 As a rule, mechanical joints intended for use in systems conveying flammable media and in essential purpose systems shall be fire-resistant.

2.4.5.7 The use of mechanical joints for direct connection to side openings and tanks with combustible liquids is not allowed.

2.4.5.8 Mechanical joints used on intake sections of pipelines shall be serviceable in pumpdown (vacuum) conditions.

2.4.5.9 The number of mechanical joints shall be kept to the minimum. Their assembling shall be performed in accordance with the manufacturer requirements.

2.4.5.10 The possibility of mechanical joints application in cargo holds, tanks and other not easily accessible positions is a matter of special consideration by the Register in each case.

Their use inside the tanks may be permitted when homogeneous media are contained in tanks and pipes.

2.4.5.11 The use of mechanical joints depending on pipes class shall be made in compliance with the requirements of Table 2.4.5.11.

2.4.5.12 Mechanical joints shall be tested according to the program approved by the Register. Such tests shall include at least the following checks: proof pressure $p_{pr.} = 4p$, vibration, fire-resistance, holding force in axial direction, serviceability in pumpdown (vacuum) conditions.

The Register may nominate additional checks considering the peculiarities of structure and purpose of the pipeline.

2.4.5.13 The use of other types of pipelines joints not mentioned in the present Chapter is subject to special consideration by the Register in each case.

Table 2.4.5.11

Types of joints	Class of pipeline		
	I	II	III
Screwed nipple and nipple unions:			
soldered and welded	+[1]	+[1]	+
with a ring inserted	+[1]	+[1]	+
with pipe flaring	+[2]	+[1]	+
Socket joints	—	+	+

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

[1] For pipes with external diameter up to 60,3 mm.
[2] For pipes with external diameter up to 33,7 mm.

3 PLASTIC PIPING

3.1 TERMS AND DEFINITIONS

3.1.1 Plastic materials are thermoplastic (thermoplasts) and thermosetting (thermosets) materials with reinforcement and without it, such as polyvinylchloride (PVC) and fibre reinforced plastic (FRP).

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 the 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.

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, pipelines tunnels, etc. shall obtain characteristic of slow spreading of flame on the surface, not exceeding the average values fixed in the IMO Resolution A.653(16) and determined according to the procedure given in Annex 3 to the Resolution 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 ration 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

Table 3.3.1.2

Application of plastic pipelines

Nos	Medium to be conveyed	Location											
		Piping systems	A	B	C	D	E	F	G	H	I	J	K
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	O	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 rooms 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".

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 Pipelines may be connected with the use of glued, welded, flanged and other connections.

3.5.1.3 Glues used for assembling of pipelines 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 are to include at least one joint of pipe with pipe and pipe with formed component.

3.5.2.2 After setting of a test joint junction the hydraulic test with pressure 2,5 times higher than the design pressure shall be performed during at least 1 hour. 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 should 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 should be 200 mm or to be equal to 25 % of the maximum diameter of the coupling, whatever is greater.

3.6 PLASTIC PIPING LAYING

3.6.1 Where plastic pipes pass through watertight fire decks and bulkheads of "A" and "B" types 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 for grounding 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 are to 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 is to 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 are to 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 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 are to 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 is not to 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 led down to each valve, or to a separate pipe leading directly to the valve actuator.

4.1.1.5 The supply tank of the hydraulic remote control system of the valves inside cargo tanks is to be located as high as practicable above the level of the top of cargo tanks, and all supply pipes are to enter the cargo tanks through the highest part of the tanks.

The supply tank is also to have an air pipe led to a safe position on the open deck and fitted with a flame-arresting gauze at the open end.

This tank is to be fitted with a low level audible and visual alarm.

4.1.2 Marking of fittings.

4.1.2.1 The shut-off fittings are to 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 are to have identification plates, as well as position indicators "open" and "closed".

Where the remote control is used only to close the valve, 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 are not to be through holes.

4.1.3.2 The valve chests and the hand-controlled valves are to 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 should be fitted above the plating.

4.1.3.3 The measuring instruments of fuel oil and lubricating oil systems should be provided with valves or cocks to shut the instruments off from piping. Thermometer sensors should be encased in compact sleeves.

4.2 FILTERS

4.2.1 The design and construction of filters which need maintenance should facilitate cleaning.

4.2.2 Filters should be provided with a device to indicate the absence of pressure therein before they are opened.

The tubes of such devices should 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 should be so arranged that they are readily accessible for maintenance.

Filters and strainers forming part of systems with a combustible working medium should be located as far away as practicable from sources of ignition.

4.3 SEA-INLET WATER BOXES AND ICE BOXES. BOTTOM AND SIDE FITTINGS. OPENINGS IN SHELL PLATING

4.3.1 Sea-inlet water boxes and ice boxes.

4.3.1.1 In ships with the ice strengthening of categories **ЛУ4** and **ЛУ5** one of the inlet water boxes should function as an ice box. In icebreakers and ships with **ЛУ6 — ЛУ9** ice categories, at least two water boxes are to be ice boxes.

In icebreakers and ships with the ice strengthening or categories **ЛУ4 — ЛУ9** the ice box design should 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 are to be secured directly to water boxes or ice boxes.

4.3.1.2 In icebreakers and ships strengthened for ice navigation, provision is to be made for the heating of the sea inlet and ice boxes as well as of the ship side valves and fittings above the load waterline. For this purpose:

cooling water recirculation is to be used for ice and inlet water boxes;

ship side valves and fittings are to be supplied with heating medium through a non-return shut-off valve. The heating arrangements are to be so designed as to prevent the side valves and fittings and shell plating from being damaged under the influence of lowest temperatures.

For ice boxes the recirculated water pipes are to be led to the upper and lower part of the box, and the total sectional area of these pipes is not to be less than the area of the cooling water discharge pipe.

For inlet water boxes, the diameter of the water recirculating pipe is not to be less than 0,85 of the discharge pipe diameter.

4.3.1.3 Provision is to be made for the access into these boxes via detachable gratings or manholes. If a manhole is provided in the ice box it should 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 is to be kept to a minimum. Therefore, whereover possible, discharge pipes are to be connected to common discharges.

4.3.2.2 The location of sea inlet and discharge openings in ship sides should 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 are to 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 inlet water boxes and ice boxes are to be fitted with gratings. Instead of gratings, holes or slots in shell plating are permissible. The net area through the gratings or slots is not to 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 is to be about 20 mm. The gratings of the inlet water boxes are to be provided with a steam or compressed air connection for clearing purposes. For ice boxes, clearing arrangements are not compulsory.

Clearing pipes are to be provided with screw-down non-return valves. The pressure of steam or compressed air in the clearing system should not exceed 0,5 MPa.

4.3.2.4 The overboard discharges, except pipings mentioned in 4.3.2.7 from spaces below the freeboard deck likewise from enclosed superstructures and deckhouses on the freeboard deck (see 7.5.1.2, Part III "Arrangements, Equipment and Outfit") are to be provided with the following:

.1 where the vertical distance from the summer load waterline (in ships with a timber freeboard — from the summer timber freeboard) to the inboard end of the discharge pipe does not exceed 0,01 of the ship length, the discharge opening should be provided with a non-return shut-off valve, its control gear should be positioned above the bulkhead deck in case of ships having a subdivision mark in the class notation and above the freeboard deck in all other cases.

As an alternative to this, a non-return and a shut-off valve may be installed, the latter being operated from the bulkhead deck or freeboard deck.

The valve controls are to have an indicator showing whether the valve is closed or open.

In ships having no subdivision mark in the class notation, the valves of overboard sanitary discharges and scuppers may be operated locally in way of manned machinery spaces;

.2 where the vertical distance from the summer load waterline (in ships with a timber freeboard — from the summer timber load waterline) to the inboard end of the discharge pipe exceeds 0,01 of the ship length, the discharge opening may have two non-return valves without positive means of closing provided one of them is fitted at the side and the other located above the deepest waterline in sea water allowed for the ship readily accessible under service conditions.

Where a shut-off valve is fitted between those non-return valves or the valve at the side is of non-return shut-off type, the second non-return valve need not be fitted above the deepest load line in sea water allowed for the ship;

.3 where in ships having no subdivision mark in the class notation the vertical distance from the summer load waterline (in ships with a timber freeboard — from the summer timber load waterline) to the inboard end of the discharge pipe exceeds 0,02 of the ship length, the discharge opening may have a non-return valve without positive means of closing;

.4 in ships assigned a subdivision mark in the class notation, one non-return valve is permitted at the shell if the distance from the damage waterline to the inboard end of the discharge pipe exceeds 0,3 m as calculated for the most unfavourable flooding conditions.

The above requirements for non-return valves are not applicable to overboard discharge openings which must be kept closed while at sea (e.g. openings in top side ballast tanks for drainage by gravity).

4.3.2.5 In ships of less than 24 m in length, the discharge 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 should 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 are to be fitted with non-return valves (dampers) at the shell. In this case, the wall thickness of scuppers and discharge pipes should not be less than stated in column 3 of Table 2.3.3-1

No valves are to be provided unless 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 are to be determined by linear interpolation.

In open superstructures and deckhouses, overboard scuppers are to be provided.

In spaces intended for the carriage of motor vehicles with fuel in their tanks, overboard scupper pipes should 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 should have non-return valves at the shell. The valves may be omitted where the pipe thickness below the margin line is not less than that of the shell plating, however, it need not exceed 12 mm.

4.3.2.7 In machinery spaces, all the sea inlets and discharges of the pumping and piping arrangements serving the main and auxiliary machinery are to have readily accessible valves or sluice valv es locally controlled. The valve controls are to be fitted with an indicator to show whether the valve is open or closed.

The discharge valves at the shell are to be of the non-return shut-off type.

4.3.2.8 The driving means for operating bottom and side inlet fittings are to be located in readily accessible places and be fitted with an arrangement indicating whether the valve is open or shut.

In passenger ships, these means are to 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 should be made to operate them from a position above this level.

4.3.2.10 Bottom and side fittings are to 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 is not permitted. The design of connections shall be submitted to the Register for approval.

The wall thickness of a distance piece is not to be less that the minimum thickness of shell plating in the ship extremities.

The stud holes are not to penetrate the shell plating and must be only within the welded pads.

4.3.2.11 Side fittings below the bulkhead deck, bottom fittings or gaskets should 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 should be manufactured of corrosion-resistant materials.

4.3.2.13 Garbage chutes, instead of a non-return valve at the side with positive means of closing from a position above the freeboard deck, may be provided with two gate valves operated from the deck, where the garbage chute is charged, and incorporating an interlocking system. The lower gate valve should be additionally operated from a position above the freeboard deck. The two gate valves should be so located that the interlocking system cannot be rendered inoperative.

It is recommended that the charging end of the garbage chute rises to a height of at least 1000 mm above the summer load waterline and remains above the waterline when the ship lists up to 8,5° either way from this position.

If the charging end of the garbage chute rises above the summer load waterline to a height exceeding $0{,}01L$, the gate valve need not be operated from a position above the freeboard deck, provided that the gate valve at the side is accessible at all times under service conditions.

As an alternative to this, the upper gate valve may be replaced by a hinged cover impenetrable to ingress of sea water.

Instead of the lower gate valve a damper should be fitted. The cover and damper should be interlocked to prevent them from being simultaneously opened.

Structural components of the garbage chute, including the cover, should have thickness sufficient to impart strength.

The control gear of the gate valves and/or hinged cover should be conspicuously marked: "Keep closed when not in use".

The charging end of the garbage chute should be situated at a height of 300 mm above the margin line in a passenger ship or the deepest damage waterline in a cargo ship covered by the requirements of Part V "Subdivision".

5 PIPING LAYING

5.1 PIPING LAYING THROUGH WATERTIGHT AND FIRE-RESISTING STRUCTURES

5.1.1 The number of pipelines led through the watertight bulkheads is to be kept to a minimum.

Pipelines passing through main watertight bulkheads, are, as a rule, to be situated at a distance from the ship's side of at least one-fifth of the ship's breadth (see 7.3.5).

Where this requirement is impracticable, measures are to 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 is not to 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 led through the collision bulkhead, i.e. one for each compartment.

Each pipe piercing 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 piercing 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 piercing 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 are to 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 piercing 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/deck pieces (sleeves, bushes), welded pads and other details to ensure the integrity of the structure concerned.

The holes for studs are not to penetrate the plating of watertight structure and must 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 bulkheads and decks shall, depending on diameters, be increased in thickness by 1,5 — 3 mm beyond the thickness of the branch pipe connected to the socket.

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 are to be fitted.

The valves are to be of steel or another material equivalent to steel in fire resistance.

This requirement does not apply to ballast pipes led 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" are to be complied with.

5.1.7 Where plastic pipes pass through a division of the main vertical fire zone, provision is to be made for steel sleeves of appropriate length, with valves that may be closed from either side of the bulkhead. These valves are to be of steel or another material equivalent to steel in fire resistance.

5.2 PIPING LAYING IN TANKS

5.2.1 Drinking water and feed water pipes shall not be led through fuel and lubricating oil storage tanks, nor shall fuel and lube oil pipes pass through drinking water and boiler feed water tanks, unless the pipes are led 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 are to 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 is to be considered, pipe bends are to be arranged inside the tank.

Where pipes are led in ducts, it is recommended that thermal compensators be arranged outside the duct.

5.2.3 The pipes led in oil tankers are to comply with requirements of 9.2.

5.3 PIPING LAYING IN CARGO HOLDS AND OTHER SPACES

5.3.1 Pipes are to 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 are to be adequately protected.

5.3.3 Fuel, steam and water pipes as well as pressure pipes of the hydraulic drives should 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 led in ducts or where the pipes employed are of increased thickness and protected by strong steel casings.

5.3.4 Steam pipes shall not be led in paint room, lantern room or other spaces intended for the carriage of readily flammable materials.

5.3.5 Where hot pipes pierce bulkheads made of combustible materials, structural precautions should be taken to prevent the bulkheads from being effected by increased temperature.

5.3.6 Pipes conveying oil fuel shall not be led 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 led through sanitary spaces, provided the pipes used have a thickness of not less than 5 mm and no detachable joints are employed.

5.3.7 Pipes conveying hot media and having considerable longitudinal extension shall have thermal compensators or as many bends as will provide adequate self-compensation of the pipeline.

The radii of bends are to be in compliance with 2.2.1.

5.3.8 The pipes of all the systems and the vent ducts should, where necessary, be fitted with arrangements for blow-down of the working me-dium or draining of liquid, if any.

Appropriate structural measures are to be taken to protect ship's hull and equipment from adverse effect of the agents discharged.

5.4 PIPING LAYING IN REFRIGERATED CARGO SPACES

5.4.1 It is recommended that no pipes be led through refrigerated cargo spaces, unless they are intended to serve these spaces. Where leading of such pipes cannot be avoided, they are to be carefully insulated. This requirement equally applies to air and sounding pipes. In these spaces the pipes are not to have sections in which water may collect and freeze.

5.4.2 The pipes of fire fighting system are to be led in conformity with requirements of 3.1.4.1.3, Part VI "Fire Protection".

5.5 PIPING LAYING IN THE VICINITY OF ELECTRICAL AND RADIO EQUIPMENT

5.5.1 Pressure pipes are not permitted to be carried 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 Leading of pipes through special electrical spaces (see 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 Leading of pipes through the space containing the gyrocompass is not allowed, with the exception of cooling pipes for gyrocompass.

5.5.4 Leading of pipes through the radioroom is not allowed.

5.6 PIPING LAYING IN UNATTENDED MACHINERY SPACES

5.6.1 Class 1 pipes conveying oil fuel and lubricating oil are to have welded joints. Detachable joints are permitted to be used, but their number is to be kept to a minimum; if considered necessary, protective casings are to 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 should be provided with compensators where necessary and protected against damage.

Damage to these pipes should 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 chemical cargo, crude oil, oil products, fuel oil, 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 hoses with end components by means of clamps is permitted only by agreement with the Register.

6.1.5 When welding is used in the structure of end components, such welding shall be performed by certified welders and is subject to 100 % check by 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 %, provided the hose is completely immersed in sea water and completely filled with it. The hose buoyancy reserve is calculated as follows:

$$K = \frac{B - (W_h + W_w)}{W_h + W_w} \times 100\%,$$

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.

Any 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 is to 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 each hose the following shall be clearly marked:

name of the manufacturer or trade mark;
serial number of the hose according to the manufacturer's data;
month and year of production;
nominal 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. Spaces for storage of hoses shall meet the requirements of 2.4, Part VI "Fire Protection". Measures for prevention of wearing through of the hoses while handling and operation shall be taken.

6.1.12 For the transfer of cargo vapors hoses with the permissible nominal pressure of at least 0,034 MPa and vacuum of at least 0,014 MPa shall be used. Disruptive pressure of the hose shall be not less than 5 times nominal pressure of the hose. The last meter from each end of the hose shall be painted in compliance with Fig. 6.1.12 and marked with the sign "vapors" made in black letters with the height not less than 50 mm. Each flange shall have an additional bore on the line of coupling bolts enabling to connect the flange to vapor discharge connector branch pipe (see Fig. 10.3.12-1). In the system for vapor to shore discharge only electrically conductive hoses shall be used.

6.2 TESTING OF HOSES

6.2.1 During the type tests enumerated in the present paragraph, the tests according to 6.2.2 shall be performed in full scope.

6.2.1.1 Sterngth test by disruptive pressure.

In this case the allowable nominal pressure p_n is determined as follows:

$$p_n = p_{disr}/K\ , \qquad (6.2.1.1)$$

where p_{disr} = pressure at which the break of hose or end connection tightness occurs;
K = coefficient assumed equal to:
4 for transfer of crude oil and oil products, bilge and polluted ballast water;
5 for transfer of chemical cargoes, liquefied gases and cargo vapors.

Nominal 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 of non-standard length may be allowed, but in this case its length shall not be less than 10 nominal diameters, but at least 1 m.

6.2.1.2 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 $2R$, where R is a minimum bending radius; after that the 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.

Upon the consideration with the Register another method for elasticity test with allowance made for special features is accepted.

6.2.1.3 Minimum hose bending radius for each standard size shall be checked as follows: an empty hose is five times bent in the opposite direction as per the radius R being equal to minimum radius of the hose bending. After completion of the minimum bend radius test, there will be no permanent deformation, such as kinking or ovalling, when returned to the straight position.

6.2.1.4 The samples manufactured as strip test pieces in accordance with the procedure approved by the Register are subject to adhesion test of all the sleeve layers. The adhesion strength of rubber contact faces is determined as a ration of the mean force F originated at detachment, divided by the strip width B, and shall be at least 4 N/mm, and the adhesive strength of rubber and polyurethane faces shall be not less than 3 N/mm (see Fig. 6.2.1.4). Such tests shall be performed for each batch of sleeves used for manufacturing of hoses.

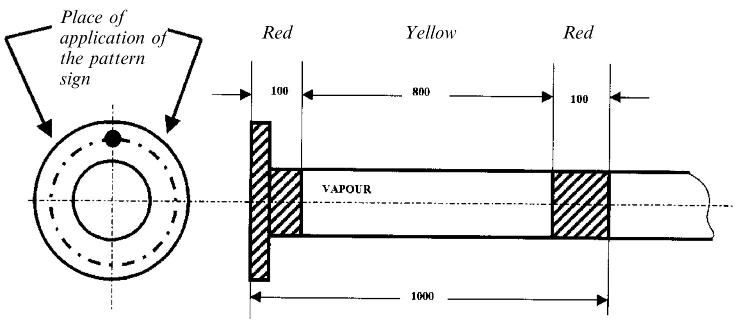


Fig. 6.1.12 Marking of cargo vapor discharge hose

6.2.2 Each hose after the manufacturing shall be subjected to the testing stated in 6.2.2.1 - 6.2.2.4.

6.2.2.1 Determination of weight.

After weighting the hose weight shall be recorded in the certificate. For floating hoses the buoyancy reserve shall be defined according to 6.1.6.

6.2.2.2 Hydrostatic tests with determination of elongation.

They are performed according to 6.2.3.

6.2.2.3 Vacuum test with negative pressure 85 kPa during 10 min.

After testing the hose shall be examined and rejected in case any deformation or flattening is revealed.

6.2.2.4 Electrotechnical tests.

Such tests include:

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 4,5V and a bulb for testing.

6.2.3 Hydrostatic test of the hoses with determination of elongation.

The tests shall be carried out as follows:

.1 hose shall be placed in such a way that nothing prevents its extension;

.2 to fill the hose with water with blowing air off, for fifteen times to build up the pressure inside the hose from zero up to nominal pressure and to release pressure up to zero; in each case spending the period of time to be calculated based on the ratio: 1 second per 50 mm of the hose diameter;

.3 to increase the pressure up to 0,07 MPa and measure the total length of the hose;

.4 during 5 minutes to build up pressure up to nominal and to keep it for ten minutes and maintain the pressure for ten minutes. Then to examine the hose for the availability of leakage;

.5 without pressure drop to measure the total length of the hose and to determine in percentage the live elongation with reference to the initial hose length measured at the pressure of 0,07 MPa. The live elongation shall not exceed 2,5 %.

.6 during 5 minutes to decrease the pressure up to zero. Then, not earlier than in 15 minutes, to build the pressure up again, measure the total length of the hose and define the residual elongation expressed in percentage with reference to the initial hose length measured at the pressure of 0,07 MPa. The residual elongation shall not exceed 0,7 %.

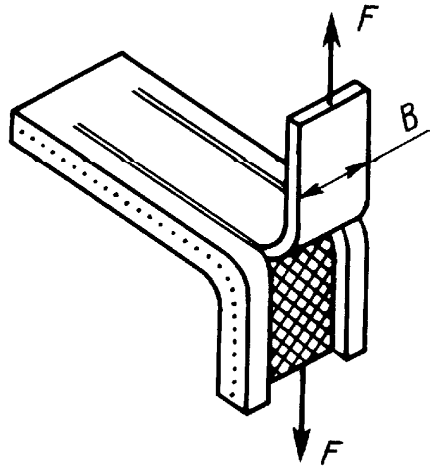


Fig. 6.2.1.4

7 BILGE SYSTEM

7.1 PUMPS

7.1.1 Each self-propelled ship is to 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 3.2.3.3, Part VI "Fire Protection" is to be met.

In cargo ships of less than 500 gross tonnage navigating in restricted areas II, II СП, III СП and III, 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 having a subdivision mark [2] and over in their class notation (see Part V "Subdivision"), the number and arrangement of bilge pumps should be specially considered by the Register in each case.

7.1.2 Passenger ships, special purpose ships carrying more than 50 special personnel are to 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 2.3.1.1, 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 water fire fighting system is installed, the Register may require the bilge pumps to be increased in capacity or number.

7.1.3 Centrifugal bilge pumps are to be of the self-priming type, or alternatively the system is to 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 (see 2.3.1.1, Part V "Subdivision"), the arrangement of bilge pumps is to 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 pumps required in 7.1.1 and 7.1.2 is to have a capacity determined on the assumption that the rated speed of water in the bilge main, the diameter of which is found by formulae given in 7.2.1 and 7.2.2 with regard to 7.2.5, is not less than 2 m/s under normal conditions of service.

The capacity of drainage pump Q in m^3 per hour shall be not less than those determined according to the formula $Q = 5,65 \times 10^{-3} d^2$, where d - inner diameter of the main determined in accordance with 7.2.1.

One of the bilge pumps may be replaced by two pumps with a total capacity not less than that specified above.

7.1.7 For drainage of non-propelled ships having no power-driven machinery, at least two hand pumps of reciprocating type are to be installed, and these should have a total capacity not less than specified in Table 7.1.7.

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.

Table 7.1.7

0,8 LBD[1], m^3	Total pump capacity, m^3/s
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), see Part IV "Stability".

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 are total length and height of enclosed cargo spaces, respectively.

The pumps are to be arranged above the bulkhead deck and are to 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 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 is to comply with the requirements of this Chapter.

7.1.9 In berth-connected ships, at least two bilge pumps should 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 should not be less than 2 m/s under normal service conditions.

The pumps are to ensure drainage of any space below the bulkhead deck, and their drives are to 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 П1, П1В, П2, П2В in the class notation are to 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 and number of the pumps are to be specified by the designer and agreed upon with the customer and the Register.

The capacity of the pumps is to be not less than 40-50% of the capacity of the special water fire-extinguishing system pumps (see 2.13.10, Part VI "Fire Protection").

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, is to be determined by the formula:

$$d_1 = 1{,}68\sqrt{L(B+D)} + 25 . \qquad (7.2.1\text{-}1)$$

In vessels of dredging fleet having hopper spaces, the diameter of the bilge main and the direct bilge suctions may be obtained from the formula:

$$d_1 = 1{,}68\sqrt{L(B+D) - l_1(b+D)} + 25, \qquad (7.2.1\text{-}2)$$

where l_1 = length of hopper space, m;
b = mean width of hopper space, m;
for L, B, D, see 7.1.7.

In cargo ships of less than 500 gross tonnage navigating in restricted areas II, IIСП, IIIСП and III, the internal diameter of the bilge main and of direct bilge suctions may be obtained from the formula:

$$d = 1{,}5\sqrt{L(B+D)} + 25. \qquad (7.2.1\text{-}3)$$

7.2.2 The internal diameter d_0, in mm, of the branch bilge suctions connected to the bilge main, and that of the hand pump suction, are to be determined by the formula:

$$d_0 = 2{,}15\sqrt{l(B+D)} + 25, \qquad (7.2.2\text{-}1)$$

where l = length of hopper space, as measured at its bottom, m;
for B, D, see 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 II, II СП, III СП and III, the internal diameter of branch bilge suctions connected to the bilge main and the diameter of the hand pump suction may be obtained from the formula:

$$d = 2{,}0\sqrt{l(B+D)} + 25 . \qquad (7.2.2\text{-}2)$$

7.2.3 The internal diameter of the main bilge line and bilge suctions determined from Formulae 7.2.1-1, 7.2.2-1 is not to be less than 50 mm, and the internal diameter determined from Formulae 7.2.1-3 and 7.2.2-2 is not to be less than 40 mm. The internal diameter of the main bilge line and direct bilge suctions should, in any case, be not 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 be not 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 is to be not 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 is to be determined in compliance with 7.3.8.

7.3 PIPING LAYING

7.3.1 The bilge lines and their branch suctions are to 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.

Where the spaces are not fitted with bilge suctions, other means for draining water are to 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 is to 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 is to 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, are to 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 are to 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 are to be fitted with means enabling them to be controlled from above the bulkhead deck.

In the places of their installation they are to 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 is to be independent of the main system and is to 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 are to 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 are to be led outside the double bottom. Where it is necessary to lead these pipes through the tanks for storage of oil fuel, lubricating oil, boiler feed water and drinking water, the pipes are to meet the requirements of 5.2.1.

Where the pipe is led within the double bottom, the bilge suctions in each watertight compartment are to be fitted with non-return valves.

7.3.8 In all self-propelled ships provision is to be made for emergency bilge drainage of the engine rooms, in addition to the suctions required by 7.4.1 — 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, is to be fitted with bilge direct suction pipes leading from the drainage level of the engine room and fitted with screw-down non-return valves. The diameter of this direct suction is to be at least two-thirds of that of the pump suction in steam ships, and is to be of the same size as the suction branch of the pump in motor ships.

Where the pumps specified above are not suitable for operation as bilge pumps, a direct emergency bilge suction is to be led 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 is to exceed that required in 7.1.6 by an amount satisfactory to the Register.

The diameter of the emergency bilge suction is to be not less than that of the pump suction branch.

The spindles of the screw-down non-return valves fitted to the suction branches are to extend above the engine room floor plates to a sufficient height and are to have nameplate "For emergency use only".

The use of fire pumps for emergency bilge drainage of engine rooms must 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 II, IIСП, IIIСП and III, 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.

7.3.9 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 s ame 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 should 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 are to be provided, one of which is to 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 are 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 are to be adopted as set forth in 7.6. In ships having in the class notation a mark of subdivision, each of these compartments is to 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, is to 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 is to be located on the port and the other on the starboard side. The independent power bilge pumps 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 are to be fitted in the forward wings of the space. On agreement with the Register, one or two suctions should be provided depending on the shape of the aft end.

7.4.5 Suctions for bilge drainage of machinery spaces and tunnels are to be fitted with readily accessible mud boxes. The pipes between the mud boxes and bilges are to be as straight as practicable. The lower ends of these pipes need not be fitted with strum boxes. Mud boxes are to 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 No strum boxes or strainers should be fitted on the suction for emergency bilge drainage.

7.4.7 Where there is a double bottom, the machinery spaces are to be fitted with bilge wells of a capacity not less than 0,2 m^3.

7.4.8 Additional bilge suctions are to be led 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 are to be such that the bilge wells under the propulsion motors are properly drained and automatic alarms are fitted to give warning at excess of permissible level in the wells.

Automatic drainage of bilge wells is recommended to be used.

7.4.10 The space of ammonia refrigerating machinery is to have an independent bilge system. Where a water spraying system is provided in this space, the capacity of the bilge pump is to be sufficient for the water consumption during the operation of that system. The discharge pipe of the bilge system is to be led 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 are to be drained by a bilge suction situated in the after part of the tunnel.

Where required, additional suctions are to be provided in the fore part of the tunnel. The bilge suctions of the shaft tunnel are to 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, is to 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 are to be arranged in the after part of the hold, one at each side.

The capacity of the wells is to comply with requirements of 7.4.7.

7.6.3 In spaces where the inner bottom plating has an inverse camber, provision is to 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 led to this well.

7.6.4 Where manholes for access to bilge wells are provided, they are to 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 are to be fitted, one at each side of the hold.

7.6.6 Where the length of a hold exceeds 35 m, the bilge suctions are to 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 led 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 7.7.

7.6.9 Where a ceiling or removable covers is fitted over the bilges or wells in cargo spaces, provision is to be made for free access of water into the bilges or wells.

7.6.10 Branch bilge suctions are to be fitted with strum boxes or strainers having perforations 8 — 10 mm in diameter. The total area of these perforations is to be not less than twice the clear area of the given suction pipe.

The strum boxes and strainers are to be removable, or provision is to be made for cleaning them without having to disassemble the suction.

7.6.11 In bulk carrier spaces the bilge system is to 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 are to 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 4.3.2.2.

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 led 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;

.3 water contaminated with petrol or other dangerous substances is not 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.

7.7 DRAINAGE OF CARGO PUMP SPACES OF OIL TANKERS

7.7.1 The cargo pump rooms of oil tankers should 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 should meet the requirements of 4.2.5, Part VII "Machinery Installations".

The cargo pump rooms should be provided with a 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 is to 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 led into the bilges of refrigerated spaces.

7.8.3 Each drain pipe of refrigerated cargo spaces is to be fitted with a liquid sealed trap or with another equivalent arrangement. The head of liquid is to be such that the arrangement will work effectively under any conditions of service.

The liquid sealed traps are to be placed in accessible positions outside the insulation. Where drain pipes from the 'tween-deck spaces and the hold are led into a common bilge well, non-return valves are to 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 DEEP TANKS

7.9.1 In deep tanks which can be used for the carriage of dry cargo there shall be fitted bilge suctions, as well as effective shut-off means isolating the fuel and ballast lines, when dry cargo is carried in the tanks, and isolating the bilge line when the tanks are containing oil fuel.

The arrangement of the bilge suctions is to comply with the requirements of 7.6.

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 should 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 led into the bilges of shaft tunnel or engine room. The drain pipes are to be fitted with readily accessible self-closing valves and are to be of not less than 39 mm in 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 led 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 7.11.2).

Drain pipes from these spaces may be led 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 led into the bilges (wells) of the engine room or the holds.

In ships having in the class notation a mark of subdivision, these pipes are to be fitted with valves controllable from a place above the bulkhead deck to prevent penetration of water in the above-mentioned spaces should the engine room or hold become flooded.

7.12.5 Drain pipes of storerooms for explosives are to be fitted with valves controllable from locations outside these rooms.

7.13 DRAINAGE OF FLOATING DOCK COMPARTMENTS

7.13.1 Machinery spaces and dry compartments are to 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 2.8.5, Table 2.8.2-3, 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 is to be determined from Formula (7.2.1-1).

7.14.3 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.

7.14.4 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.

7.14.5 Cargo spaces may be drained by gravity overboard or into a closed drainage tank situated outside the engine room.

7.14.6 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.

7.14.7 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 is to be served by at least one pump. The capacity of the ballast pump should 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 is to 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 (see 8.1.3).

Fire pumps may be permitted subject to compliance with 3.2.3.2, Part VI "Fire Protection".

8.1.3 Where the oil fuel 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 requirements for ballast pumps and systems in oil tankers are given also in 7.11.1 and 8.3.4.

8.1.5 The pumps used for pumping out ballast water from the double-bottom tanks are to be of self-priming type.

8.1.6 In passenger ships, ballast tanks are not, generally, to be intended for the carriage of fule oil. Possible relaxations from this requirement, are to be specially considered by the Register in each case (see also 13.1.2).

8.2 PIPING DIAMETERS

8.2.1 The internal diameter d_i, in mm, of the ballast pipes for separate tanks is to 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 is to be not 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 is to be such as to ensure pumping of the water from any of the ballast tanks, whether the ship is upright or listed 5°.

8.3.2 In icebreakers and ships with ice strengthening of **ЛУ4 — ЛУ9** 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 inlet boxes and pipelines servicing cargo tanks.

8.3.4 Ballast, sounding and air piping of segregated ballast tanks are not to pass through cargo tanks, and cargo and similar piping not intended for servicing cargo and slop tanks (see definitions in 1.2 and 1.5.4, Part VI "Fire Protection") are not to pass through segregated ballast tanks. Exemptions to this requirement may be granted for short lengths of piping, provided they are completely welded or equivalent, with thickened flanged connections, the number of which is to be kept to a minimum. The method of pipe thermal expansion compensation is to comply with the requirements of 9.2.5.

As an example, a recommended construction of an air pipe is shown in Fig. 8.3.4.

Piping is to be seamless and made of steel. The wall thickness of the pipes is to be not less than that indicated in Table 8.3.4.

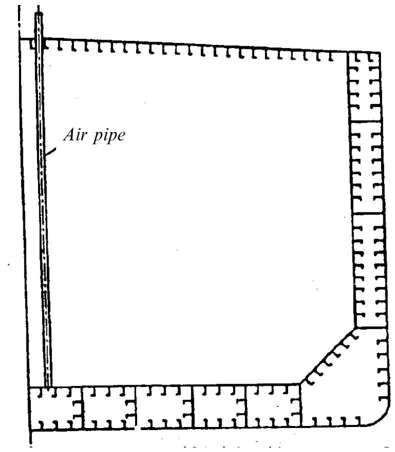


Fig. 8.3.4

Table 8.3.4

Pipe internal diameter, mm	Minimum wall thickness, mm
Up to 50	6.3
Up to 100	8.6
Up to 125	9.5
Up to 150	11.0
Up to 200 and over	12.5

Use of pipes made of another material is subject to special consideration by the Register in each particular case.

Provision is to be made for emergency discharge of the segregated ballast by means of a connection to a cargo pump through a portable spool-piece. The spool-piece is to be mounted in a conspicuous, readily accessible position in the pump room. To prevent the passage of petroleum products to the ballast tanks, a non-return valve is to be fitted on the segregated ballast connections. The ballast pump is to be located in the cargo pump room or equivalent space with a safety level equivalent to the cargo pump room not containing sources of ignition within the cargo tank area.

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 are to be located in warmed spaces of the dock or are to 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 led to above the safety deck. In this case, the distributing valves are recommended to be fitted with a device automatically closing them, should supply from the power source by interrupted.

8.5 HEEL AND TRIM SYSTEMS

8.5.1 The heel and trim systems are to be in conformity with 8.3.2 and 8.3.3.

9 CARGO PIPING SYSTEM OF OIL TANKERS AND OIL RECOVERY SHIPS. OIL RECOVERY SYSTEM OF OIL RECOVERY SHIPS

9.1 PUMPS AND THEIR DRIVES

9.1.1 Cargo pumps and cargo stripping pumps are to serve only the direct purpose, except as provided for in 7.7.1 and 8.3.4 These pumps are not to have any connections to tanks other than cargo tanks.

The cargo and cargo stripping pumps shall be arranged in a separate space.

9.1.2 The arrangement of cargo pump driving machinery is to comply with the requirements set forth in 4.2.5, Part VII "Machinery Installations".

9.1.3 The construction of pumps, fittings and pump driving machinery shall preclude spark formation to the maximum.

9.1.4 Arrangements are to be provided for stopping each cargo pump and cargo stripping pump from the top flat of the pump room situated at the level of the main deck.

Where a central control station is provided for the operation of system, stopping arrangements for the pumps are to be also fitted therein.

Switching devices of pump electric motors are to comply with requirements of 19.2.4.5, Part XI "Electrical Equipment".

9.1.5 The pressure gauges of the cargo oil discharge and cargo stripping mains are to be placed at the pumps and on the top flat of the pump room or at the central control station of cargo operations.

9.2 PIPING LAYING

9.2.1 The ends of filling pipes inside cargo tanks shall be carried as near the bottom of these tanks as is practicable but not less than 1/4 of the internal diameter of the pipe.

The cargo oil pipes shall not be carried through the tanks not intended for cargo oil and shall not be connected to other tanks or pipelines, including the oil fuel piping of the machinery installation.

The cofferdams are not to have any connections to cargo oil tanks. Cargo transfer valves are not permitted to be fitted inside cofferdams.

The pipes of systems in which different cargo oil may become mixed or contaminated by water are to have duplicate isolating valves.

9.2.2 Remote-controlled valves are to meet the requirements of 4.1.1.2 to 4.1.1.5.

The spindles used to operate valves placed inside the 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 are to have arrangements showing whether the valve is open or closed.

The drives are to be so constructed as to prevent accumulation of oil residues in them.

9.2.3 The temperature of steam or heating medium (in closed spaces) inside the cargo area shall not exceed 220°C.

9.2.4 The pipe flanges and fastening pieces intended for hose connection from shore installations, are to be made of materials precluding spark formation.

9.2.5 The piping on the deck and in cargo tanks is to be efficiently secured and fitted with thermal compensators. Thermal expansion is to be compensated by pipe bends. Other ways of thermal expansion compensation are not permitted. Radii of pipe bends are to comply with the requirements of 2.2.1.

9.2.6 All the sections of the cargo line interconnected by flanges are to have a reliable electrical connection, and a metallic connection to the ship's hull at one place minimum (2.5, Part XI "Electrical Equipment").

9.2.7 Remote-controlled valves fitted between the cargo mains and the pumps are to be capable of being operated also by hand.

Where the rubbing parts of valve drives pass inside cargo tanks and cofferdams, as well as on the cargo deck, precautions are to be such as to preclude spark formation.

9.2.8 Slop tanks of oil tankers are normally to be serviced by a separate piping system. Where such a system is not provided, spectacle flanges or other blanking arrangements are to be fitted on the suction and filling pipes of slop tanks.

9.2.9 In combination carriers, reliable means are to be provided for isolating the piping connecting the pump room with the slop tanks.

The means of isolation should consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement is to be located adjacent to the slop tank, but where this is unreasonable or impracticable it may be located within the pump room directly after the piping penetrates the bulkhead.

In combination carriers in the dry cargo mode, the system for transfer of slops to the open deck should be a permanent installation. This system should have no connection to other systems. Connection to other systems by means of removable spool pieces may be accepted subject to special approval of the Register in each case.

The slop transfer manifold on the open deck should be provided with a shut-off valve and a blank flange.

9.2.10 In combination carriers, where cargo wing tanks are provided, cargo lines below deck should be installed inside these tanks. However, the Register may permit cargo lines to be placed in special ducts which should be capable of being adequately cleaned and ventilated to the satisfaction of the Register.

Where cargo wing tanks are not provided, cargo lines below deck should be placed in special ducts.

9.2.11 In order to prevent the passage of flame into cargo holds, materials which easily lose their properties under the effect of heat shall not be used for fittings, cargo pipes and venting arrangements.

9.3 HEATING OF CARGO TANKS

9.3.1 As a heating medium for heating of cargo tanks the use of steam, hot water and organic coolants is allowed.

Application of other coolants is subjected to the special consideration by the Register in each case.

9.3.2 Upstream from each steam heating coil a stop-check valve shall be fitted, and upstream to stop fittings at the outlet the control device for checking of condensate quality shall be installed.

9.3.3 The return of condensate from the heating system shall be performed via the check tank.

Air pipes of the check tank of 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 the safety place.

9.3.4 Thermal liquid systems for tank heating shall be used with regard to the requirements of 21.10.

9.3.5 The maximum heating temperature shall be lower than the flash point of the carrying cargo at least for 15° C.

9.3.6 The heating system shall be equipped with the means for control of cargo temperature in tanks. Control of the current temperature in tanks, as well as light and audible alarms on exceeding of the maximum permissible cargo temperature shall be provided.

9.4 OIL RECOVERY SYSTEM OF OIL RECOVERY SHIPS

9.4.1 The system and devices for the recovery and transfer of oil should be installed outside machinery spaces and accommodation spaces.

9.4.2 The system should ensure both recovery and transfer of oil being recovered.

9.4.3 Where, in multi-purpose ships, the permanently installed oil recovery system is incompatible with the cargo of the installed cargo system, relevant isolating arrangements should be provided.

9.4.4 Where the ship is fitted with portable oil recovery equipment, not more than two suctions connected by piping to all oil collecting tanks should be provided on the upper deck for connecting to the discharge hoses of the oil recovery equipment.

The arrangement of the suctions on the upper deck should make it possible to simultaneously connect two oil recovery systems installed at the opposite sides of the oil recovery ship.

Piping connecting suctions to tanks should not pass through accommodation spaces or spaces located as high as the open deck.

Routing of pipes through enclosed intrinsically safe spaces (see 19.2.3.4, Part XI "Electrical Equipment") is subject to the special consideration by the Register in each case.

9.5 FORE AND AFT CARGO GEAR OF OIL TANKERS

9.5.1 The fore and aft cargo piping of oil tankers shall be permanently installed. Where necessary, the connections of such piping may be detachable.

9.5.2 Fore 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 The points of fore and aft cargo piping are to be welded joints. If need be, expansion joints may be used. Within the cargo area, piping may have detachable joints.

For pipe-to-valve connections, flange connections as mentioned under 2.4 may be used. Cargo piping of this type shall be marked accordingly and be disconnectable either with two valves in the cargo zone provided with devices for their sealing when shut (readily checkable for efficient shutting) or with one valve used alongside another closure ensuring reliable pipe disconnection, such as spool piece.

9.5.4 The pipe section used as shore connection shall be fitted up with a shut-off valve and a blank flange, and provided with a tray. Should a special coupling be used the blank flange may be omitted.

9.5.5 In cargo piping, arrangements for the discharge of cargo residues shall be provided. Outside the cargo zone, cargo piping shall be fitted up with arrangements to make it clean of cargo and fill it up with inert gas. Between cargo piping and inert gas system, an isolating device shall be fitted.

9.5.6 In oil tankers equipped with fore cargo gear and adapted for mooring at point berths carried out to sea, an emergency high-speed system shall be provided for the disconnection of cargo hose. The design and arrangement of such a system are subject to special consideration by the Register in each case.

9.5.7 In ships mentioned under 9.5.6, the air pipe heads of the fore peak shall be as distant as possible from gas dangerous zones.

10 AIR, VENTING, 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 and sea inlet boxes, are to have air pipes.

The air pipes of ice and sea inlet boxes are to have shut-off valves fitted directly on the boxes.

Air pipes of double-bottom tanks and of tanks adjoining the shell plating, as well as the air pipes of ice and sea inlet boxes, are to be carried to above the bulkhead deck.

10.1.2 The air pipes are to 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 are to 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 10.4 shall be complied with.

10.1.3 The tanks extending from side to side of the ship are to be fitted with air pipes at either side. The air pipes must 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 led into a common line.

10.1.4 The height of the air pipes from the deck to the point where water may have access below is to be not 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 II, IIСП, IIIСП and III the above pipe heights may be reduced on agreement with the Register. However, they are to be not less than 600 and 380 mm, accordingly.

Minimum wall thicknesses of the air pipes above deck are to be:

6 mm for $d \leqslant 80$ mm,

8,5 mm for $d \geqslant 165$ mm.

Intermediate sizes are to be determined by linear interpolation.

Air pipes are to 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 is to be made as a bend, with its opening facing downwards or is to have another construction agreed upon with the Register.

10.1.6 The open ends of air pipes of fuel and lubricating oil tanks, as well as those of cofferdams and double - hull spaces on oil tankers separating cargo or slop tanks shall be led to positions on the open deck where the issuing vapours cannot incur a fire hazard and shall be protected with flame-arresting fittings of a type approved by the Register. The clear area through the fittings shall be not less than the cross-sectional area of the air pipe.

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 (see 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 (see 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. The covers shall comply with the following requirements:

.1 the cover design shall provide access inside to examine the space within the casing and replace the seals;

.2 the aperture of the covers shall be equal to the inlet diameter at least;

.3 the covers shall be operable at a heel of 40°;

.4 for floating covers, guides shall be provided so they might be operable at any heel and trim to occur in service;

.5 the covers shall be reliably secured;

.6 the covers shall be self-draining;

.7 the maximum wall thickness allowance for spherical covers of fuel tanks shall not exceed ±10% of the nominal thickness;

.8 the cover casings shall be manufactured from metallic materials approved by the Register and agreeably protected from corrosion;

.9 the covers and their attachments of non-metallic materials shall be compatible with the media contained in the tanks and sea-water resistant at temperatures from −25°C to 85°C.

.10 the covers shall be tested in accordance with 20.4.

10.1.9 The total cross-sectional area of the air pipes in tanks filled by gravity shall be not 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, is to be not 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 is to be at least 1,25 times the area of the common filling pipeline of these tanks, the requirements of 10.4.3 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 is to be not 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 is to be at least one-third of the area of the common filling pipe of these tanks, the requirements of 10.4.3 being complied with.

10.1.12 Notwithstanding the requirements of 10.1.11 and 10.1.12 an inner air pipe diameter should be at least 50 mm under all conditions.

10.1.13 The arrangement of the air pipes is to preclude the formation of hydraulic seals in the pipes.

10.1.14 The air pipes of oil fuel and lubricating oil tanks in way of accommodation and refrigerated cargo spaces are not to have detachable connections.

10.1.15 Nameplates are to be affixed to the upper ends of all air pipes.

10.1.16 The air pipes from crankcases of internal combustion engines are to comply with the requirements of 2.3.4, Part IX "Machinery".

10.1.17 The air pipes from ballast compartments of floating docks shall be led to a height not less than 300 mm above the margin line.

It is permitted to lead 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 led through the superstructure side.

10.2 VENTING SYSTEM OF OIL TANKERS AND COMBINATION CARRIERS

10.2.1 The cargo tanks and the slop tanks are to have the gas venting system providing in the tanks pressure or vacuum within designed parameters as well as:

.1 the flow of the small volumes of vapour, air or inert mixtures caused by thermal variations in a cargo tank in all cases through pressure/vacuum valves; and

.2 the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging;

.3 a secondary means of allowing free flow relief of vapour, air or inert gas mixtures to prevent over-pressure or under-pressure in the event of failure of the arrangements referred to in 10.2.1.2. Alternatively, pressure sensors may be fitted in each tank protected by the arrangement required by 10.2.1.2, with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment shall provide an alarm facility which is activated by detection of over-pressure or under-pressure conditions within a tank.

Arrangement limiting the pressure/ vacuum (P/V) grouth, fitted in the inert gas systems according to 3.9.4.2, Part VI "Fire Protection", may serve as secondary means of allowing flow of mixtures of vapour, air and inert gas. In case in the ship the method of free flow is used and the stop valve disconnecting the venting pipeline to the masthead from the tank is closed, the inert gas system will serve as an initial means of protection, and the pressure/vacuum (P/V) valve - as a secondary means of venting system protection. The requirements of 10.2.7 to 10.2.9 and 20.3 are not applicable to the abovementioned valves.

For similar cargoes the gas venting system from several tanks may be combined in groups or led into a common line and may be incorporated into the inert gas system.

The cargo tank venting system is not to have connections with air pipes or ventilation systems of other compartments and spaces.

The cargo tank venting system should be sized for a maximum loading rate.

When calculating the capacity of the tank venting system, the pressure drop across flame arresting devices, if fitted, should be dependent on the design of the flame arrester and on the type of cargo. However, the pressure drop value adopted should, in any case, be increased by 50% as compared to the pressure drop of a flame arresting device in clean condition.

10.2.2 Where the venting pipes are combined into a common pipe line, flame arresters of the type approved by the Register, stop valves or other acceptable means, which shall be under the control of a responsible ship's officer, are to be fitted on the pipes leading from each tank.

The flame arresters are to be so located that they will not be overrun by cargo liquid in any conditions of service, including seaway.

Where provision is made in the ship for special systems (e.g., air drying system) through which communication of cargo tanks is possible, each pipe of such systems, led into the tank, is to be fitted with a flame arrester.

The through part of flame arresters is not to be affected by sea conditions.

Where stop valves are fitted, they shall be provided with locking arrangements for fixing them both in the open and closed positions and clear visual indication of the operational status of the valves.

Before cargo loading or ballasting or discharging of the tanks is commenced, it shall be ensured that relevant isolating valves are opened and arrangements referred to in 10.2.1.3 are in operation.

In case of closing these devices, the vapour/air mixtures are to be kept removed from the isolated tank in compliance with the requirements of 10.2.1.1.

10.2.3 The venting system should be provided with devices, type-approved by the Register, to prevent the passage of flame into the cargo tanks. The design, testing and locating of these devices should comply with the requirements of 20.3.

The vent outlets, including the pressure/vacuum valve outlets and high-speed devices, are to be so constructed as to discharge the vapour/air mixture vertically upwards.

The venting arrangements are to be connected to the top of each tank and shall be self-draining to the cargo tanks under all normal conditions of trim and list of the ship. Where it may not be possible to provide self-draining lines, special arrangements are to be provided to drain liquid from the vent lines or portions thereof.

Provision shall be made to guard against liquid rising in the venting system to a height which would exceed the design head of the cargo tanks. This shall be accomplished by high-level alarms or overflow control systems or other equivalent means, together with gauging devices and cargo tank filling procedures.

10.2.4 The internal diameter of the separate vent pipes shall be not less than 80 mm and that of the main line, not less than 100 mm.

10.2.5 The pressure/vacuum valves shall be so designed and set:

.1 that the pressure in the tanks is not more than 21 kPa, when all other outlets of the venting system are closed; if an inert gas system is provided, this requirement is to be fulfilled also during loading of cargo with maximum designed capacity, and

.2 that the vacuum in the tanks is not more than 7 kPa; if the inert gas system is provided, this requirement is to be fulfilled also during discharging of cargo with maximum designed capacity of cargo pumps and when inert gas blowers are out of order.

In case of combining the cargo tank venting system with inert gas system, pressure/vacuum valves may be fitted in the main pipeline of inert gas (see 3.9.4.2, Part VI "Fire Protection").

10.2.6 The area of vent pipes is to be sufficient to permit removal of a volume of vapour/air mixture from the cargo tanks, exceeding by 25 per cent the maximum loading capacity with regards to the gas evolution during the loading of cargo.

Means are to be provided to prevent the tanks being subjected to excessive pressure or vacuum during any phase of the cargo handling operations.

10.2.7 The pressure/vacuum valve outlets are to be located at a height of not less than 2 m above the cargo deck and not less than 5 m from air intakes and opening leading to closed spaces containing sources of ignition, as well as from the deck machinery and equipment which may present the risk of ignition. Pressure/vacuum valves fitted in the common line or masthead riser may be provided with by-passing arrangement having indicators to show whether the by-pass is open or closed.

10.2.8 The outlets of vent pipes without high-speed devices:

.1 shall be located at a height of not less than 6 m above the cargo deck or the gangway, if the outlets are within 4 m from it;

.2 shall be not less than 10 m measured horizontally from air intakes and openings leading to closed spaces containing sources of ignition, as well as from the machinery and equipment which may present the risk of ignition.

10.2.9 The outlets of vent pipes fitted with high-speed heads, that expel the vapour/air mixture with a velocity not less than 30 m/s, may be located at a height of at least 2 m above the cargo tank deck and at a distance of not less than 10 m measured horizontally from air intakes and openings leading to closed spaces containing sources of ignition, as well as from the deck machinery and equipment which may present the risk of ignition.

10.2.10 Venting systems of boiling petroleum products which have a Reid vapour pressure greater than atmospheric, are subject to special consideration by the Register.

10.2.11 In combination carriers such arrangements as spectacle flanges for isolating slop tanks from cargo tanks are to be provided.

Each closed space adjacent to cargo and slop tanks is to be provided with mechanical ventilation which may be effected by portable fans.

An alarm system capable of operating under the effect of flammable gases is to be provided in cargo pump room, cargo lines as well as in cofferdams adjacent to the slop tanks.

10.2.12 For purging and gas freeing arrangements (other than those referred to in 10.2.8 and 10.2.9) capable to maintain a vertical efflux velocity of at least 20 m/s with simultaneous supply of inert gas to any three tanks may be provided. The outlets of the purging pipes are to be at least 2 m above the cargo tank deck level and be provided with flame-arresting and closing devices.

10.2.13 All tankers are to be equipped with at least one portable instrument for measuring flammable vapour concentrations, together with a sufficient set of spares. Suitable means are to be provided for the calibration of such instruments.

10.2.14 The requirements of 9.2.11 apply to the materials used in the venting system.

10.2.15 The venting pipes of each cargo tank are to be located as far as possible from the inert gas/air intakes. The intakes of the purging pipes are to be arranged either at the deck level or not more than 1 m above the tank bottom.

10.3 CARGO VAPOR DISCHARGE SYSTEM

10.3.1 The present Chapter of the Rules applies to cargo vapor discharge systems of oil tankers and chemical carriers. Oil tankers are equipped with the above mentioned systems as the shipowner wish.

10.3.2 Cargo vapor discharge system shall be arranged so that not to prevent the normal operation of venting system.

10.3.3 Cargo vapor discharge system shall be designed basing on the maximum capacity of loading. The pressure drop in the cargo vapor discharge piping, obtained by means of hydraulic calculation, shall not exceed 80 % of the opening pressure of any discharge valve of venting system.

10.3.4 The instruction approved by the Register shall be constantly kept on the ship by which the allowable loading speed of different cargoes considering the requirements of 10.3.2 and 10.3.3 may be defined.

10.3.5 Vapors of incompatible cargoes shall not be mixed when passing via the vapor collecting and discharge system.

10.3.6 When the inert gas distributive pipeline is used for collecting of cargo vapors, the measures for insulation of inert gas pipes from the cargo vapor discharge system shall be taken.

10.3.7 The provision shall be made for elimination of liquid condensate which may be accumulated in the system.

10.3.8 The piping of the system shall be electrically continuous and have safety earthing.

10.3.9 The cargo vapor discharge manifolds shall be fitted with a pressure sensor and alarm system to produce warning signals at high level (when the pressure is not higher than the lowest pressure value at which the high-speed venting device is actuated) and at low level (at the pressure closest to the atmospheric pressure) of the vacuum valve actuating.

10.3.10 In the area of the adapter sleeve of the cargo vapor discharge manifold the easily accessible check valve with manual control shall be installed.

10.3.11 Hoses applied in the vapor discharge system shall meet the requirements of 6.1.12.

10.3.12 To prevent an incorrect connection of vapor discharge piping to onshore terminal liquid cargo piping on the vapor discharge connecting flanges the studs with the diameter of 12,7 mm and the length not less than 25,4 mm shall be mounted in the upper point of the coupling bolts line, as shown at Fig. 10.3.12-1. The vapor discharge manifold marking shall comply with Fig. 10.3.12-2.

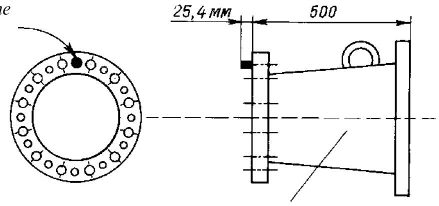


Fig. 10.3.12-1

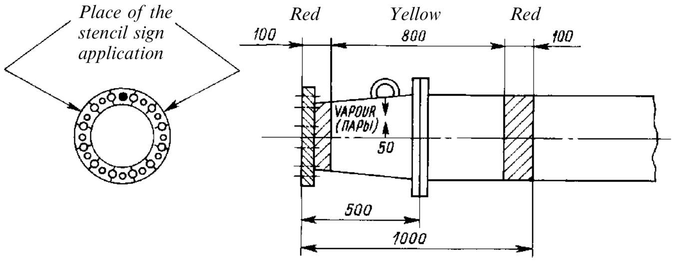


Fig. 10.3.12-2

10.4 OVERFLOW PIPES

10.4.1 Oil fuel tanks should be provided with overflow pipes directing fuel to an overflow tank or storage tank the capacity of which is to be increased by a value not less than the overflow tank capacity as stipulated by 10.5.1 and which is to be equipped in accordance with 10.5.2.

No overflow pipes may be fitted where the oil fuel system is so designed that no spilling overboard can occur during the loading and transfer of fuel.

10.4.2 The cross-sectional area of overflow pipes should be as indicated in 10.1.11 and 10.1.13 for air pipes.

Where it is highly probable that the fuel may freeze in the line, the Register may require the cross-sectional area of overflow pipes in heavy fuel tanks to be increased.

10.4.3 Where the overflow pipes from several integrated tanks located in different watertight compartments are led to a common header or pipe, this header or pipe should 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.

10.4.4 Where air pipes are simultaneously used as overflow pipes, they should not be connected to the air pipes of overflow tanks. In this case, the overflow pipes or a common overflow pipe are to be connected directly to the tank.

10.4.5 Where a tank is used alternatively for the carriage of oil fuel, water ballast or liquid and dry cargoes, then in the case of a common overflow system the overflow pipes are to 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.

10.4.6 The overflow pipes of daily tanks and of fuel and lube oil settling tanks should be led to overflow tanks located below the tanks mentioned above.

10.4.7 A sight glass is to be fitted on vertical overflow pipes at a readily visible and accessible location, or an alarm device is to be provided to give warning when the predetermined level is reached in the overflow tank (see also 10.5.2).

10.4.8 Minimum overflow pipe bore should be 50 mm.

10.4.9 Overflow pipes should be extended up to the bottom of the overflow tanks with a minimal clearance. The flow area of the clearance should not be less than the sectional area of the overflow pipe.

10.5 OVERFLOW TANKS

10.5.1 The capacity of an overflow fuel tank should not be less than the maximum capacity of the fuelling and fuel transfer system within 10 minutes.

10.5.2 An overflow tank shall be provided with audible and visual alarms operating whenever the tank filling reaches 75 per cent.

10.6 SOUNDING ARRANGEMENTS

10.6.1 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 should be provided with sounding pipes generally extended to the open decks. In tanks, other sounding arrangements may be used whose design is approved by the Register.

Sounding pipes of independent tanks are not required to be carried to the open deck.

Upper ends of the sounding pipes of the fuel and lubricating oil tanks are not to be led to the spaces which may present the risk of ignition of leakage from the sounding pipes. Leading of the sounding pipes of the fuel tanks to accommodation and service spaces is prohibited.

10.6.2 Other oil-level gauges may be used, provided they are protected by casing of steel or other equivalent fire-resisting material. Besides, in passenger ships, such means are not to require penetration below the top of the tank and their failure or overfilling of the tanks are not to permit release of fuel.

In cargo ships the level indicators of the oil fuel and lubricating oil tanks, fitted with transparent inserts are to be protected against damage.

The transparent inserts of the oil fuel lubricating oil tanks are to be made of flat glass or shockproof plastics which do not lose transparency under the action of oil fuel and lubricating oil.

A self-closing cock is to be fitted at the lower end of level indicator at the connection to the tank. If the level indicator is connected to the tank below the maximum liquid level, the self-closing cock is to be fitted at the top end.

10.6.3 Where the double bottom forms bilges at the wings, or the ship has a flat bottom, the sounding pipes are to be installed at each side. These pipes are to be led to positions above the bulkhead deck which are at all times accessible for taking soundings. The sounding pipes are to be as straight as practicable and are not to interfere with taking soundings with a sounding rod.

10.6.4 In cargo ships, sounding pipes of the double-bottom tanks for oil fuel and lubricating oil storage are permitted to be led to above the engine room floor plates, or into the shaft tunnel, if idequate structural protection is provided or the sounding pipes terminate at such posiions, where occasional spillage of fuel or lubricating oil will not come into contact with hot surfaces of boilers, engines, exhaust gas pipes, etc., and also with electric machines and switchboards. Such pipes are to be fitted with self-closing valves and their height is to be at least 0,5 m from the floor level. These pipes are not to be used as air pipes.

Below self-closing blanking devices, self-closing control cocks should be fitted.

Laying of sounding pipes of oil fuel tanks through cargo tanks is to comply with the requirements of 8.3.4.

10.6.5 The sounding pipes of the double-bottom water storage tanks are permitted to be led into spaces below the bulkhead deck that are located above them and are accessible at all times. Such pipes are not to be used as air pipes and are to be fitted with self-closing cocks.

10.6.6 Provision should 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 are to be provided.

10.6.7 The internal diameter of the sounding pipes is to be at least 32 mm and for ships of the restricted area of navigation IIIСП it is not to be less than 25 mm. Sounding pipes which pass through refrige-rated 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 are to have a internal diameter of not less than 50 mm.

10.6.8 Nameplates are to be affixed to the upper ends of the sounding pipes.

10.6.9 Each oil tanker equipped with a fixed inert gas system is to be provided with closed measurement devices for taking ullages of cargo and slop tanks.

Open sounding devices are admitted in oil tankers ($>60°$) and as a reserve means in oil tankers not equipped with the inert gas system.

10.6.10 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-level alarms in cargo tanks to ship's operator and to cargo handling room (if available);

.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 on the ship. Signals, pumps and valves shall be switched off by ship operators. Application of ship's automatically closed valves is allowed only upon the permission and under the agreement with Port Administration.

10.6.11 The ends of the sounding pipes led to the exposed decks are to be fitted with tight plugs complying with the requirements of 2.1.9.

The use of closings of a different type will 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.

10.6.12 In floating docks the sounding pipes of ballast compartments shall be led to the top deck of the side walls.

11 EXHAUST GAS SYSTEM

11.1 EXHAUST GAS PIPING

11.1.1 The exhaust gas pipes are, as a rule, to be led to the open decks.

11.1.2 Where the exhaust gas pipes are led through the shell plating in the vicinity of load waterline or below it, provision is to 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 (see 1.2, Part VI "Fire Protection") and on ships servicing or towing the above-mentioned ships, the uptakes of boilers, 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 must be led at a distance not less than 450 mm from the oil fuel tanks.

11.1.5 Each main engine is to 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 II, IIСП, IIIСП and III, 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.

11.1.6 The waste heat 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, are to 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 are to 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 2.1.1.1, Part VI "Fire Protection" are to be met.

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 are to 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 vent openings of crankcases in internal combustion engines should 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 should be fitted with non-disconnectable draining devices to prevent the entry of water into the engine. The devices should be readily accesible for maintenance and clearing and should have a drain pipe bore not less than 25 mm, boilers and incinerators.

11.1.11 The exhaust gas pipes of engines are to be fitted with thermal compensators. Where practicable, handholes and drain cocks should be provided for maintenance.

11.2 SILENCERS AND SPARK ARRESTERS

11.2.1 The silencers and spark arresters are to be so arranged as to permit cleaning and are to be fitted with appropriate handholes or drain cocks.

11.2.2 Where waste heat boilers and spark arresters of the wet type are installed, measures are to be taken to prevent the entry of water into the engines. The drain pipes are to be led into the bilges of the engine room and are to have hydraulic seals.

12 VENTILATION SYSTEM

12.1 VENTILATION DUCTS AND VENTILATOR HEADS, AIR INLETS

12.1.1 Generally, ventilation ducts shall not be led through watertight bulkheads below the bulkhead deck. Where it is not practicable to avoid leading 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 carried 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 are to 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 are to be gastight and are not to communicate with the ducts of other spaces.

12.1.5 Ventilation ducts leading to cargo spaces, machinery spaces and other spaces fitted with smothering facilities are to have closing arrangements complying with 2.1.4.1, Part VI "Fire Protection".

12.1.6 In places of possible sweating the ventilation ducts are to be properly insulated. Drain plugs are to be provided for the portions of ducts where water is likely to accumulate.

The inlets and outlets of the ventilation systems are to 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 are to 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 of category **ЛУ6 — ЛУ9** precautions are to 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 are to 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 is to comply with the requirements of 2.1.4.7, Part VI "Fire Protection".

12.2 VENTILATION 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 are to comply with requirements of this Chapter.

12.2.2 The ventilation ducts are to be constructed of non-combustible materials. However, ducts with a cross-sectional area not exceeding 200 cm^2 and a length not over 2 m may be constructed of material having low flame spread characteristics (see 1.6.2, 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 60 cm, measured along the duct, from the penetration of an "A" or "B" class division (see 2.1.2, Part VI "Fire Protection"), including continuous "B" class ceilings.

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 should 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 should comply in this part with the following:

.1 the sleeves should have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length should be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, should be provided with fire insulation. The insulation should 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 should be fitted with fire dampers in addition to the requirements of 12.2.3.1.

The fire damper should operate automatically but should also be capable of being closed manually from both sides of the bulkhead or deck. The damper should be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where the ducts pass through spaces surrounded by "A" class division, without serving those spaces, provided those ducts have the same fire integrity as the division which they pierce.

12.2.4 Ducts provided for the ventilation of machinery spaces of category A, galleys, cargo spaces of ro-ro ships, car deck spaces or special category spaces shall not pass through, accomodation and service spaces or control stations, except where:

.1 the ducts are constructed of steel having a thickness of at least 3 and 5 mm for ducts the width or 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 is to be determined by interpolation;

.2 the ducts are suitably supported and stiffened;

.3 the ducts are fitted with automatic fire dampers close to the boundaries penetrated, and

.4 are insulated to A-60 standard to a point at least 5 m beyond each fire damper, or

.5 the ducts are constructed of steel in accordance with requirements of 12.2.4.1 qnd 12.2.4.2, and

.6 are insulated to A-60 standard throughout the accommodation spaces, service spaces or control stations.

The above-stated requirements also apply to ducts intended for the ventilation of accommodation spaces, service spaces and control stations which pass through machinery spaces of category A, galleys, cargo spaces of ro-ro ships, car deck spaces and special-category spaces.

If a ventilation duct is led through the main vertical fire zone divisions, the requirements of 12.2.8 are to be also complied with.

12.2.5 Where ventilation ducts with a cross-sectional area exceeding 200 cm^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 bulkhead, this length shall be divided into 450 mm on each side of the bulkhead.

12.2.6 All necessary measures are to 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 are to be provided with the inlets of ducts so arranged that the risk of both inlets drawing in smoke simultaneously is minimized.

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 are to be separate from the ventilation systems serving other spaces.

The exhaust ducts from galley ranges should be constructed of "A" class divisions where they pass through accommodation spaces or spaces containing combustible materials.

Each exhaust duct should 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.

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. 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 is to be made of steel or other equivalent material and, where necessary, is to be provided with insulation corresponding to the degree of fire integrity of the division. At least at one side of the division the damper is to be fitted with a readily visible indicator showing whether the damper is open.

12.2.9 Provision should be made for closing the main inlets and outlets of all ventilation systems from outside the ventilated spaces.

12.2.10 The ventilation ducts and their passages through "A" or "B" class divisions in ships of less than 500 gross tonnage are, generally, to be constructed in compliance with the requirements of this Chapter. The relaxations from these requirements are subject to special consideration by the Register in each case.

12.2.11 Provision shall be made for switching off the mechanical ventilation in the accommodation, service and cargo spaces, on the control stations and in machinery spaces, to be carried out from an easily accessible position outside the space to be served. Arrangements for switching off the mechanical ventilation of machinery spaces shall be independent of those intended for other spaces.

12.2.12 The following arrangements are to be tested in accordance with the Fire Test Procedures Code (see 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.

12.3 VENTILATION 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 are to comply with the requirements of 12.2, besides meeting the requirements of this Chapter.

12.3.2 In general, the ventilation fans and ducts are to be disposed within the main vertical fire zone which they serve.

12.3.3 Where the ventilation ducts are led through the decks, measures are to be taken to minimize the possibility of smoke and flammable gases passing from one 'tween-deck space to another. If necessary, the vertical ducts are to be insulated as required by 2.2.1.3, Part VI "Fire Protection".

12.3.4 Except in cargo spaces, ventilation ducts are to be constructed of the following materials:

.1 ducts with a cross-sectional area more than 750 cm^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 750 cm^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 should be given to ensuring the fire integrity of the divisions;

.3 short lengths of ducts not, in general, exceeding 200 cm^2 in sectional area nor 2 m in length - of materials mentioned in 12.2.2.

12.3.5 Ventilation systems of stairway enclosures should be independent of other systems.

12.3.6 Exhaust ducts from galley ranges in which grease or fat is likely to accumulate should meet the requirements of 12.2.4 and should 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;

.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 should be placed in a position close to the entrance to the galley. Where a multi-branch system is installed, means should 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.

12.3.7 Where public spaces span three or more decks and contain combustibles such as furniture and enclosed spaces such as shops, offices and restaurants, such spaces are to be equipped with a ventilation activated by a smoke extraction system and capable to ventilate the entire volume during not more than 10 minutes. Provision is to be made for manual control of the fans.

12.4 VENTILATION 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 are to comply with requirements of this Chapter.

12.4.2 The ventilation inlets of accommodation spaces, service spaces and control stations are to be located on the end 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 should be given to location of these vents in oil tankers equipped to load and discharge at the stern.

12.4.3 The cargo pump rooms of tankers are to have mechanical exhaust ventilation fitted separately for each space. This ventilation shall have sufficient capacity to give at least 20 air changs per hour based upon the gross volume of the space and to prevent the accumulation of flammable vapours in the space. Inlet ventilation of these spaces may be natural. The interlocking between the devices for starting of electrical engines of cargo pumps and electrical motors of fan drives shall meet the requirements of 19.2.4.11.2, 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 are to 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 should be provided on the exhaust duct. This intake shall have a damper capable of being operated from the main deck and lower grating level. The damper may be omitted if the areas of the inlets are chosen such that at least 20 air changes per hour will be ensured through the lower inlets, and at least 15 air changes per hour through the upper inlets in case of the lower inlets being flooded.

Where the ventilation system of the pump room is used for ventilating the cargo line and the communicating cargo tanks, duplicate shut-off fittings shall be provided at the connections of the ventilation duct to the cargo line.

12.4.5 The construction of the ventilation fans in cargo pump rooms shall comply with requirements of 5.3, Part IX "Machinery" and the location of their driving motors shall meet the requirements of 4.2.5, Part VII "Machinery Installations".

12.4.6 The outlets of exhaust ducts for cargo pump rooms are to be not less than 2 m remote from any opening leading into ship spaces which may contain a source capable of ignition oil vapours, and are to be so located that no contamination of air entering the inlets of ventilation systems will occur.

The outlets of ventilation ducts are to be fitted with flame-arresting fittings.

The air intakes are to 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 should 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 are to 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 should 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 are to be such as to prevent plugging. Where plastic materials are used, they are to be electrically conductive and pipes are to 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 should 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 are to 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 are to be properly ventilated. The pipe tunnels led in the double bottom are to have mechanical exhaust ventilation.

12.5.3 In the space containing emergency diesel-generator (automatically started), provision should 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 should be installed. The construction of fans is to 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 are to have mechanical exhaust ventilation independent from other ventilation systems.

If individual spaces have effective closures, ventilation ducts are to be separate for each of them.

The fans are to 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 is to be equipped with devices indicating any loss or reduction of theventilating capacity and operation of the fans. These devices are to 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 requirements of 5.3, Part IX "Machinery".

12.6.5 Arrangements are to be provided for effective closure of the ventilation system in case of fire taking the weather conditions into account.

12.6.6 The ventilation ducts and their closures are to be made of steel.

12.7 VENTILATION OF CARGO SPACES ADAPTED FOR THE CARRIAGE OF DANGEROUS CARGOES*

12.7.1 Closed cargo spaces in cases mentioned in 2.8.2, Part VI "Fire Protection" are to have mechanical exhaust ventilation, separate for each such space, sufficient to give at least 6 air changes per hour, based upon the volume of an empty hold.

Supply ventilation of these spaces may be natural.

In well-founded cases specially agreed with the Register, mechanical supply and natural exhaust ventilation systems are permissible, provided the requirements of 2.8.12, Part VI "Fire Protection" are fulfilled.

The number of air changes may be reduced with regard to the method of transportation (see Note 11 to Table 2.8.2, 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 2.8.6, 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 is to be such as to provide uniform change of air within the cargo space and to prevent formation of trapped zones.

The ventilation system is to 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 is to comply with the requirements of 5.3, Part IX "Machinery".

The electric motors of the fans are to be of flameproof design. It is not recommended to arrange them in way of gas exhaust.

The inlets and outlets of ventilation systems are to be protected by screens.

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 pumps servicing cargo holds for carriage of dangerous cargoes shall be provided with separate artificial exhaust ventilation sufficient to give at least 6 air changes per hour.

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 — 3.3.8, Part XII "Refrigerating Plants".

12.9 VENTILATION OF FOAM FIRE-EXTINGUISHING AND SMOTHERING STATIONS

12.9.1 The foam fire-extinguishing and smothering stations are to be equipped with efficient ventilation systems.

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 are to 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.

*For "dangerous cargoes", see 1.2, Part VI "Fire Protection".

12.10 VENTILATION OF ACCUMULATOR BATTERY ROOMS AND BOXES

12.10.1 The accumulator battery rooms and boxes are to be provided with independent ventilation system capable of removing air from upper part of the ventilated spaces.

The exhaust ducts are to be gastight.

12.10.2 The inlet air is to be supplied into the lower part of the ventilated space.

12.10.3 The outlets of ventilation ducts are to be so constructed as to preclude the admission of sea water, atmospheric precipitation and solids.

No flame-arresting fittings should be installed.

The discharges of exhaust ducts are to be led 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 is to be not 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, is to be not less than determined by the formula:

$$F = 1{,}04Q, \qquad (12.10.6)$$

but not less than 0,004 m^2.

Here 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 $2{,}36 \cdot 10^{-2}$ m^3/s;

.2 the angle of the duct deflection from the vertical is less than 45°;

.3 the number of bends of the duct does not exceed 2;

.4 the length of the duct does not exceed 5 m;

.5 the operation of ventilation system does not depend on the direction of the wind;

.6 the cross-sectional area of the duct shall be taken not less than that determined by Formula (12.10.6).

12.10.8 Where the rate of air flow determined by Formula (12.10.5) is $2{,}36 \cdot 10^{-2}$ m^3/s and over, the accumulator battery room is to be provided with mechanical exhaust ventilation.

12.10.9 The internal surfaces of the exhaust ducts, as well as the ventilating fans are to be protected against the action of the electrolyte.

12.10.10 The motors of the ventilating fans shall not be arranged in way of gas exhaust.

The construction of the ventilating fans is to comply with the requirements of 5.3, Part IX "Machinery".

12.11 VENTILATION OF HANGARS FOR HELICOPTERS

12.11.1 The hangars for helicopters are to be provided with mechanical exhaust ventilation sufficient to give at least 10 air changes per hour.

12.12 VENTILATION OF SPACES IN OIL RECOVERY SHIPS

12.12.1 Ventilation systems serving dangerous and safe spaces are to be independent of each other. Spaces in zones belonging to different classes as listed under 19.2.3, Part XI "Electrical Equipment" should be served by different systems.

12.12.2 Safe spaces and air locks should be equipped with mechanical supply ventilation to ensure excessive pressure therein as compared to adjacent dangerous spaces.

12.12.3 Provision should 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 should be located outside dangerous spaces on open decks.

12.12.5 Exhaust duct openings should 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) % of the lower limit of the explosive range is reached in the atmosphere of the space.e range is reached in the atmosphere of the space.

Dangerous spaces in Zone 2 should be provided with ventilation to ensure at least 10 air changes per hour.

12.12.7 In dangerous spaces, the exhaust ventilation ducts should be gas-tight, rigid enough and should not pass through safe spaces (except where the ducts of the pressure part of ventilation are led through safe spaces in gas-tight tunnels).

12.12.8 In spaces and air locks, the ventilation systems should 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 is to 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 3.9.9.3, Part VI "Fire Protection", provision shall be made for artificial forced ventilation which is to ensure the number of air changes not less than stipulated under 12.13.1.

13 OIL FUEL SYSTEM

13.1 PUMPS

13.1.1 At least two pumps are to be provided for fuel transfer, one of which being a standby pump.

Any suitable pump, including the oil fuel separator pump, may be used for standby purpose.

For cargo ships of less than 500 gross tonnage navigating in restricted areas II, IIСП, IIIСП and III, 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 oil fuel tanks, including the deep tanks, are used also for water ballast, provision is to be made for reliable arrangements disconnecting the ballast system from these tanks when carrying oil fuel and the oil fuel system, when containing water.

In addition, the requirements of the Rules for the Prevention of Pollution from Ships are to be complied with.

13.1.3 The fuel transfer pumps and the separator pumps, besides local hand control, are to be provided with stopping means operable from always accessible positions outside the space where the pumps are installed.

13.1.4 Shut-off valves should be fitted on the pressure side and suction side of fuel oil pumps.

13.2 PIPING LAYING

13.2.1 In general, the oil fuel pipeline shall have no communication with other piping systems. Where the oil fuel tanks are used also for water ballast, the requirements of 13.1.2 are to be complied with.

13.2.2 Pressure pipes conveying oil fuel heated above 60°C are to be arranged in clearly visible and accessible positions the number of detachable joints being reduced to a minimum.

13.2.3 The fuel pipes are not to be led 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 lead 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 50 *l* 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 dayly 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 OIL FUEL TANKS

13.3.1 For oil fuel heating the heat-carrying agents enumerated in 9.3.1 may be applied. In case of using electric heating appliances for oil fuel heating, the requirements of 15.3, Part XI "Electrical Equipment" are to be complied with.

13.3.2 Heating coils and electric heating appliances should 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 should be so positioned above the heating coils and electric heating appliances that the latter remain submerged as far as practicable.

13.3.4 Oil fuel in storage tanks shall not be heated to temperatures within 15° below the flash point of the fuel oil.

Oil fuel 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 the vent pipes from such tanks and/or a cooling device is sufficient for cooling the vapours to at least 15°C below the flash point of the fuel oil;

.2 a temperature sensor is fitted in the vent pipe and adjusted to give alarm if the temperature should exceed a limit set at 15°C below the flash point of the fuel oil;

.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 OIL FUEL TANKS

13.4.1 For draining water from the bottom of the daily service and settling tanks, these tanks are to be fitted with self-closing valves and pipes connected to drain tanks.

The drain pipes are to 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 oil fuel leakage.

13.5.2 Drain pipes from the drip trays are to lead into oil fuel drain tanks.

Drainage of oil fuel into the bilges and overflow tanks is not permitted.

13.5.3 The internal diameter of the drain pipes is to be at least 25 mm.

13.5.4 The ends of the drain pipes are to be led to the tank bottom with a gap the diameter of which is to be 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 are to 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 should be made for an alarm device to give warning if the oil fuel reaches the upper predetermined level in the drain tank.

13.5.5 If drain pipes from drip trays fitted in different watertight compartments are led into a common drain tank, structural precautions are to 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 is to 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 are to 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 is to be led to the tank bottom with a gap the diameter of which is to be not less than 1/4 of the internal diameter of the pipe.

13.6.2 In passenger ships provision is to be made for bunkering stations which are separated from the other spaces, and fitted with drain pipes leading into oil fuel drain tanks.

13.6.3 The filling pipes of the tanks situated above the double bottom are to be connected to the tanks near the top.

Where this is impracticable, the filling pipes are to 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 is to be replaced by a remote-controlled shut-off valve operable from accessible position outside the space in which the tank is located.

13.7 OIL FUEL TANKS

13.7.1 The structural members of oil fuel tanks are to comply with the requirements of Part II "Hull".

13.7.2 The arrangement of the fuel tanks in the machinery spaces is to 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 are to be protected against the action of sunrays.

13.7.4 In glass-reinforced plastic ships (see 2.9, Part VI "Fire Protection") the fuel tanks shall not directly adjoin the accommodation spaces. The air gap between the fuel tank and accommodation space is to be efficiently ventilated.

In general, the fuel tanks are not to be located in machinery spaces. If they are located in such spaces, they are to be constructed of steel or equivalent material (see 1.2, Part VI "Fire Protection").

13.7.5 Oil fuel tanks are to be separated from the feed water and vegetable oil tanks by cofferdams the structural members of which should 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 are not to be used for carriage of oil fuel or other flammable liquids.

13.7.7 In ships having distinguishing mark of provision with means for fire fighting in the class notation the fuel oil tanks are to contain oil fuel reserve sufficient to provide the operation of pumps of special fire-extinguishing systems during 24 hours for ships with distinguishing mark П3В and 72 hours for ships with distinguishing marks П1, П1В, П2 or П2В.

13.8 OIL FUEL SUPPLY TO INTERNAL COMBUSTION ENGINES

13.8.1 The equipment of fuel system shall be capable of supplying oil fuel duly prepared and cleaned to the extent required for the given engine.

The main and auxiliary engines are to be supplied with fuel oil from two fuel oil service tanks for each type of fuel used on board or equivalent arrangements are to be provided.

The capacity of each tank is to 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 oil fuel systems are shown in Fig. 13.8.1-1 and 13.8.1-2.

Exemption from these requirements may be granted by the Register for ships of restricted service

a)	Heavy fuel oil service tank with a capacity for 8 h operation of main engine, diesel generators and auxiliary boilers	Heavy fuel oil service tank with a capacity for 8 h operation of main engines, diesel generators and auxiliary boilers	Diesel oil service tank for starting at low temperature or repairs of engines and boilers
b)	Heavy fuel oil service tank with a capacity for 8 h operation of main engines, diesel generators and auxiliary boilers	Diesel oil service tank with a capacity for 8 h operation of main engines, diesel generators and auxiliary boilers	

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.

Where pilot burners are used in auxiliary boilers, an additional diesel oil tank with a capacity for 8 h operation may be required.

a)	Heavy fuel oil service tank with a capacity for 8 h operation of main engines and auxiliary boilers	Heavy fuel oil service tank with a capacity for 8 h operation of main engines and auxiliary boilers	Diesel oil service tank with a capacity for 8 h operation of auxiliary engines	Diesel oil service tank with a capacity for 8 h operation of auxiliary engines
b)	Heavy fuel oil service tank with a capacity for 8 h operation of main engines and auxiliary boilers	Diesel oil service tank with a capacity for 4 h operation of main engines, diesel generators and auxiliary boilers or for 8 h operation of diesel generators and auxiliary boilers, whichever is the greater	Diesel oil service tank with a capacity for 4 h operation of main engines, diesel generators and auxiliary boilers or for 8 h operation of diesel generators and auxiliary boilers, whichever is the greater	

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.

area III СП of less than 500 gross tonnage, as well as for dredging vessels and ships less than 24 m in length.

13.8.2 The filters fitted in the oil fuel supply lines to the engines are to be such that any filter can be cleaned without interrupting the operation of the engine.

13.8.3 Where one booster pump is fitted to serve the main engines, except where the machinery installation comprises two or more main engines, each having its own booster pump, the arrangements are to be such that the engines are supplied with oil fuel in the event of damage to the booster pump.

The Register may grant an exemption for cargo ships of less than 500 gross tonnage that navigate in restricted areas II, IIСП, IIIСП and III.

13.8.4 Where the main 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 are to 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. The tank capacity is to be such as to ensure operation of the diesel generator for the period stated in 19.1.2.1, and 9.3.1 Part XI "Electrical Equipment".

13.9 OIL FUEL SUPPLY TO BOILERS

13.9.1 The oil fuel supply system with mechanical atomization, serving the main boilers and the auxiliary boilers for essential services (see 1.2, Part X "Boilers, Heat Exchangers and Pressure Vessels") is to include at least two sets of fuel pumps, suction and discharge filters.

Each set of machinery is to be calculated for the full steam generating capacity of the boilers served.

Apart from the local controls, the fuel pumps are to have means enabling them to be stopped from easily accessible positions outside the spaces in which they are situated.

The main boilers are generally to be supplied from two fuel tanks.

13.9.2 The pumps supplying oil fuel to the boilers are not to be used for other purposes.

13.9.3 The pipes conveying oil fuel to the burners of each boiler are to 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 oil fuel to the burners.

13.9.4 Where oil fuel is fed to the burners by gravity, filters are to be fitted in the supply pipeline to the burners.

13.9.5 It should 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 is to 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 is to comply with the requirements of Section 5, Part X "Boilers, Heat Exhangers and Pressure Vessels".

13.9.8 Thermometers and pressure gauges are to be installed in suitable positions on the pipes supplying oil fuel to the burners.

13.10 OIL FUEL SUPPLY TO GAS TURBINES

13.10.1 The main gas turbine installation shall have at least two fuel pumps: main and standby, of which one may be driven from the main turbine.

The capacity of the standby pump shall be not less than that of the main pump.

Where the installation includes two or more gas turbines, one independent standby pump will suffice.

13.10.2 An appropriate system for removing the remainder of fuel from turbine casing, combustion chambers and gas lines shall be provided.

13.10.3 An interlock device should be provided to preclude admission of fuel into combustion chambers, with the turbine stopped.

13.10.4 The oil fuel system of a gas turbine installation shall comply also with requirements of 13.8.

13.10.5 Provision shall be made for discharge of oil fuel from pressure piping, the starting and main burners after a stop of the turbine or burner operation.

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 are to 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 or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to 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 are to be proved to be satisfactory in operation with crude oil.

The whole surface of the boilers shall be gastight separated from the engine room.

The boilers themselves are to 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 should be led to a separate observation tank installed together with the above-mentioned components.

This closed tank is to be fitted with a venting pipe led to the atmosphere in a safe position according to the requirements of 10.2.8 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 is to be automatically controlled and a high temperature alarm is to 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 1.3.4.3.

The number of connections for these pipes shall be minimum.

The pipe 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 are to be fitted within metal duct which is to 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 is to be fitted at a distance from the ship's side of at least 20% of the ship's beam amidships.

It is to 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 are to be fitted on the drainage tank specified in 13.11.2.

Also a vent pipe is to be fitted at the highest part of the duct and is to be led to the open in a safe position according to the requirements of 10.2.8 for oil tankers. The outlet is to be fitted with easily removable flame proof wire gauze.

The duct is to 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 are to 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 is to 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 is to be fitted with a venting pipe led to the open in a safe position and with the outlet fitted with wire gauze easily dismountable for cleaning.

This draining pipe is to be fitted with arrangements to prevent the return of gas 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 is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with an easily dismountable flame wire gauze.

At least two mechnaically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room.

The exhaust fans are to 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) is to be of certified safe type as required by an appropriate authority.

13.11.11 When using fuel oil for delivery to and return from boilers fuel oil burning units in accordance with 13.10 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 are to be fitted with a mechanical ventilation plant and shall be designed in such a way as to avoid the formation of gas pockets. Ventilation is to 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 Section 12.

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.

An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided.

13.11.14 Means are to 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 is to 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 should automatically stop the exhaust fan of the boiler hood (see also 13.11.8 of this Part and 3.1.2.8, Part VI "Fire Protection").

13.11.16 A warning notice is to be fitted in an easily visible position near the boiler front. This notice must specify that when an explosive mixture is signalled by the gas detector plant defined in 13.11.13, the watchkeepers are to 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 FOR DUAL-FUEL INTERNAL COMBUSTION ENGINES

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 Section 12.

13.12.4.2 Engine rooms shall be equipped with the effective gas detection system in the places of possible gas lock and leakage. When the concentration of gas is equal to 30 % of low flammability limit, the audible and visible alarms shall be actuated, and when the concentration of gas is equal to 60 % of low flammability limit, the supply of gas fuel to the engine room shall be cut off.

13.12.5 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 (see Table 9.7.1, Part IX "Machinery").

13.12.7 Gas line shall have sufficient structural strength with regard to stresses caused by the weight 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 radiographycally 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 shall meet the requirements of Section 9, Part IX "Machinery".

13.13 OIL FUEL SYSTEM FOR HELICOPTERS

13.13.1 The oil fuel system for supplying other ships and helicopters with fuel having a flash point below 43°C should comply with the requirements of 2.1.11, Part VI "Fire Protection".

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 a reserve pump is available which may be assembled on board, no standby pump may be provided.

Where two main engines are installed, each of them is to have its own lube oil pump, with provision for one standby pump driven independently and having a capacity sufficient to ensure the operation of one main engine.

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 II, IIСП, IIIСП and III, standby pumps need not be installed irrespective of the number of main engines.

This exception shall not apply to the following ships of restricted navigation area II:

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 lube oil pump, provision should 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 is to be ensured at stoppage of the pump at work.

Means are to 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, are to comply with requirements of 14.1.1 — 14.1.4 for the main engines.

14.1.7 Each auxiliary engine and each emergency diesel generator engine (see 2.2.5, Part IX "Machinery") is to have a separate lubricating system.

A common lubricating system of the auxiliary engines is, in each case, subject to special consideration by the Register.

14.2 LUBRICATING OIL SUPPLY TO INTERNAL COMBUSTION ENGINES AND GEARS

14.2.1 The lubricating oil drain pipes from the engine crankcase are to 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 lube oil drain pipes of two or more engines.

14.2.2 The pipes of the lubricating oil system are not to communicate with other piping systems, except where they are connected to separators which may be used for oil fuel separation. In the latter case, arrangements are to be fitted which will preclude mixing of oil fuel and lube oil.

While separating lube oil, precautions are to be taken to prevent mixing of lube oil for main and auxiliary engines.

14.2.3 The lubrication system is to provide effective cleaning of oil for which purpose filters are to 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 pump; two parallel filters or one duplex filter or a self-cleaning filter on the discharge side of the main engine pump.

14.2.4 The capacity of each oil filter is to exceed by 10 per cent the maximum capacity of the pump.

14.2.5 The lubricating system is to be fitted with adequate instrumentation.

The pressure gauge indicating the pressure after the oil cooler is to 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 is to 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 is to 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 are to be of self-priming type and are to be so disposed that reliable start-up is always possible.

14.3.3 In general, the lubricating oil for main turbine sets is to 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 should 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, is to 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 is to 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 are to 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 is to be not less than a 5-minute consumption of oil, with the turbine running at rated output.

The tank is to 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 is to be at least 1,25 times that of the discharge pipe of the pump.

It shall be possible to supply lube oil to consumers from the pump, excepting the tank.

14.4.5 The lubrication system of the main turbine set is to 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 requirements of 14.1.6, 14.2.3 and 14.2.5.

14.4.7 The branch pipes of the circulating oil pipeline are to be fitted with throttles for regulating the amount of oil supplied to each consumer.

14.5 LUBRICATING OIL TANKS

14.5.1 The lubricating oil tanks are to be separated from the feed water and vegetable oil tanks by cofferdams the structural members of which should comply with the requirements of Part II "Hull".

14.5.2 The lubricating oil drain tanks of main turbines should in any case be separated from the bottom shell plating by a cofferdam the structural members of which are to 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.

14.5.3 Provision is to 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 II and III, the lubricating oil storage tank need not be provided.

14.5.4 The suction pipes from the tank situated outside the double bottom are to 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 are to comply with the requirements of 13.3.

14.5.6 For lubricating oil tanks arranged in machinery spaces of category A (see 1.2, Part VII "Machinery Installations") and, whenever practicable, in other machinery spaces, the requirements of 13.5.1 of this Part and 4.3.3, 4.3.4, Part VII "Machinery Installations", are to 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 same requirements as set out for oil fuel systems in 13.5 are applicable to unattended machinery spaces.

14.7 LUBRICATING OIL SUPPLY TO GAS TURBINES

14.7.1 The lubricating oil system of a gas turbine plant shall comply with requirements of 14.1 — 14.5 as far as these requirements are applicable to the given plant.

15 COOLING WATER SYSTEM

15.1 PUMPS

15.1.1 Water cooling systems of main engines are to comply with the following requirements:

.1 a sea water cooling system of one main engine is to include two cooling water pumps, one of which is standby. The capacity of the standby pump is to be not less than that of the main pump. At least, one pump is to be driven independently.

A fresh water cooling system of the main engine is also to comply with these requirements.

One common independent standby pump may be used for both fresh and salt water cooling; the capacity of this pump is to be not less than that of the main pumps; precautions are to 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 is to 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 is also to comply with these requirements.

It is permitted to install one common independent standby pump, the capacity of which is to ensure fresh or sea water cooling of any engine; precautions are to 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 is to be sufficient for simultaneous cooling of all engines when running at maximum load. One standby pump, the capacity of which is to be not less than that of the main pump cooling simultaneously all engines, is to be provided.

The cooling pipe is to have a water control valve at inlet to each engine;

.4 in the installations with an automation mark in the class notation provision is to be made for separate fresh water and salt water standby pumps, the capacity of which is to be not less than that of the main pumps;

.5 in ships of restricted areas of navigation, special standby facilities are not compulsory; however, it should be possible to cool the engine by sea water directly.

In ships of restricted areas of navigation II, II СП, III СП and III, 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 are to 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 should 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 requirements contained in 3.2.3.3, 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 are generally to be served by the circulating pumps of the main condensers.

Where for servicing the oil coolers an independent circulating pump is fitted, provision is to 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 is to be provided in an independent sea water cooling and lubricating system for stern bearings. Any sea water general purpose pump 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 II, II СП, III СП and III, 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 should 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 heating of sea chests in ships with ice strengthening are given in 4.3.1.2.

15.3 COOLING WATER FILTERS

15.3.1 Filters are to be fitted on the suction lines of water cooling system servicing the main and auxiliary engines. Filters are to 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 is to 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 is to be connected to the suction piping of the pumps and may be common for the cooling system of several engines.

The tank should be provided with a device for monitoring the water level.

In the cooling system of engines, the arrangement of the sea water discharge pipes is to 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 is to be fitted with thermometers and temperature control devices.

It is recommended that suitable alarms should be provided to warn on the limit value of the cooling water temperature.

15.4.3 The cooling system of an engine to be used as emergency engine should 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 are to 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 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 **ЛУ4 — ЛУ9** 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 stand-by cooler shall be provided to keep each engine running. For ships of restricted area of navigation equipped with two or more main engines the stand-by 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 cooling medium to coolers the check valves shall be provided in compliance with the requirements of 4.3.2.

15.6.6 Installation of valves shall be in compliance with 4.3.2.10, and the operating gear shall meet the requirements of 4.3.2.8, 4.3.2.9.

15.6.7 Arrangements for discharge of cooling medium from the coolers shall be provided.

16 COMPRESSED AIR SYSTEM

16.1 NUMBER AND CAPACITY OF STARTING AIR RECEIVERS

16.1.1 The compressed air system of the main engines is to ensure simultaneous starting and reversing of all the main engines.

The requirements for the starting system of gas turbines are given in 8.1.9, Part IX "Machinery".

16.1.2 The total amount of starting air for the main engines starting and the associated pneumatic control systems is to 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 is to be at least 50 per cent of that required in 16.1.3 and 16.1.4 (see also 16.1.6).

Where an electric tyfon is used in ships of restricted areas of navigation II and III, 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 is to 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 **ЛУ6 — ЛУ9** 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, is to 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 is to be provided.

16.1.5 For starting of the auxiliary engines provision is to 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 should 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 should 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 is to 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 should comply with the requirements of 9.5.2, 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 is to be at least two. The total capacity of the main compressors is to 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 manoeuvres referred to in 16.1.13 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 is to be approximately the same. The capacity of the independently driven compressors is to be not 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 **ЛУ6 — ЛУ9** provided 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 III and III СП with reversible main engines, one independently driven compressor is permitted, whereas with main engines of a non-reversible type, one attached compressor is permitted. The capacity of the compressors is to 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 is to be made for the possibility of 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 whose 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 II, II СП, III СП and III.

16.3 PIPING LAYING

16.3.1 All pressure pipes from starting air compressors should lead directly to the starting air receivers, and all starting pipes from the air receivers to main or auxiliary engines should be entirely separated from the compressor pressure pipe system.

16.3.2 Each of the starting air receivers specified in 16.1 is to be capable of being filled from each main compressor specified in 16.2. Possibility of back flow is to be precluded (see 16.1.7).

16.3.3 Non-return shut-off valves are to be installed on the discharge pipe of each compressor.

The manifold supplying starting air to each engine is to 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 (see 2.9.1, Part IX "Machinery").

16.3.4 The temperature of air or compressed gas entering the receivers is not to exceed 90°C. Where required, provision is to be made for appropriate coolers.

The compressed gas pipes are not to be led under the engine room floor plating.

16.3.5 The pipes are to be led as straight as practicable with a slope for water drainage.

The pipes are not to have a slope in the direction of the master starting valve of the engine.

16.3.6 Suitable arrangements for draining the accumulations of oil and water are to 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 and fuse plugs fitted on the air receivers are arranged to discharge compressed air outside the engine room, the sectional area of discharge pipes shall be not less than a two-fold section of the pressure relief valves or fuse plugs; appropriate arrangements for draining water from the pipes are to be provided.

16.3.8 The pneumatic sound devices of the alarm system stipulated by 7.3, Part XI "Electrical Equipment" should be connected to starting air receivers by means of special piping.

17 FEED WATER SYSTEM

17.1 PUMPS

17.1.1 Each main boiler and an essential auxiliary boiler or a group of boilers are to 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 is to be not 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 is to be not 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 are to 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 are to be taken to prevent feed water being contaminated by oil and oil water.

17.2.4 The main boilers and essential auxiliary boilers are to be provided with automatic devices for monitoring of feed water salinity.

17.3 TANKS

17.3.1 Feed water tanks should be separated from tanks containing oil fuel, lubricating oil and vegetable oil by cofferdams the structural members of which are to 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 Steam for the ship's whistle is to be supplied through a separate line directly from the main boiler. This requirement does not apply to ships which, apart from the steam whistle, have pneumatically or electrically operated sound signal means.

18.1.4 The machinery connected with the steam lines is to be relieved of the stresses caused by thermal expansion of pipes. The may be achieved by means of self-compensation (pipe bends) or by installation of thermal compensators in appropriate positions.

18.1.5 In the steam lines supplying the machinery and arrangements designed for a lesser pressure than the boiler pressure, there should be fitted reducing valves, and requirements of 1.4.3 are to be complied with.

18.1.6 If provision is made for a steaming system for fuel and cargo oil tanks, each tank is to be fitted with non-return shut-off valves.

18.1.7 The steam pipelines in the engine and boiler rooms are to be led in the upper parts of these spaces, where practicable, in a position accessible for observation and servicing.

Leading 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 led near the oil fuel tanks.

Steam lines with working temperatures above 220°C are not permitted to be led in cargo pump rooms of tankers.

18.2 BLOW-OFF ARRANGEMENTS OF STEAM LINES

18.2.1 Pipelines coveying live steam are to 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 are to be led below the floor plates of the engine and boiler rooms (see also 5.3.8).

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, should, 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 are to be calculated in cold condition for a 100%-prestressing considered as great as the displacements due to full thermal expansion (displacements of supports included), but with an opposite sign. Where a steam pipe in hot condition undergoes displacements, it should be calculated in view of these displacements and, after that, for a 100%-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 joining parts (elbows, T-joints, etc.) may be assumed rigid and need not be calculated for flexibility.

18.3.4 The design stress in pipes is to be calculated depending on the pipe cross-sectional area, including the positive manufacturing tolerance for pipe wall thickness. The same sizes should be used for determining the stresses from displacements. As for the stresses caused by internal pressure, they should 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 by desk computers, the three components of reaction for a plane frame in general and the six components for a space frame should 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 should 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 should be determined by the formulae:

for $\lambda \geqslant 0,4$

$$k = \frac{10 + 12\lambda^2}{1 + 12\lambda^2} \qquad (18.3.7\text{-}1)$$

and for $0,2 \leqslant \lambda < 0,4$

$$k = 1,65/\lambda, \qquad (18.3.7\text{-}2)$$

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 should be shown also for a cold pipeline at they hydraulic test pressure.

18.3.9 The resultant stress in a straight pipe when exposed to internal pressure and to the bending and twisting moments should be determined by the formula:

$$\sigma_{res} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_1\sigma_3 - \sigma_2\sigma_3 + 3\tau^2}\ , \qquad (18.3.9)$$

where σ_1 = total normal stress from bending and internal pressure, MPa;
σ_2 = circumferential stress due to internal pressure, MPa;
σ_3 = radial stress due to internal pressure, MPa;
τ = shearing stress, MPa.

18.3.10 The total stress acting on the inside of a bent pipe should 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 circumferential stress from internal pressure.

18.3.11 Safety factors, relating to the yield point and average stress producing rupture, which should 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 PROVISIONS

19.1.1 Each main turbine set is to 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 is to be serviced by two circulating pumps one of which is a standby pump.

The capacity of the standby pump shall be not 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.

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 is to be serviced by two circulating 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 is to meet the requirements of 19.2.1.

19.2.4 The condensate system of a steam turbine installation is to be serviced by two condensate pumps. The capacity of each pump is to 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 arrangement of pipes and their connections are to comply with requirements of 15.2 and 15.3.

19.3.2 The condensate collector, discharge pipe and condensate pump are to 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 is to be made for a handhole for cleaning the collector.

19.3.3 The nozzles of the ejectors of the condenser installations are to be protected against damage and clogging, for which purpose a metal screen is to be fitted in the steam pipe.

19.4 INSTRUMENTATION

19.4.1 The condenser installation is to 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 TESTS

20.1 HYDRAULIC TESTS OF FITTINGS

20.1.1 The fittings intended for Class I and Class II piping are to be subjected to a hydraulic test by the pressure indicated in 1.3.1, Part IX "Machinery".

20.1.2 The fittings intended to work under a design pressure of 0,098 MPa and less, as well as in vacuum conditions are to be tested by a pressure not less than 0,196 MPa.

20.1.3 Valves, cocks and other fittings intended to be fitted on the ship side below the loadline are to be tested by hydraulic pressure not less than 0,5 MPa.

20.1.4 After assembly, the fittings are to be checked for leakage by a hydraulic pressure equal to the design pressure.

20.2 HYDRAULIC TESTS OF PIPING

20.2.1 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, are to be tested by hydraulic pressure in the presence of a Surveyor to the Register after completion of manufacture and before insulating and coating, by a test pressure, in MPa:

$$p_{test} = 1{,}5p \,, \qquad (20.2.1\text{-}1)$$

where p = design pressure (see 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 $2p$:

$$p_{test} = 1{,}5\frac{\sigma_{100}}{\sigma_t}\, p, \qquad (20.2.1\text{-}2)$$

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 (20.2.1-2), may be reduced to $1{,}5p$ on agreement with the Register.

In no case shall be stresses arising during the test exceed 0,9 of the yield point at the temperature of testing.

20.2.2 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.

20.2.3 All the piping systems shall be checked for leakage 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 are to be tested by $1{,}5p$, but not less than 0,4 MPa, and for pipelines containing fuel oil heated above 60°C, not less than 2,1 MPa;

.2 liquefied gas pipelines are to be leak tested (by air, halogens, etc.) to a pressure chosen depending on the leak detection method applied.

20.2.4 Where, for technical reasons, the hydraulic test of the entire pipeline cannot be carried out, proposals are to be submitted to the Register for testing of separate pipe lengths, in particular, the end joints.

20.2.5 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.

20.3 TESTING OF DEVICES TO PREVENT THE PASSAGE OF FLAME INTO CARGO TANKS IN TANKERS

20.3.1 Prior to assembly on board, flame arresters, flame screens, high velocity vents and pressure/vacuum valves along with protective devices against atmospheric precipitation should be tested in accordance with the IMO procedure to be found in Circ.677 of the Maritime Safety Committee.

20.4 TESTING OF AIR PIPE AUTOMATIC CLOSING DEVICES

20.4.1 Each type and size of air pipe closing device should be tested at the manufacturer's works including the following:

.1 tightness test during immersing/emerging in water

The test should be carried out in the normal position and at an inclination of 40 degrees. The maximum allowable leak per cycle should not exceed 15 ml per 100 mm of nominal diameter.

.2 determining the flow characteristic of the air pipe closing device

Measuring of the pressure drop versus rate of volume flow is to be carried out using water. The test results are to be backed up by relevant documents.

20.4.2 At the manufacturer's works, impact and pressure loading tests should be carried out on non-metallic ball floats with due regard for Table 20.4.2 and conditions as follows:

Table 20.4.2

Test condition	Test temperature, °C		
	−25	+20	+85
Dry	yes	yes	yes
After immersing in water	yes	yes	yes
After immersing in fuel oil	no	yes	no

Note: Immersing in water and fuel oil is to be for at least 48 hours.

.1 the impact test should be conducted on a pendulum type testing machine. The floats should be subjected to 5 impacts of 2,5 N·m each and should not suffer either permanent deformation, cracking or surface deterioration. Subsequently, the floats should be subjected to 5 impacts of 25 N·m each. At this impact energy level some localised surface damage at the impact point may occur, but no permanent deformation or cracking of the floats must appear;

.2 the compression loading test should be conducted with the floats mounted on a supporting ring of a diameter and bearing area corresponding to those of the valve seating with which it is intended that the float would be used. Loads should be applied through a concave cap of the same internal radius as the test float.

A load of 3432 N should be applied over one minute and maintained for 60 minutes. The deflection should be measured at intervals of 10 minutes after attachment of the full load.

The record of deflection against time is to show no continuous increase in deflection and, after release of the load, there should be no permanent deflection;

.3 testing of metallic ball and float closures should be conducted in accordance with 20.4.2.1 and should be carried out at room temperature and in the dry condition.

20.5 TESTING OF PLASTIC PIPES

20.5.1 Plastic pipes should be tested in accordance with the provisions of the IMO resolution A.753(18) both at the manufacturer's works and after assembly on board.

21 THERMAL LIQUID SYSTEMS

12.1 PUMPS

21.1.1 For the circulation of heat-transfer agent, at least two pumps shall be provided, one of them being a standby pump.

21.1.2 On the outlet side of the heat-transfer agent, manometers shall be fitted.

21.1.3 To fill up the expansion tank and to pump the thermal fluid, provision shall be made for a transfer pump.

21.1.4 The heat-transfer agent circulating pumps shall be fitted up with disconnectors complying with 5.7.1, Part XI "Electrical Equipment".

21.2 EXPANSION TANK

21.2.1 Systems containing thermal liquids shall include an expansion tank.

The tank capacity shall be at least by 1,5 times greater than the volume of the expanded heat-transfer agent being heated to its working temperature. The expansion tank shall be located highest in the system.

21.2.2 The expansion tank shall be equipped with a level indicator in accordance with 10.5.

On the level indicator, the lowest permissible level of liquid shall be marked off.

21.2.3 The expansion tank shall be equipped with an overflow pipe led to a storage tank or a bilge tank.

21.2.4 Provision shall be made for signals to be activated when the lowest or the highest level of liquid is reached in the tank. When the level of liquid drops below the permissible level, the heating of thermal liquid shall be stopped automatically.

21.2.5 In the case of systems operating in the inert gas atmosphere, the expansion tank shall be equipped with a manometer and a safety valve.

21.2.6 Provision shall be made for an efficient device, connected to the expansion tank through a pipeline, for collecting and removal of vapour and gas emanations.

21.3 STORAGE TANK

21.3.1 The storage tank capacity is to be sufficient for the system component largest in capacity to be filled up with thermal liquid.

21.3.2 Where thermal liquid is discharged into the storage tank, the capacity of the latter is to be sufficient for the discharge of thermal liquid from the system having regard for the storage as mentioned under 21.3.1.

In this case, the location of the tank shall be such as to facilitate the discharge of thermal liquid from the system.

21.4 PIPING LAYING

21.4.1 Piping containing thermal liquids shall be laid in conformity with the requirements of Section 5.

21.5 AIR PIPES

21.5.1 The air pipes of tanks containing thermal liquids shall comply with 10.1.

21.6 ARRANGEMENTS FOR LEAKAGE COLLECTING AND THERMAL LIQUID DISCHARGE

21.6.1 Arrangements for collecting thermal liquid leakage shall comply with 13.5.

21.6.2 Where shut-off devices as mentioned under 3.5.7, Part X "Boilers, Heat Exchangers and Pressure Vessels" are not remotely controlled, provision shall be made for an arrangement to quickly discharge the thermal liquid from the system.

Thermal liquid discharge shall be effected into a bilge tank or a storage tank as mentioned under 21.3.2.

21.6.3 Combination boilers shall be fitted up with arrangements to preclude the ingress of thermal liquid into the engine in case of leakage.

21.7 COOLING OF HEAT-TRANSFER AGENT

21.7.1 In thermal liquid systems which are equipped with combination boilers, provision shall be made for an arrangement to cool the heat-transfer agent.

21.8 COMBINATION BOILERS FOR THERMAL LIQUIDS

21.8.1 Combination boilers for thermal liquids shall comply with 3.5, Part X "Boilers, Heat Exchangers and Pressure Vessels".

21.9 INSULATION

21.9.1 The insulation of piping and equipment forming the system shall comply with 4.6, Part VII "Machinery Installations".

21.10 HEATING OF LIQUID CARGOES

21.10.1 Thermal liquid systems may be permitted for heating liquid cargo having an ignition temperature below 60°C only where provision is made for an independent intermediate system installed in the cargo zone.

However, the autonomous intermediate system may be omitted if the following is provided:

the system is so arranged that a positive pressure in the coil shall be at least 0,03 MPa above static head of the cargo when the circulating pump is not in operation;

means shall be provided in the thermal oil system expansion tank for detection of flammable cargo vapours;

valves for the individual heating coils shall be provided with locking arrangement to ensure that the coils are under static pressure at all times.

21.11 THERMAL LIQUID PIPING TESTING

21.11.1 Thermal liquid pipes shall be tested in accordance with 20.2 in the same way as fuel oil piping.

PART IX. MACHINERY

1 GENERAL

1.1 APPLICATION

1.1.1 The present Part of the Rules is applicable to the following engines and machinery:

.1 main internal combustion engines;

.2 main steam and gas turbines;

.3 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 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 and lubricating oil.

1.2 SCOPE OF SUPERVISION

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 Supervision.

1.2.2 The Register carries out the supervision during the manufacture of engines and machinery listed in 1.1.1, except for manually driven machinery.

1.2.3 Prior to manufacturing of the machinery, the following documents are to 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;

.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 (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 drawing of 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 and arrangement of foundation bolts;

.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 high pressure delivery fuel oil piping and their protection in case of damage;

.1.19 drawings of the crankcase safety valves and scavenging air manifold and their arrangement;

.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 operating and maintenance instruction;

.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;

.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	Forges 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	Shaft and rotor of the turbocharger, including blades	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
1.18	Main, connecting-rod, crank bearings	—	—
1.19	High pressure fuel oil pumps	—	—
1.20	Nozzles	—	—
2	**Steam turbines**		
2.1	Casings of turbines	Cast iron	3.9, 3.10
		Cast steel	3.8
		Rolled steel	3.3

Table 1.2.4 - continued

Nos	Item	Material	Chapter of Part XIII "Materials"
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
		Cast steel	3.8
3.4	Coupling components transmitting the torque:		
	.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
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

Table 1.2.4 - continued

Nos	Item	Material	Chapter of Part XIII "Materials"
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 supervision of 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 and tillers 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 are also to 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 are to 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 are to be tested according to the requirements specified in Table 1.3.3.

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% 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	1,5p
Casings of the high pressure fuel pumps (pressure side), fuel valves and fuel pipes	1,5p or $p+30$ MPa, whichever is less
Scavenging pump cylinder	0,4 MPa
Hydraulic system pumps and pipings, valve hydraulic drive cylinders	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 are to be subjected to hydraulic test only from the water side.

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 are to 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.

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 are to 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 is to 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 are to 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 are to be properly designed or to have special arrangements aimed at preventing their self-loosening and self-releasing.

1.5.5 The heated surfaces of machinery and equipment are to be insulated according to the requirements of 4.6.1, Part VII "Machinery Installations".

1.5.6 The machinery parts that are in contact with a corrosive medium are to be made of an anticorrosive material or to have corrosion-resistant coatings.

Sea water cooling spaces of engines and coolers should 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 are to comply with the relevant requirements of Part VIII "Systems and Piping".

1.5.9 Electrical equipment of engines and auxiliaries is to 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 appro-

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

priate chapters of Part XIII "Materials". Materials of parts stated in items 1.13, 2.5, 2.7, 2.8, 2.9, 3.4, 3.5, 5.3, 6.3, 6.4, 6.5, 7.3, 7.4, 7.5, 8.1 to 8.5, 9.1, 9.2, 9.3, 10.6, 10.8, 10.9, 10.10 and 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 supervision of the Register during manufacture.

Materials of the parts of internal combustion engines are subject to supervision of the Register in accordance with Table 1.6.2.

At the discretion of the Register the supervision 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) are to 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.

2.2 GENERAL REQUIREMENTS

2.2.1 The engines are to 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 is to be such that the amplitude of angle oscillations of the generator shaft does not exceed 3,5°/P, where P is the number of pairs of generator poles.

2.2.4 The crosshead-type engines whose scavenge spaces are in open connection with the cylinders are to be provided with the fire extinguishing system approved by the Register which is entirely separate from the fire extinguishing system of the engine room (see 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 are to be equipped with a timely fire alarm and fire detection system (see 4.2.3.1, Part VI "Fire Protection").

2.2.5 The diesel generating sets intended as emergency units are to 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 The rated power of the engines is to 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".

2.2.7 Fuel oil and lubricating oil pipes, fittings, flanged connections, filters are to be screened or otherwise protected so that in case of their failure petroleum products falling onto hot surfaces (see 4.6.1, Part VII "Machinery Installations") is prevented.

2.3 ENGINE FRAME

2.3.1 The mating surfaces of the frame parts forming the engine crankcase are to be close-fitting and oil- and gastight as well as are to be fixed together by means of calibrating pieces.

2.3.2 The crankcase and the detachable covers of the crankcase inspection ports shall be sufficiently strong, with the covers being securely fastened in such a way as to exclude the possibility of their displacement in the event of an explosion.

2.3.3 The engine frame and conjugated parts are to 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 are to be fitted with drain arrangements providing complete drainage.

2.3.4 Ventilation of crankcases, and any arrangement which could produce a flow of external air within the crankcase, is forbidden. If a forced extraction of the gases from the crankcase is provided (for smoke detection purpose, for instance), the vacuum in the crankcase must not exceed 250 Pa.

For engines with power output up to 750 kW suction of gas from the crankcase by turbo-blowers or blowers may be admitted, provided reliable oil separators are fitted to prevent the oil from being carried into the engine with suction gas.

Joining together of vent pipes of two or more engines is not permitted, not interconnection of crankcases by oil drain pipes.

Vent pipes, where provided, must be as small as practicable. The ends of the vent pipes are to be fitted with flame-arresting devices and arranged so as to prevent water from getting into engine.

Vent pipes are to be led to the weather deck to the positions preventing the suction of vapours into accommodation and service spaces.

2.3.5 Engine crankcases are to be provided with the safety valves as follows:

.1 engines having a bore 200 mm and more, but not exceeding 250 mm, shall have at least one valve near each end but, over 8 crankthrows, an additional valve shall be fitted near the middle of the engine;

.2 engines having a bore exceeding 250 mm, but not exceeding 300 mm, shall have at least one valve in way of each alternate crankthrow with a minimum of two valves;

.3 engines having a bore exceeding 300 mm shall have at least one valve in way of each main crankthrow;

.4 additional safety valves shall be fitted on separate spaces of crankcase, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces is 0,6 m^3 and more.

Spaces in open connection with the crankcase having free area greater than 115 cm^2 per each cubic metre of the crankcase volume shall not be considered as separate spaces. Spaces in open connection with the crankcase, having free area less than 45 cm^2, shall not be considered in estimating the crankcase gross volume;

.5 no crankcase safety valve is required for engines having a bore not exceeding 200 mm or having a crankcase gross volume not exceeding 0,6 m^3.

2.3.6 Safety valves of crankcases shall be of the type approved by the Register. Crankcase safety valves shall be designed to meet the following requirements:

.1 to open quickly at an overpressure of not more than 0,02 MPa in the crankcase and to close quickly in order to avoid inrush of air in the crankcase;

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

2.3.7 The total free area of the safety valves fitted on an engine crankcase is not to be less than 115 cm^2 per cubic metre of the crankcase gross volume. In calculating the gross volume of the crankcase the moving engine parts located inside the crankcase need not be included.

Each safety valve to be fitted in the crankcase as required in 2.3.5 may be replaced by not more than two safety valves of smaller area, provided the free area of each valve is not less than 45 cm^2.

2.3.8 The crankcase drain holes are to be fitted with gratings or screens to prevent stray objects from getting into the drain piping.

The above requirement also applies to engines having a dry crankcase.

2.3.9 When a cylinder bore exceeds 230 mm, each working cylinder is to be fitted with a relief (signal) valve set to a pressure exceeding the maximum combustion pressure by not more than 40 per cent when working at the rated power.

Alarm device with audible or visual signals for overpressure approved by the Register may be used instead of the relief valves.

2.3.10 Engines with the power output of 2250 kW and over or with a cylinder bore of more than 300 mm installed in the periodically unattended machinery spaces are to 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 rotating engines the equivalent device means a number of structural measures to prevent explosions in the engine crankcase.

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 are to be formed in such a way that the safety margin against fatigue at the oil bores is not less than that acceptable in the fillets. The engine Manufacturer, if requested by the Register, should submit documentation supporting his oil bore design.

2.4.3 For the calculation of crankshafts, the documents and particulars listed in the following are to be submitted:

crankshaft drawing which must contain all scantlings required by this 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);

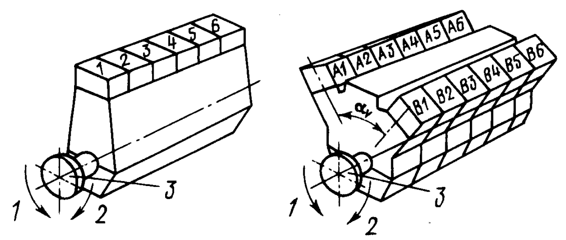


Fig. 2.4.3-1 Sense of crankshaft rotation:
1 — counter-clockwise
2 — clockwise
3 — driving shaft flange

firing order with the respective ignition intervals and, where necessary, V-angle α_v, deg. (see Fig. 2.4.3-1);

cylinder diameter, mm;

stroke, mm;

maximum cylinder pressure P_{max}, MPa;

charge air pressure, in MPa, before inlet valves or scavenge ports, whichever applies;

nominal compression ratio;

connecting rod length L_H, mm;

oscillating weight of one crank gear, in kg (in case of V-type engines, where necessary, also for the cylinder unit with master and articulated-type connecting rod or forked and inner connecting rod);

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, see 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 strength, 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 (see Fig. 2.4.3-2), the following details should be submitted additionally:

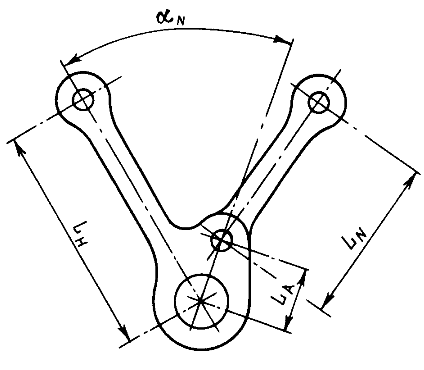


Fig. 2.4.3-2 Articulated-type connecting rod

distance to link point L_A, mm;

link angle α_N, deg.;

connecting rod length L_H, mm;

articulated-type connecting rod length L_N, mm.

2.4.4 Calculation of alternating stresses due to bending moments and shearing forces.

2.4.4.1 Assumptions.

The calculation is based on a statically determined system, so that only one single crankthrow is considered of which the journals are supported in the centre of adjacent bearings and which is subject to gas and inertia forces (see Figs 2.4.4.1-1 and 2.4.4.1-2).

The nominal bending moment is taken as a moment with the bending lever (distance L_1), 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

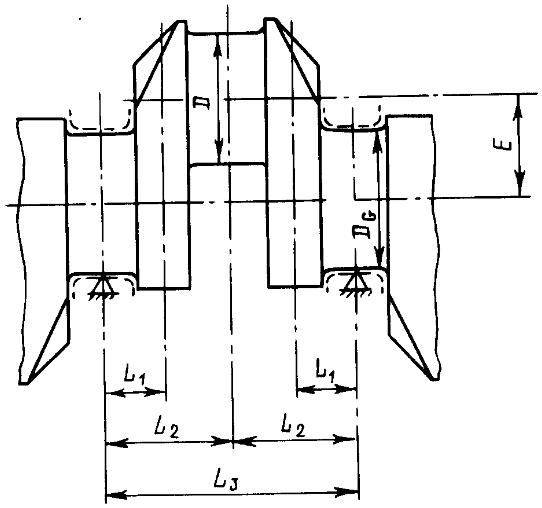


Fig. 2.4.4.1-1 Crank throw for in-line engine

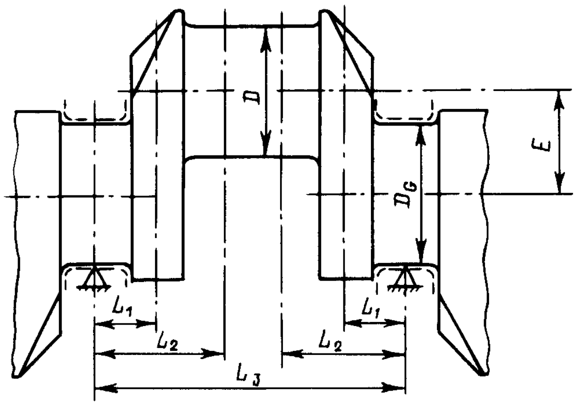


Fig. 2.4.4.1-2 Crank throw for engine with 2 adjacent connecting rods

bending moment obtained by superposition of two bending moment loads according to phase.

The nominal alternating stresses due to bending moments and shearing forces are to be related to the cross-sectional area of the crank web in the centre of the overlap of the pins or at the centre of the adjacent generating lines of the two pins if they do not overlap (see Fig. 2.4.6.1).

2.4.4.2 Calculation of nominal alternating bending and shearing stresses.

The maximum and minimum bending moment values $M_{B\max}$ and $M_{B\min}$ as well as the maximum and minimum shearing force values $Q_{\max}$ and $Q_{\min}$ should 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, will 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 σ_{BN}, in MPa, will 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;
K_e = factor equal to 0,8 for 2-stroke engines and 1,0 for 4-stroke engines.

The nominal alternating shearing stress σ_{QN}, MPa, will be determined by the formula:

$$\sigma_{QN} = \pm\frac{Q_N}{F}K_e \qquad (2.4.4.2\text{-}3)$$

where $Q_N = \pm 0{,}5(Q_{\max} - Q_{\min})$
$F = BW$
Q_N = nominal alternating shearing force, N;
F = area related to cross-section of web, mm^2.

2.4.4.3 Calculation of alternating bending stresses in fillets.

The alternating bending stress in a crankpin fillet σ_{BH}, in MPa, will be determined by the formula:

$$\sigma_{BH} = \pm(\alpha_B \sigma_{BN}) \qquad (2.4.4.3\text{-}1)$$

where α_B = stress concentration factor for bending in crankpin fillet (for determination, see 2.4.6).

The alternating bending stress in a journal fillet σ_{BG}, in MPa, will be determined by the formula:

$$\sigma_{BG} = \pm(\beta_B \sigma_{BN} + \beta_Q \sigma_{QN}) \qquad (2.4.4.3\text{-}2)$$

where β_B = stress concentration factor for bending in journal fillet (for determination, see 2.4.6);
β_Q = stress concentration factor for shearing (for determination, see 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 is to be undertaken by the engine manufacturer according to the information below. The maximum values obtained from such calculations should be submitted to the Register.

The maximum and minimum alternating torques are to 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 must be made for the dampings that exist in the system and for unfavourable conditions (misfiring in one of the cylinders). The speed ranges should 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 should be determined by the formula:

$$\tau_N = \pm \frac{M_T}{W_P} 10^3 \qquad (2.4.5.1)$$

where M_T = nominal alternating torque, N·m, to be determined by the formula

$$M_T = \pm \frac{1}{2}(M_{T\,max} - M_{T\,min});$$

$M_{T\max}$, $M_{T\min}$ = 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}, see 2.4.6.

2.4.5.2 Calculation of alternating torsional stresses in fillets.

In the crankpin fillet, the alternating torsional stress, MPa, should be determined by the formula:

$$\tau_H = \pm(\alpha_T \tau_N) \qquad (2.4.5.2\text{-}1)$$

where α_T = stress concentration factor for torsion in crankpin fillet (for determination, see 2.4.6).

In the journal fillet, the alternating torsional stress, in MPa, should be determined from the formula:

$$\tau_G = \pm(\beta_T \tau_N) \qquad (2.4.5.2\text{-}2)$$

where β_T = stress concentration factor for torsion in journal fillet (for determination, see 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 and 2.4.6.3 applicable to the fillets 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.

For the calculation of stress concentration factors in crankpin and journal fillets, the following related dimensions will be applied:

$$s = S/D \text{ with } -0{,}5 \leqslant s \leqslant 0{,}7;$$

$$w = W/D \text{ with } 0{,}2 \leqslant w \leqslant 0{,}8;$$

$$b = B/D \text{ with } 1{,}2 \leqslant b \leqslant 2{,}2;$$

$$d_G = D_{BG}/D \text{ with } 0 \leqslant d_G \leqslant 0{,}8;$$

$$d_H = D_{BH}/D \text{ with } 0 \leqslant d_H \leqslant 0{,}8;$$

$$t_H = T_H/D;\ t_G = T_G/D;$$

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 valid if:

$$t_H \leqslant R_H/D \text{ and } t_G \leqslant R_G/D$$

and is to be applied within the range:

$$-0{,}3 \leqslant s \leqslant 0{,}5.$$

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 $f(s,w) = -4{,}1883 + 29{,}2004w - 77{,}5925w^2 + 91{,}9454w^3 - 40{,}0416w^4 + (1-s)(9{,}5440 - 58{,}3480w + 159{,}3415w^2 - 192{,}5846w^3 + 85{,}2916w^4) + (1-s)^2 \times (-3{,}8399 + 25{,}0444w - 70{,}5571w^2 + 87{,}0328w^3 - 39{,}1832w^4)$;

$f(w) = 2{,}1790w^{0{,}7171}$;

$f(b) = 0{,}6840 - 0{,}0077b + 0{,}1473b^2$;

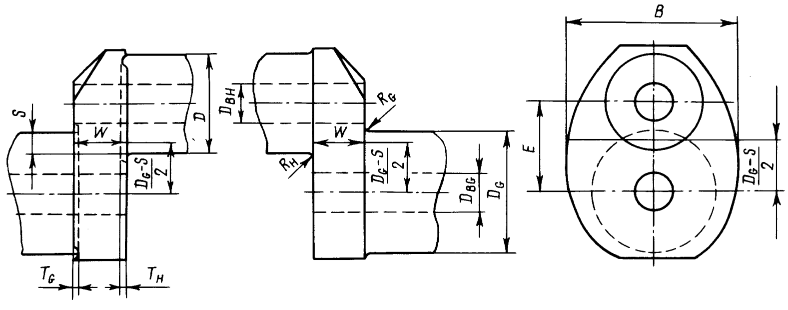


Fig. 2.4.6.1 Crank dimensions necessary for the calculation of stress concentration factors:

D — crankpin diameter (mm)
D_G — journal diameter (mm)
E — pin eccentricity (mm)
D_{BH} — diameter of bore in crankpin (mm)
D_{BG} — diameter of bore in journal (mm)
S — pin overlap (mm) $S = (D + D_G)/2 - E$
R_H — fillet radius of crankpin (mm)
R_G — fillet radius of journal (mm)
W and B — web thickness and width (mm)
T_H — recess of crankpin (mm)
T_G — recess of journal (mm)

$f(r) = 0{,}2081r^{(-0{,}5231)}$;
$f(d_G) = 0{,}9993 + 0{,}27d_G - 1{,}0211d_G^2 + 0{,}5306d_G^3$;
$f(d_H) = 0{,}9978 + 0{,}3145d_H - 1{,}5241d_H^2 + 2{,}4147d_H^3$;
$f_t = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$.

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 $f(r,\ s)$; $f(b)$; $f(w)$ are to 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 $r = R_G/D_G$.

2.4.7 Additional bending stresses.

In addition to the alternating bending stresses in fillets (see 2.4.4.3) further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered by applying σ_{add} as given in Table 2.4.7.

Table 5.1.3.3-1

Values of coefficient k'

Type of engine	σ_{add}, MPa
Crosshead	± 30
Trunk piston	± 10

2.4.8 Calculation of equivalent alternating stresses.

For the crankpin fillet, the equivalent alternating stress σ_{VH}, in MPa, is to 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, is to 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 other parameters, see 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} and σ_{DWC}, 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:

$$\sigma_{DWG} = \pm K(0{,}42\sigma_B + 39{,}3)(0{,}264 + 1{,}073D_G^{-0{,}2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B}\sqrt{\frac{1}{R_G}}) \qquad (2.4.9\text{-}2)$$

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;
1,0 for free form forged crankshafts;
0,93 for cast steel crankshafts.
σ_B = minimum tensile strength of crankshaft material, MPa.

For other parameters see 2.4.6.1. However, it is to be considered that for calculation purposes R_H and R_G are not to be taken less than 2 mm.

Where no results of the fatigue tests conducted on full size crankthrows or crankshafts which have been subjected to surface treatment are available, the K factors for crankshafts without surface treatment are to be used.

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 is not to be less than 80% of the average value.

2.4.10 Calculation of shrink-fits of semi-built crankshafts.

2.4.10.1 All crank dimensions necessary for the calculation of the shrink-fit are shown in Fig. 2.4.10.1.

The radius of the transition from the journal to the shrink diameter should not be less than the greater of the two values:

$$R_G \geqslant 0{,}015D_G \text{ and } R_G \geqslant 0{,}5(D_s - D_G).$$

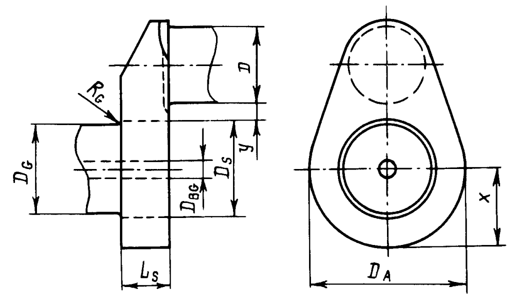


Fig. 2.4.10.1 Crank throw of semi-built crankshaft:
D_S — shrink diameter (mm);
L_S — length of shrink-fit (mm);
D_A — outside diameter of web or twice the minimum distance x between centre-lines of journals and outer contours of web, whichever is less (mm);
y — distance between the adjacent generating lines of journal and pin (mm) $y \geqslant 0{,}05D_S$:
Where y is less than $0{,}1D_S$, special consideration is to be given to the effect of stress due to the shrink on the fatigue strength at the crankpin fillet (For other parameters, see 2.4.6.1)

The actual oversize Z of the shrink-fit must 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 $Z_{\min}$ is to be carried out for the crankthrow with the maximum torque $M_{T\max}$ (see 2.4.5.2) using the formula:

$$Z_{\min} \geqslant \frac{4 \cdot 10^3\, S_R M_{T\max}}{\pi \mu E_m D_S L_S} \; \frac{1 - Q_A^2 Q_S^2}{(1 - Q_A^2)(1 - Q_S^2)} \qquad (2.4.10.2)$$

where $Z_{\min}$ = minimum oversize, mm;
S_R = safety factor against slipping to be taken not less than 2;
μ = coefficient for static friction equal to 0,20 where $L_S/D_S \geqslant 0{,}40$;
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, is also to be calculated according to the following formula:

$$Z_{\min} \geqslant \sigma_S D_S / E_m \qquad (2.4.10.3)$$

where σ_S = minimum yield strength 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:

$$Z_{\max} \leqslant \frac{\sigma_S D_S}{E_m} + \frac{0{,}8 D_S}{1000}. \qquad (2.4.10.4)$$

2.4.11 Acceptability factor.

Adequate dimensioning of a crankshaft is ensured if the acceptability factors (the ratio of the equivalent alternating stress to the fatigue strength) for both the crankpin and journal fillets satisfy the criteria:

$$Q_H = \sigma_{DWH}/\sigma_{VH} \geqslant 1{,}15,$$

$$Q_G = \sigma_{DWG}/\sigma_{VG} \geqslant 1{,}15.$$

2.4.12 At the junction of the web with the journal or pin, the radius of the fillet is not to be less than $0{,}05D$.

Where crankshafts have flanges, the radius of the fillet at the junction of the flange with the journal is not to be less than $0{,}08D$.

2.4.13 The edges of the oil holes are to 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 should 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 is not to be less either than that of the crankshaft or 1.1 the diameter of the intermediate shaft determined in accordance with 5.2.2, Part VII "Machinery Installations".

2.5 SCAVENGING AND SUPERCHARGING

2.5.1 In the event of failure of one of the turbochargers, the operation and manoeuvrability of the main engine are to be guaranteed (for emergency operation of the engine, see 2.1.7, Part VII "Machinery Installations").

The builder must prove the possibility of continuous operation of the engine under operating conditions with the power obtained during the tests. In case of time restrictions, permissible operating time is to be indicated.

2.5.2 In the case of main engines which, when started or operating at low loads, do not receive enough air from the turbochargers, an auxiliary supercharging system should be provided to ensure engine operation at which supercharging from the turbochargers would be sufficient.

For the case of failure of this system, an additional means to duplicate its functions should provided.

2.5.3 Where supercharging air is cooled, the scavenge manifolds are to be fitted with thermometers and condensate drain arrangements after each air cooler.

2.5.4 The scavenge manifolds of two-stroke engines with positive displacement-type scavenging pumps, as well as the scavenge manifolds having direct connection with the cylinders, are to 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 is not to 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 are to 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 are to be fitted with safety gauzes.

2.6 FUEL SYSTEM

2.6.1 The fuel injection pumps are to be equipped with a device for 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 oil fuel injection pipes are to be made from thick-walled seamless steel pipes without welded or soldered intermediate joints.

2.6.3 All 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 shall be provided for an alarm to be given of a fuel line failure.

A suitable enclosure on engines with an output of 375 kW or less having fuel injection pumps serving more than one injector may be used as an alternative to the jacketed piping system.

When in return piping the propulsion of pressure with peak to peak values exceeds 2 MPa, shielding of this piping is also required.

2.7 LUBRICATION

2.7.1 The lubricators supplying oil for lubricating the cylinders are to 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 are to 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 are to be provided with a non-return valve.

2.7.3 The turbochargers and governors with ball or roller bearings are to 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 is to 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 is to 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 is to 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 (see 6.3.3, Part VIII "Systems and Piping").

2.9.2 Flame arresters or bursting discs are to 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 is to 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 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 prime mover characteristics are to comply with the requirements of 6.1.8, Part VIII "Systems and Piping", and 9.3.4.2, 19.1.2.4.2 and 9.5, Part XI "Electrical Equipment".

If necessary, provision is to be made for heating devices to ensure safe starting and taking up the load according to the requirements stated above.

2.10 EXHAUST ARRANGEMENTS

2.10.1 In two-stroke engines fitted with the exhaust gas turbo-blowers which operate on the impulse systems, provision is to 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 controllable-pitch propeller, is to be provided with a separate overspeed device so adjusted that the engine speed cannot exceed the rated speed by more than 20 per cent.

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 100 per cent of the generator rated power is suddenly thrown off, the transient speed variations shall not exceed 10 per cent of the rated speed;

.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 is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case the power required for the electrical equipment to be automatically switched on after 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;

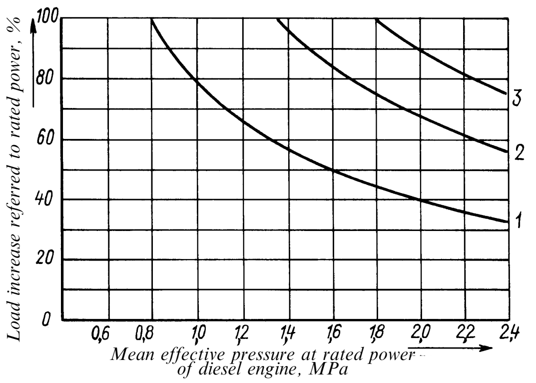


Fig. 2.11.3.2 Limiting curves for loading 4-stroke diesel engines step by step from no load to rated power as function of the brake mean effective pressure: *1* — 1st load step, *2* — 2nd load step, *3* — 3rd load step

.3 where A/C generators operate in parallel within 20-100% of the total load, the load distribution between the generators is to be in proportion to their power and is not to differ by more than 15% from the design load for the greater generator or by more than 25% from the design load for the generator considered whichever is less;

.4 at all loads between no-load and rated power the permanent speed variation shall not exceed the rated speed by more than 5 per cent of the rated speed;

.5 when the rated power is suddenly thrown off or thrown on as it is stated in 2.11.3.1 and 2.11.3.2, steady state conditions shall be achieved in not more than 5 s;

.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 should 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.

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.

2.11.5 Provision shall be made for local and remote control of speed variation within $-20 \div +10\%$ 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 is to 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 this Chapter, electric (electronic) speed governors shall also comply with 2.1, Part XV "Automation".

2.11.9 Protection system of main and auxiliary engines, 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 should 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 gas temperature in front of turbochargers and behind them.

Note. 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 must be fitted with an alarm device with audible and visual signals for the failure of lubricating oil system.

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 should be equipped with instruments in accordance with 2.12.1.1 — 2.12.1.3, 2.12.1.7, 2.12.1.9 (where media other than circulation oil are used), 4.1.6.1 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 should be provided with indicators of the direction of propeller shaft rotation.

2.12.4 Local control stations of auxiliary engines should be equipped with instruments in compliance with 2.12.1.1 — 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 should make air removal possible when filling the damper with oil or silicone liquid, and the silicone damper design should also enable a sampling of the liquid.

2.13.2 Lubrication of a spring damper should, 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 should make it possible to connect devices for measuring torsional vibration to the crankshaft.

3 STEAM TURBINES

3.1 GENERAL REQUIREMENTS

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 are to be started without preheating.

3.1.4 In single-screw ships fitted with multi-cylinder steam turbines arrangement is to be such as to enable the safe navigation when the steam led to any one of the cylinders is cut off. For this 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 are to be provided for these emergency conditions so that the pressure and temperature of the steam will not exceed those which the turbine and condenser can safely withstand.

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 is to 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 is to 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 is to 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 should 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 be not in excess of 15 s.

The manoeuvring gear is to 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 are to 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 is to 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 is to 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, are to 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 are to comply with the requirements of 2.11.3 to 2.11.5.

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 is to 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 are to 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 should be made for a warning alarm system.

3.6.9 Safety valve or an equivalent arrangement is to be provided at the exhaust end of all turbines.

The safety valve discharge outlets are to be visible and suitably guarded if necessary.

3.6.10 Efficient steam strainers are to be provided close to the inlets to ahead and astern high-pressure turbines or alternatively at the inlets to the manoeuvring valves.

3.7 INSTRUMENTATION

3.7.1 The main turbine installation control stations are to 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 are to 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 REQUIREMENTS

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 should be statically balanced, while those rotating at speeds over 20 m/s should be dynamically balanced. The accuracy of dynamic balancing should be determined on the basis of the formulae:

$$v = 24000/n \quad \text{with } v > 300; \tag{4.1.2-1}$$

$$v = 63000/n \quad \text{with } v = 20 \tag{4.1.2-2}$$

where v = distance between the centre of gravity and the geometrical axis of rotation of the part concerned, μm;
n = rotational speed, min^{-1};
v = peripheral velocity, m/s.

For peripheral velocities between 20 and 300 m/s, is to be determined by interpolation.

The rigid elements of couplings should 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 are to 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 are to be provided with venting arrangements.

The vent pipes are to be led to the upper weather deck or other positions where uptake is provided.

The ends of the vent pipes are to 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 provisions.

4.2.1.1 The requirements of this 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 are to 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 should be fitted with equalizers. The rim of epicyclic wheel with more than 3 planetary pinions should be flexible in the radial direction.

4.2.2 Gears.

4.2.2.1 The pinions of main gearing should 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 must 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 is to be not less than $0{,}3m_n$.

4.2.2.4 The strength of teeth and other pinion and wheel elements is to 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) are to be based on the requirements of this 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 this 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 is to 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;

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 should 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:

$$F_t = \frac{2000T_1}{d_1 a_p}$$

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:

$$d_1 = d_{m1} = m_{te}Z_1(1-0{,}5b_1/R_{we}). \qquad (4.2.2.6\text{-}2)$$

4.2.2.7 The gear must 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, see 4.2.2.7.1, 4.2.2.7.3;
for σ_{Hp} and σ_{Fp}, see 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.

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_{H0}, see 4.2.2.7.1.1;
for K_A, see 4.2.2.7.1.7;
for K_γ , see 4.2.2.7.1.8;
for K_v , see 4.2.2.7.1.9;
for $K_{H\beta}$, see 4.2.2.7.1.10;
for $K_{H\alpha}$, see 4.2.2.7.1.11.

4.2.2.7.1.1 At nominal load, the contact stress for the pinion teeth is calculated by the equation:

$$\sigma_{HO_1} = Z_B Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{w_t}{d_1}\frac{u \pm 1}{u}} \ . \qquad (4.2.2.7\text{-}2)$$

For wheel teeth:

$$\sigma_{HO_2} = \frac{Z_D}{Z_B}\,\sigma_{HO_1}$$

where $w_t = \frac{F_t}{\tau b_w}$;

$\tau = 1$ for spur gears;
$\tau = 0{,}85$ for bevel gears;
$u = Z_2/Z_1$ = gear ratio;
for Z_1, Z_2 and b_w, see 4.2.2.5;
for F_t and d_1, see 4.2.2.6;
for Z_B (Z_D), see 4.2.2.7.1.2;
for Z_H, see 4.2.2.7.1.3;
for Z_E, see 4.2.2.7.1.4;
for Z_ε, see 4.2.2.7.1.5;
for Z_β, see 4.2.2.7.1.6.

In equation (4.2.2.7-2) and later the above sign is for external meshing, the below sign - internal meshing.

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,

$$Z_B = M_1 = \frac{\operatorname{tg}\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \frac{2\pi}{Z_1}\right]\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} \mp (\varepsilon_\alpha - 1)\frac{2\pi}{Z_2}\right]}}$$

where for ε_α, see 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 $\varepsilon_\beta < 1$,

$$Z_B = M_1 - \varepsilon_\beta(M_1 - 1) \geqslant 1;$$

$$Z_D = M_2 - \varepsilon_\beta(M_2 - 1) \geqslant 1$$

where for ε_β, see 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, see Formula (4.2.2.6-1)

$$d_2 = Z_2 m_t, \qquad (4.2.2.7\text{-}8)$$

where for m_t, see Formula (4.2.2.6-1);

coefficients of displacement:

$$\Delta y = x_2 \pm x_1 - y$$

$$y = (a_w - a)/m_n$$

where

$$a_w = a\cos\alpha_t/\cos\alpha_{tw}, \qquad (4.2.2.7\text{-}9)$$

$$a = 0{,}5(Z_2 \pm Z_1)m_t;$$

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)

$$a_{02} = 0{,}5(Z_2 - Z_0)m_t,$$

$$\operatorname{inv}\alpha_{tw02} = \operatorname{inv}\alpha_t + \frac{2(x_2 - x_0)\operatorname{tg}\alpha_n}{Z_2 - Z_0} \ ;$$

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:

$$d_{b1} = d_1\cos\alpha_t; \qquad (4.2.2.7\text{-}11)$$

$$d_{b2} = d_2 \cos \alpha_t. \qquad (4.2.2.7\text{-}12)$$

Transverse contact ratio:

$$\varepsilon_\alpha = \frac{0{,}5\sqrt{d_{a1}^2 - d_{b1}^2} \pm 0{,}5\sqrt{d_{a2}^2 - d_{b2}^2} \mp a_w \sin \alpha_{tw}}{\pi m_t \cos \alpha_t} \qquad (4.2.2.7\text{-}13)$$

and overlap ratio:

$$\varepsilon_\beta = \frac{b_w \sin \beta}{\pi m_n}. \qquad (4.2.2.7\text{-}14)$$

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 ($E_1 = E_2 = 2{,}06 \cdot 10^5$ MPa, $\nu_1 = \nu_2 = 0{,}3$)

$$Z_E = 189{,}8 \text{ MPa}^{0{,}5}.$$

4.2.2.7.1.5 The contact ratio factor which accounts for the total contact line is determined by the following formulae:

for spur gears,

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}}; \qquad (4.2.2.7\text{-}15)$$

for helical gears with $\varepsilon_\beta < 1$,

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}(1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}, \qquad (4.2.2.7\text{-}16)$$

with $\varepsilon_\beta \geqslant 1$,

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}. \qquad (4.2.2.7\text{-}17)$$

4.2.2.7.1.6 The helix angle factor:

$$Z_\beta = \sqrt{\cos \beta}.$$

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 in the absence of special procedures for its determination.

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.

Table 4.2.2.7-1

Type of gearing	Engine	Type of coupling on input	K_A
Main propulsion		Any type	1
	Turbine ICE	Hydraulic or equivalent coupling	1
		High elastic coupling	1,3
		Other types	1,5
Auxiliary	Electric engine, turbine	Any type	1
	ICE	Hydraulic or equivalent coupling	1
		High elastic coupling	1,2
		Other types	1,4

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. For double helical, high power main propulsion gearing the factor K_γ should be specified with due regard for 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, and for the helical gearing with $\varepsilon_\beta \geqslant 1$, by the diagrams in Fig. 4.2.2.7-2. In these diagrams, figures 3-9 denote accuracy grade according to the State standard 1643-81 (ISO 1328).

The factor K_v may also be determined by the following formula:

$$K_v = 1 + K_0(vZ_1)/100$$

where for K_0, see Table 4.2.2.7-2;

$v = \frac{d_1 n_1}{19098}$ - circumferential velocity.

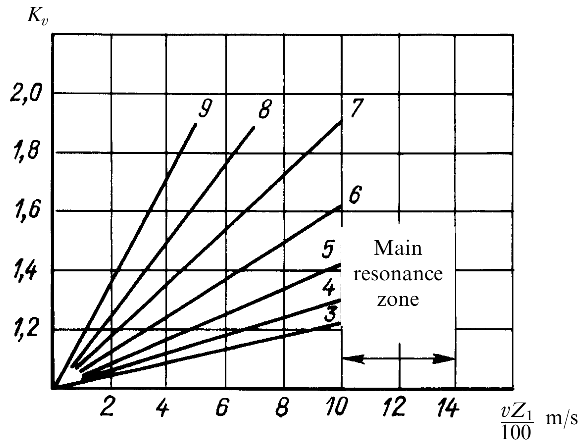


Fig. 4.2.2.7-1 K_v values for spur gears

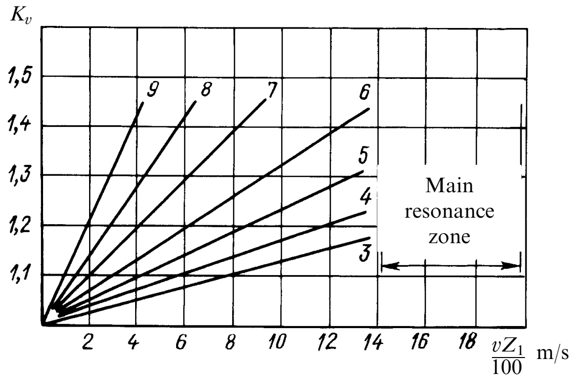


Fig. 4.2.2.7-2 K_v values for helical gears ($\varepsilon_\beta \geqslant 1$)

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 and 4.2.2.7-2 respectively, calculated with the same accuracy grade.

Table 4.2.2.7-2

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

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:

a) the gears are made of steel and have toothing of the large cross section;

b) $F_t/b_w > 150$ N/mm and $Z_1 < 50$;

c) 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} should be determined from Table 4.2.2.7-2-1.

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 are to be obtained from Table 4.2.2.7-3. Where $F_t/b_{eH}K_A < 100$ N/mm, the value 100 N/mm should be used.

Table 4.2.2.7-3

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

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).

Table 4.2.2.7-2-1

Parameter	Notation	Method of determination
1. Resonance speed of pinion (main resonance) min[-1]	n_{E1}	$n_{E1} = \frac{30 \cdot 10^3}{\pi Z_1}\sqrt{\frac{C_\gamma}{m_{red}}}$
.1 tooth mesh stiffness of a gear pair per unit face width N/(mm·μm)	C_γ	from the 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: $m_{red} = 3{,}25 \cdot 10^{-6}\frac{d_1^2}{u^2+1}$. If an additional mass is added to the pinion with a moment of inertia of γ times greater than that of the pinion: $m_{red} = 3{,}25 \cdot 10^{-6}\frac{d_1^2(1+\gamma)}{u^2+1+\gamma}$.

Table 4.2.2.7-2-1 - continued

Parameter	Notation	Method of determination
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 this Table; d) $n_1/n_{E1} \geqslant 1{,}5$ = supercritical zone determined according to item 4 of this 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 4.2.2.7-2-2
.1 factor accounting for pitch error, running-in and tooth loading influence	B_p	From the formula: $B_p = \frac{C'(f_{pb} - y_\alpha)}{(F_t/b_w)K_A K_\gamma}$, where f_{pb} = pitch error (if not specified, the permissible value of f_{pbr} is to be taken), μm; y_α = reduction in pitch error due to running-in, μm, determined according to 4.2.2.7.1.11.
.2 factor accounding for profile error, running-in and tooth loading influence	B_f	From the formula: $B_f = \frac{C'(f_f - y_\alpha)}{(F_t/b_w)K_A K_\gamma}$. where f_f = profile error (if not specified, the permissible value of f_{fr} is to be taken), μm.
.3 factor accounting for tip relief influence	B_k	From the formula: $B_k = \left\|1 - \frac{C'C_a}{(F_t/b_w)K_A K_\gamma}\right\|$, where $C_a = 1{,}5 + \frac{(\sigma_{Hlim}/97 - 18{,}45)^2}{18}$, Note. If gears are made of different materials $C_a = (C_{a_1} + C_{a_2})/2$.

4.2.2.7.1.10 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.

$F_{\beta y}$ is estimated by means of the relationships:

$$F_{\beta y} = F_{\beta x} - y_\beta;$$

$$F_{\beta x} = 1{,}33 f_{sh} + f_{ma};$$

Table 4.2.2.7-2-1 - continued

Parameter	Notation	Method of determination
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 4.2.2.7-2-2, 4.2.2.7-2-3.
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 $n_1 = 1{,}15 n_{E1}$ according to item 3 of this Table and the supercritical zone for $n_1 = 1{,}5 n_{E1}$ according to item 5 of this 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 4.2.2.7-2-2

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 4.2.2.7-2-3

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

$$f_{sh} = f_{sho} w_t K_A K_\gamma K_v.$$

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 are to 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}, see 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,

$$y_\beta = 0{,}15F_{\beta x}.$$

At any speed y_β must 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

$$C_{BS} = [1 + 0{,}5(0{,}2 - c^*)][1 - 0{,}02(20 - \alpha_n)];$$

$$q' = 0{,}23615 + \frac{0{,}7755}{Z_{v1}} + \frac{1{,}28955}{Z_{v2}} - 0{,}03175x_1 - \frac{0{,}5827x_1}{Z_{v1}} - 0{,}00965x_2 - \frac{1{,}2094x_2}{Z_{v2}} + 0{,}02645x_1^2 + 0{,}0091x_2^2;$$

$$Z_{v1} = \frac{Z_1}{\cos^2\beta_b \cos\beta};\ Z_{v2} = \frac{Z_2 Z_{v1}}{Z_1}. \quad (4.2.2.7\text{-}21)$$

For the internal gearing, $Z_{v2} = \infty$.

If $(F_t/b_w)K_A < 100$ N/mm,

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) $K_{H\beta} \geqslant 1{,}2$ should apply.

For bevel gears, the factor $K_{H\beta}$ should be determined by the following formula:

$$K_{H\beta} = 1{,}5K_{H\beta be},$$

in view of high pressure upon the working surface of teeth where for $K_{H\beta be}$, see Table 4.2.2.7.4.

Table 4.2.2.7.4

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	1,25	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 $\varepsilon_\gamma \leqslant 2$,

$$K_{H\alpha} = \varepsilon_\alpha(0{,}45 + K_4); \quad (4.2.2.7\text{-}22)$$

with $\varepsilon_\gamma > 2$,

$$K_{H\alpha} = 0{,}9 + 2K_4\sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}} \quad (4.2.2.7\text{-}23)$$

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;

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta \quad (4.2.2.7\text{-}24)$$

where for ε_α, see Formula (4.2.2.7-13);
for ε_α, see 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 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 must not exceed 3 μm.

If the pinion and wheel teeth are surface-hardened by different procedures:

$$y_\alpha = 0{,}5(y_{\alpha 1} + y_{\alpha 2})$$

where $y_{\alpha 1}$ is for the pinion and $y_{\alpha 2}$ — 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 — 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}, see 4.2.2.7.2.1;
for Z_N, see 4.2.2.7.2.2;
for S_{Hmin}, see 4.2.2.7.2.3;
for Z_L, see 4.2.2.7.2.4;
for Z_v, see 4.2.2.7.2.5;
for Z_R, see 4.2.2.7.2.6;
for Z_W, see 4.2.2.7.2.7;
for Z_X, see 4.2.2.7.2.8.

4.2.2.7.2.1 In the absence of test results, the endurance limits for contact stress $\sigma_{H\lim}$ are to be taken from Table 4.2.2.7-5.

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.

4.2.2.7.2.3 The minimum safety factor for contact stress S_{Hmin}, and minimum safety factor for bending stress S_{Fmin} are taken from Table 4.2.2.7-6.

4.2.2.7.2.4 The lubricant factor which accounts for the effect of lubricant viscosity is determined by one of the formulae:

Table 4.2.2.7-5

Thermal or chemical and thermal treatment of teeth: pinion	Thermal or chemical and thermal treatment of teeth: wheel	σ_{Hlim}, MPa
Through-hardened	Through-hardened	$0{,}46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0{,}42\sigma_{B2} + 415$
Carburized, induction-hardened or nitrided	Soft-bath nitrided	1000
Carburized, induction-hardened or nitrided	Induction-hardened	$0{,}88HV_2 + 675$
Carburized or nitrided	Nitrided	1300
Carburized		1500

Note: With the number of cycles of at least $5 \cdot 10^7$, the values of $\sigma_{H\lim}$ correspond to a failure probability of 1% or less. The criterion which accounts for $\sigma_{H\lim}$ is the pitting damage of not less than 2% for the total active flank area without surface-hardening and not less than 5% for that with surface-hardening.

Table 4.2.2.7-6

Transmission	Type of ship	$S_{H\min}$	$S_{F\min}$
Main propulsion gearing	All ships covered by Rules for the Classification and Construction of Sea-Going Ships, except small ships	1,4	1,8
	Single-screw yachts and small ships	1,25	1,5
	Multiple-screw yachts and small ships	1,2	1,45
Auxiliary gearing	—	1,15	1,4

Note: By small ships and yachts, sporting and pleasure ships are meant, as well as ships up to 24 m in length, not engaged in trade or passenger carrying or intended for charter service.

$$Z_L = C_{ZL} + \frac{1 - C_{ZL}}{\left(0{,}6 + \frac{40}{v_{50}}\right)^2}$$

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 should 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 4.2.2.7-7.

Table 4.2.2.7-7

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:

$$\sigma_F = \sigma_{F0} K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \qquad (4.2.2.7\text{-}26)$$

where for σ_{FO}, see 4.2.2.7.3.1;
for K_A, see 4.2.2.7.1.7;
for $K\gamma$, see 4.2.2.7.1.8;
for K_v, see 4.2.2.7.1.9;
for $K_{F\beta}$, see 4.2.2.7.3.5;
for $K_{F\alpha}$, see 4.2.2.7.3.6.

4.2.2.7.3.1 Bending stress under nominal loading:

$$\sigma_{F0} = \frac{F_t}{\tau b m_n} Y_F Y_S Y_\beta \qquad (4.2.2.7\text{-}27)$$

where for b and m_n, see 4.2.2.5;
for F_t, see 4.2.2.6;
for τ, see 4.2.2.7.1.1;
for Y_F, see 4.2.2.7.3.2;
for Y_S, see 4.2.2.7.3.3;
for Y_β, see 4.2.2.7.3.4.

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}, see Fig.4.2.2.7-3.

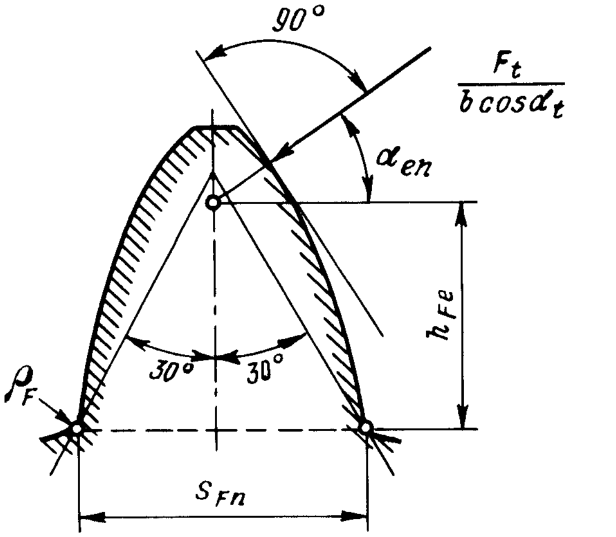


Fig. 4.2.2.7-3 Illustration to the definition of Y_F for external tooth

To determine h_F^* and S_{Fn}^* the following equation must be used:

$$p_{bt} = \pi m_t \cos\alpha_t$$

where α_t is determined by Formula (4.2.2.7-3);

$$d_e = 2\sqrt{\left[p_{bt}(1 - \varepsilon_\alpha) + 0{,}5\sqrt{d_a^2 - d_b^2}\right]^2 + (0{,}5 d_b)^2}$$

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}, see Figs 4.2.2.7-4, 4.2.2.7-5;
x_{sm} is equal to zero for cylindrical gears, as to bevel gears, see 4.2.2.7.6;

$$e = \frac{\pi}{4}m_n - m_n x_{sm} - h_{a0}\,\mathrm{tg}\,\alpha_n + h_k(\mathrm{tg}\,\alpha_n - \mathrm{tg}\,\alpha_0) - \frac{(1-\sin\alpha_0)}{\cos\alpha_0}\rho_{a0}$$

where for h_k and a_0, see Fig. 4.2.2.7-5;
when the tool has no protuberance,

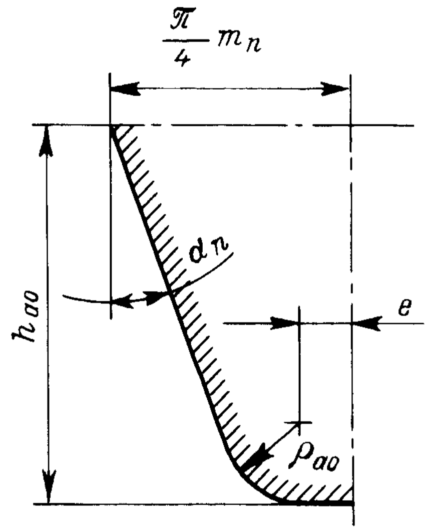


Fig. 4.2.2.7-4 Non-protuberance hob

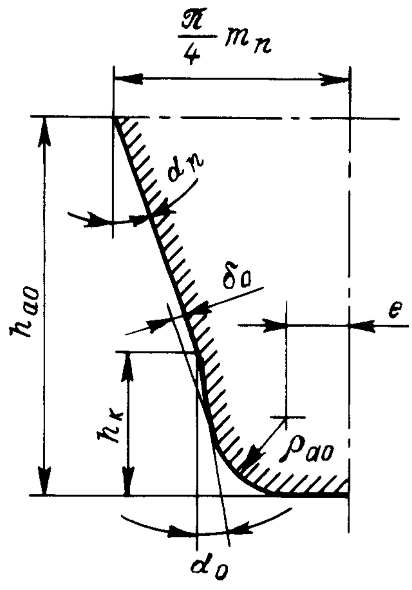


Fig. 4.2.2.7-5 Protuberance hob

$$h_k = 0,\ \alpha_0 = \alpha_n;$$

$$H = \frac{2}{Z_v}\left(\frac{\pi}{2} - \frac{e}{m_n}\right) - \frac{\pi}{3}$$

where Z_v is determined by Formulae (4.2.2.7-21);

$$\psi = \frac{2G}{Z_v}\,\mathrm{tg}\,\psi - H;$$

when solving this equation as an approximation take $\psi = \pi/6$;

$$\beta_e = \mathrm{arctg}\left(\frac{d_b}{d\cos\alpha_{et}}\,\mathrm{tg}\,\beta\right)$$

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);

$$\alpha_{en} = \mathrm{arctg}\,(\mathrm{tg}\,\alpha_{et}\cos\beta_e);$$

$$S^*_{Fn} = Z_v\sin(\pi/3 - \psi) + \sqrt{3}\left(\frac{G}{\cos\psi} - \rho^*_{a0}\right);$$

$$h^*_F = \frac{1}{2}\left\{\frac{Z}{\cos\beta}\left(\frac{\cos\alpha_t}{\cos\alpha_{et}} - 1\right) + Z_v\left[1 - \cos\left(\frac{\pi}{3} - \psi\right)\right] - \frac{G}{\cos\psi} + \rho^*_{a0}\right\}.$$

In the case of internal gearing,

$$Y_F = \frac{6h^*_{F2}\cos\alpha_{en}}{(S^*_{Fn2})^2\cos\alpha_n}.$$

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}, see Fig. 4.2.2.7-6) the following equations are calculated:

$$d_{f_2} = 2a_{w02} + d_{a_0}$$

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);

$$h^*_{F_2} = \frac{d^*_{f2} - d^*_{e2}}{2\cos^2 a_n} - \left(\frac{\pi}{4} + h^*_{a_{02}}\mathrm{tg}\,\alpha_n\right)\mathrm{tg}\,\alpha_n - 0{,}5\rho^*_{a_{02}};$$

$$S^*_{Fn_2} = \frac{2(\rho^*_{a_{02}} - \delta^*_0)}{\cos\alpha_n} + 2(h^*_{a_{02}} - \rho^*_{a_{02}})\,\mathrm{tg}\,\alpha_n - \sqrt{3}\rho^*_{a_{02}} + 0{,}5\pi$$

where $d^*_{f_2} = d_{f_2}/m_n$, $d^*_{e_2} = d_{e_2}/m_n$, $\delta^*_0 = \delta_0/m_n$;

$$\delta_0 = \left[\frac{h_k - \rho_{a0}(1 - \sin\alpha_0)}{\cos\alpha_0}\right]\sin(\alpha_n - \alpha_0),$$

see Fig.4.2.2.7-5.
If $\alpha_n = 20°$,

$$h^*_{F_2} = 0{,}56624(d^*_{f_2} - d^*_{e_2}) - 0{,}13247h^*_{a_{02}} - 0{,}5\rho^*_{a_{02}} - 0{,}28586;$$

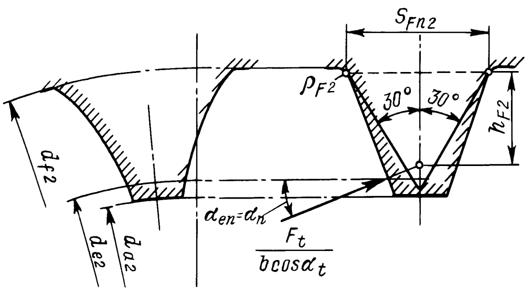


Fig. 4.2.2.7-6 Illustration to the definition of Y_F for internal tooth

$$S^*_{Fn_2} = 0{,}72794h^*_{a02} - 0{,}33163\rho^*_{a02} + 0{,}93969\delta^*_0 + 1{,}5708.$$

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 $\rho^*_F = \rho^*_{a0} + \frac{2G^2}{(Z_v\cos^2\psi - 2G)\cos\psi}$.

In the case of internal gearing,

$$L = \frac{S^*_{Fn2}}{h^*_{F2}};$$

$$q_s = \frac{S^*_{Fn2}}{\rho^*_{a02}}. \qquad (4.2.2.7\text{-}29)$$

In case of external and internal gearing the following condition is to be met:

$$1 \leqslant q_s < 8.$$

For equivalent cylindrical gears of bevel gearing, the expression $Y_{FA}Y_{SA}Y_\varepsilon$ is to be substituted for the product Y_FY_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, see (4.2.2.7-14);
β is in degrees; if $\varepsilon_\beta > 1$, then $\varepsilon_\beta = 1$ should 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, $b/2$ is to be substituted for b;

$h = (2h^*_a + c^*)m_n - \Delta ym_n$ is the tooth depth.

For cylindrical gears with end relief and crowning and for bevel gears, $N = 1$ should be used.

4.2.2.7.3.6 The design values of $K_{F\alpha} = K_{H\alpha}$ should satisfy the condition:

$$1 \leqslant K_{F\alpha} \leqslant \frac{\varepsilon_\gamma}{0{,}25\varepsilon_\alpha + 0{,}75}.$$

$K_{H\alpha}$ is to 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} see 4.2.2.7.4.1;
for Y_{ST}, see 4.2.2.7.4.2;
for Y_N, see 4.2.2.7.4.3;
for Y_D, see 4.2.2.7.4.4;
for $Y_{\delta relT}$, see 4.2.2.7.4.5;
for Y_{RrelT}, see 4.2.2.7.4.6;
for Y_x, see 4.2.2.7.4.7;
for S_{Fmin}, see 4.2.2.7.2.3.

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 4.2.2.7-8.

Table 4.2.2.7-8

Thermal or chemical and thermal treatment of teeth	σ_{Flim}, MPa
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided	330
Surface hardened	$0{,}35HV + 125$
Gas nitrided	390
Cr, Ni and Mo carburized steel	450
Other carburized steel	410
Note: The values of σ_{Flim} are determined during the bending endurance test of pinion teeth under the unidirectional pulsating stress with a minimum stress of zero and they correspond to a failure probability of 1% or less with the number of cycles 3×10^6.	

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), $Y_N > 1$ can be permitted on agreement with the Register.

4.2.2.7.4.4 The values of the factor Y_D are adopted as follows:

for idler gears, $Y_D = 1{,}5$;

for gears with occasional part load in the reverse direction, $Y_D = 1{,}1$;

for gears (except idler gears) with shrink-fitted gear rings, $Y_D = 1{,}25$,

or if the shrink diameter d_s and radial pressure p_r on the shrinkage surface are known,

$$Y_D = 1 + \frac{0{,}2 d_s^2 \; d p_r b}{F_t \sigma_{Flim}(d_f^2 - d_s^2)} ,$$

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 sensitivity to stress concentrations is taken from Table 4.2.2.7-9.

Table 4.2.2.7-9

Thermal or chemical and thermal treatment of teeth	$Y_{\delta relT}$
Through-hardening	$1 + 0{,}036(q_s - 2{,}5)(1 - \sigma_T/1200)$
Surface-hardening	$0{,}956 + 0{,}0234\sqrt{1 + q_s}$
Nitriding	$0{,}79 + 0{,}112\sqrt{1 + q_s}$

Notes: The value of q_s is determined either by Formula (4.2.2.7-28) or by Formula (4.2.2.7-29).
For the range $1{,}5 < q_s < 4$, $Y_{\delta relT} = 1$.

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 takem from Table 4.2.2.7-10.

Table 4.2.2.7-10

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 4.2.2.7-11.

Table 4.2.2.7-11

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 4.2.2.7-6.

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 are to 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 (must be known),

$$x_{hm_{1,2}} = \frac{h_{am_{1,2}} - h_{am_{2,1}}}{2m_{mn}};$$

tooth thickness modification coefficients (must 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 $\alpha_{vt} = \text{arctg}\left(\frac{\text{tg}\alpha_n}{\cos \beta_m}\right)$;

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,

$$n_{v_1} = \frac{d_{m1}}{d_{v_1}} n_1.$$

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) are to be additionally examined for depth strength. The rated safety factor for contact depth strength S_{Hd} should be determined separately for pinion and wheel and is to 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:

$$\sigma_{Hdlim} = 5,5\ HBc \quad \text{if } \varphi \leqslant 0,6$$

and

$$\sigma_{Hdlim} = (4,58 + 1,57\varphi - 0,06\varphi^2) HBc \mu_T \text{ if } \varphi > 0,6.$$

Here 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;

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 $S_{Hd\min} = 1,4$.

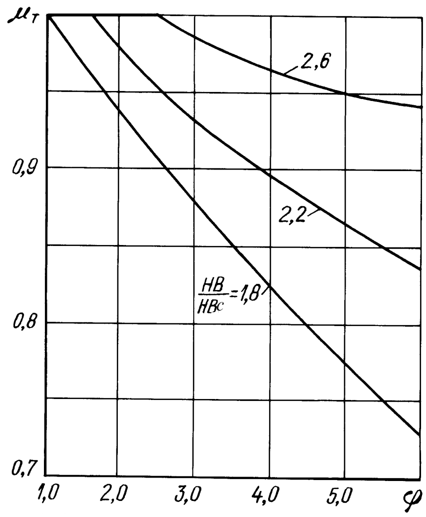


Fig.4.2.2.8 Diagram for determining the factor μ_T versus φ and HB/HBc

4.2.3 Shafts.

4.2.3.1 The shaft diameter of a larger wheel is not to 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 are to be calculated for a torque $T = K'_A T_1$ where for K'_A, see Table 4.2.3.2 (see also 2.1.2, Part VII "Mashinery Installations").

Table 4.2.3.2

Factor	Ice category					
	ЛУ3	**ЛУ4**	**ЛУ5**	**ЛУ6**	**ЛУ7-ЛУ9 ЛЛ6-ЛЛ7**	**ЛЛ8-ЛЛ9**
K'_A	1,15	1,25	1,5	1,75	2,0	2,5

4.2.4 Lubrication.

4.2.4.1 Provision should be made for forced lubrication of the toothing and sleeve bearings of main gears. The possibility of oil pressure regulation is to be provided. A safety device is to be fitted to exclude oil pressure rise above the permissible value.

4.2.4.2 Lubricating oil is to be delivered to the toothing through sprayers.

The sprayers should provide an oil feed in the form of a fanned-out compact jet with the adjacent jets overlapping.

The sprayers are to 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 is to be so arranged that there is no oil foaming or emulsification.

4.2.4.3 Lubricating oil system is to 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 are to comply with the requirements of 3.2 of Part VII "Machinery Installations".

4.2.5.2 Provision should 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 is to 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 should be made for a warning alarm system

4.3 ELASTIC AND DISENGAGING COUPLINGS

4.3.1 General.

4.3.1.1 The requirements of this 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 should satisfy the requirements of 2.4, Part VII "Machinery Installations".

4.3.1.3 Coupling bolts and coupling flanges should satisfy the requirements of 5.2 and 5.3 and, keyless-fitted shaft couplings should satisfy the requirements of 5.4, Part VII "Machinery Installations".

4.3.1.4 The elastic and disengaging couplings intended for ice-strengthened ships should satisfy the requirements of 4.2.3.2.

4.3.1.5 In ships with one main engine, the shaft coupling design should 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 should 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 should be considered (see Section 8, Part VII "Machinery Installations").

4.3.2.3 The elastic couplings of diesel generator sets should withstand moments arising as a result of short-circuit. Where no such information is available, the maximum torque should be at least 4,5 times the nominal torque transmitted by the coupling.

4.3.2.4 The spossibility should 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 should be provided with devices to prevent slipping during appreciable periods of time.

4.3.3.2 It should 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 should 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 should 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 is to be provided with an interlocking to preclude the possibility of the drives and couplings engagement when the turning gear is engaged (besides, see 3.1.6, Part VII "Machinery Installations" and 2.11.1.4 of this Part).

5 AUXILIARY MACHINERY

5.1 POWER-DRIVEN AIR COMPRESSORS

5.1.1 General requirements.

5.1.1.1 The air inlets of compressors are to be fitted with strainers.

5.1.1.2 The compressors are to be so designed that the air temperature at the air cooler outlet is not in excess of 90°C and they are to 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 are to be fitted with drain arrangements.

5.1.2 Safety devices.

5.1.2.1 Each compressor stage or directly after it is to 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 are to be fitted with safety valves meeting the requirements of 2.3.5.

5.1.2.3 The casings of the coolers are to 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 are to 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 is not to 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 is to be taken in accordance with 2.2.2 of Part XII;

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, is to be not less than that determined by the formula:

$$h_c = 1{,}105k_1 D_{cal} \sqrt{(\psi_1\psi_2 + 0{,}4)p_c c_1 f_1 / b} \qquad (5.1.3.4)$$

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 should 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.

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 are to be taken valid for ratio $\varepsilon/$

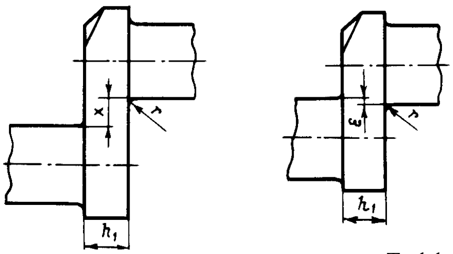


Table 5.1.3.4-2

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

b — web width, mm;

f_1 — factor taken from Table 5.1.3.4-3.

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 are to comply with the requirements specified in 2.4.12 to 2.4.13.

5.1.4 Instruments.

5.1.4.1 A pressure gauge is to 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 is to be subject to special consideration by the Register in each case.

5.2 PUMPS

5.2.1 General requirements.

5.2.1.1 Provision is to 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 is to 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 is to be effected into the suction side of the pump or to the suction portion of the pipe.

5.2.2.3 Provision is to 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 is not to be less than 1,3 of the rated speed.

5.2.3.2 The pump elements are to 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 are to 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 is to 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 should be excluded.

5.2.5.3 When the materials of low electrical conductivity (plastics, rubber, etc.) are used in the pump structure, provision is to 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 4.1.5, Part VII "Machinery

Installations" should be provided with temperature sensors.

5.3 FANS, BLOWERS AND TURBOCHARGERS

5.3.1 General requirements.

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 are to be dynamically balanced in accordance with 4.1.2.

5.3.1.3 The suction pipes of fans, blowers and turbochargers are to be protected against entry of foreign materials.

5.3.1.4 The lubricating oil system of the turbocharger bearings is to 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 are to 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 are to 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 is to be tested by one of the approved non-destructive methods.

On agreement with the Register other safety factors for the turbo-blowers 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 be not 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 are to be fitted in the inlet and outlet of ventilation ducts 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 are to be made of antistatic materials. Furthermore, the installation on board of the ventilation units is to 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) are to 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 SEPARATOR

5.4.1 General requirements.

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 should be checked under stresses arising at rotational speeds exceeding the design speed at least by 30%; in this case, the total stresses in the parts should 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 should be tested by a rotation speed exceeding the design speed by 30% at least.

5.4.3 Instrumentation and protection.

5.4.3.1 A device for the control over the separation process shall be provided.

5.4.3.2 The separator shall be equipped with an instrument for measuring the speed of the bowl.

5.4.3.3 It is advisable that the separators be provided with a device automatically shutting off the drive and stopping the separator when inadmissible vibration occurs.

6 DECK MACHINERY

6.1 GENERAL REQUIREMENTS

6.1.1 The brake straps and their fastenings are to be resistant to sea water and petroleum products. The brake straps are to be heat-resistant at temperatures up to 250°C.

The permissible heat resistance of connections between the brake strap and the frame is to 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 is to be provided with interlocking arrangements preventing their simultaneous operation.

6.1.3 The deck machinery control arrangements are to 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 is to 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 are to 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 should be intrinsically safe, and relevant safety certificates are to be issued for them by a competent body (for the definition of danger zones see 19.2, Part XI "Electrical Equipment").

6.2 STEERING GEAR

6.2.1 General requirements.

6.2.1.1 Main and auxiliary steering gear (see 1.2.9, Part III "Equipment, Arrangements and Outfit") are to 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 (see 2.9.4, Part III "Equipment, Arrangements and Outfit") is to be so arranged that a single failure in its piping or in one of the power units will not impair the integrity of the remaining part of the steering gear.

In oil tankers, oil tankers (⩾60°C), chemical carriers or gas carriers of 10000 gross tonnage and upwards, hydraulic steering gear is to 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 is to 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 are to provide for a continuous operation under the most severe service conditions.

The design of the steering gear is to 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° is not to 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 is to 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 is to 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 is to be provided with a minimum water level alarm.

6.2.1.8 Every oil tanker, oil tanker (⩾60°C), chemical carrier or gas carrier of 10000 gross tonnage and upwards is to comply with the following requirements (see also 6.2.1.9):

.1 the main steering gear is to 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 is to 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 is to be provided. Loss of hydraulic fluid from any power actuating system is to 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 are to achieve equivalent standards.

6.2.1.9 Hydraulic steering gear shall comply with the requirements of Section 7 of this 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 2.1.8, 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 is to 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 is to 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 is to 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 are to permit a torque overload of at least 1,5 times the rated torque for a period of 1 min.

The steering gear electric motors are to 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 is to be of self-braking design.

The auxiliary hand-operated steering gear is to be either of self-braking design or to 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 speed 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 are to 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 is to exceed the total pump capacity by 10 per cent.

In this case, the pressure of the hydraulic steering gear cavities is not to 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 are to 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 is to 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 is to 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 is to 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 are to 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 is to 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 is to 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 are not to 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 is to be designed to transmit no less than double rated torque M_d stated in 6.2.1.5. The height of the hubs of loose segment racks and auxiliary tillers is not to 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 is to be taken not more than 0,13.

6.2.9.3 The split hubs are to be fastened with at least two bolts on each side and have two keys. The keys are to 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 is to 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:

$$P_1 = ad^2 \tag{6.3.1.1-1}$$

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, see 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 is not to be less than:

$$P_2 = 11{,}1(gh + G) \qquad (6.3.1.1\text{-}2)$$

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 (see 3.2 of Part III "Equipment, Arrangements and Outfit");
G = anchor mass, kg.

Heaving-in speed of the anchor chain is to 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 should 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 (see 6.3.1.1) without any requirement for speed.

6.3.2 Brakes and clutches.

6.3.2.1 The anchor machinery is to 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 is to ensure a braking torque without slip corresponding to a force in the chain on the sprocket not less than 1,3 P_1 or 1,3 P_2.

6.3.2.3 Each chain sprocket is to 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 stopped 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 is not to 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 is to be not 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 is not to 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 are to 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. 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 are to 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.

6.3.6 Additional requirements.

6.3.6.1 The anchor machinery intended for handling with mooring operations is to comply with the requirements of 6.4, in addition to those of this Chapter.

6.3.6.2 The requirements of this 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 is to 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 and the minimum speed will not be less than 1,4 m/s without regard to the initial acceleration. 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 is to 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 is to 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 are to be manually operated from the local position. The failure of any element or the whole remote control system is not to affect adversely the normal operation of the anchor machinery and equipment manually operated from the local position (see also 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 of heaving in a mooring line on the first rope winding layer on the drum is to be at least:

0,25 m/s at the pull up to 80 kN;

0,20 m/s at the pull from 81 to 160 kN;

0,16 m/s at the pull from 161 to 250 kN;

0,13 m/s at the pull over 250 kN.

The speed of heaving-in of a mooring line by the use of a warping drum both at the rated pull and without load is to be not 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 (see 6.4.1.1) its drive is to 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 is to be provided.

6.4.3 Brake.

6.4.3.1 The mooring machinery is to 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 is to be provided with a brake, a braking torque of which should 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 is not to 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 are to 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 are to 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 is to 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 are not to be inferior to the similar-purpose non-automatic machinery.

6.4.5.2 Automatic winches are to 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 is to be made to enable checking the value of tension at every moment. The tension indicators are to 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 is to be provided.

6.5.3 The drums of the towing winches are to comply with the requirements of 6.1.6 and are to be provided with fairleads. If two or more drums are provided, the fairleads are to be independent. Rope drum is to be fitted with a coupling to ensure its disconnection from the driving machinery.

Geometrical dimensions of the winch heads are to provide the possibility for paying out of the towline.

6.5.4 The design of the winch is to 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 are to 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 is to 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 is to be provided with manual control as well. The brake design is to 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 are to 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 are to 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 REQUIREMENTS

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 is to be serviced by two separate pump units each of which should ensure the anchor gear operation with nominal pull and at nominal heaving-in speed.

7.1.3 The hydraulic system failure is not to 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 (see 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 are to 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 are to 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 are to 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 are to 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 are to 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 is to be protected by safety valves whose operating pressure is not to 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 is to 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 are to be provided.

7.3.4 The hydraulic systems are to 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 is to 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 should be of "metal on metal" type.

Oil seals between moving parts forming a part of external pressure limit are to 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 are to be protected against such effects.

7.3.7 The hydraulic machinery is to be provided with a sufficient amount of the instruments to monitor its operation.

8 GAS TURBINES

8.1 GENERAL REQUIREMENTS

8.1.1 The requirements of the present Section are applicable to the main and auxiliary marine gas turbines with combustion chambers.

The application of converted aircraft gas turbines in sea-going ships is to be agreed with the Register in each case.

8.1.2 The design output refers to the design conditions, i.e. the specified values of temperatures of ambient air and water, of air humidity, of atmospheric pressure and of resistance of exhaust and suction adopted when designing gas turbines.

8.1.3 When one gas turbine is employed in ships of unrestricted service, the necessity of application of the emergency device ensuring the ship movement is to be agreed with the Register in each case.

8.1.4 The gas turbine with air intercooling shall develop an output not less than 20 per cent of the design one, when water supply to the air cooler is completely shut off.

8.1.5 The gas turbine installation with a reversing device shall provide reversing from full ahead to full astern and vice versa.

The gas turbine installation without a reversing device may be installed provided the ship is equipped with other means and devices ensuring astern running.

When the astern turbine is employed, the requirements of 3.1.2 and 3.6.2 shall be complied with, when the reverse-reduction gearing is used the requirements of 4.1.1 of the present Part and in case of controllable-pitch propeller the requirements of 6.5.5, Part VII "Machinery Installations" shall be met.

When using the compressed air for the reverse systems, its store is to provide at least 25 resettings of the reverse; refuelling of compressed air store is to be performed automatically from at least two sources of compressed air.

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 at the permissible deposits on gas turbines and under tropical conditions (air temperature is not less than 45°C, relative air humidity is 95 per cent at 35°C and sea water temperature is 35°C) shall be proved by calculations and experiments.

Increases and drops of load are to be performed at the speed taken for the gas turbine bridge control systems throughout the operating range.

The program of the gas turbine operation stability control is to be agreed with the Register in each case; the control is to be performed both at the Manufacturer's test bench and after installation of the gas turbine in the ship.

8.1.7 Throughout the operating and starting ranges there are to be no zones restricting the operation of the gas turbine due to vibration.

The vibration is to be determined by the vibration speed (root-mean-square value) of the gas turbine casing in way of bearings and is not to exceed the values stated in Table 9.4.1, Part VII "Machinery Installations".

8.1.8 For the gas turbines of ships with ice strengthening of category **ЛУ4 — ЛУ9** the requirements of 2.1.2, Part VII "Machinery Installations" shall be complied with; if these requirements cannot be fulfilled, the loads on units transmitting the power from the gas turbine to propeller shall be agreed with the Register.

8.1.9 The starting device of each gas turbine is to be operated from at least two sources of power. A change-over from one source of power to the other for starting up the gas turbine is to be performed in not more than 60 s. The possibility is to be provided for starting up the gas turbine to the full stop of the rotor.

One source of power is permitted for dynamically supported craft. The provision is to be made for ensuring at least four successive starts of the gas turbine.

8.1.10 Provision is to be made for cleaning the blading of the gas turbine by ship's means, including the possibility of cleaning without stopping the gas turbine.

For the dynamically supported craft it is permitted to carry out cleaning in a port by means of shore appliances.

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 turbine.

The provision shall be made for devices for quick closing of air suction inlets.

The location of the air suction inlets shall prevent the entry of water, vapours or blowout from a fan into compressor.

Provision shall be made for preventing the suction duct from icing if the risk of icing exists under the ship's operating conditions.

The reserve intake of 60 per cent of air volume in case of icing of the suction inlet is to be provided.

On agreement with the Register, measures against icing and the reserve intake need not be taken for dynamically supported ships.

Drainage systems of the air suction inlets are to be fitted with hydroseals.

8.1.12 Gas exhaust systems shall be provided with the remote-controlled arrangements to prevent gas and air circulation through the gas turbine both in the case of fire and when in port.

If one air duct or exhaust manifold is intended for two or more engines, it is necessary to exclude the recirculation of air and gas through a non-operating engine.

8.1.13 Air suction and gas exhaust trunks, fuel, refrigeration and other piping shall be so connected to the engine that no expansion stresses are transmitted to the place of connection.

8.1.14 In air ducts and trunks of air supply to compressors all inner components shall be manufactured from materials resistant to corrosion in sea conditions. Dimensions of components and fastenings shall exclude the possibility of their penetration through the protective gratings before compressor. All inner mountings shall be fixed. Trunks and ducts shall provide the possibility of periodical checking of the condition of inner surfaces.

8.1.15 All turbocompressors and gas turbines shall be fitted with a turning arrangement. Provision shal be made for interlocking a shaft-turning gear with a gas turbine starting device or for an automatic disconnection of the shaft-turning gear.

Quick-disconnecting couplings are to be provided with interlocking, excluding starting up the gas turbine with a 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 system. In addition to automatic starting, manual starting shall be provided.

8.1.17 Before each subsequent starting provision is to be made for an automatic discharge of fuel remained after failed starting or forced stop.

Each main gas turbine is to be provided with a fire extinguishing system independent of the fire extinguishing systems of a machinery space.

When there are several gas turbines in a ship, provision is to be made for supply of fire extinguishing agent from a fire extinguishing system of one gas turbine to another.

8.2 ROTORS OF GAS TURBINES

8.2.1 The strength calculation of the rotating parts of the gas turbines shall be performed for the condition of the rated output and for conditions when the stresses can reach their maximum values. The check calculation is carried out for the number of revolutions exceeding the rated number by 20 per cent.

8.2.2 The calculation for the enlarged torque corresponding to the operation of gas turbines at the outside air temperature reduced by 20°C as compared to the design temperature is to be performed for the rotating parts of the gas turbine.

8.2.3 The strength calculation of the rotating parts of the astern gas turbines shall be performed to the maximum torque corresponding to th-e crush stop from full ahead to full astern at the maximum output of astern turbine.

8.2.4 The strength calculation of the units transmitting the gas turbine power for driving the electric generators shall be performed according to the torque for the condition of the short circuit if the system "engine-generator" does not use special sliding couplings.

8.2.5 The rotating blades whose dimensions do not permit to ensure the safety of casings or special sheaths shall have the increased factors of the static and dynamic strength.

8.2.6 The critical speed of the rotor shall be determined with regard for brackets and meet the requirements of 3.2.2. For over-hanging rotors the precession calculation and calculation of the additional loads from the gyroscopic moment shall be carried out.

8.2.7 The requirements of 3.2.3 to 3.2.5 shall be complied with as well.

8.2.8 The dynamic stresses in the compressor blades shall be experimentally determined throughout all operating ranges, the starting ranges included, and blading shall be set so that dangerous vibrations do not occur. Factor of fatigue strength of the blades shall be not less than 3 for the operational ranges and 2,5 for the transient ranges. If the corroding medium effect is taken into account, this factor may be reduced by 1,2.

8.3 CASING OF GAS TURBINES

8.3.1 Special sight holes for the inspection of the blading shall be provided in the casings of gas turbines and compressors, and gas turbines proper shall be equipped with special instruments for inspection.

8.3.2 The casing of the gas turbine shall be in conformity with the requirements of 3.3.4 and 3.3.7; in this case, requirements of 3.3.7 are applicable only to the constructions of gas turbines with sleeve bearings.

8.3.3 When the internal lagging of the gas turbine casing is applied, its safe fastening and covering with a sheath shall be provided, excluding its local stripping and entering of the ladding into the blading.

8.3.4 The oil sealing shall prevent lubricating oil and its vapours from entering into the blading of the turbines and compressors and blow out of oil and vapours outside.

8.3.5 Each turbine and compressor shall have drain holes in the lower points of the casing. Provision is to be made for blowing down the turbine casing for removing the unburnt fuel from the combustion chambers and gas piping.

8.4 GAS TURBINES BEARINGS

8.4.1 The sleeve bearings of the gas turbines shall comply with the requirements of 3.4.

8.4.2 The use of the ball and roller bearings is allowed for all types of ship gas turbines.

8.5 COMBUSTION CHAMBERS

8.5.1 The arrangement of the combustion chambers of the gas turbines shall provide the convenience of servicing and the possibility of replacement of burners and flame tubes by ship's means.

8.5.2 The possibility of inspection of the flame tubes of the combustion chambers without disassembling shall be provided.

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 The possibility of blowing down the combustion chambers and gas pipelines shall be provided for the purpose of removing the unburnt fuel.

8.6 HEAT EXCHANGERS

8.6.1 The possibility of detection of the 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 air coolers).

The regenerators shall be tested for tightness on the gas side, as well as on the air side. The procedure and the method of detecting the leakages and the location of the 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 components of the heat exchangers shall be excluded.

8.6.3 The regenerator shall be provided with a fire extinguishing system in conformity with the requirements of 3.1.2, Part VI "Fire Protection" (see item 11 of Table 3.1.2.1 of the named Part).

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 for muffling of any tubes without removing the covers.

8.6.6 The air coolers of the gas turbines shall be provided with arrangements for continuous removal of moisture falling out of the air during the operation of the gas turbines.

8.6.7 The heat exchangers shall also be in compliance with the requirements of Sections 1, 2 and 6, Part X "Boilers, Heat Exchangers and Pressure Vessels", with the exception of 6.3.1 to 6.3.4, 6.3.6 and 6.4.2.

8.7 CONTROL, PROTECTION AND REGULATION

8.7.1 The main gas turbine is to be provided with the automatic regulation and remote control systems ensuring the following:

.1 setting of the necessary rates and steady maintaining thereof throughout the whole range of operating speeds;

.2 starting and stopping under any operating conditions;

.3 maintaining of steady operation of the compressors and combustion chambers in the manoeuvring mode of operation;

.4 prevention of the sudden increase of gas temperatures;

.5 unified control of the gas turbine and propeller by the single lever or hand wheel; however, provision is to be made for separate control;

.6 restriction of torque at the power take-off shaft, if necessary;

.7 Purge of all components of accumulated liquid or gaseous fuel oil before ignition at start or after unsuccessful start.

Starting devices are to be so constructed that the ignition process stops and the main fuel valve is closed at the ignition failure (see 8.1.17, 8.5.4).

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 impeller directly driven by the turbine shaft may be used as an overspeed device.

The overspeed device shall operate so that racing the turbine above the specified "maximum permissible" speed is not allowed. Control system which stops the turbine from the overspeed device shall be executed with the minimum number of power sources so that in the case of de-energizing in the control system, the speed of the gas turbine will not be increased.

The maximum permissible speed shall not exceed the rated speed by more than 15 per cent.

8.7.3 In cases specified in 3.6, the gas turbines are to be fitted, in addition to the overspeed device, with a speed governor which shall comply with the requirements contained in the above Chapter.

When reducing the fuel supply by the governor, stopping of the gas turbines is not allowed.

8.7.4 The main gas turbine is to 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 is not to exceed 3 min^{-1}.

Unlimited readiness of the gas turbine for immediate use for at least 20 min is to 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 are to be fitted with an arrangement for emergency stopping of the gas turbines under any operating conditions by at least two independent means.

When operating from a bridge control at the wheelhouse, provision is to be made for emergency stopping of the gas turbine from the control station of the engine room.

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 of the present Part. The manoeuvring ahead and astern valves shall be interlocked. Adequate stall safety factor of gas turbine compressors shall be provided in any position of the manoeuvring valves.

8.7.8 In addition to the overspeed device, protection system of the gas turbine shall provide full interruption of fuel supply in cases of:

.1 lubricating oil pressure drop in the system below the permissible value;

.2 rise of gas temperature before or after the turbine above the permissible value;

.3 limit value of vibration;

.4 flame-out;

.5 excess of revolutions of a low pressure compressor (for three-shaft gas turbines with a free propeller turbine and gas reverse);

.6 limiting rotor shift (excluding gas turbine engine with roller bearings);

.7 limit value of depression at the compressor inlet.

In case of emergency the provision is to made for the manual interruption of fuel supply from the control station.

8.7.9 Automated main gas turbines should comply with the requirements of 4.2, Part XV "Automation".

8.7.10 The control system of gas turbines shall 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 and shall not be readily flammable.

The system of filters and heat exchangers shall provide the necessary temperature and purity of the working medium.

8.7.12 Provision is to be made for checking the tachometer readings for main gas turbines.

8.7.13 The control systems of the auxiliary gas turbines intended for driving generators shall comply 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 the parameters in accordance with 8.7.9 and devices specified in 3.7.2.1-3.7.2.4, as well as instruments necessary to carry out thermal check of the gas turbine operation.

8.8.2 The control station of the auxiliary gas turbines is to be provided with instruments for measuring:

.1 rotor rotation speed;

.2 lubricating oil pressure before the gas turbine;

.3 fuel pressure before the gas turbine;

.4 lubricating oil temperature before the gas turbine;

.5 gas temperature before or after the turbine.

8.9 WASTE-HEAT CIRCUIT OF GAS TURBINE

8.9.1 When the gas turbine units are provided with a waste-heat circuit, a steam turbine is to comply with the requirements of Section 3 of the present Part and a waste-heat boiler — with the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels".

8.9.2 The waste-heat circuits are to be fitted with an arrangement to lead the steam into the condenser; measures are to be provided against increasing the pressure in a condenser beyond permissible.

8.9.3 Provision is to be made for an automatic disconnection of the shaft-turning gear of a steam turbine at the beginning of the rotor rotation.

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).

9.2 CONDITIONS OF OPERATION ON TWO KINDS OF FUEL

9.2.1 When operated on two kinds of fuel DF-engines should 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 must be provided.

9.2.2 Start of DF-engines should 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 is to be used.

9.2.4 In case of unexpected gas fuel cut off DF-engine should continue operation on liquid fuel without stop.

9.2.5 DF-engines are to 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 are to be fitted with safety valves in way of each crankshaft crank. Design and actuating pressure of the safety valves are to 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 DF-engine, the crankcase should be protected as follows:

.1 to prevent accumulation of gas fuel leakage, the ventilation of crankcases is to be provided. Air pipe ends are to be led to safety place and fitted with flame arresters;

.2 detectors of gas fuel leakage or any other equivalent equipment are to be installed. Device for automatic admission of inert gas is recommended for installation;

.3 mounting of oil mist concentration sensor in the crankcase is to be provided.

9.3.3 When a cross-head type engine is used as DF-engine, the engine crankcase should 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 are to 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 should be fitted with safety valves or other protective devices.

9.5.2 Exhaust gas pipelines from DF-engines should not be combined with exhaust gas piping from other engines, boilers or incinerators.

9.6 STARTING AIR PIPING

9.6.1 Branch pipes of starting air piping led to each cylinder should be equipped in compliance with the requirements of 2.9.2.

9.7 COMBUSTION CONTROL

9.7.1 The range of combustion control should 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.

9.8 GAS FUEL SUPPLY

9.8.1 At the inlet of gas fuel supply collector to the DF-engine cylinders the flame arrester is to be fitted.

9.8.2 An arrangement for manual cut-off the gas fuel supply to the DF-engine from the local control station is to be provided.

9.8.3 Gas fuel supply piping should meet the requirements of 13.12, Part VIII "Systems and Piping".

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 should 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 (see 9.7.1 of the present Part and 8.12.6, Part VIII "Systems and Piping").

9.9.3 Gas fuel supply to DF-engines is to be automatically terminated when the concentration of gas in the engine room reaches 60 % of the lower inflammability level. The requirements of 9.2.4 are to be met.

Table 9.7.1

NN	Controlled parameter	Location of measuring	Parameter limit values	Automatic closing of gas fuel supply valves	Indication in main control station	Explanations
1	Supply pressure of gas or liquid fuel	At the engine inlet	min	X	Constant	For gas fuel operation, in case of failure of valves of gas fuel supply into combustion chambers of DF-engines, automatic closing in to be provided for these valves. Automatic closing is also recommended for the main cut-off (pilot) valve of gas fuel supply into DF-engines.
2	Exhaust gas temperature	At the outlet of each cylinder	max	X	Constant	
3	Combastion pressure	In each cylinder	max	X	Constant	

PART X. BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

1 GENERAL

1.1 APPLICATION

1.1.1 The present Part of the Rules applies to boilers, heat exchangers and pressure vessels, excluding:

.1 water heating boilers (see 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 standard liquefied gas cylinders (see 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 (see 1.3.2.1 and 1.3.2.3).

1.1.2 The present Part also applies to oil burning installations of boilers.

1.2 DEFINITIONS AND EXPLANATIONS

The definitions and explanations relating to general terminology of the Rules are given in General Regulations for the Supervision.

For the purpose of the present Part of the Rules the following definitions have been adopted:

Automatic boiler oil burning installation is an installation for combustion of oil fuel, 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 between the stop valves, including the walls of branch pieces and valve bodies.

1.3 SCOPE OF SUPERVISION

1.3.1 General provisions.

1.3.1.1 The general provisions relating to procedure of classification, supervision of construction and survey are given in General Regulations for the Supervision and in Part I "Classification".

1.3.1.2 Boilers, heat exchangers and pressure vessels are classified in accordance with Table 1.3.1.2 depending on the parameters and design features.

1.3.1.3 Boilers and heat exchangers of class I and II shall be produced by Manufacturers having the Recognition Certificate of the Register.

Table 1.3.1.2

Item	Class I	Class II	Class III
Boilers (including waste-heat boilers and water heating boilers designed for water temperatures above 115 °C), steam superheaters and steam accumulators	$p > 0,35$	$p \leqslant 0,35$	—
Thermal fluid boilers, pressure vessels and heat exchangers with toxic, flammable 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 $t > 350$ or $s > 35$	$1,6 < p \leqslant 4$ or $120 < t \leqslant 350$ or $16 < s \leqslant 35$	$p \leqslant 1,6$ and $t \leqslant 120$ and $s \leqslant 16$

Symbols:
p = design pressure, MPa;
t = design wall temperature, °C;
s = wall thickness, mm.

1.3.2 Scope of supervision.

1.3.2.1 Subject to supervision of 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, 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 (see 1.2, Part VII "Machinery Installations");

.6 oil burning installations of boilers;

.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 supervision of 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 of the Rules.

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 of the Rules.

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 recognized by the Register. The additional requirements of 6.4.5 shall also be observed.

1.3.2.5 The scope of supervision 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 supervision.

1.3.3.1 The components specified in Table 1.3.3 are subject to supervision of 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:

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.

.1 construction drawings with sections and descriptions, giving all necessary data for checking the calculations and structures (scantlings, materials, electrodes, location and dimensions of weld seams, fastenings, heat treatment methods to be used, etc.);

.2 construction drawings for the components listed in Table 1.3.3, unless all necessary data are shown in the drawings mentioned in 1.3.4.1.1;

.3 arrangement drawings for mountings and fittings and their specifications;

.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 installations, 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 4.1.9, 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 supervision of 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, mountings 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 (see 2.1.4.1.2), 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 100000 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 100000 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 mountings and fittings of thermal fluid boilers is not permitted.

1.4.6 Boiler mountings and fittings up to 200 mm in diameter 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".

1.4.7 Components and fittings of heat exchangers and pressure vessels with working pressures up to 1 MPa and diameters up to 1000 mm 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".

The use of cast iron for other conditions is subject to special consideration by the Register.

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 (see also 3.2.14).

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.

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 installation components subject to oil fuel 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 mountings 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	$2,5p_w$	To be tested for tightness of closure at $1,25p_w$
10	Fittings of heat exchangers and pressure vessels	As per 1.3 of Part IX "Machinery"	To be tested for tightness of closure at $1,25p_w$

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, see Table 1.3.3, Part IX "Machinery".
[2] With $p_w = 15 \div 16,6$ MPa, $p_h \geqslant 22,5$ MPa.

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 are to 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 - 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".

2 STRENGTH CALCULATIONS

2.1 GENERAL PROVISIONS

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.

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 (see 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] See 2.1.3.4.
[2] See 2.1.3.3.

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 (see 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.

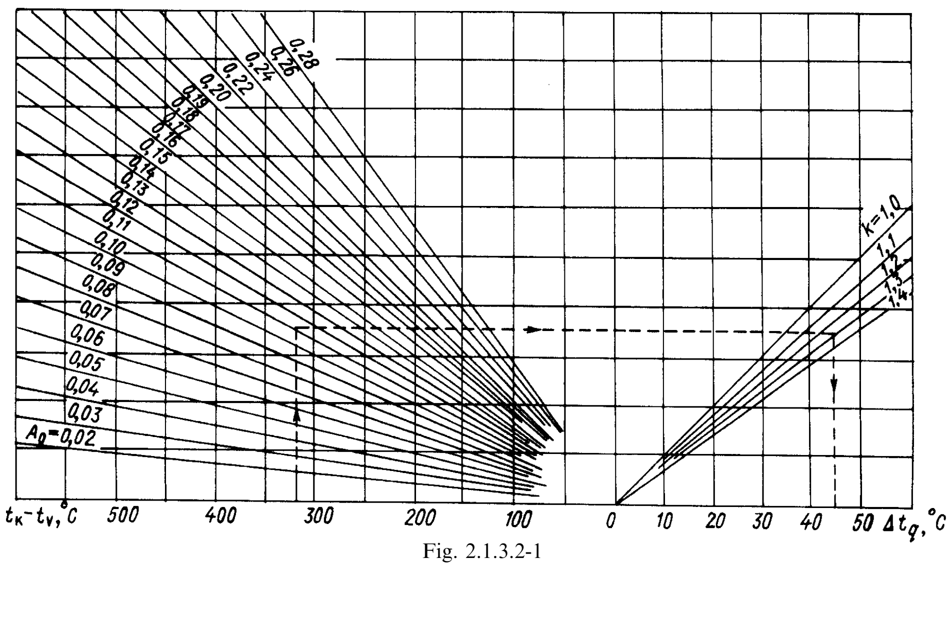


Fig. 2.1.3.2-1

For determination of Δt_q an auxiliary value A_0 is derived from the formula:

$$A_0 = k_0 \frac{1{,}6\alpha_1 + \alpha_3}{\alpha_2} \quad (2.1.3.2\text{-}2)$$

where k_0 = coefficient obtained from Fig. 2.1.3.2-2.

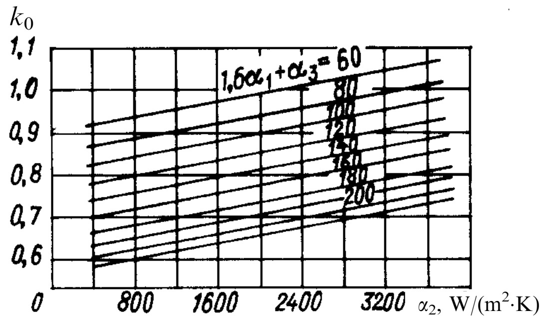


Fig. 2.1.3.2-2

For heated tubes of steam superheaters Δt is dependent upon the coefficient k of uneven heat absorption over the width of the superheater gas flue and upon the steam temperature increment Δt_v at the portion measured from the point of steam entry into the tube to the cross-section under consideration, the value t being obtained from Fig. 2.1.3.2-3.

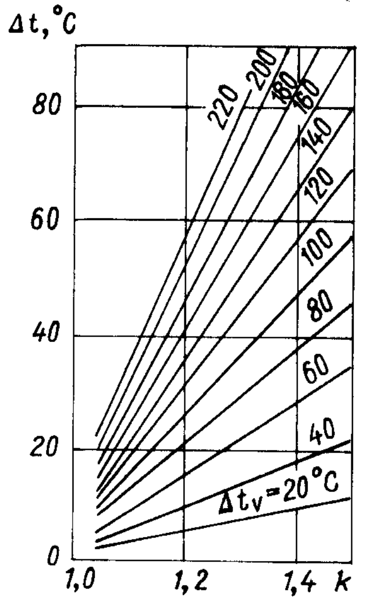


Fig.2.1.3.2-3

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 be not 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 100000 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 cast iron and non-ferrous alloys the minimum tensile strength value R_m at 20 °C shall be taken as the design strength characteristic.

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 — 2.1.4.5 in mind):

$$\sigma = \frac{R_{m/t}}{n_t},$$

$$\sigma = \frac{R_{1(10^5)/t}}{n_{cr}},$$

$$\sigma = \frac{R_{eL/t}}{n_y} \quad \left(\text{or } \sigma = \frac{R_{p0,2/t}}{n_y}\right), \qquad (2.1.4.6)$$

$$\sigma = \frac{R_m/t_{100000}}{n_{av}}$$

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 are to 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:

$$n_y = n_{av} = 2{,}2; \quad n_t = 3{,}0; \quad n_{cr} = 1{,}0.$$

For items that are under external pressure in service, the safety factors are to be increased by 20 per cent (except for n_{cr} which is to remain equal to 1).

2.1.5.4 For essential boiler components being under thermal pressure, 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 For items made of cast iron, the safety factor n_t shall be adopted equal to 4,8 both for the case of internal and external pressure.

For non-ferrous alloys, the safety factor shall be adopted equal to 4,6 for the case of internal pressure and 5,5 for the case of external pressure.

For conical walls under external pressure n_t may be adopted equal to 5,0.

2.1.6 Ligament efficiency factor and efficiency factor of welded joints.

2.1.6.1 Efficiency factor of welded joints shall be selected from Table 2.1.6.1-1 depending on the type

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

N o t e s: 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.

of joint and welding method used; efficiency factor of welded joints depending on the class of boilers, heat exchangers and pressure vessels (see 1.3.1.2) shall not be below the values given in Table 2.1.6.1-2.

Table 2.1.6.1-2

Item	Efficiency factor of welded joints φ		
	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

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 (see Fig. 2.1.6.2.1), as determined by the following formula:

$$\varphi = (a - d)/a; \quad (2.1.6.2.1)$$

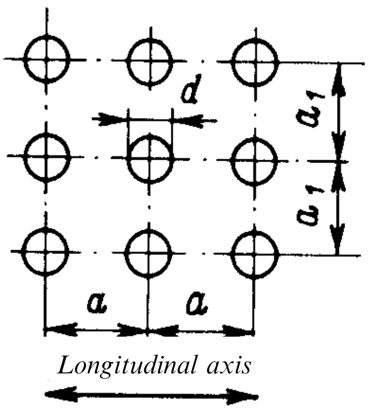


Fig. 2.1.6.2.1

.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:

$$\varphi = 2(a_1 - d)/a_1; \quad (2.1.6.2.2)$$

.3 the ligament efficiency factor, reduced to the longitudinal direction, of cylindrical walls weakened by a field of staggered and equally-spaced holes (see Fig. 2.1.6.2.3), as determined by the following formula:

$$\varphi = k(a_2 - d)/a_2 \quad (2.1.6.2.3)$$

where d = diameter of the hole for expanded tubes or inside diameter of welded-on tubes and upset nozzles, mm;
a = pitch between two adjacent hole centres in the longitudinal direction, mm;
a_1 = pitch between two adjacent hole centres in the transverse (circumferential) direction (taken as a mean circumference arc), mm;
a_2 = pitch between two adjacent hole centres in the diagonal direction, in mm, as determined by the following formula:

$$a_2 = \sqrt{l^2 + l_1^2};$$

l = centre-to-centre distance between two adjacent holes in the longitudinal direction (see Fig. 2.1.6.2.3), mm;
l_1 = centre-to-centre distance between two adjacent holes in the transverse (circumferential) direction (see 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.

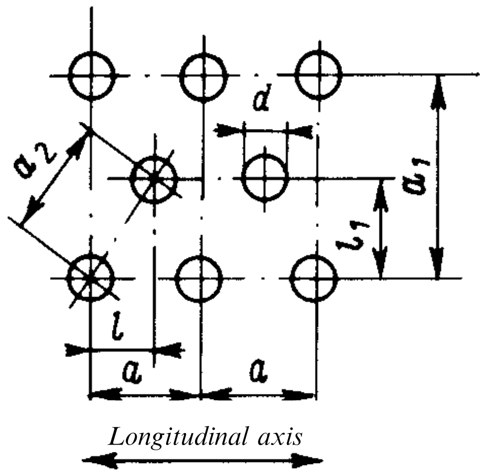


Fig. 2.1.6.2.3

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 welded joints have holes, the efficiency factor shall be taken as equal to the product of the efficiency factor of welded joints by the ligament efficiency factor of the wall weakened by holes.

2.1.6.5 For seamless cylindrical walls not weakened by welds or rows/fields of holes, the ligament efficiency factor is to 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 Determination of the ligament efficiency factor for walls weakened by openings to be fully or partially compensated is dealt with in 2.9.

2.1.6.10 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 (see 2.1.2), MPa;
D_a = outside diameter, mm;
D = inside diameter, mm;
φ = efficiency factor (see 2.1.6);
σ = allowable stress (see 2.1.4.6), MPa;
c = allowance (see 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 $A = 20\frac{\sigma}{D_m}\left(1 + \frac{D_m}{10l}\right)\left(1 + \frac{5D_m}{l}\right)$; (2.2.2.2-2)

$$B = p\left(1 + 5\frac{Dm}{l}\right); \qquad (2.2.2.2\text{-}3)$$

$$C = 0{,}045pD_m; \qquad (2.2.2.2\text{-}4)$$

p = design pressure (see 2.1.2), MPa;
D_m = mean diameter, mm;
σ = allowable stress (see 2.1.4.6 and 2.1.5.3), MPa;
c = allowance (see 2.1.7), mm;
l = design length of cylindrical portion between stiffening members, mm.

Assumed as stiffening members may be end plates, furnace connections to end plates and combustion chamber as well as reinforcing rings shown in Fig. 2.2.2.2, or similar structures.

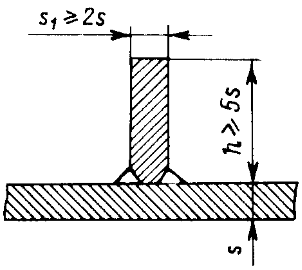


Fig. 2.2.2.2

2.2.2.3 Corrugated furnaces shall have a wall thickness s, in mm, not less than:

$$s = \frac{pD}{2\sigma} + c \qquad (2.2.2.3)$$

where p = design pressure (see 2.1.2), MPa;
D = minimum inside diameter of the furnace over the corrugated portion, mm;
σ = allowable stress (see 2.1.4.6 and 2.1.5.3), MPa;
c = allowance (see 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 be not less than 7 mm nor more than 20 mm. The thickness of corrugated furnaces shall be not 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 should be arranged in alternate planes.

2.2.2.7 Holes and openings in cylindrical and spherical walls are to be compensated for as per 2.9.

2.2.2.8 The thickness s_1, in mm, of the ogee rings (see Fig. 2.2.2.8) connecting furnace bottoms of the vertical boilers to the shell and bearing vertical loads is not to be less than that determined by the following formula:

$$s_1 \geqslant \frac{3{,}7}{\sigma}\sqrt{pD_1(D_1 - D_0)} + 1 \qquad (2.2.2.8)$$

where σ = allowable stress (see 2.1.4.6), MPa.
p = design pressure (see 2.1.2), MPa;
D_1 = inside diameter of the boiler wall, mm;
D_0 = outside diameter of combustion chamber where it joins the ogee ring.

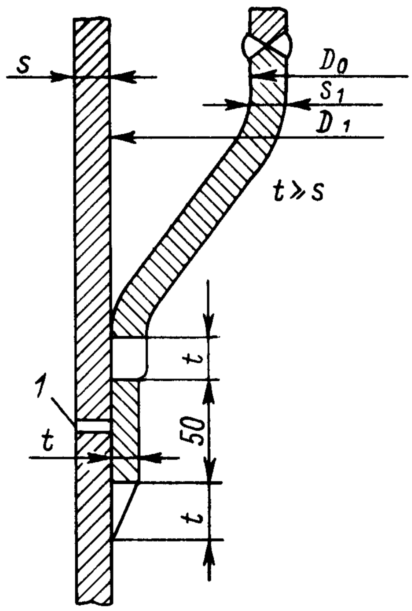


Fig. 2.2.2.8:
1 — at least 4 openings 10 mm in diameter equispaced over the shell

2.3 CONICAL ELEMENTS

2.3.1 The wall thickness s, in mm, of conical elements subject to internal pressure shall not be less than:

.1 at $\alpha \leqslant 70°$

$$s = \frac{D_a p y}{4\sigma\varphi} + c \qquad (2.3.1.1\text{-}1)$$

$$s = \frac{D_c p}{2\sigma\varphi - p}\frac{1}{\cos\alpha} + c; \qquad (2.3.1.1\text{-}2)$$

.2 at $\alpha > 70°$

$$s = 0{,}3[D_a - (r+s)]\sqrt{\frac{p}{\sigma\varphi}}\frac{\alpha}{90°} + c \qquad (2.3.1.2)$$

where D_c = design diameter (Figs 2.3.1-1 — 2.3.1-4), mm;
D_a = outside diameter (Figs 2.3.1-1 — 2.3.1-4), mm;
p = design pressure (see 2.1.2), MPa;
y = shape factor (see Table 2.3.1);
α, α_1, α_2, α_3 = angles (see Figs 2.3.1-1 — 2.3.1-4), deg.;
σ = allowable stress (see 2.1.4.6), MPa;
φ = efficiency factor (see 2.1.6); in Formulae (2.3.1.1-1) and (2.3.1.2) the efficiency factor of a circumferential welded joint shall be used, and in Formula (2.3.1.1-2) that of a longitudinal welded joint; for seamless shells, as well as in situations where circumferential weld is removed from the edge to a distance exceeding $0{,}5\sqrt{D_a s/\cos\alpha}$ the efficiency factor of the welded joint shall be taken equal to 1;
c = allowance (see 2.1.7), mm;
r = radius of edge curvature (see Figs 2.3.1-1, 2.3.1-2 and 2.3.1-4), mm.

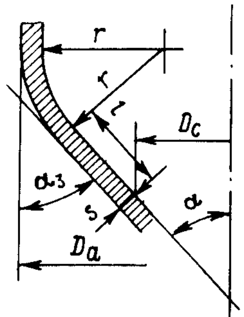


Fig. 2.3.1-1

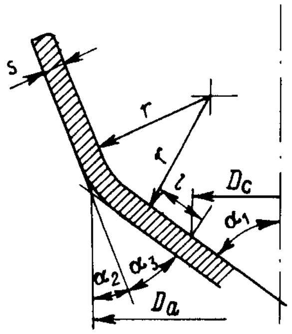


Fig. 2.3.1-2

In Figs 2.3.1-1, 2.3.1-2 and 2.3.1-4 l is the distance, in mm, from the edge of the wide end of the conical shell, parallel to the generatrix of the conical shell assumed equal to 10 thicknesses, but not larger than half the length of the conical shell generatrix.

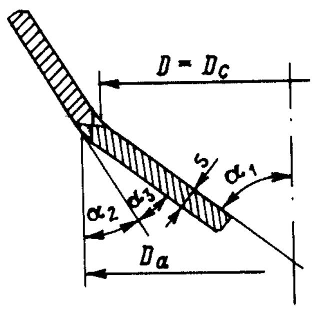


Fig. 2.3.1-3

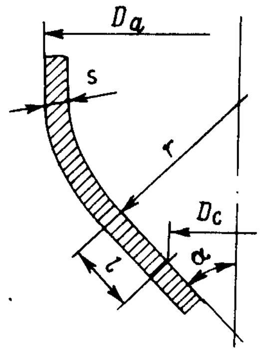


Fig. 2.3.1-4

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:

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 $r/D_a = 0{,}01$.

$$D_c = \frac{d_1 + d_2}{2} \frac{1}{\cos\alpha} \qquad (2.3.2.3)$$

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:

$$p_1 = 26E \cdot 10^{-6} \frac{D_c}{l_1} \left[\frac{100(s - c)}{D_c}\right]^2 \sqrt{\frac{100(s - c)}{D_c}} \qquad (2.3.2.4)$$

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 (see Fig. 2.3.1-3) are allowed only at $\alpha_3 \leqslant 30°$ and $s \leqslant 20$ mm. The joint is to 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 should not be used on boilers.

2.3.4 Holes and openings in conical walls are to 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 — 2.4.1.1-8 and 1.2 of the Appendix) shall not be less than:

$$s = kD_c\sqrt{\frac{p}{\sigma}} + c \qquad (2.4.1.1\text{-}1)$$

where k = design factor according to Figs 2.4.1.1-1 — 2.4.1.1-8 and 1.1 to 1.6 of the Appendix;
D_c = design diameter (see Figs 2.4.1.1-2 — 2.4.1.1-7 and 1.6 of the Appendix), mm;
for end plates shown in Figs 2.4.1.1-1 and 1.1 of the Appendix the design diameter shall be:

$$D_c = D - r; \qquad (2.4.1.1\text{-}2)$$

for rectangular or oval covers (see Fig. 2.4.1.1-8) the design diameter shall be:

$$D_c = m\sqrt{\frac{2}{1 + (m/n)^2}}; \qquad (2.4.1.1\text{-}3)$$

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 (see Fig. 2.4.1.1-8), mm;
p = design pressure (see 2.1.2), MPa;
σ = allowable stress (see 2.1.4.6), MPa;
c = allowance (see 2.1.7), mm.
D_b = circle diameter of fastening bolts (see Fig. 2.4.1.1-6), mm;

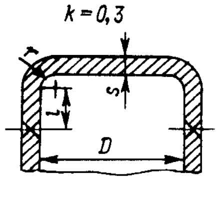


Fig. 2.4.1.1-1

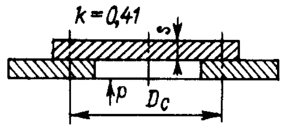


Fig. 2.4.1.1-2

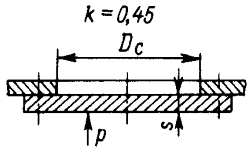


Fig. 2.4.1.1-3

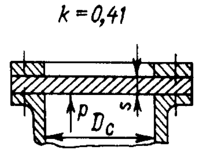


Fig. 2.4.1.1-4

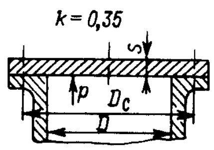


Fig. 2.4.1.1-5

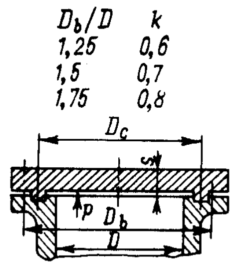


Fig. 2.4.1.1-6

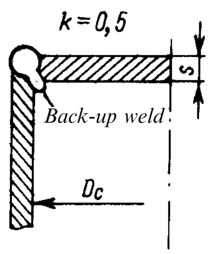


Fig. 2.4.1.1-7

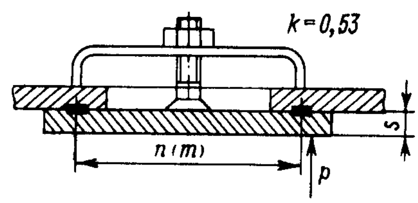


Fig. 2.4.1.1-8

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).

Additionally, the following conditions are to be satisfied:

.1 for circular end plates

$$0{,}77s_1 \geqslant s_2 \geqslant \frac{1{,}3p}{\sigma}\left(\frac{D_c}{2} - r\right); \qquad (2.4.1.2.1)$$

.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 (see 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 is not to 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.

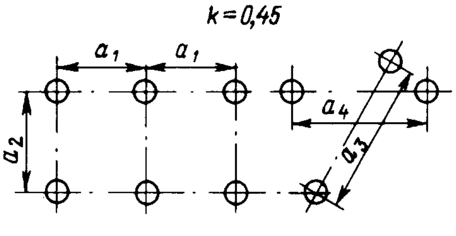


Fig. 2.4.2.1-1

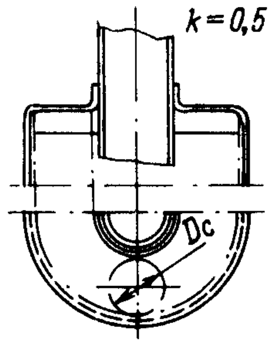


Fig. 2.4.2.1-2

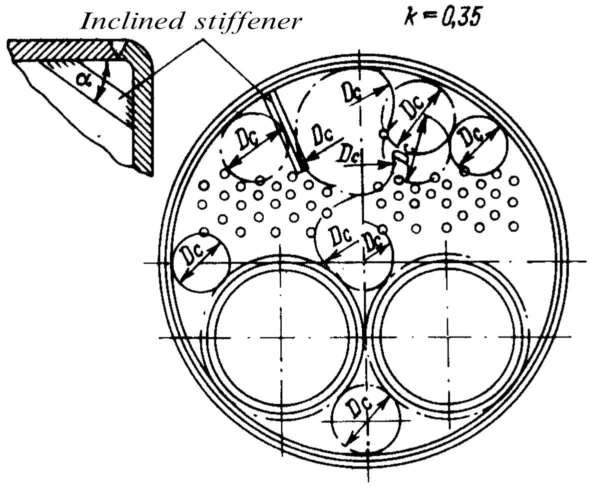


Fig. 2.4.2.1-3

2.4.3 Flanging of flat walls.

2.4.3.1 In flat wall and end plate calculations, the flanging is only taken into account when the flanging radii are not less than those given in Table 2.4.3.1.

Table 2.4.3.1

Radius of flanging, mm	Outside diameter of end plate, mm
25	⩽350
30	351 to 500
35	501 to 950
40	951 to 1400
45	1401 to 1900
50	>1900

The minimum flanging radius shall be not 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 $0{,}5\sqrt{Ds}$ (see 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:

$$d = 8s_f(1{,}5\frac{s_f^2}{s^2} - 1) \qquad (2.4.4.2)$$

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.

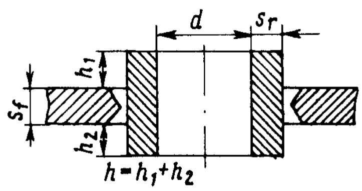


Fig. 2.4.4.3

2.4.4.4 The design heights h_1 and h_2, in mm, of reinforcing elements (nozzles and branches) (see 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 (see 2.1.2), MPa;
σ = allowable stress (see 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 (see 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 (see 2.5.2).

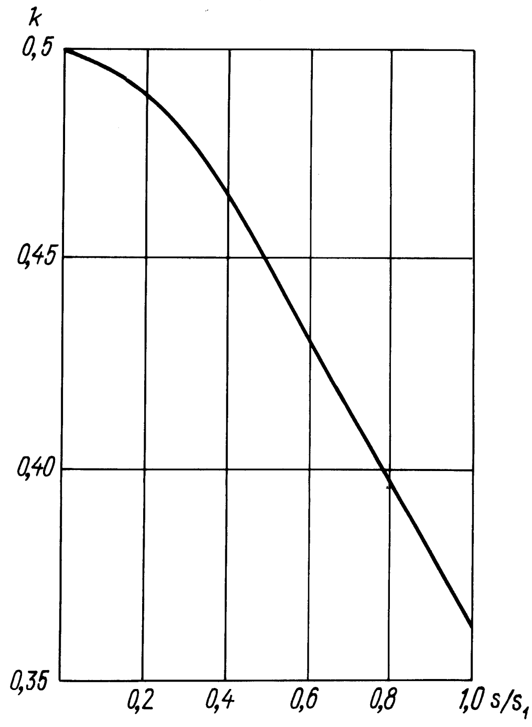


Fig. 2.5.1

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:

$f_{min} \geqslant 5d$ (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:

$s_1 = 10 + 0{,}125d$. (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 (see 2.1.2), MPa;
D_a = outside diameter of the end, mm;
φ = efficiency factor (see 2.1.6);
σ = allowable stress (see 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 (see Fig. 2.6.1).
To choose y using Table 2.6.1 the value s is to be selected from a number of standard thicknesses. The finally accepted value s is not to be less than that determined by Formula (2.6.1);
c = allowance to be taken equal to:
2 mm at internal pressure and
3 mm at external pressure.
At wall thickness exceeding 30 mm the above allowance values may be reduced by 1 mm;
d = the larger dimension of the non-reinforced opening, mm.

The symbols for dished end elements are shown in Fig. 2.6.1.

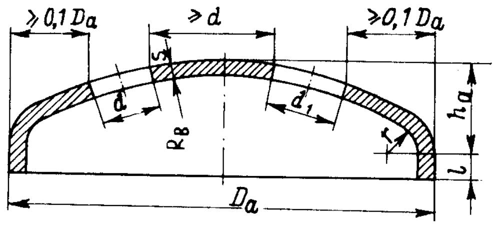


Fig. 2.6.1

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

Table 2.1.6.1-1

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	
Dished ends, 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
Dished ends, 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
Dished ends, 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

outline of the cylindrical portion and measuring not more than $4s$ in diameter and never more than 100 mm. In the flanged area of the end, non-reinforced openings are allowed, with diameters less than the wall thickness but not more than 25 mm.

2.6.4 The wall thickness of dished ends in combustion chambers of vertical boilers may be calculated as for unpierced ends, also where the flue-gas outlet branch passes through the end.

2.6.5 Dished ends subject to external pressure, except for those of cast iron, shall be checked for stability by calculation based on the following relation:

$$\frac{36{,}6E_t}{R_B^2}\,\frac{(s-c)^2}{100p} > 3{,}3 \qquad (2.6.5)$$

where E_t = modulus of elasticity at design temperature, MPa; for modulus of elasticity for steel, see 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.

2.7 FLANGED END PLATES

2.7.1 Unpierced flanged end plates (Fig. 2.7.1) subject to internal pressure shall have a thickness s, in mm, not less than:

$$s = (3pD)/\sigma + c \qquad (2.7.1)$$

where p = design pressure (see 2.1.2), MPa;

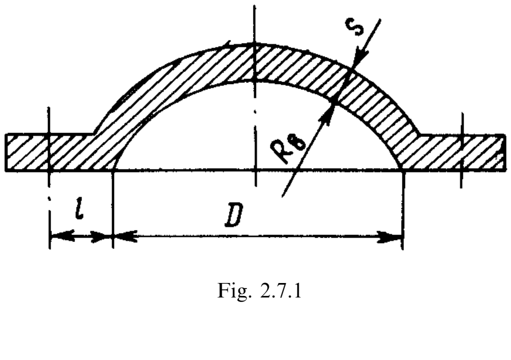


Fig. 2.7.1

D = inside diameter of the end plate flange to be equal to the inside diameter of the shell, mm;
σ = allowable stress (see 2.1.4.6), MPa;
c = allowance (see 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

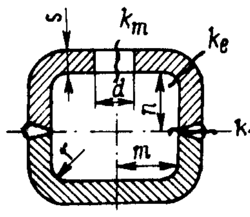


Fig. 2.8.1-1

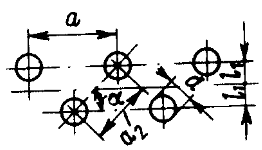


Fig. 2.8.1-2

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 (see 2.1.2), MPa;
n = half the width in the clear of the header side normal to that being calculated, mm;
σ = allowable stress (see 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 (see 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 should 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 (see 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 with the weakening in the opening area being compensated by providing surplus thickness as compared to the design value (Figs 2.9.1.1-1 and 2.9.1.1-2);

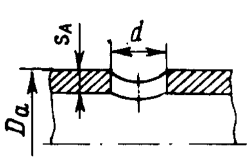


Fig. 2.9.1.1-1

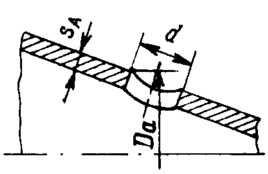


Fig. 2.9.1.1-2

.2 openings reinforced by means of disc-shaped reinforcing plates (pads) attached by welding to the wall to be reinforced (Figs 2.9.1.1-3 and 2.9.1.1-4);

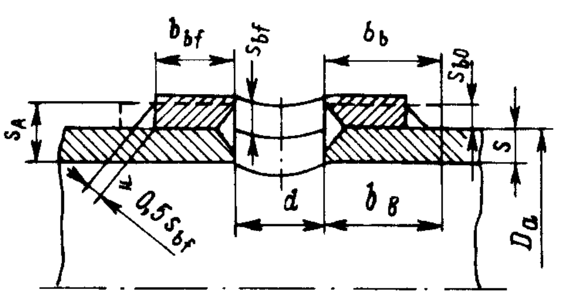


Fig. 2.9.1.1-3

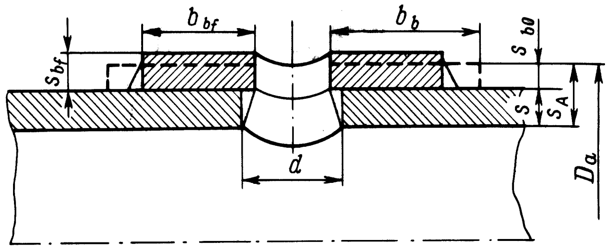


Fig. 2.9.1.1-4

.3 openings reinforced by means of welded-on tubular elements, such as nozzles, sleeves, branch pieces, etc. (Figs 2.9.1.1-5 — 2.9.1.1-7).

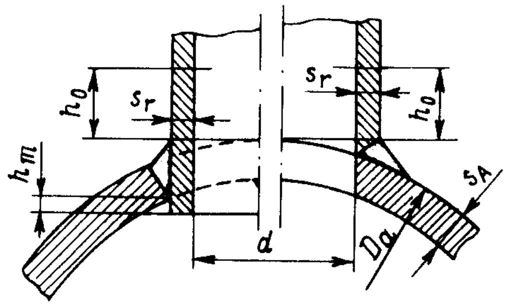


Fig. 2.9.1.1-5

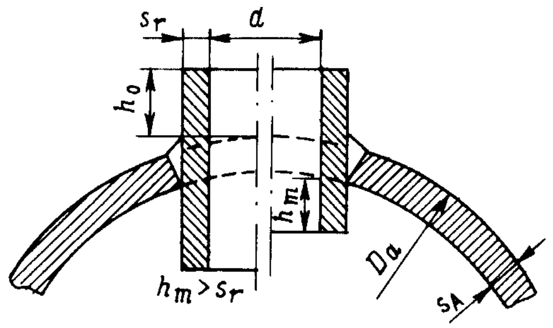


Fig. 2.9.1.1-6

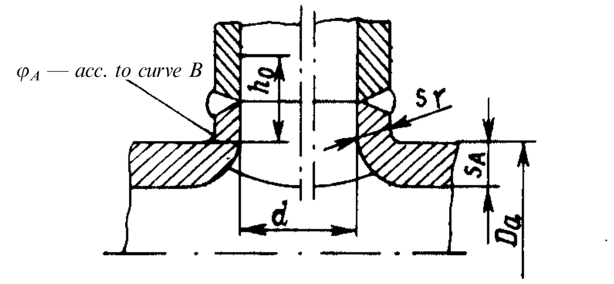


Fig. 2.9.1.1-7

The reinforcing elements for openings, such as shown in Figs 2.9.1.1-5 — 2.9.1.1-7, are recommended for welding in place using a removable backing strip or some other technique ensuring necessary penetration at weld root.

2.9.1.2 The thickness of walls having openings shall be in accordance with the requirements specified in 2.2 for cylindrical walls, in 2.3 for conical walls, and in 2.6 for dished ends.

2.9.1.3 The materials used for the wall to be reinforced and for the reinforcing elements shall have identical strength characteristics as far as possible. Where use is made of reinforcing materials with inferior strength characteristics compared to those of the wall to be reinforced, the area of the reinforcing sections shall be increased accordingly.

The reinforcing elements shall be reliably attached to the wall to be reinforced.

2.9.1.4 Openings in walls shall be located at the distance of at least 3*s*, but not less than 50 mm away from the welded joints.

The arrangement of openings at the distance of less than 50 mm from the welded joints and in the area of welded joints is subject to special consideration by the Register in each case.

2.9.1.5 The largest dimension of a reinforced opening shall not exceed 500 mm.

Reinforcement of openings measuring over 500 mm is subject to special consideration by the Register in each case.

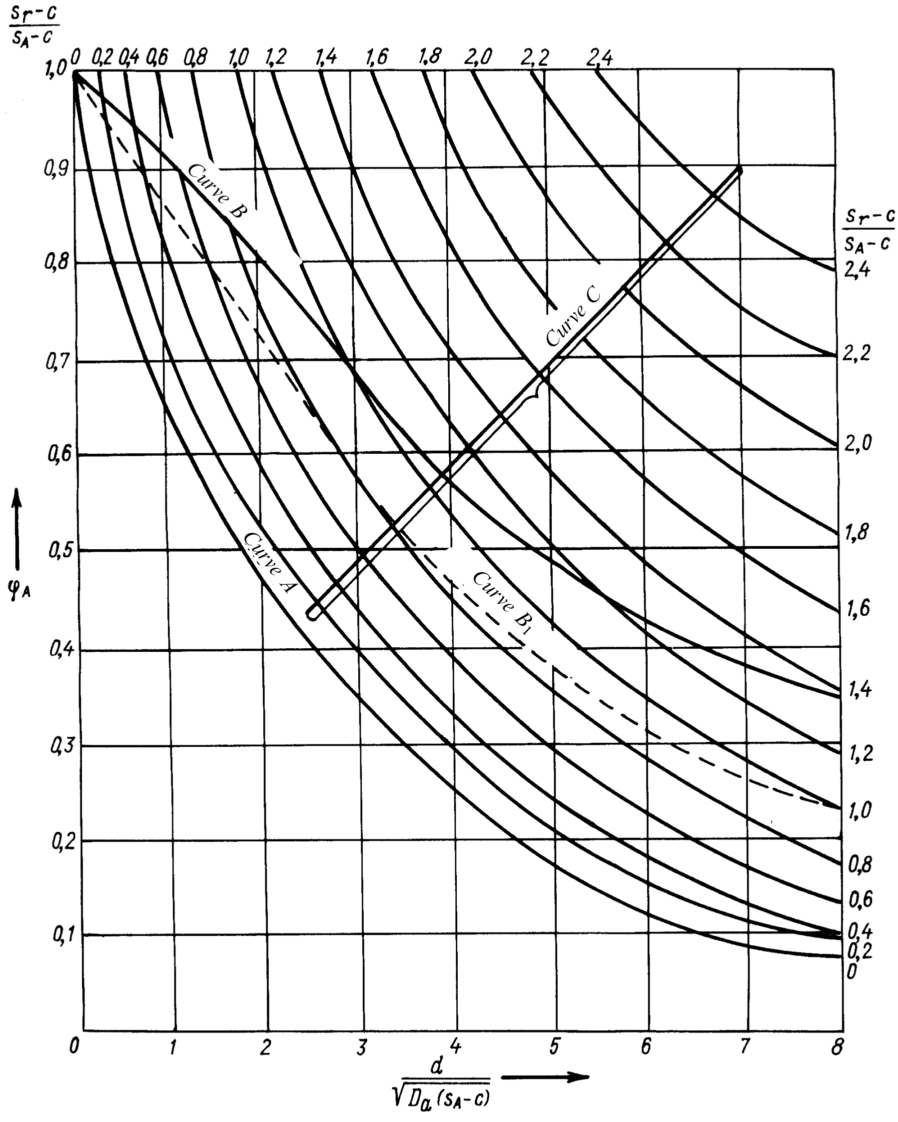


Fig. 2.9.2

2.9.1.6 The minimum thicknesses of tubular elements (branches, sleeves, or nozzles) attached by welding to the walls of boilers, heat exchangers or pressure vessels shall generally be taken as not less than 5 mm. Cases where the thicknesses are below 5 mm are subject to special consideration by the Register in each case.

2.9.2 Dimensions of reinforcing elements.

2.9.2.1 An opening may be reinforced by providing surplus thickness, compared to the design value. In this case, the increased thickness s_A, in mm, shall not be less than:

for cylindrical walls

$$s_A = \frac{pD_a}{2\sigma\varphi_A + p} + c; \qquad (2.9.2.1\text{-}1)$$

for spherical walls

$$s_A = \frac{pD_a}{4\sigma\varphi_A + p} + c; \qquad (2.9.2.1\text{-}2)$$

for conical walls

$$s_A = \frac{pD_c}{2\sigma\varphi_A - p}\,\frac{1}{\cos\alpha} + c \qquad (2.9.2.1\text{-}3)$$

where φ_A = efficiency factor of the wall weakened by an opening to be reinforced, which is determined in dependence upon the dimensionless parameter $d/\sqrt{D_a(s_A - c)}$ from curve A as represented in Fig. 2.9.2.1. It shall be noted that the value of s_A in the expression for the dimensionless parameter should be the same as obtained from Formulae (2.9.2.1-1) to (2.9.2.1-3);

d = diameter of the opening (inside diameter of a nozzle, sleeve, or branch) or the size of an oval or elliptical opening on the longitudinal axis of the shell, mm.

Other symbols used are the same as in 2.2.1.2 and 2.3.1.

2.9.2.2 Where disc-shaped reinforcing plates (pads) are used as reinforcement for openings in cylindrical, spherical or conical walls, the dimensions of the reinforcing plate shall be determined by the following formulae:

$$b_b = \sqrt{D_a(s_A - c)}\ ; \qquad (2.9.2.2\text{-}1)$$

$$s_{b0} \geqslant s_A - s_f \qquad (2.9.2.2\text{-}2)$$

where b_b = maximum effective width of the plate (see Figs 2.9.1.1-3 and 2.9.1.1-4), mm;

s_{b0} = height (thickness) of the plate (see Figs 2.9.1.1-3 and 2.9.1.1-4), mm;

s_A = total thickness of the wall to be reinforced and of the reinforcing plate, determined from 2.9.2.1, mm;

s_f = actual thickness of the wall to be reinforced, mm.

Other symbols used are the same as in 2.9.2.1.

Where the actual plate width is less than that specified above, the actual plate height (thickness) s_{bf}, in mm, shall be increased accordingly, in compliance with the relation:

$$s_{bf} \geqslant s_{b0}\left(1 + \frac{b_b}{b_{bf}}\right)/2 \qquad (2.9.2.2\text{-}3)$$

where b_{bf} = actual width of the plate, mm;

s_{bf} = actual plate height (thickness), mm.

The weld seam joining the reinforcing plate to the wall shall not be less than $0{,}5s_{bf}$ in size (see Fig. 2.9.1.1-3).

2.9.2.3 Where welded tubular elements are used as reinforcement of openings in cylindrical, spherical and conical walls, the dimensions of the said elements shall be not lower than the values obtained as follows:

.1 The wall thickness s_r of a tubular element (nozzle, sleeve, branch piece, etc.), in mm, is determined in relation to the dimensionless parameter $d/\sqrt{D_a(s_A - c)}$, and the efficiency factor φ_A from curves C represented in Fig. 2.9.2.1. In this case, the values s_f and φ_f shall be substituted for s_A and φ_A (see Fig. 2.9.2.1).

Here s_f = actual wall thickness, in mm; φ_f = actual efficiency factor of a wall having thickness s_f, as determined by Formulae (2.2.1.2-1), (2.2.1.2-2), (2.2.1.3-1), (2.2.1.3-2) and (2.3.1.2) by solving the equations as related to φ.

The ratio of $(s_r - c)/(s_A - c)$ obtained from Fig. 2.9.2.1 is used to determine the minimum thickness s_r in mm, of a nozzle, sleeve, or branch piece. It should be noted that in the above ratio s_A denotes the actual thickness s_f.

.2 The minimum design height h_0, in mm, of a tubular reinforcement is determined from the formula:

$$h_0 = \sqrt{d(s_r - c)}\ . \qquad (2.9.2.3.2\text{-}1)$$

If the actual height of a tubular reinforcement h_f is less than that determined by Formula (2.9.2.3.2-1), the thickness s_{rf} shall be increased respectively according to the formula:

$$s_{rf} = s_r h_0 / h_f\ . \qquad (2.9.2.3.2\text{-}2)$$

2.9.2.4 Openings in dished ends shall be reinforced as follows:

.1 For unreinforced openings the thickness of the ends shall be determined with due regard for openings by way of replacing the term y in Formula (2.6.1) with the term y_A obtained from Table 2.6.1.

.2 For openings reinforced by means of disc-shaped reinforcing plates the plate dimensions shall be determined as specified in 2.9.2.2, the overall thickness of the wall to be reinforced s_A being determined by the formula:

$$s_A = \frac{pD_a y_0}{4\sigma\varphi_A} + c \qquad (2.9.2.4.2)$$

where y_0 = shape factor selected from Table 2.6.1.

Other symbols used are the same as in 2.9.2.2.

.3 For openings with tubular reinforcements the reinforcement dimensions shall be determined from 2.9.2.3; in the dimensionless parameter $d/\sqrt{D_a(s - c)}$ the value $2(0{,}5D_a + s)$ is substituted for D_a; the actual efficiency factor of the ends with thickness s being determined by Formula (2.6.1) for φ and by substituting $\varphi = \varphi_A$, $y = y_0$ and $s = s_A$ (see 2.6.1).

2.9.2.5 For through tubular reinforcements, with the inward projecting portion $h_m \geqslant s_r$ (see Figs 2.9.1.1-5 and 2.9.1.1-6), the thickness of a nozzle, sleeve or branch piece may be reduced by 20 per cent, but shall not be less than that required for the design pressure.

2.9.2.6 The ratio of the thickness of tubular reinforcement s_r to the thickness of the wall to be reinforced s shall be not higher than 2,4. If, for design reasons, this ratio is taken greater than 2,4, the thickness value for the tubular reinforcement s_r equal to not more than 2,4 times the thickness of the wall to be reinforced shall be used in the calculations.

2.9.2.7 Disc-shaped reinforcing plates and tubular reinforcements may be used in combinations as compensation for openings (Fig. 2.9.2.7). In such a case, the dimensions of the reinforcing elements shall be determined with regard to the requirements for the disc-shaped and tubular reinforcements.

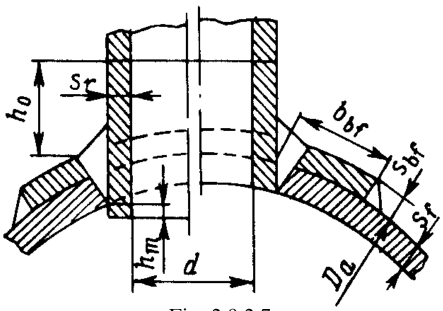


Fig. 2.9.2.7

2.9.2.8 For upset nozzles (see Fig. 2.9.1.1-7) the thickness s_A shall not be less than that determined by Formulae (2.9.2.1-1) to (2.9.2.1-3) and (2.9.2.4.2) where φ_A = the efficiency factor of the wall, weakened due to the provision of an upset nozzle, to be determined:

from curve B for $d/D_a \leqslant 0{,}4$ (see Fig. 2.9.2.1);

from curve B_1 for $d/D_a = 1{,}0$ (see Fig. 2.9.2.1);

by interpolation of curves B and B_1 for $0{,}4 < d/D_a < 1{,}0$ (see Fig. 2.9.2.1).

The thickness of the upset shoulder s_r, in mm, shall be more than that determined according to the relation:

$$s_r \geqslant s_A d/D_a\ , \qquad (2.9.2.8)$$

but not less than that required for the design pressure.

2.9.3 Interdependence of openings.

2.9.3.1 The interdependence of openings may be disregarded provided that:

$$l + s_{r1} + s_{r2} \geqslant 2\sqrt{D_a(s_f - c)} \qquad (2.9.3.1\text{-}1)$$

where $l + s_{r1} + s_{r2}$ = distance between two adjacent openings (Figs 2.9.3.1-1 and 2.9.3.1-2), mm;

D_a = outside diameter of the wall to be reinforced, mm;

s_f = actual thickness of the wall to be reinforced, mm;

c = allowance (see 2.1.7), mm.

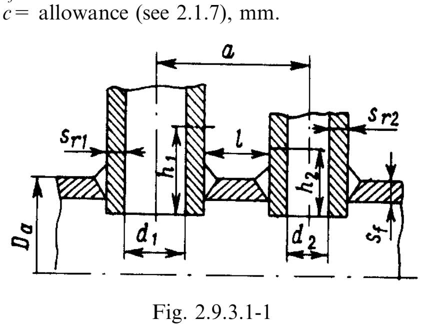


Fig. 2.9.3.1-1

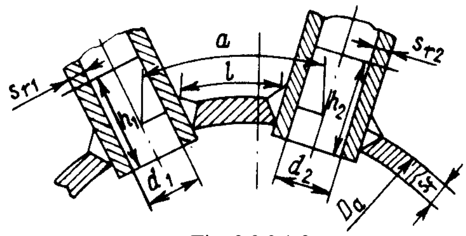


Fig. 2.9.3.1-2

If the distance $l + s_{r1} + s_{r2}$ is smaller than the value of $2\sqrt{D_a(s_f - c)}$ given in Formula (2.9.3.1-1), a check shall be made to ascertain the stress occurring in the section between the openings due to design pressure. The stresses involved shall not exceed, both longitudinally and transversely, the allowable values according to the relation:

$$F/f_c \leqslant \sigma \qquad (2.9.3.1\text{-}2)$$

where σ = allowable stress (see 2.1.4.6), MPa;

F = load caused by the design pressure upon the section between the openings (see 2.9.3.2), N;

f_c = design sectional area between the openings (see 2.9.3.3), mm^2.

2.9.3.2 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

$$F_a = Dpa/2\ ; \qquad (2.9.3.2.1)$$

.2 for openings arranged circumferentially in cylindrical or conical walls as well as for openings in spherical walls

$$F_b = Dpa/4\ ; \qquad (2.9.3.2.2)$$

.3 for openings in dished ends

$$F_b = Dpya/4 \qquad (2.9.3.2.3\text{-}1)$$

where D = inside diameter (for conical walls measured at the centre of the opening), mm;

p = design pressure (see 2.1.2), MPa;

y = shape factor (see 2.6.1);

a = pitch between two adjacent openings on the circumference (determined on the outside of the wall as shown in Fig. 2.9.3.1-2), mm.

Where openings are arranged in cylindrical walls at a diagonal pitch, the load involved is determined by Formula (2.9.3.2.2), the results being multiplied by a factor:

$$k = 1 + \cos^2\alpha \qquad (2.9.3.2.3\text{-}2)$$

where α = angle of inclination of the line through the opening centres to the longitudinal axis, deg.

2.9.3.3 The design sectional area f_c, in mm^2, between two adjacent openings with tubular reinforcements shall be determined by the following formula:

$$f_c = l(s - c) + 0{,}5[h_1(s_{r1} - c) + h_2(s_{r2} - c)] \qquad (2.9.3.3)$$

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 (see Figs 2.9.3.1-1 and 2.9.3.1-2), mm;

s = thickness of the wall to be reinforced, mm;
s_{r1} and s_{r2} = thicknesses of the tubular reinforcements (see Figs 2.9.3.1-1 and 2.9.3.1-2), mm;
c = allowance (see 2.1.7), mm;
h_0 = design height of the tubular reinforcement (see Formula 2.9.2.3.2-1), mm;
h_m = inward projecting portion of the tubular reinforcement (see Figs 2.9.1.1-5, 2.9.1.1-6, 2.9.2.7), 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.

2.9.3.4 For upset nozzles arranged in a row the efficiency factor determined by Formula (2.1.6.2.1) for this row shall not be less than the efficiency factor φ_A determined from curves B and B_1 in Fig. 2.9.2.1. If $\varphi < \varphi_A$, the value of φ shall be used for determination of the wall thickness as specified in 2.9.2.7.

This requirement is also applicable to welded-on nozzles arranged in a row, the thickness of which is determined only on the basis of the internal pressure effect.

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 (see 2.1.2), MPa;
σ = allowable stress (see 2.1.4.6), MPa;
α = angle between the corner stay and the wall to which the stay is attached (see 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.

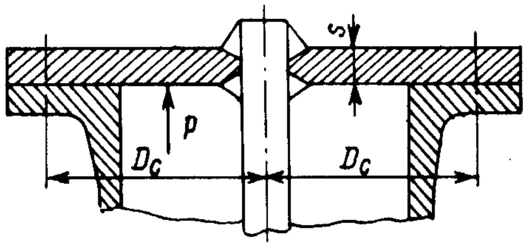


Fig. 2.10.1.3

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 (see 2.10.1.1), mm^2.

2.10.2.2 For expanded tubes the length of the expansion belt in the tube plate shall be not 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 value obtained from the formula:

$$pf_s/20sl \qquad (2.10.2.3)$$

does not exceed:

15 for joints of plain tubes,

30 for joints with sealing grooves,

40 for joints with flanging of tubes.

Here s = thickness of the tube wall, mm;
l = length of the expansion belt, mm.
l shall be taken as not more than 40 mm.

Other symbols used are the same as in 2.10.1.1.

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 is to 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 (see 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 is to be not more than $8s_1$, mm;
l = design length of the girder, mm;
p = design pressure (see 2.1.2), MPa;
a = spacing of girders, mm.

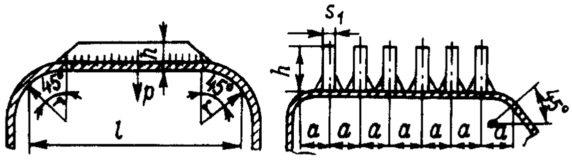


Fig 2.11.1

3 BOILERS

3.1 GENERAL PROVISIONS

3.1.1 The general provisions concerning supervision, 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 should 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 be not 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. Where flat walls are reinforced with welded-on girders, this should 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 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. It is recommended that in vertical gas-tube boilers the gas uptake pipe passing through the steam space of the boiler be protected from direct exposure to hot gases.

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 particulars 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 Finned-tube boilers are to be provided with an effective soot-blowing system and to have access for inspection of heating surfaces.

3.2.16 Waste-heat boilers connected to exhaust gas systems of two-stroke diesels swith inlet gas temperature of 270° C and lower shall meet the following requirements:

.1 hydraulic resistance of the boiler shall be such that the outlet velocity of gases is not less than 10 m/s;

.2 for disconnection of the boiler when the engine is operated at partial loads the transfer arrangement shall be provided;

.3 design of the heating surface of the boiler shall as much as possible ensure the elimination of sediments formation and soot removal devices efficiency;

.4 the boilers shall be equipped with the stationary system of washing and sediments removal. At the same time measures shall be taken to exclude washing products entering in the engine gas duct;

.5 as regards fire-extinguishing facilities the requirements of 3.1.2.1, Part VI "Fire Protection" shall be observed.

3.3 FITTINGS AND GAUGES

3.3.1 General requirements.

3.3.1.1 All boiler mountings 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 are to 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 natural-circulation boiler with free water evaporating surface shall be provided with at least two independent water level indicators with transparent faces (see 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.

Natural circulation 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 accumulators 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.

A second alarm is not required if it is fitted in the oil burning installation according to 4.3, Part XV "Automation".

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 an error 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 is to 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 duly tested and marked with the date of testing carried out by competent bodies recognized by the Register.

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 be not 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 $h/d \leqslant 0.25$, 1.25 at $h/d > 0.25$;
d = minimum valve diametr, mm;
h = height of valve lifting, mm.

Spring safety valves shall be not 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 are to be so adjusted that the maximum pressure during their operation should 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 be not 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 be not 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 is to 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 accumulators (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 be not 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 sight 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 sight 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, mountings 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 should, 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 are to 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 should 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 should 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 (with organic working medium).

3.5.2 The general provisions relating to supervision, technical documentation, construction, strength calculation standards and also the general requirements are set forth in Sections 1 and 2 and in paragraphs 3.2.1, 3.2.2, 3.2.6 to 3.2.10, 3.2.12, 3.2.13.

3.5.3 The boilers shall generally be installed 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, if the thermal fluid circulation is stopped, no temperature increase of the thermal fluid above the permissible value is possible.

The maximum working temperature of the thermal fluid is to be at least 50 °C below its thermal stability.

3.5.5 The boiler furnace and burning installation shall be designed so that uniform distribution of heat flux is ensured.

Only such non-uniformity may be permitted at which at any point of the heated surfaces the temperature of the fluid boundary layer will not be in excess of the value specified for the thermal fluid used.

The arrangement of the burning installation and the design of the furnace shall be such as to keep the flame-jet from touching the heated surfaces.

The burning installation shall be arranged so that no increase in the boiler thermal output above the rated value is possible.

The boiler furnaces over 1000 kW in output shall be fitted with closing appliances and independent fire smothering appliances of the type approved by the Register.

3.5.6 Each boiler shall be equipped with:

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 be remotely controlled or provision shall be made for an arrangement to quickly discharge the thermal liquid from the system (see 16.6.2, Part VIII "Systems and Piping");

at least two spring-loaded safety valves of encased type having the same dimensions and design and the capacity not less than the capacity of the circulating pump. Safety valves shall be not less than 32 mm and not more than 100 mm in bore diameter. Waste-heat boilers may be fitted with one safety valve (for the requirements for safety valves, see 3.3.6.4, 3.3.6.10, 3.3.6.11);

pressure gauge;

thermal fluid sampling device;

arrangement for emergency drainage of a thermal fluid and remote stopping of circulation pumps;

devices required by 3.3.11.

3.5.7 Each boiler shall be provided with an effective system of soot removal.

3.5.8 Boiler tubes shall be attached to drums and headers by welding.

3.5.9 Boilers shall be equipped with mountings and fittings having bellows seals. The use of the gasket type mountings and fittings is subject to special consideration by the Register. The mountings and fittings shall be attached by welding. The requirement of 3.3.1.3 is applicable to the boiler mountings and fittings.

3.5.10 Provision shall be made for limiting temperature signalling and protection at the inlets and outlets of gases and thermal fluid.

3.5.11 Waste-heat boilers shall be provided with a shut-off device to stop gas supply in case of operation of protective devices.

3.5.12 Thermal fluid boilers are to be provided with automatic combustion controls, audible and visual alarms in compliance with 4.3.1, interlocking as in 5.3.2 and protective devices referred to in 5.3.3.

4 CONTROLS, GOVERNORS, PROTECTIVE DEVICES AND ALARMS FOR BOILERS

4.1 GENERAL PROVISIONS

4.1.1 The requirements of the present Section apply to boilers for which continuous attendance is necessary.

The requirements for controls, governors, protective devices and alarms for unattended boilers are specified in 4.3, Part XV "Automation".

4.1.2 Control and monitoring systems and their elements shall comply with the requirements of Sections 2 and 3, Part XV "Automation".

4.2 GOVERNORS AND CONTROLS

4.2.1 The main water-tube boilers and auxiliary water-tube boilers for essential services shall be equipped with feed water governors and combustion controls. For other types of boilers these governors and controls are recommended.

4.2.2 Governors and controls shall be capable of maintaining the water level and other controlled parameters within the predetermined limits over the entire steaming load range and shall ensure a quick change-over from one state of operation to another.

4.3 PROTECTIVE DEVICES

4.3.1 Boilers shall be equipped with non-disconnectable protective devices for the lowest water level limit in the boiler (see 3.3.4).

4.3.2 Boilers with automatic combustion controls shall be protected according to the requirements of 5.3.

4.4 ALARMS

4.4.1 Boilers with automatic feed water governors and combustion controls shall be equipped with visual and audible alarms at the boiler control station.

4.4.2 Light and sound alarms shall function in cases of:

water level reaching its lowest limit;

water level reaching its highest limit;

failures in the automatic control systems and protective devices;

failures in the boiler oil burning system (see 5.3.3);

feed water salinity rise above the permissible value (see 17.2.4, Part VIII "Systems and Piping" and Table 4.3.9, Part XV "Automation").

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.

4.4.5 Air ducts and boiler uptakes are to be provided with means for timely fire detection and alarms operating if fire occurs.

5 OIL BURNING INSTALLATIONS OF BOILERS

5.1 GENERAL PROVISIONS

5.1.1 The general provisions concerning the 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 burning installations, 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 burning installations shall comply with the requirements of Part XI "Electrical Equipment".

5.1.4 Oil fuel 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 burning installations are to comply with the requirements of Part VIII "Systems and Piping".

5.1.6 Sight devices are to be provided for observation of the burning process.

5.1.7 Suitable devices are to be provided for extinguishing 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 should be made for controlling the amount of combustion air.

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 are to 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 are to 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 are to 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 are to be provided in places where oil may leak.

5.3 BURNING INSTALLATIONS

5.3.1 The requirements of the present Chapter apply to burning installations equipped with automatic combustion controls in continuously attended boilers.

5.3.2 Burning installations 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 air is fed into the boiler furnace;

.4 the pilot burner is alight or electrical ignition is switched on;

.5 water level in the boiler is normal.

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 a burner;

.3 water level in the boiler reaching its lowest limit.

Fuel supply shall be cut off by two self-closing series-connected valves.

This requirement is not obligatory in case the fuel service tank of the boiler is arranged below the burning installation.

5.3.4 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.

5.3.5 The capacity of the pilot burner is to be such that the burner itself could not maintain the boiler under pressure with the steam consumption completely stopped.

Where the pilot and main burners are simultaneously in operation and the protective devices are caused to function under conditions specified in 5.3.3, the pilot burner shall cease operation at the same time as the main burner.

5.3.6 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.

5.3.7 Provision shall be made for the burning installation to be shut off from two stations, one of which shall be situated outside the boiler room.

6 HEAT EXCHANGERS AND PRESSURE VESSELS

6.1 GENERAL PROVISIONS

6.1.1 The general provisions concerning the supervision, 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".

6.2 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".

6.3 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 departures 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.

In deaerators cylindrical glasses may be used.

6.3.6 Heat exchangers and pressure vessels are to be provided with welded-on pads or short rigid connecting pieces for mounting fittings. Use of threaded connections is permitted for hydrophores.

6.3.7 Pressure vessels and heat exchangers shall be equipped with blow-down and drainage devices.

6.3.8 Manholes shall be provided to enable inspection of the internal surfaces of heat exchangers and pressure vessels. Where provision of manholes is not possible, sight holes shall be fitted in suitable places. Where the length of the heat exchanger or pressure vessel is over 2,5 m, sight holes shall be provided at both ends.

Manholes or sight 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 sight holes is not necessary in heat exchangers and pressure vessels whose construction excludes the possibility of inspection through such holes.

For the dimensions of manhole openings, see 3.3.11.2.

6.3.9 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.

6.3.10 On fuel heaters where the temperature of fuel may exceed 220°C the transmitter of warning signal system giving an indication of temperature rise or failure of fuel flow shall be installed in addition to temperature controller.

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 are to 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 is to 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 9.4, 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 cylinders manufactured to the current standards and fixed in ship's systems and units for storage of compressed or liquefied gases (air and carbon dioxide included) and also to refrigerant store cylinders for ship's refrigerating plants.

6.4.5.2 Where the dimensions and wall thickness of a steel cylinder are predetermined, the maximum permissible pressure p_D, in MPa, 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, to be taken in compliance with 2.1.4.6. The safety factors n_T and n_B shall be taken in compliance with 2.1.5.1 and 2.1.5.3 for rolled and cast steel cylinders accordingly;
φ = efficiency factor (see 2.1.6);
S = wall thickness, mm;
D_a = outside diameter of the cylinder, mm.
c = allowance taken in compilance with Table 2.3.1-1, Part VIII "Systems and Piping". Without corrosion $c = 0$.

In case the design pressure p for particular gas is above the maximum permissible pressure p_D, the ambient temperature shall be maintained within such limits that the gas design pressure is not in excess of p_D at this temperature.

When the ambient temperature cannot be kept below the critical value for particular gas, the design pressure shall be controlled by changing the filling ratio of gas in the cylinder assuming: $p < p_D$,

where p = design pressure, MPa, determined depending on the gas properties and filling ratio in the cylinder from the diagrams of gas state at the design temperature:
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.

6.4.5.3 Each cylinder or its valve head shall be fitted with a non-disconnectable safety device (breaking diaphragm, safety valve or fusible plug) preventing inadmissible pressure rise in case of temperature increase. Safety valves and fusible plugs shall satisfy the requirements of 6.3.3, 6.4.1.1, and 6.4.1.3.

The opening pressure of breaking diaphragms shall be $1{,}1p$ where p = 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 (see also 2.1.6.2, Part VI "Fire Protection").

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 discharge from the safety valves of air receivers the requirements of 3.1.2.7, 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.

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 15ХМ	440	225	226	221	216	216	206	196	191
Alloy steel 12Х1МФ	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 15ХМ	440	225	—	—	—	—	—	—	—	—
Alloy steel 12Х1МФ	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 12X1MΦ	440	255	—	—	—	196	186	177	167	152	137
Alloy steels 16ΓC and 09Γ2C	450	265	88	78	69	—	—	—	—	—	—
High-manganese steel 22ΓK	530	335	103	93	83	74	69	59	49	34	25

APPENDIX

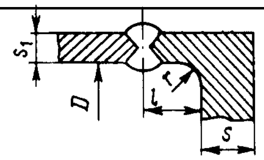
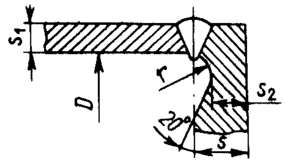
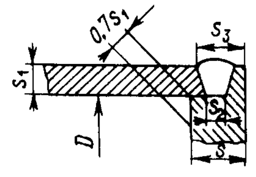
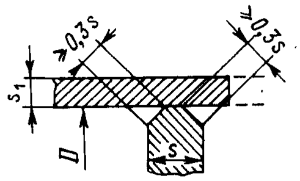
TYPICAL EXAMPLES OF ALLOWABLE WELDED JOINTS FOR BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

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.

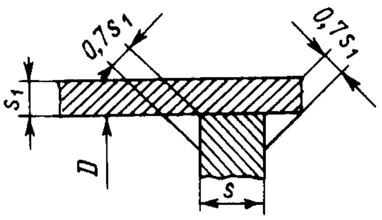
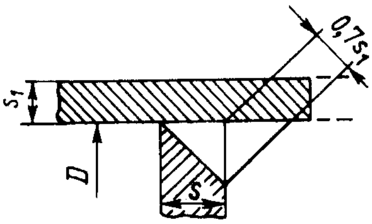
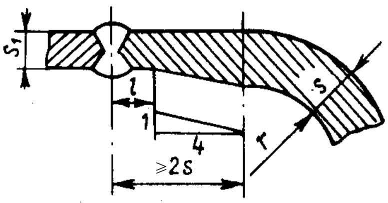
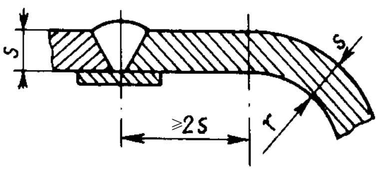
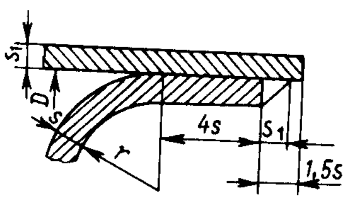
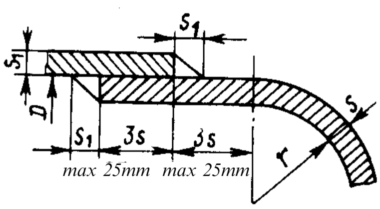
The typical examples of allowable welded joints are given in the present Appendix. Different types of welded joints shall not be considered as equivalents, and the order in which they are presented is not indicative of their strength characteristics. The types of welded joints shown for the elements 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.

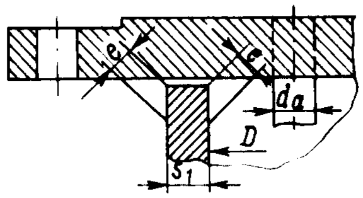
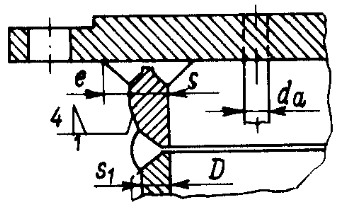
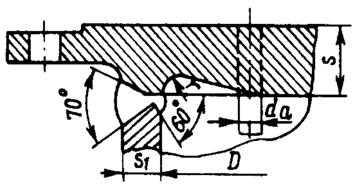
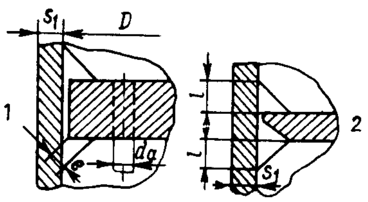
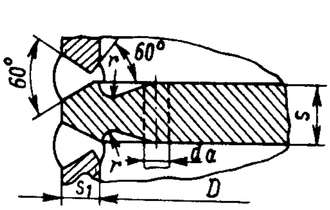
ALLOWABLE WELDED JOINTS

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. See Note 1
1.3		$k = 0{,}5$, $s_2 \leqslant s_1$, but not less than 6,5 mm, $s_3 \geqslant 1{,}25s_1$. See Note 1
1.4		$k = 0{,}45$. See Note 1

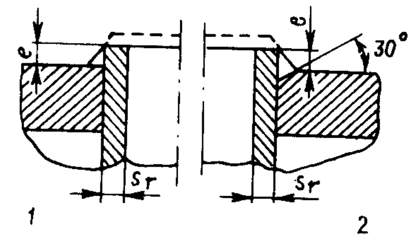
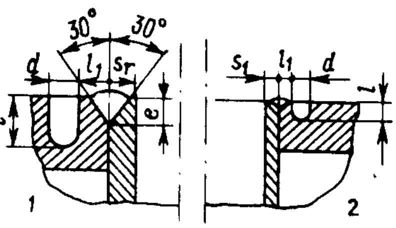
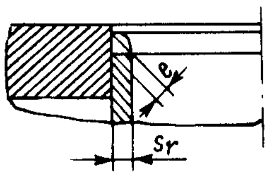
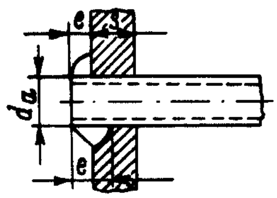
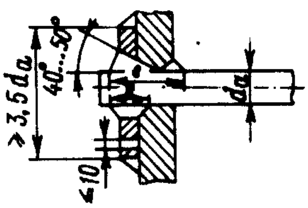
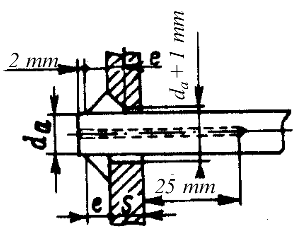
Appendix — continued

1.5		$k = 0{,}55$. See 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 See Notes 2, 17
2.2		It is permitted for boilers and pressure vessels of Classes II and III
2.3		This joint should 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

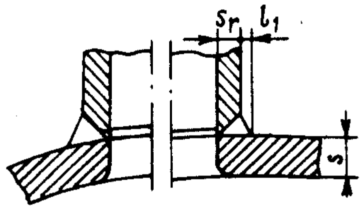
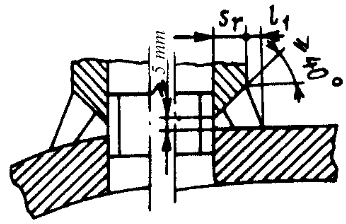
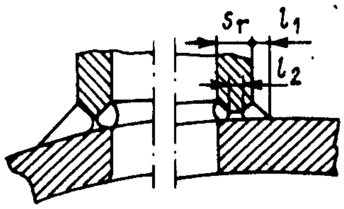
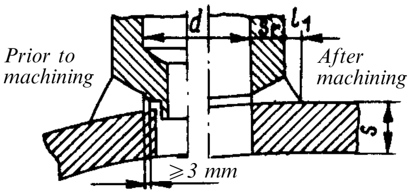
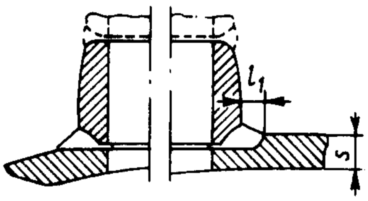
Appendix — continued

3. Tube plates		
3.1		$k=0{,}45$, $e=0{,}71s_1$, $s_1 \leqslant 16$ mm. See Notes 3, 4
3.2		$k=0{,}45$, $e=s_1/3$, but not less than 6 mm, $s_1>16$ мм. See 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. See Note 7
3.5		$k=0{,}45$, $r \geqslant 0{,}2s$, but not less than 5 mm

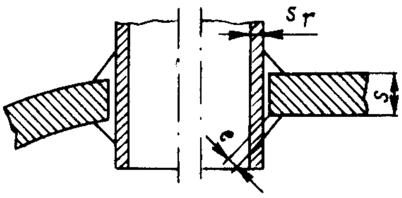
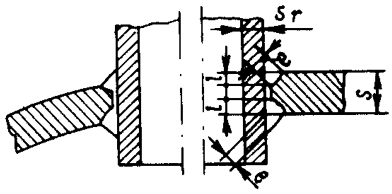
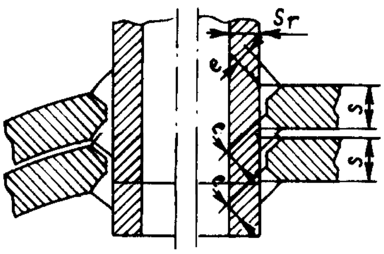
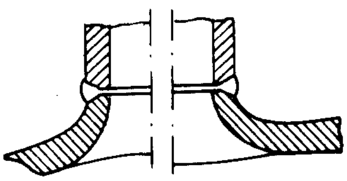
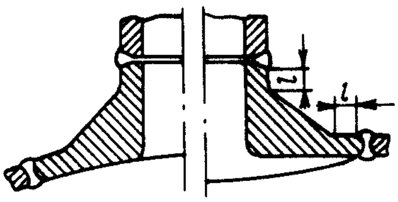
Appendix — continued

	4. Tubes	
4.1		$e = s_r$ $e \geqslant 5$ mm, $s_r \geqslant 2{,}5$ mm, See 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. See Note 11
4.3		$e = 0{,}7s_r$ $s_r \geqslant 3$ mm. See 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 (See 3.2.2)

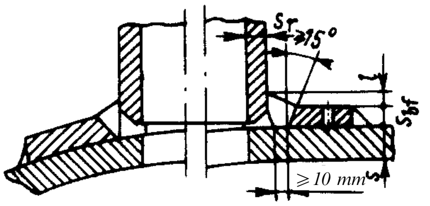
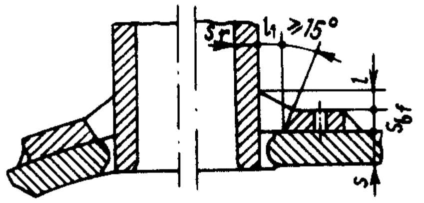
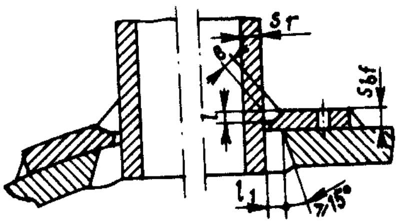
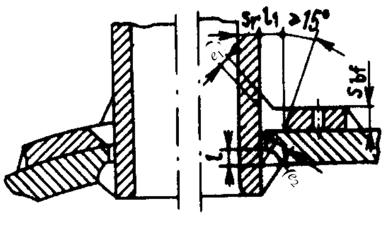
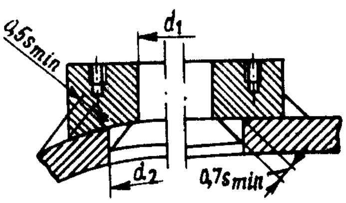
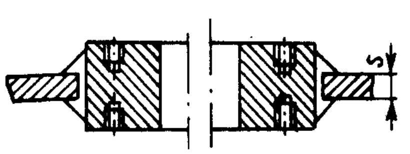
Appendix — continued

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. See Note 13
6.1.3		$l_2 = 1{,}5...2{,}5$ mm $l_1 \geqslant s_r/3$, but not less than 6 mm. See Note 14
6.1.4		$l_1 \geqslant s_r/3$, but not less than 6 mm. See Notes 15, 16
6.1.5		$l_1 = 10...13$ mm. See Note 15

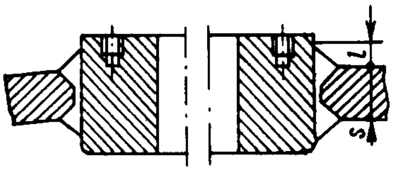
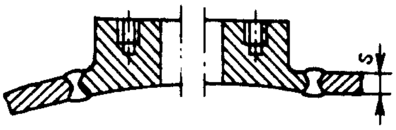
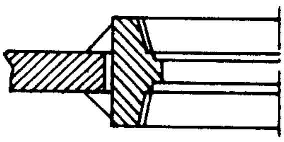
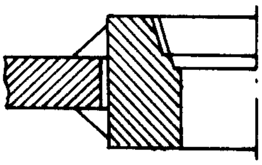
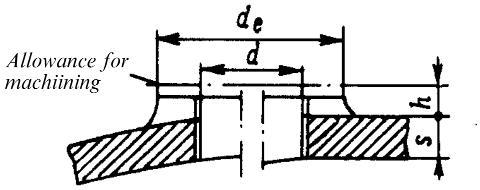
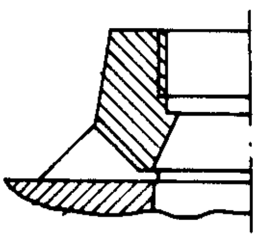
Appendix — continued

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		See Note 17

Appendix — continued

6.4 Branches with disc-shaped reinforcing plates		
6.4.1		$l \geqslant s_r/3$, but not less than 6 mm
6.4.2		$l \geqslant s_r/3$, but not less than 6 mm, $l_1 \geqslant 10$ mm
6.4.3		$e+l=s_r$ or $e+l=s_{bf}$, whichever is the less, $l_1 \geqslant 10$ mm
6.4.4		$e_2+l \geqslant s_r$, $l_1 \geqslant 10$ mm, $2s_r \leqslant (e_2+l)+$ the lesser of the values $(s_{bf}+e_1)$ or l_1
6.5 Pads and nozzles for studs		
6.5.1		$d_2 \leqslant d_1+2s_{\min}$. See Note 18
6.5.2		$s \leqslant 10$ mm. See 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, $h \leqslant 0{,}5s$. See 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 be not 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 be not 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 should be $s_r \geqslant 2{,}5$ mm.
11. It is recommended when the tube plate deformations resulting from welding should 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 present Part of the Rules applies to electrical installations in ships subject to supervision of the Register, 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 of the Rules should 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

Definitions and explanations relating to the general terminology of the Rules are given in General Regulations for the Supervision.

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 temporary 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 voltage failure on the main switchboard.

Emergency temporary source of electrical power is a source of electrical power intended to supply necessary ship's services from the moment of the voltage failure on the main switchboard busbars until the emergency diesel generator starts running.

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.

Earthing is electrical connection of a part of electrical equipment to be earthed to ship's hull.

Thunderstorm protection zone is the area within the limits of which the ship's space is protected against direct lightning strokes.

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 protective system 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 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; these services are covered by 1.3.2.1 of the present Part of the Rules.

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 sustained the tests according to the requirements of the Guidelines on Technical Supervision during Construction of Ships and Manufacture of Materials and Equipment.

Electrical installation of low power is an electrical installation of a ship with the total power of supply sources equal to 50 kW (kVA).

1.3 SCOPE OF SUPERVISION

1.3.1 General provisions.

General provisions applicable to the classification procedure, supervision during ship's construction and manufacture of the equipment and to surveys are stated in General Regulations for the Supervision and in Part I "Classification".

1.3.2 Supervision of ship's electrical equipment.

1.3.2.1 The following kinds of equipment, systems and devices are subject to supervision on board the ship:

.1 electric propulsion plant;

.2 main and emergency sources of electrical power;

.3 power and lighting transformers and converters used in equipment, systems and devices listed in 1.3.2.1;

.4 distribution gear and control and monitoring desks or panels;

.5 electric drives of auxiliaries ensuring operation on the main machinery, steering gear, CP-propellers, anchor and mooring machinery, towing winches, launching devices for lifeboats and liferafts, starting air and sound signal air compressors, bilge and ballast pumps, cargo pumps in oil tankers, pumps and compressors of fire extinguishing systems, mechanisms of watertight and fire doors, fans in machinery spaces, cofferdams, cargo holds and galleys;

.6 main lighting for spaces and locations of essential machinery and equipment, means of escape and emergency lighting;

.7 navigation and flashing lights;

.8 electric engine-room telegraphs;

.9 service telephone communication;

.10 general alarms;

.11 fire detection system and warning system indicating the release of the fire smothering medium;

.12 signalling systems of watertight and fire doors;

.13 electrical equipment in dangerous spaces and zones;

.14 cable network;

.15 hull earthing facilities in oil tankers;

.16 thunderstorm protection;

.17 electric drives of refrigerating machinery indicated in 1.1, Part XII "Refrigerating Plants";

.18 electric fuel and oil heaters;

.19 stationary electrical heating and cooking appliances;

.20 other mechanisms and devices not listed above as required by the Register.

1.3.2.2 Electrical equipment intended for domestic, living and technological application is subject to supervision on board the ship only in relation to:

.1 influence of operation of this equipment on the performance of the ship's electric generating plant;

.2 choosing of types and cross sections of cables and wires as well as means of installation of cables;

.3 resistance of insulation, earthing and means of protection.

1.3.3 Supervision during manufacture of electrical equipment.

1.3.3.1 The following kinds of electrical equipment intended for use in installations and systems listed in 1.3.2.1 are subject to supervision 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 storage 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 accessories;

.17 stationary lighting fixtures;

.18 control and monitoring devices;

.19 other mechanisms and devices not listed above as required by the Register.

1.3.3.2 The safe type electrical equipment is to be supervised (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 supervision according to 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 Guidelines on Technical Supervision during Construction of Ships and Manufacture of Materials and Equipment.

1.4 TECHNICAL DOCUMENTATION

1.4.1 General provisions applicable to the procedure of approval of technical documentation are set forth in General Regulations for the Supervision. The scope of technical documentation on electrical equipment for the entire ship to be submitted to the Register for consideration is stated in 3.1.11, Part I "Classification".

1.4.2 Before starting to supervise the manufacture of electrical equipment, the following documentation is to 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% and a temperature of +45±2°C or at a relative air humidity 80±3% and a temperature of +40±2°C, or at a relative humidity of 95± 3% and a temperature of +25±2°C.

2.1.1.3 The structural parts of electrical equipment shall be fabricated from the materials resistant to sea air or reliably protected against such effects.

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 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.

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 (see also 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 under steady conditions in

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° shall not lead to failure of the elements, devices and systems.

all cases, except as noted in 10.8.2, 14.1.3.2-14.1.3.5 at all variations from the rated supply voltage and frequency as specified in Table 2.1.3.1 (see also 3.1.2.2 and 16.8.3.3).

Table 2.1.3.1

Characteristics	Variations from rated values, %		
	for long periods, %	for short periods	
		value, %	time, s
Voltage	+6 ... −10	±20	1,5
Frequency	±5	±10	5

Note: When the consumers are fed from the accumulator battery:
long-period voltage variation within +30 to −25% for the equipment fed from the accumulator battery connected to the charging unit;
long-period voltage variation within +20 to −25% for the equipment which is not connected to the charging unit.

2.1.3.2 In ships of restricted area of navigation III 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 will be applicable to electrical equipment, radio equipment and navigational equipment of ships to ensure electromagnetic compatibility on board.

2.2.1.2 Failure-free performance of the equipment should 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.

Table 2.2.1.2.1

Class of equipment	Intensity, A/m	
	static field	variable field (50 Hz)
1	100	10
2	400	400
3	1000	1000

Installation of equipment is permitted:

class 1 — at a distance of 2 m and more from a powerful field source (busbar, group transformer);

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;

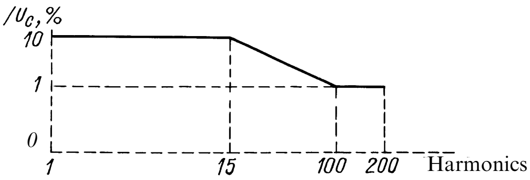


Fig. 2.2.1.2.2 Diagram of higher harmonics for ship mains

.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 — 50 MHz with a root-mean-square voltage of 1 V and 30% 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 For power supply circuit, the non-linear voltage distortion factor should not exceed 10% and is to be determined by the formula:

$$K_u = \frac{1}{U_c} \sqrt{\sum_{n=2}^{200} U_n^2} \cdot 100\%,$$

where U_c = actual circuit voltage;
U_n = n - harmonic component voltage;
n = higher harmonic.

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 (See 2.2.2.2).

2.2.1.4 The intensity level of radio interference from equipment at the electric power supply terminals is not to exceed the values shown in Fig. 2.2.1.4.

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 equip-

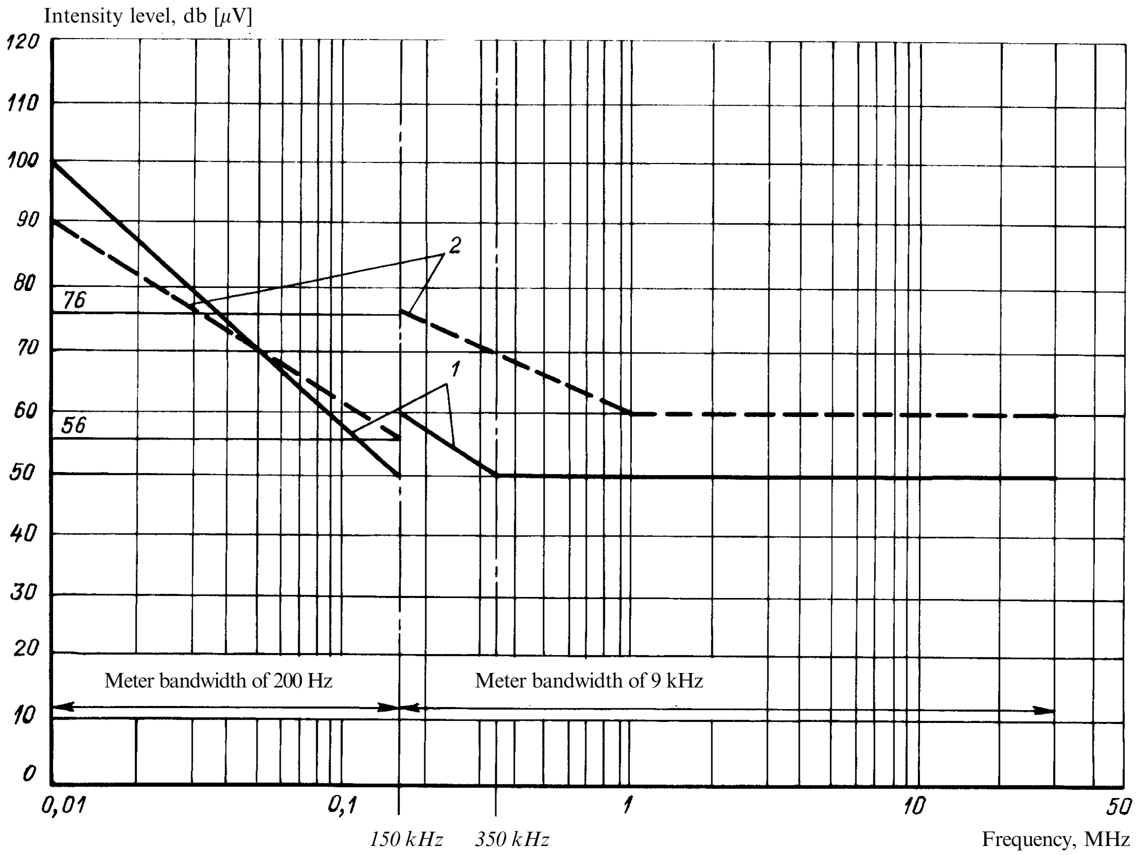


Fig. 2.2.1.4 Permissible levels of radio interference intensity:

1 — from navigational and radio equipment as well as from electrical and automation equipment installed on the wheelhouse deck and higher;
2 — from equipment installed below the wheelhouse deck

ment should 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 should 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 (See 2.2.2.8).

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 Rules for the Equipment of Sea-Going Ships should be considered.

2.2.2.2 For the purpose of dividing the supply system of the ship, rotary converters, special transformers and filters should be used.

2.2.2.3 Power cable screens or metal armour should be connected to the metal casing of relevant equipment and should be earthed as frequently as possible, at each end as a minimum.

2.2.2.4 The screens of signal cables should be earthed at one point on the side of the initial signal processing block. The cable is to have an external insulating sheath.

2.2.2.5 Continuous screening should be ensured, and for this purpose cable screens should be connected to equipment casings, and it should 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 should have an electric resistance not greater than 0,02 ohm, minimum length possible, should be resistant to vibration and corrosion, and should be readily accessible for inspection.

2.2.2.7 Cable screens should not be used as return conductors.

2.2.2.8 By the type of signals conveyed, ship cables are subdivided as follows:

.1 coaxial cables of radio receivers and conveying video signals with the level of signals 0,1 μV — 500 μV;

.2 screened or coaxial cables conveying analogue or digital signals with a level 0,1 — 115 V;

.3 screened cables of telephone and radio broadcasting apparatus with the level of signals 0,1 — 115 V;

.4 unscreened and located below the deck or screened and located above the deck cables of power, lighting, control and signalling network with the level of signals 10 — 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 — 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 should be laid at least 0,1 m apart and their intersections are to be effected at right angles. The radar installation and echo sounder cables mentioned in 2.2.2.8.5 should either be double-screened or, if they are coaxial, laid inside a metal pipe. The outer screen should 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 Rules for the Equipment of Sea-Going Ships should be considered.

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 are to be shielded or otherwise protected from radio interference, and all the equipment on board those ships is to be fitted with devices for radio interference suppression (See 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.

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 are to 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, see 16.3.

2.4 STRUCTURAL REQUIREMENTS AND PROTECTION OF ELECTRICAL EQUIPMENT

2.4.1 General requirements.

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.) should 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 should 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 are to 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 are not to 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 is to be made of electrical equipment in appropriate protective enclosure, or other suitable measures are to 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 protection of electrical equipment installed in ship's spaces and zones should 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) should have a reliable electric contact with a component fitted with an earth terminal (see also 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 housings of specially insulated bearings;

.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 insulating transformer.

2.5.1.3 The shields and metal armour of cables should be earthed.

2.5.1.4 The secondary windings of all instrument transformers for current and voltage are to be earthed.

2.5.2 Earthing of aluminium structures in steel ships.

Superstructures of aluminium alloys fastened to the ship's steel hull but insulated therefrom, are to be earthed with at least two special wires, each having a cross-sectional area not less than 16 mm^2, that will not start electrolytic corrosion at the points of their contact with the superstructure and the hull. Such earthing connections are to be provided at different locations around superstructure perimeter, 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 are to 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 are not to be used for other purposes.

The bolts screwed into material (without nuts) are to be manufactured of brass or other corrosion-resistant material.

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* (See .2.9, 19.2.4)	–	*Ex* (See.2.9, 19.2.4)	–	*Ex,* (See.2.9, 19.2.4)
Dry spaces, dry accommodation spaces		1P20	1P20	1P20	1P20	1P20
Navigating bridge, radio room		1P22	1P22	1P22	1P22	1P22
Service spaces, steering gear rooms, refrigerating plant rooms (except for ammonia equipment), emergency diesel generator rooms, general purpose stores. Pantries, provision stores		1P22	1P22	1P22	1P22	1P22
Engine and boiler rooms	Above plating	1P22	1P22	1P44	1P22	1P22
	Below plating	1P44	–	1P44	1P44	1P44
	Control stations (dry)	1P22	1P22	1P22	1P22	1P22
	Enclosed separator rooms	1P44	1P44	1P44	1P44	1P44
Refrigerated spaces, galleys, laundries, bathrooms and showers		1P44	1P44	1P55	1P44	1P44
Catch processing spaces[1], shafting tunnels, cargo holds		1P55	1P55	1P55	1P55	1P55
Open decks		1P56	1P56	1P56	1P56	1P56

[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.

Note: 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.

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 is to 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 is to 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 is to be not 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 is to 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 be not 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 should 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 are to be accessible for inspection and protected against getting loose and mechanical damage.

2.6 THUNDERSTORM PROTECTION

2.6.1 General requirements.

2.6.1.1 In ships provision shall be made for lightning conductors covering the zone to be protected.

In ships, where consequential effects of lightning strokes may cause a fire or explosion, thunderstorm protection earthing devices shall also be fitted to preclude consequential sparking.

2.6.1.2 A lightning conductor shall consist of an air termination, down conductor and earth termination. On metal masts, no lightning conductor 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 thunderstorm protection.

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	

2.6.2.2 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 topmast of non-conducting material an effectively earthed lightning conductor shall be fitted.

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.

2.6.3.2 Down conductors shall run on the outer side of masts and superstructures with a minimum number of bends which should 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 protective system 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 earth termination network 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 1.2.8.

2.6.5 Connections in lightning conductor.

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 be not 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 Thunderstorm protection earthing devices.

2.6.6.1 Thunderstorm protection earthing is to be provided for isolated metal structures, flexible connections, pipes, screens of power and communication 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 is to 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 are to 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 is to 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 is to be so designed as to ensure its normal operation under these conditions or to mounted on relevant shock absorbers.

2.7.5 Electrical equipment is to 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 are not to 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 should be taken, if necessary, to prevent electrolytic corrosion.

2.8 SPECIAL ELECTRICAL SPACES

2.8.1 The doors of special electrical spaces are to be locked. These doors are to 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 is to be placed on the door. From the inside of the space the door is to open without a key.

2.8.2 Special electrical spaces are not to 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 are to 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 this paragraph are applicable to all ships in whose 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 and combination carriers are specified in 19.2, and the requirements for installation of electrical equipment in ships with holds and other spaces containing motor vehicles with fuel in their tanks, tank-wagons and tank-cars with flammable liquids are specified in 19.3.

2.9.2 In dangerous spaces and zones, the equipment is subject to technical supervision (from the point of view of its safety) of specialized authorities whose documentation is recognized by the Register irrespective of whether such equipment is subject to supervision proceeding from 1.3.3.1 or not.

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.

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 should 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 holds intended for carriage of flammable cargoes in containers no electrical equipment or cables shall be installed. If provision of electrical equipment is necessary, it shall be of the following safe types: intrinsically safe (*Exi*), pressurised enclosure (*Exp*), flameproof (*Exd*), increased safety (*Exe*).

It is permitted to install electrical equipment of non-safe type in case it may be completely isolated from the ship's mains by means of removal of special disconnectors.

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.

The through runs of cables may be permitted in the above spaces and zones provided the requirements of 2.9.11 to 2.9.16 are met.

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.

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 is to 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 are to 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 whose 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.

3 MAIN ELECTRICAL POWER SOURCE

3.1 COMPOSITION AND CAPACITY OF MAIN ELECTRICAL POWER SOURCE

3.1.1 In every ship, a main electrical power source should be provided with a capacity sufficient to supply all the electrical equipment on board necessary under conditions specified in 3.1.4. Such a source should 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 transducers of which the main electrical power source is composed should be such that if any of them failed the rest would ensure:

.1 supply to electrical equipment necessary under conditions specified in 3.1.4 with normal habitable conditions on board guaranteed;

.2 maintenance or immediate restoration of power supply to the equipment essential for propulsion and steering and to ensure safety of the ship;

.3 start of the most powerful electric motor with the greatest starting current. The motor start should 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;

.4 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 — 19.1.2.3 (see also 2.1.6, Part VII "Machinery Installations").

3.1.3 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.

3.1.4 The number and power output of generators forming the main source of electrical power are to 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.

3.1.5 Where accumulator batteries are the main source of electrical power, their capacity should be sufficient to satisfy the requirements of 3.1.2.1 for 8 hours without recharging.

3.1.6 In ships of restricted area of navigation III (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 requirements.

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 this 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 with independent prime movers should be regulable within the range set down by 10.6 and 10.7, and their frequency should be regulable within the range specified in 2.11.3, Part IX "Machinery".

3.2.1.5 For alternators, the deviation from sine voltage should be not more than 5% of the first-harmonic peak value.

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 should be within the limits specified in 2.11.3, Part IX "Machinery".

3.2.3 Shaft generator sets.

3.2.3.1 Shaft generators used for feeding the ship's mains shall be equipped with devices for regulation of voltage within the limits specified in 10.6 and 10.7 and for regulation of frequency within the limits specified in 2.11.3, Part IX "Machinery".

In case the network frequency is below the permissible value, automatic connection of one or more independently driven generators to the ship mains should be provided, or an alarm should be activated in the engine room or at the main control station.

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 3.2.3.1.

3.2.3.3 Shaft generators and semiconductor transducers (inverters) supplying the ship mains should not be damaged by short circuits at the main distribution board busbars. In this case, a steady short-circuit current should be ensured, sufficient for protection to be activated.

3.2.3.4 As a minimal requirement, shaft generators should 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 should 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 should 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 should 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 to 10.7 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 Waste-recovery turbogenerators used for ship's mains supply should be fitted up with devices to keep the voltage within the limits prescribed by 10.6 and 10.7 and the frequency within the limits prescribed by 2.11.3, Part IX "Machinery".

3.2.4.2 Exhaust-heat turbogenerators supplying particular consumers may, if approved by the Register, have performance characteristics different from those stated under 3.2.4.1.

3.2.4.3 The exhaust-heat turbogenerators mentioned under 3.2.4.1 should be designed for parallel operation with generators having an independent prime mover. In this case, the distribution of load between the generator sets should 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 are to 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 II, IIСП and IIIСП, with the electrical installation of low power as well as in ships of restricted area of navigation III, 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 is to be installed in the ship (see also 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 should be connected to the main switchboard directly.

3.4.2 At the external supply switchboard, the following facilities should be provided:

.1 terminals for flexible cable connections;

.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 are both to 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 is to be installed in the main switchboard.

Where synchronizing is arranged to operate automatically, a standby manual synchronizer is to 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 is to be subdivided into at least two parts which are normally to be connected by circuit breakers or other approved means (e.g. circuit breaker without release or disconnector).

So far as it is practicable, the connection of generating sets and other duplicated equipment is to 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 1000V:

.1.1 three-phase three-wire insulated system;

.2 additionally for current up to and including 500V:

.2.1 three-phase four-wire insulated system;

.2.2 single-phase two-wire insulated system;

.2.3 single-phase single-wire system with hull return for voltage up to 50V (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 50V (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 (see 4.6.4.7).

The use of other distribution systems is subject to special consideration by the Register in each case (see also 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 is to be found under 4.1. Additonal requirements for apparatus designed for a voltage in excess of 1000 V are to be found in Section 18.

4.2.2 Permissible voltage across the terminals of sources of electrical power and direct current sources should 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 should not exceed the values specified in Table 4.2.3.

4.2.4 Permissible voltage across the terminals of direct-current consumers should not exceed the values specified in Table 4.2.4.

4.3 POWER SUPPLY OF ESSENTIAL SERVICES

4.3.1 The following consumers shall be supplied by separate feeders from the main switchboard busbars:

.1 steering gear electric drives (see also 5.5.2);

.2 anchor gear electric drives (see also 4.3.3);

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 (see 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 rein-forced insulation and not isolated electrically	50

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 should 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.

.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 consumers combined on the principle of uniformity of their functions;

.14 switchboards of integrated bridge control console (see also 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 consumers not listed above as required by the Register.

It is permitted to supply consumers indicated in 4.3.1.4, 4.3.1.6, 4.3.1.10 — 4.3.1.12, 4.3.1.15, 4.3.1.16, 4.3.1.18 — 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 consumers.

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 II, IIСП, IIIСП and III, and in particular cases in ships of unrestricted service and ships of restricted area of navigation I, 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 are to 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 is to satisfy the requirements of Part XV "Automation".

4.4.2 Power supply of automation devices necessary for starting and operating the emergency diesel generator is to 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 (see 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 inter- locking.

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 (see 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 should 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 are to be located in spaces where the conditions are such that no vertically falling drops of liquid can get into the switchboard (see also 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 are not to 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 be not 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 be not 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 should 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 operating 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 be not 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 operating 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 should 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 should 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 should 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 should 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 should 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 are to be placed in locations where the possible concentration of gases, water vapours, dust and acid evaporations is eliminated.

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

4.6.6.2 If the switchboard having protective enclosure of IP10 type and below is located in a special space, cabinet or recess, then such spaces are to be made of non-combustible material or to have a lining of such material.

4.6.6.3 Arrangement of pipelines and tanks near the switchboards is to conform to the requirements of 5.5, Part VIII "Systems and Piping".

4.6.6.4 The navigation lights switchboard is to be located in the wheelhouse where it is readily accessible and visible to the personnel on watch.

4.6.6.5 The main switchboard shall be positioned in the same space (in the same main vertical fire zone for passenger ships) as generating sets. 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.

4.6.7 Access to switchboards.

4.6.7.1 In front of the switchboard, a passageway is to be provided not less than 800 mm wide for switchboards up to 3 m long, and not less than 1000 mm wide for switchboards over 3 m long.

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 is to be not less than 1000 mm wide.

4.6.7.3 The space behind the free standing switchboards with open live parts is to 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 should 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 REQUIREMENTS

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 should 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 should 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 is to 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 are to 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 is to 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 whose electric motors or switchgear require additional ventilation in normal operation is to be possible only with ventilation in action.

5.3 SAFETY ISOLATION DEVICES

5.3.1 Control systems of mechanisms whose operation under certain conditions may endanger human or ships safety are to 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 are to 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 is to 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 is to 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 are to be taken into consideration.

5.4.5 For each electric motor rated at 0,5 kW and more and its control gear, provision is to 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 is to 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 should 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 (see also 16.8.4.13).

When the collecting busbars in the main switchboard are subdivided, each feeder shall be supplied from different sections (see also 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 is to 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 are to be designed for operation under the most severe loads, and the change-over arrangement is to 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 2.9.7, 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 should 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 (see also 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 should 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, are to be effected from the steering room and from the wheelhouse.

5.5.10 The starting devices are to 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 is to agree with the direction of putting the rudder over.

In the push-button control system, the push-buttons are to 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 should 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 is to be made for overload protection of the electric motor.

5.6.4 The supply of electric drives of anchor capstans should 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 are to 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 are to 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 (see 7.1.4, Part VIII "Systems and Piping") are to be provided with remote starting devices located above the bulkhead deck.

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.

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 are to be provided with remote cut-off arrangements located in the vicinity of discharge manifolds, provided no telephone 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 are to be provided with at least two disconnecting switches, one of which is to 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 are to 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 should 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.

5.9 ELECTRIC DRIVES OF BOAT WINCHES

5.9.1 The electric drives of boat winches are to comply with the requirements of 6.20, Part II "Life-Saving Appliances" of Rules for the Equipment of Sea-Going Ships.

5.9.2 The winch electric drive controls are to be provided with self-return to the "stop" position.

5.9.3 A switch in power circuit of the electric motor is to 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 are to 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 is to 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 (see 2.1.3.4, Part VI "Fire Protection") should:

.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.

6 LIGHTING

6.1 GENERAL REQUIREMENTS

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 are to 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 are to be provided with protection gratings.

6.1.3 Lighting fixtures are to 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 are to 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 are to be illuminated with lighting fixtures located in adjacent safe spaces through gastight windows, or with safe-type lighting fixtures located inside the compartment (see also 2.9).

6.2 POWER SUPPLY OF MAIN LIGHTING ELECTRIC CIRCUITS

6.2.1 The switchboards of the main lighting are to 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 16A, 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 is to 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 are to be supplied from different distribution boards which, in case of application of the lighting subdivided busbars in the main switchboard, are to 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 are to 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 is to be supplied by two feeders supplying the lighting circuits in other fire zones.

The lighting feeders are to 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 accommodating 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 are to take power supply from a special switchboard. Apart from the switchgear and protective devices, this switchboard is to 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 (see 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 is to be sufficient to easily find one's way to the means of escape (or is to 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 are to 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 is to 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 are to be located outside these spaces.

6.4.4 The lighting switches behind free-standing switchboards are to 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 are to 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 are to 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 are to 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 are to be mounted with their face looking downward.

6.6.4 Socket outlets should 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 is not to be below that specified in Table 6.7. 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 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.

Table 6.7

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 NAVIGATION LIGHTS

6.8.1 The navigation lights switchboard is to 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 is to supply also permanently mounted lights listed in Table 2.4.1, Part III "Signal Means" of 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.

6.8.2 The navigation lights switchboard is to 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 are to be connected to the fixed supply circuit by a flexible cable with a plug connector.

6.8.4 The supply circuits of navigation lights are to 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 is to 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 Rules for the Equipment of Sea-Going Ships.

The indication device of the navigation light switching is to 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 should not exceed 5 per cent at rated vol-tage 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 is to 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 are to 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 are to comply with the requirements of 3.1.7, Part III "Signal Means" of Rules for the Equipment of Sea-Going Ships.

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 are to meet the requirements of 3.3.1, Part VII "Machinery Installations".

7.1.2 Engine room telegraphs are to 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 are to be provided with an illuminated dial of regulated illumination.

7.1.4 Engine room telegraphs are to 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 is to 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 is to 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 should 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 are to 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 is to 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 is not to stop (see also 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 should 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 (see also 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 should 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.

7.2.5 A damage to or disconnection of one telephone set is not to 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 13.1, Part IV "Radio Equipment" of Rules for the Equipment of Sea-Going Ships.

7.3 GENERAL ALARM SYSTEM

7.3.1 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, are to be fitted with electrical general alarm system that will ensure good audibility of signals in all such places.

7.3.2 Sound devices are to 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.

7.3.3 General alarm system should be supplied from the ship mains or 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 source of electrical power is necessary.

7.3.4 The general alarm system is to be energized continuously, no matter if the accumulator battery is set in position for charging or discharging.

7.3.5 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.

7.3.6 In circuits supplying the general alarm system the protection only from short circuit is to be provided. Protective devices are to 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.

7.3.7 General alarm sound devices are to 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 are to be fitted with luminous indicators.

The sound of general alarm devices is to differ in tone from the sounds of all other kinds of signalling. With the exception of bells, audible alarms should have a signal frequency between 200 Hz and 2500 Hz. Facilities may be provided for regulating the audible signal frequency within the above limits.

7.3.8 The general alarm system is to 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 is to 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.

7.3.9 No switching devices are to be incorporated into the circuits of the general alarm system other than the switch specified in 7.3.8. Where a power supply switch is installed on the general alarm system switchboard, provision is to be made for its interlocking in the "on" position or it is to 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 section.

7.3.10 Sound devices, switches and distribution devices of the general alarm system are to be provided with readily visible distinctive symbols.

7.3.11 It is necessary that the supply circuit of general alarm sound devices should consist of at least two sections controlled by one switch, and sound devices should be so positioned that in spaces of large area (machinery spaces, boiler rooms, fish- processing shops and other special spaces) they are connected to different sections.

7.4 FIRE DETECTION SYSTEM

7.4.1 Besides this Chapter, fire detection systems should comply with Section 4, Part VI "Fire Protection".

7.4.2 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.

7.4.3 For the fire detection system, at least two sources of electrical power should be provided. One of these sources should be the emergency source of electrical power. The power should be supplied by separate feeders intended solely for this purpose. In case of failure of the main source of electrical power, provision should be made for an automatic change-over of supply to the emergency source with operation of a sound and visual signal.

Where an accumulator battery is the main source of power supply, two independent accumulator batteries (main and reserve) should be provided, the capacity of either being sufficient for operation of the fire detection system for at least 3 days without recharging.

7.4.4 The fire detection system operating on the principle of sampling the air coming from the protected spaces into the indicating unit and the fans of this system are to be fed by separate feeders from the main and emergency sources or another independent source of electrical power.

7.4.5 Indicating units of the fire detection system, other than the those indicated in 7.4.4, 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 is to 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.

7.4.6 Indicating units of the fire detection system shall produce information specified in Table 7.4.6.

A visual signal of fire detection should be executed in such a manner that is consists of two indicators (two lamps or a double filament), or a special device is to be provided to check the proper condition of signalling lamps. The colour of a light signal is to comply with the requirements of 4.6.5.

Visual signals are to 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 are to 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 7.4.6 is to function continuously irrespective of the nature of supply.

7.4.7 If the fire detection alarm in the indicating unit has not received attention within 2 min in the machinery, accommodation and other spaces where members of the crew may be present, automatic fire alarms shall operate.

7.4.8 Fire detection systems with a zone address identification capability should be so arranged that:

.1 a loop cannot be damaged at more than one point by a fire;

.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;

.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 WARNING ALARM OF SMOTHERING SYSTEM RELEASE

7.5.1 The warning alarm system is to comply with the requirements of 4.3, Part VI "Fire Protection".

7.5.2 The warning alarm system is to be energized from the ship's mains and an accumulator battery having a capacity sufficient for feeding the system during 30 min.

Provision is to 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.

7.6 INDICATION OF CLOSURE OF WATERTIGHT AND FIRE DOORS

7.6.1 Indication of closure of watertight doors is to comply with the requirements of 7.1.9, 7.1.11, 7.1.13, 7.4.1.7, 7.12.4 — 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".

7.7 SOUND SIGNALS IN ENGINEERS' ACCOMMODATION SPACES

7.7.1 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.

Table 7.4.6

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	Discontinuity in detector circuits	Visual Audible	—
7	Location of faults in detector circuit	Visual	—
8	Open position of detector line[1]	Visual	—
9	Power supply failure	Visual Audible	Visual Audible

[1] Recommended.

8 PROTECTIVE DEVICES

8.1 GENERAL REQUIREMENTS

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 is to 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.

8.2 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 recommended that the devices used for generator overload protection should 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 should 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 recommended that for a setting of the protection to operate at 150 per cent of the rated generator current the time delay should 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.

This requirement may be dispensed with in the case of electrical installations of low power if approved by the Register.

8.2.4 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. Reverse-current protection for direct-current generators shall be

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 Direct	2-6% of rated output of generator, kW 2-15% of rated current of generator, A	8-15% of rated output of generator, kW 2-15% of rated current of generator, A

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 should 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 should exclude the possibility of generator-to-busbar connection at a voltage less than 35 per cent of rated voltage. Besides, it should disconnect the gene-rators 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 should 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.

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 conditions 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 abovementioned 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.

8.5 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 should 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 should 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 should 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 pro-tection of which is rated for current not exceeding 25 A.

8.8 PROTECTION OF POWER SEMICONDUCTOR UNITS

8.8.1 Provision should be made for protecting power semiconductor units from internal and external overvoltage.

8.8.2 Semiconductor element units should be protected against short-circuit. The overload protection of diodes and thyristors should 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 thyristor units, and power circuits.

9 EMERGENCY ELECTRICAL INSTALLATIONS

9.1 GENERAL REQUIREMENTS

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 diesel 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 should 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 is to be sufficient to restore propulsion to the ship (in conjunction with other machinery, as appropriate) from a dead ship condition within 30 minutes 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 diesel 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 of emergency distribution board and distribution board of emergency lighting should be located above the uppermost continuous deck outside machinery casings and behind the collision bulkhead. The abovementioned spaces in ships covered by the requirements of Part V "Subdivision" should be also located, as a minimum, at a height of 300 mm above the deepest (damage) waterline.

The exits from the spaces should be easily accessible and should 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, is to 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 should 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 should be as close as possible to the emergency source of electrical power.

9.2.5 Where a diesel generator serves as the emergency source of electrical power, the emergency distribution board should 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 should also be installed in this space provided the requirements of 13.2 are complied with.

9.2.6 The emergency 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 7.5.3, 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 of 300 gross tonnage and upwards of unrestricted service and restricted area of navigation I the emergency sources of electrical power shall supply the services listed below for a period of 18 hrs:

.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;

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 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 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 summoning 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 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.

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 restricted areas of navigation II, IIСП, IIIСП and III with a 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 I and to 3 hours in the case of restricted areas of navigation II, IIСП, IIIСП and III.

9.3.2 The emergency source of electrical power is to 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 Rules for the Equipment of Sea-Going Ships.

9.3.3 The supply of steering gear should 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 should be:

.1 driven by an internal combustion engine (see 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 should be automatically supplied by the emergency generator. The total time of starting and load take-over by the generator should not exceed 45 s;

.3 in case the automatic start of emergency unit stipulated by 9.3.4.2 is not to take place within 45 s, an emergency transitional source of electrical power should be provided which should 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 should:

.1 operate without recharging with voltage variations across the terminals within 12 per cent of rated voltage during the whole discharge period;

.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.

9.3.6 As transitional emergency source of electrical power stipulated by 9.3.4.3, an accumulator battery should be used which is to operate without recharging with voltage variations across the terminals within 12 per cent of rated voltage during the whole discharge period.

9.3.7 The capacity of the battery serving as the transitional source of electrical power should 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 13 of Table 2.3.4, Part IV "Radio Equipment" of Rules for the Equipment of Sea-Going Ships;

.6 closing gear of watertight doors, their position indicators and signals warning of their closure.

Services listed under 9.3.7.2 — 9.3.7.6 may not be supplied from the intermediate source if they have their own accumulator batteries by which they are supplied during the required period of time;

9.4 DISTRIBUTION OF ELECTRICAL POWER FROM EMERGENCY SOURCES

9.4.1 Under normal service conditions, emergency distribution board should be supplied from the main distribution board. The supply feeder should have an overload and short-circuit protection fitted at the main distribution board.

At the emergency distribution board, a switch should be provided which is to switch off automatically in the case of de-energizing the busbars of the main distribution board.

Where the main distribution board is to be supplied from the emergency distribution board, the automatic switch at the emergency distribution board should be provided with short-circuit protection at least.

9.4.2 If the emergency diesel generator is to supply, in particular cases for short periods of time, non-emergency consumers as well:

relevant measures should be taken to ensure emergency arrangements operation under any emergency conditions;

provision should be made, wherever necessary, for automatic disconnection of non-emergency consumers from the emergency distribution board to ensure the supply of emergency consumers.

9.4.3 Consumers listed under 9.3.1 and 19.1.2 should 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 should be supplied through a special distribution board on the feeders of which no switches are to be fitted.

9.4.5 The switchboards for emergency services should 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 should 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 should 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.

10 ELECTRICAL MACHINES

10.1 GENERAL REQUIREMENTS

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-wond 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 is not to 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.

10.2 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 is to 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 should 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 are to 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 should 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.

10.6 ALTERNATING-CURRENT GENERATORS

10.6.1 General requirements.

10.6.1.1 Each alternating-current generator shall have a separate, independent automatic voltage regulation system.

10.6.1.2 Failure in the automatic voltage regulation system of the generator shall not cause inadmissible rise of voltage at its terminals.

10.6.1.3 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.

10.6.1.4 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. Following such a change, the generator voltage is to be restored within not more than 1,5 s to ± 3 per cent of the rated value. 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".

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

10.7 DIRECT-CURRENT GENERATORS

10.7.1 General.

10.7.1.1 Shunt-wound direct-current generators shall be equipped with automatic voltage regulators.

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 genrators 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 is to 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 are to 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 (see also 5.4.3).

11 TRANSFORMERS

11.1 GENERAL PROVISIONS

11.1.1 The requirements of this Section apply to power and lighting transformers listed in 3.3.

For additional requirements for transformers with voltages over 1000 V, see 18.8.

11.2 GENERAL REQUIREMENTS

11.2.1 Dry-type transformers shall be used in ships.

The use of other type transformers is subject to special consideration by the Register.

11.2.2 Transformers shall have electrically separated windings for primary and secondary voltages.

11.3 OVERLOAD, VOLTAGE VARIATION AND OPERATION IN PARALLEL

11.3.1 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.

11.3.2 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.

11.3.3 Transformers intended to operate in parallel must have their winding connections grouped together, their transformation ratios should be the same, and their short circuit voltages are to 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.

11.3.4 Nominal capacities of transformers for parallel work shall not differ from each other more than twice.

12 POWER SEMICONDUCTOR UNITS

12.1 GENERAL REQUIREMENTS

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 if cooling is disconnected.

The activation of protection is to 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 nonlinear distortion factor K_u for the ship's 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.

The nonlinear distortion factor K_u 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 value shall not exceed 30 per cent.

Factor U_w shall be determined by the formula:

$$\Delta U_w = \frac{\Delta U_m}{\sqrt{2} U_1}, \quad (12.2.2)$$

where U_m = maximum deviation value,
U_1 = effective value of the first harmonic of the voltage.

12.3 CONTROL AND SIGNALLING SYSTEMS

12.3.1 Semiconductor arrangements should be provided with light signals for connection or disconnection of power circuits and control circuits.

12.3.2 The power section of semiconductor arrangements should be electrically insulated from the control system.

12.3.3 The long-term current deviation in the parallel branches of semiconductor arrangements should not exceed 10 per cent of average current value.

12.3.4 The operation of semiconductor arrangements should not be hampered by the failure of particular gates. Where the load upon particular gates exceeds permissible values, it should be reduced automatically.

When a gate fails, light and sound signals should be activated.

12.4 MEASURING INSTRUMENTS

12.4.1 Semiconductor arrangements should 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 should be marked off. Where forced cooling is applied, the maximum permissible temperature should be marked off clearly in the scale of the instrument for measuring the cooling air temperature.

13 ACCUMULATOR BATTERIES

13.1 GENERAL REQUIREMENTS

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.

13.2 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, are to be located in special battery compartments accessible from the deck, or in appropriate boxes installed on deck. These spaces are to 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 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 are not to be placed in one compartment or in one box. The vessels and instruments intended for the batteries with different electrolytes are to 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 are to be suitably protected.

13.2.4 Accumulator batteries and individual cells are to be properly fixed in position. In case they are installed on shelves in two or more rows, all the shelves must 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 is to 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 are to 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 are to 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 are to be located outside the battery compartments.

13.3.3 The shipboard air conditioning system is not to be used for heating the battery compartments.

13.4 VENTILATION

13.4.1 The battery compartments and boxes are to have sufficient ventilation that will prevent accumulation of explosive air-gas mixture.

The ventilation system is to meet the requirements of 12.10, Part VIII "Systems and Piping".

13.4.2 The battery compartments equipped with mechanical ventilation are to be provided with devices that will prevent charging of accumulator batteries before ventilation has been switched on.

Charging cycle is to be automatically discontinued, should the ventilators stop.

13.5 CHARGING OF ACCUMULATOR BATTERIES

13.5.1 Provision is to 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 are to 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 is to 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 are to 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 is to 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.

13.7.1.2 For ships of restricted area of navigation III and also for ships of restricted area of navigation II 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 is to 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 is to 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.

13.7.2.3 In computing battery capacity, the duration of each start is to be considered not less than 5 s.

13.7.3 Charging facilities.

13.7.3.1 A starter battery charging facility is to 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 III and also for ships of restricted area of navigation II 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 requirements.

14.1.1.1 The design of switchgear with renewable contacts shall be such that renewal of contacts should 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 are to 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 requirements.

14.2.1.1 The enclosures of accessories and fittings shall be constructed from materials of adequate mechani-cal 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 refrige-rated 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 is to 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 should 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 is to 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 should be fitted.

15 ELECTRICAL COOKING AND HEATING APPLIANCES

15.1 GENERAL REQUIREMENTS

15.1.1 Only stationary-type electrical cooking appliances are permitted for use.

15.1.2 Electrical cooking appliances should 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 should 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 are to 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 The heating appliances are to be installed in accordance with the requirements of 2.1.14, Part VI "Fire Protection".

15.2.3 If built-in disconnecting devices are not provided in the heating and cooking appliances, such devices are to be installed in the rooms wherein these appliances are located.

Switches shall disconnect power supply at all poles or phases.

15.2.4 The enclosures of electric heating appliances shall be so constructed as to prevent the possibility of any objects being placed upon them.

15.2.5 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.

15.2.6 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.

15.3 OIL AND FUEL HEATERS

15.3.1 Oil and fuel having a flash point above 60°C may be heated by means of electric heaters provided the requirements of 15.3.2 and 15.3.3 are fulfilled.

15.3.2 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.

15.3.3 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.

15.3.4 Oil and fuel heaters should be fitted up with devices for temperature control of the medium heated. Irrespective of those devices, a manually disengaged device should be provided for de-energizing the heaters as soon as their surface temperature reaches 220°C.

16 CABLES AND WIRES

16.1 GENERAL REQUIREMENTS

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 (see also 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 tightened, 1:1,8.

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 cables and wires, insulating materials specified in Table 16.3.1 may be used.

Application of other insulating materials is subject to special consideration by the Register in each case.

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.

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.

Application of alternative sheathing materials is subject to special consideration by the Register in each case.

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

16.4.2 Sheathing should be of uniform thickness within allowable limits, throughout the manufacturing length of cable, and are to envelope the cable cores concentrically. The sheaths are to 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 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 is to be made of tinned copper wire. If plain copper wire is used, it is to be protected by suitable sheath. Non-shielding braids may be made of galvanized steel wires. The braid is to be uniform and its density is to 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 is to 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 is to be effectively protected against corrosion.

16.5.4 Armour bedding is to 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 should 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.

16.7 HOOKUP WIRES

16.7.1 For internal wiring of distribution boards and electric devices, single-wire insulated conductors may be used (see also 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 requirements.

16.8.1.1 Use is to be made of non-combustible and flame-retarding cables and conductors with copper cores manufactured in accordance with the requirements of the present Part or current standards approved by the Register. The use of other cables, as well as the use of wires is subject to special consideration by the Register.

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 is to 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 is to 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 is to 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 (see 16.8.8).

16.8.1.6 In locations where cables may be subjected to mechanical damage, the use is to be made of cables having an appropriate armour, while other types of cables in such locations are to be protected with special reliable covers or to be installed in metallic pipes (see 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, are to 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 service communication, command broadcast apparatus, fire detection system, alarms warning of starting the fire smothering system, general alarm system, indication of closing watertight doors and lighting and also supply feeders for emergency consumers shall be routed clear of machinery spaces of category A, boiler rooms, galleys and other enclosed spaces of high fire risk, as well as their cassings, except for cases when the devices or mechanisms of those systems are installed in such spaces.

On the external bulkheads of these spaces, cables shall be laid at the distance not less than that specified in 16.8.4.1.

In ships whose dimensions do not permit of these requirements to be met, steps are to be taken to ensure effective protection of cables running through fire-hazardous spaces.

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.

The current ratings given in this table are applicable to the following cases of cable installation:

.1 when installing not more than 6 cables in one bunch or in one row closely adhering to one another;

.2 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:

$$I = \alpha S^{0,625}, \qquad (16.8.2.2)$$

Table 16.8.2.2

Factor α for nominal cross-sectional area S, mm²	Maximum permissible conductor temperature, °C						
	60	65	70	75	80	85	90
⩾2,5 mm²	9,5	11	12	13,5	15	16	18
<2,5 mm²	8	10	11,5	13	15	16	20

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, mm²	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	—

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.

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.

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 is not to 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

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

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 are to 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 are to 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 are to be installed not closer than 100 mm to sources of heat.

16.8.4.2 No cables are to be installed at a distance less than 50 mm from the double bottom and from the fuel and oil tanks.

Cable runs are to 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 must be taken during installation to limit the propagation of fire:

.1 fire-retarding divisions should be used, B-O class at least, (see also 2.1.2.9, 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(a));

.2 in closed and semi-enclosed rooms and spaces, bunches installed in partly enclosed and open cable runs should 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(b)); or

B-O fire-retarding divisions at least at every second deck or every 6 mm apart for vertical cable runs and every 14 m apart for horizontal cable runs (Fig. 16.8.4.3 (c)). Fire-retarding divisions should be made of steel plates at least 3 mm thick and having dimensions as shown in Fig. 16.8.4.3((c));

.3 bunches installed in cargo holds are to be protected by B-O 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.

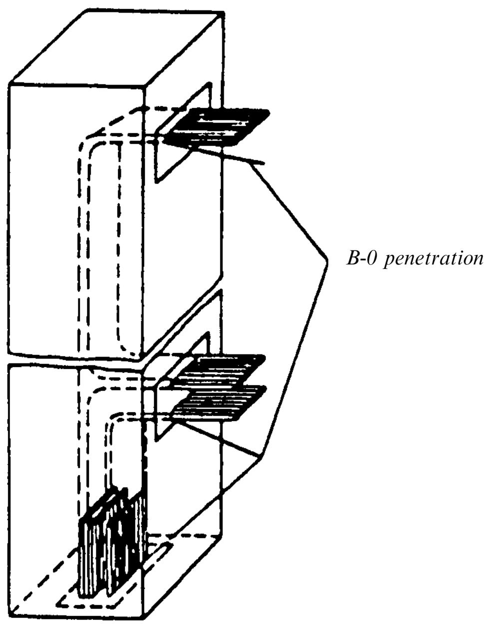


Fig. 16.8.4.3(a)
Fully enclosed cable run protected with B-O fire-retarding divisions

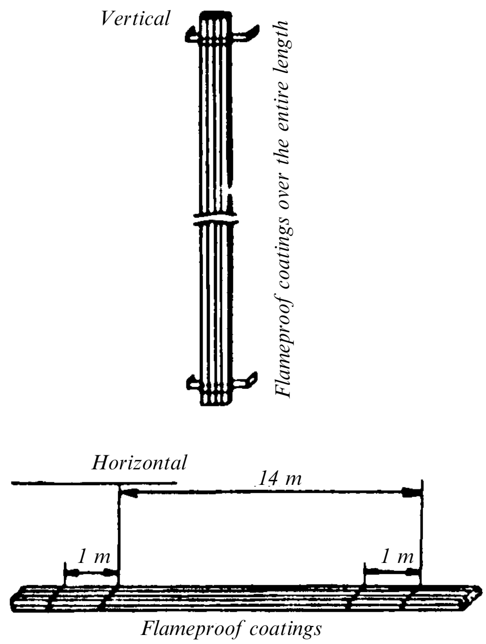


Fig.16.8.4.3(b) Cable runs protected with flameproof coatings

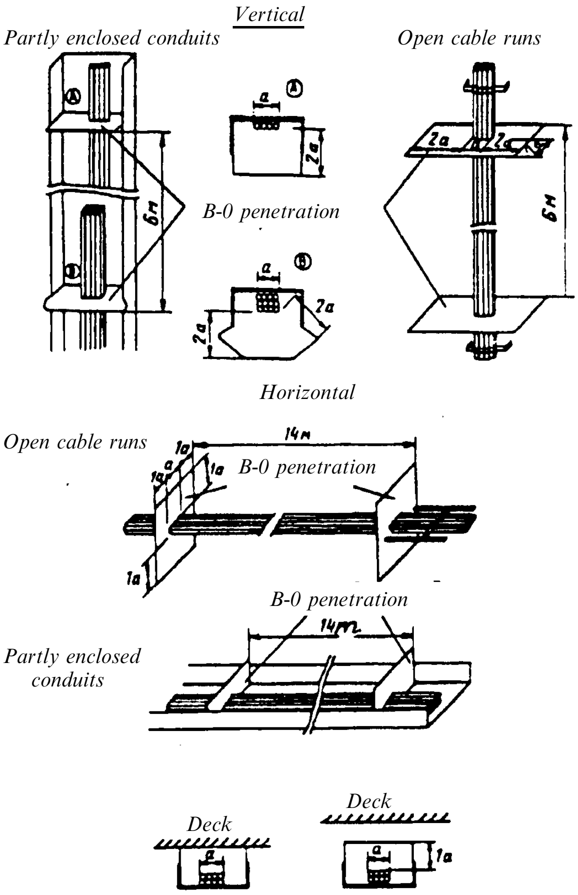


Fig. 16.8.4.3(c) Cable runs protected with B-O fire-retarding divisions

16.8.4.5 In the holds of dry cargo ships intended for the carriage of dangerous cargoes, no through runs of cables are, generally, to 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 and special purpose ships at locations subjected to the action of salt are to be adequately protected with covers 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 are to be laid in metallic pipes or in closed conduits (see 16.8.8).

16.8.4.8 Cables installed across expansion joints in the hull structure are to be provided with expansion loops having a radius adequate for such joint. The inside diameter of a loop is to be not less than 12 outside diameters of the cables.

16.8.4.9 Installation of cables having insulation intended to withstand different permissible temperatures in the common cable runs is to 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 are not to 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 should 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 are not to be used for supplying power and control currents to essential services not associated with one another.

Multi-core cables are not to be used simultaneously for safety voltage and service voltages exceeding the safety level.

16.8.4.13 When machinery is energized through two sepa-rate feeders, these feeders are to 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 instal-lation are to 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 are to be provided with protective sheath of metal, polychloroprene composition, or of any other material resistant to the action of the cooling agent.

If cables are provided with armour, this armour is to be adequately protected against corrosion.

16.8.4.17 Cables in refrigerated spaces are to be instal-led 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 are to be protected against corrosion.

If cables cross the thermal insulation of a refrigerated space, these cables are to run at right angles through an appropriate gland pocket on both ends.

16.8.4.18 When installing the cables, minimum internal bending radii are to be maintained in accordance with Table 16.8.4.18.

16.8.4.19 Cables and earthing conductors of equipment mounted on shock absorbers are to be installed in such a manner that they cannot be damaged in service.

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*

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

16.8.4.20 Cables laid on the open parts of the ship and masts are to be protected against direct exposure to sun radiation.

16.8.5 Fastening of cables.

16.8.5.1 Cables are to be adequately fastened in position by means of clips, holders, hangers, etc., manufactured of metal or other non-combustible material.

The fastener surface is to be sufficiently wide and to have no sharp edges. The fasteners are to 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 are not to exceed the values given in Table 16.8.5.2.

For vertical runs of cables these distances may be increased by 25 per cent.

16.8.5.3 Cables are to 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 are to be fastened to ship's structures.

On watertight bulkheads and masts, cables are to be fastened on special supports (saddles, tray plates, chocks, etc.).

16.8.5.5 Cables running parallel to bulkhead subject to sweating are to 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 are to be installed with a minimum number of crossings. Bridges are to be used at places where cables cross each other. An air gap of not less than 5 mm is to 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 should be sealed.

Sealings where cables penetrate through the above bulkheads and decks are not to reduce their tightness; no force is to 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 are to 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 stuffing 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 is to 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 are to withstand standard fire test specified for the given type of bulkhead in 2.1.2.5, Part VI "Fire Protection".

16.8.8 Installation of cables in pipes and conduits.

16.8.8.1 Metallic pipes and conduits wherein cables are installed are to be protected from corrosion on the inside and the outside surfaces. The inside surface of pipes and conduits is to be even and smooth. Ends of pipes and conduits are to 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 are not to be installed in pipes and conduits.

16.8.8.2 Pipe bending radius is not to be smaller than the permissible radius for cable of the largest diameter installed in this pipe (see 16.8.4.18).

16.8.8.3 The total cross-sectional areas of all cables measured on their outside diameters is not to exceed 40 per cent of the inside cross-sectional area of the pipe and the conduit.

16.8.8.4 The pipes and conduits are to 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 are to be installed in such a manner that no water can accumulate therein. When required, ventilation holes are to 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, are to 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 are to 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.

16.8.9 Special precautions for single-core cables for a.c. wiring.

16.8.9.1 A.c. wiring should 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 should be observed:

.1 the cables should be armoured with non-magnetic material;

.2 cables belonging to one circuit should be placed in the same run or metal pipe and should 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, should include all the single-core cables of a circuit;

.4 the distance between the cables should not be greater than one cable diameter.

16.8.9.2 Where single-core cables pass through bulkheads or decks, there should be no magnetic material between cables belonging to the same circuit. The clearance between the cables and the magnetic material should be not 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 should 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 should 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 should 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 should be provided with protective insulation against damage (wear, etc.).

16.8.10.2 Protective covering of a cable inserted into a device should enter not less than 10 mm inside.

16.8.10.3 At places of tappings, connection of cables should 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 should be effected in suitable junction boxes provided with clamps. The joint as a whole should be protected from ambient conditions. The appli-cability of cable jointing and methods of cable connection other than those mentioned above are subject to special consideration of the Register in each case (see also 18.9.6).

17 ELECTRIC PROPULSION PLANTS

17.1 GENERAL REQUIREMENTS

17.1.1 The electrical equipment forming part of the electric propulsion plant shall comply with the requirements of other sections and chapters of the present Part of the Rules, except where otherwise specified in this Section.

17.1.2 Propulsion generators may be used for supplying auxiliary electrical machinery and devices, provided voltage and frequency stability can be assured under all running conditions, including those of manoeuvring, in accordance with the requirements of 2.1.3.

17.1.3 It is recommended that electrical heating should be provided in the spaces allotted to electric machinery, switchboards and control panels.

17.1.4 Stationary lighting shall be provided underneath the generators and motors of the electric propulsion plant.

17.1.5 Parts of electric propulsion machines (motors and generators) located under the floor shall have the degree of protection not below IPX6.

In case they are installed in a dry compartment or protected against the ingress of water by a watertight foundation, and, besides, in case a signal is provided to be activated upon water entering the compartment, IPX3 protection is permitted.

17.2 PERMISSIBLE SUPPLY VOLTAGE

17.2.1 In electrical systems of electric propulsion plants the voltage levels not in excess of those specified in 4.2 and 18.2.2 are permitted.

17.3 ELECTRIC MACHINES

17.3.1 Cooling and ventilation.

17.3.1.1 Generators and electric motors with closed-circuit ventilation shall be provided with thermocouples to measure the temperature of outgoing air and water.

17.3.1.2 It is recommended that the closed-circuit ventilation system should be provided with an air humidity indicator and with light and sound alarms operating in case of inadmissible rise of the cooling air temperature.

17.3.1.3 Visual and audible alarms shall be provided to operate when the temperature of generators and electric motors of the electric propulsion plant exceeds the limits specified in the relevant standards.

17.3.1.4 It is required that air-cooled propulsion motors should be equipped with two induced ventilation fans, each having a capacity sufficient to ensure normal conditions of motor operation.

Provision should be made for visual signals to indicate the operation of the fans and audible signals to indicate their stopping.

17.3.1.5 Generators and electric motors of the electric propulsion plant shall be equipped with filters for cleaning the cooling air both for open and closed-circuit ventilation system.

Ventilation ducts shall be so constructed as to prevent penetration of water inside the machine.

17.3.1.6 Liquid-cooled electric machinery must be so designed as to prevent sea water from getting onto its windings, and cooling system control devices should be provided.

17.3.1.7 In multi-anchor machinery, an independent liquid-cooled system is to be provided for each anchor.

17.3.2 Lubrication of bearings.

17.3.2.1 A circulatory pressure lubrication system for the bearings of electric propulsion machinery shall have two lubricating oil pumps, each with a capacity sufficient to ensure normal operating conditions of the plant.

17.3.2.2 Where a circulatory pressure lubrication of bearings is used, the oil system of the electric propulsion motor shall incorporate a filter and a gravity feed tank to ensure oil supply to the bearings for not less than 15 min with the pump out of action unless the bearing design provides for normal lubrication for the stopping distance.

17.3.2.3 A circulatory pressure lubrication system shall be provided with audible and visual signals to operate in the event of a pressure fall in the oil system, as well as with means for measuring the oil temperature at outlet.

17.3.3 Machine excitation.

17.3.3.1 The excitation system for the machines of the electric propulsion plant shall be fed from not less than two converters of electrical energy so that if one of these fails, the remaining sets shall be capable of meeting the total exciting power requirements even at elevated loads such as are incident to manoeuvring.

It is admissible for the excitation system of the electric propulsion machines to be fed from the busbars of the main switchboard, provided that power supply is ensured under all conditions in accordance with the above requirements.

17.3.3.2 An excitation systems for direct-current propulsion motors and generators shall be so designed that in case of excitation loss at the electric propulsion motor, the field current is immediately removed to zero from the generators.

This requirement may be dispensed with where d.c. systems with constant current or voltage having two or more electric motors are used and also where special excitation systems are used which make it unnecessary.

17.3.3.3 Field circuits shall embody devices for discharging magnetic field energy in the event of disconnecting the field winding (see also 5.4.3).

17.3.3.4 Excitation and automatic-control system shall be so designed that electric propulsion motors are safeguarded from overspeeding in the event of the propeller breaking down or working clear of water.

For constant-current systems this requirement shall cover all the electric motors of the constant-current circuit.

17.3.3.5 For constant-current systems protective devices shall be provided to ensure removal of the field current from the generators and electric motors in case of breaking the main current circuit.

17.4 SWITCHES IN MAIN AND FIELD CIRCUITS

17.4.1 No circuit breakers are to be installed in the field circuit, other than those designed to control machine excitation in the event of a short circuit or a failure in the main current circuit.

17.4.2 Where a definite sequence of switching operations is to be assured, provision is to be made for a reliable interlock to prevent wrong switchings.

17.4.3 Switchgear intended for selecting modes of operation in the electric propulsion plant circuits while these are de-energized shall be suitably interlocked to prevent their opening in the energized condition or closing by mistake.

17.4.4 Generators and electric motors of constant-current systems shall be connected or disconnected when the field current is removed from these machines without breaking the main current circuit.

17.5 CONTROL STATIONS OF ELECTRIC PROPULSION PLANT

17.5.1 The main control station situated in the machinery or special space shall be provided for each electric propulsion plant.

It is allowed to install additional remote control stations in positions from which the ship's control is performed.

17.5.2 Where control from the panel or desk of the electric propulsion plant involves the use of an electric, pneumatic or hydraulic actuating gear, the failure of such actuating gear should not render the electric propulsion plant inoperative, and each of the control stations on the panel or desk is to be ready for manual operation immediately.

17.5.3 When several control stations of the electric propulsion plant are provided, a control station space shall be fitted. This switch shall make it possible to connect for operation only one of the above control stations.

17.5.4 The control station switch shall be provided with an interlocking device not permitting changeover from one station to another until the excitation is removed from the propulsion plant which shall be effected by putting the handle of the control station in operation to "stop" position. In this case, whatever the position of the control handle at a station to be connected, the operation of the propulsion motor shall be started only through "stop" position.

17.5.5 Control stations of electric propulsion plant should comply with 3.2, Part VII "Machinery Installations".

17.5.6 It is allowed to use mechanically linked control stations situated in the wheelhouse (bridge) for synchronous operation using them in turn.

17.5.7 The remote control system of the electric propulsion plant shall be so designed that no time delay is required for the personnel when reversing or changing the speed by control handle at the control station situated in the wheelhouse (bridge).

17.5.8 Provision is to be made for interlocking of the control system of the electric propulsion plant to prevent the operation of the plant with the shaft-turning gear engaged.

17.5.9 Each control station should have a visual signal indicating whether the control circuit is energized or not.

17.6 ELECTRIC PROPULSION PLANTS WITH SEMICONDUCTOR CONVERTERS

17.6.1 General.

17.6.1.1 The power of electric power sources and of services connected to the busbars of electric propulsion plant is to be selected taking into account the prospective distortions of voltage and current on these busbars, as well as additional distortions resulting from the asymmetry of the first harmonic and the highest harmonics in the transient conditions of electric propulsion motor operation.

17.6.1.2 Main generators, semiconductor converters of electric propulsion motors, as well as the apparatus of main current circuits should sustain an overcurrent of at least 250% of $I_{nom.}$ during two seconds.

17.6.1.3 The power of electric propulsion motors should be chosen with due regard for prospective voltage distortions at semiconductor converter outlets.

17.6.1.4 In the event of voltage distortions due to semiconductor converter operation, the main generators and electric propulsion motors must ensure prescribed parameters in accordance with the ship purpose.

17.6.1.5 The overload capacity of main generators and electric propulsion motors should be in compliance with the requirements for the conditions of operation on board. If need be, measures should be taken to compensate for the reduction of the overload capacity as a result of generating higher voltage harmonics during the operation of semiconductor converters.

17.6.1.6 The power condensers of filters applied in semiconductor converters for upgrading electrical energy should be provided with dischargers.

17.6.1.7 Services that are particularly sensitive to the sinusoidality of supply voltage should be supplied from independent sources of electrical power or provided with local arrangements for suppressing higher harmonics to a technically feasible level irrespective of the permissible value of the non-linear distortion factor.

17.6.1.8 In case of the common electric-generating station or power take-off from the busbar of the electric propulsion plant, the ship consumer switchboard is to be supplied through rotary converters, special transformers or filters, provided the value of non-linear distortion factor of power supply voltage in compliance with 2.2.1.3 is not ensured.

The possibility of connection to the busbar of the electric propulsion plant of a consumer which has its own semi-conductor converter is subject to special consideration by the Register in each case.

17.6.1.9 Semi-conductor converters in the main current circuits of the electric propulsion plant are to ensure its operation at lower parameters in case their cooling systems fail. Visual and audible alarms on failure of the semi-conductor cooling system is to be provided.

17.6.2 A.C./D.C. propulsion plants.

17.6.2.1 For electric propulsion motors serviced with rectified current, the current pulsation factor is to be determined from the following formula:

$$K_p = \frac{\sqrt{\Sigma I_\nu^2}}{I_{dr}},$$

where ν = harmonic number,
I_{dr} = constant component of rectified current,
I_ν = effective value current of the ν-th harmonic component.

For electric propulsion motors supplied by D.C. generators, the current pulsation factor is not to exceed 2%.

17.6.2.2 Dynamic braking current must not exceed 200% of I_{nom}.

17.6.3 A.C./A.C. propulsion plants.

The power of main generators is to be chosen with due regard for the prospective irregular loading of phases as a result of using direct semiconductor converters of frequency.

17.7 PROTECTION OF ELECTRIC PROPULSION PLANTS

17.7.1 Electric propulsion plant systems shall have hull-shorting protection. The protective device shall be so designed that the earth current does not exceed 20 A.

17.7.2 Fuses shall not be used as a means of protection in the main and field circuits of the electric propulsion machinery (see also 8.2.9 and 8.8.2).

17.7.3 Where direct-current generators of the electric propulsion machinery are connected in series, protective devices shall be provided to prevent the reversal of the generating set in case of partial or complete loss of the prime mover rotation moment.

17.7.4 Arrangements shall be made to limit or utilize the power generated by the electric propulsion motor under transient conditions or during propeller reversals, if such power is likely to cause overspeeding of the generator prime movers.

Speed increase of the generator prime movers forming part of the electric propulsion plant shall be limited to the values specified under 2.11, Part IX "Machinery".

17.7.5 The electric propulsion plant shall have no-voltage protection from self-starting following the operation of any protective device.

17.7.6 The electric propulsion plant shall have short-circuit overcurrent protection and overload protection. Operation of the overload protection is to be preceded by operation of audible and visual alarms.

Overload protection is not to be operable when overload occurs during manoeuvring.

17.7.7 In the main and exciting circuits of generators and motors of electric propulsion plant, the thyristor converters should have the following protection:

.1 against external and internal short circuits and overloads;

.2 against overvoltage;

.3 against change of inverter state where the converter is to operate in the inverter mode;

.4 against de-energizing of control circuits.

17.7.8 The protection system of the electric propulsion plants is to be independent for each circuit containing a propulsion electric motor and a semi-conductor.

17.7.9 Disconnection of a semi-conductor or its components is not to result in impermissible overloads and overvoltages in the electric propulsion plant system.

17.8 MEASURING INSTRUMENTS AND ALARMS

17.8.1 Given below is a minimum list of measuring instruments that are to be provided in order to ensure permanent and direct control of the system characteristics which affect the operation of the electric propulsion plant:

.1 an ammeter in the main current circuit;

.2 a voltmeter in the main current circuit;

.3 an ammeter in the field circuit for adjustable excitation system;

.4 a voltmeter in the field circuit for adjustable excitation systems;

.5 a tachometer for propulsion motors or propeller shafts.

Additional requirements for a.c. systems:

.6 a frequency indicator;

.7 a synchronizer for generator paralleling;

.8 a wattmeter.

17.8.2 The electric propulsion plant system shall be equipped with an insulation resistance measuring instrument.

Continuous insulation resistance measuring shall be provided in the main current circuits with visual and audible alarms operating in the event of inadmissible decrease of insulation resistance.

This requirement is not applicable to electrical energy distribution systems with the neutral point earthed to the hull which are fitted up with hull shorting protection.

17.8.3 Each control station shall be provided with light alarms to indicate the presence of voltage in the control circuits.

17.9 ELECTRIC SLIP COUPLINGS

17.9.1 General requirements.

17.9.1.1 Electric slip couplings shall be so designed as to enable couplings to be dismantled without disassembling the driving motor or reducer.

17.9.1.2 Electric slip couplings shall be so designed and arranged as to be freely accessible for maintenance, brush replacement and air gap measurements without dismantling the couplings.

17.9.1.3 Enclosures and end shields shall be made of steel or materials of equivalent strength (see also 10.1.1).

17.9.1.4 The rotating parts of couplings and their windings shall be designed and secured so that they cannot be damaged in the event of a sudden stop.

17.9.1.5 Electric slip couplings shall not produce axial thrust. They shall be balanced to comply with the requirements of 4.1.2, Part IX "Machinery".

17.9.1.6 The maximum torque under field forcing conditions shall not exceed twice the rated torque of the coupling.

17.9.1.7 The requirements of the present Chapter are also applicable to electric slip couplings which are fitted in other systems.

17.9.2 Protection and interlocking.

17.9.2.1 Electric slip couplings shall have a system of connections or be so interlocked that it will be totally impossible for the coupling to be excited when the main motor is started or reversed.

17.9.2.2 Where several motors are used to drive the same transmission, the excitation system of the electric slip couplings shall be interlocked to prevent the driving motors which rotate in opposite directions from being started simultaneously.

17.9.3 Electric slip couplings excitation.

17.9.3.1 The field windings of electric slip couplings shall be protected against overvoltage.

17.9.3.2 The field circuit of an electric slip coupling shall incorporate:

.1 a two-pole switch;

.2 a magnetic field discharging device;

.3 short-circuit protection.

18 ADDITIONAL REQUIREMENTS FOR ELECTRICAL EQUIPMENT DESIGNED FOR A VOLTAGE IN EXCESS OF 1000 V

18.1 GENERAL REQUIREMENTS

18.1.1 The requirements of this Chapter are applicable to electrical equipment with voltages above 1000 V, but not in excess of 11000 V for alternating current, and they should be considered as a supplement to the relevant requirements to be found in other chapters of this Part.

18.1.2 Insulating materials used for electrical equipment shall ensure the insulation resistance of 1500 ohms per 1 V rated voltage, but not less than 2 megohms during long-term service of the ship.

18.1.3 At the entrance to the special electrical space a warning notice shall be placed which indicates the voltage. Enclosures of electrical equipment installed outside special electrical spaces shall be provided with warning notices indicating the voltage.

18.2 DISTRIBUTION OF ELECTRICAL POWER

18.2.1 Distribution systems.

18.2.1.1 The following power distribution systems may be used in ship plants:

insulated three-phase three-wire system;

three-phase three-wire system with the neutral point earthed to the ship hull through a high-capacity resistor or another current-limiting device, such as a reactor.

18.2.1.2 The impedance of the neutral earthing shall be so selected that the short-circuit current to the ship's hull is not in excess of the rated current of the largest generator in a given system, but not less than three-fold value of the current required for operation of each type of earth-fault protection.

It is permitted that all the resistors (reactors) should be connected to the common earthing busbar which shall be connected to the ship's hull at least at two points.

18.2.1.3 When the system of electrical power distribution consists of separate sections capable of operating independently, each section shall be provided with separate earthing resistor (reactor).

18.2.1.4 Neutral points of generators intended for parallel operation may be interconnected at the earthing resistor (reactor).

18.2.1.5 The neutral point of the generator shall be earthed resistor (reactor) on the switchboard or directly at the generator.

18.2.1.6 In the neutral wire of each generator provision shall be made for a disconnector which may cut out the neutral point earthing of the generator.

18.2.2 Permissible voltage.

In electrical power distribution systems, rated voltage should not exceed the values to be found in Table 18.2.2.

Table 18.2.2

Rated interphase voltage, kV	Rated frequency, Hz
3 (3,3)	50 (60)
6 (6,6)	50 (60)
10 (11)	50 (60)

18.2.3 Supply from an external source of electrical power.

Supply of the ship's mains from an external source of electrical power is permitted only for ships operating at standstill, such as floating docks, dredgers, drilling ships, etc.

18.3 PROTECTIVE DEVICES

18.3.1 General requirements.

18.3.1.1 When different voltage are applied to electrical equipment, measures shall be taken to exclude transfer of the higher voltage to the lower-voltage circuits.

18.3.1.2 Overload protection shall be provided in all phases of the alternating current systems.

No fuses are permitted.

18.3.1.3 In ship's mains with insulated neutral points, visual and audible alarms should be provided to indicate earth fault.

For ship mains with earthed neutral points, the above signals are recommended.

18.3.1.4 Electric machinery is to be provided with temperature detectors in its stator windings to actuate an alarm whenever the temperature exceeds the permissible limit.

18.3.2 Protection of generators.

18.3.2.1 Generators should have an earth-fault protection.

18.3.2.2 Generators should be de-excited in case of operation of any type of generator protective devices.

18.3.2.3 Generators should have an internal-fault protection and against short circuit in the cable connecting generators to the switchboard.

18.3.3 Protection of transformers.

18.3.3.1 On the higher-voltage side, transformers should be protected against short circuit by automatic circuit breakers.

18.3.3.2 On the lower-voltage side of transformers, overload protection should be provided.

18.3.3.3 Instrument voltage transformers should be protected against short circuit by fuses.

18.4 PROTECTION EARTHING

18.4.1 Metal enclosures of electrical equipment shall be earthed by external flexible copper conductors having a cross-sectional area designed for single-phase short-circuit current but not less than 16 mm^2. Earthing wires shall be suitably marked.

18.4.2 Earthing conductors may be connected by welding or by bolts not less than 10 mm in diameter.

18.5 ARRANGEMENT AND DEGREE OF PROTECTION OF ELECTRICAL EQUIPMENT

18.5.1 Electrical equipment shall be installed in special electrical spaces and shall have the degree of protection not below IP23 (see also 18.6).

The terminal boxes of rotating electrical machinery should have the degree of protection not lower than IP44.

In well-grounded cases, electrical equipment may be installed outside special electrical spaces, provided that the degree of protection is not below IP44 and access is ensured to current-carrying parts only in case the voltage is off and special tools are used.

18.5.2 In the special electrical space a diagram of connections and arrangement of electrical equipment shall be placed.

18.6 DISTRIBUTION GEAR

18.6.1 Switchboards shall be locked with a special key other than for the lower-voltage switchboards and distribution gear.

Opening of the door and withdrawal of separate parts shall be possible only after disconnection of the panel or the whole switchboard from the electrical power supply.

18.6.2 Circuit breakers used in switchboards shall be of the withdrawable type.

Circuit breakers shall be provided with locking facilities to fix them in the withdrawn position. These facilities shall be key-locked.

The fixed live contacts of the circuit breaker shall be automatically covered by insulation screens in the withdrawn position of the circuit breaker.

18.6.3 For the purpose of protective earthing, a short-circuiting device, incorporated in the switchboard and designed for maximum short-circuit current, should be provided on collecting busbars and outgoing feeders. On agreement with the Register, such a device may be portable.

18.6.4 Passageways shall be provided along the switchboard for inspection of the switchboard and electrical apparatus and the width of the passageway shall be not less than 800 mm between the bulkhead and the switchboard and not less than 1000 mm between the parallel sections of the switchboard.

When these passageways are intended for maintenance, their width shall be increased up to 1000 and 1200 mm, respectively.

The width of these passageways is required without regard to the applied means of protection against contact which may be provided in the form of tight doors, guard nets or rails.

Doors, continuous bulkheads and net screens shall be not less than 1800 mm in height.

Perforated or net screens shall provide for the degree of protection not below IP2X.

Two guard rails shall be fitted along the switchboard at the heights of 600 and 1200 mm.

18.6.5 Parts of the electrical installation under voltage shall be separated from the protection guards by a distance not less than that specified in Table 18.6.5.

Table 18.6.5

Nominal voltage, kV	Minimum height of passageway, mm	Minimal distance, in mm, of elements under voltage from protection guards in the form of		
		tight doors and bulkheads	doors and net screens	guard rails
3 (33)	2500	100	180	600
6 (66)	2500	120	200	600
10 (11)	2500	150	220	700

18.6.6 The air clearance between live parts with different potentials, between live parts and earthed metal parts and the casing should not be less than that contained in Table 18.6.6.

Table 18.6.6

Voltage, kV	Minimum air clearance, mm
3 (3,3)	55
6 (6,6)	90
10 (11)	120

18.6.7 The main switchboard should be provided with disconnectors so that it should be possible to split the collecting bus system into at least two independent sections, each supplied by at least one generator.

18.6.8 If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two operations of all the components.

18.7 TERMINAL BOXES

18.7.1 In generators and motors, all terminals of the stator winding shall be arranged in a separate terminal box other than that of lower voltage.

18.7.2 In cabinets, sockets and terminal boxes of electrical equipment, installation of wires and connections for lower voltages are not permitted.

18.8 TRANSFORMERS

18.8.1 Dry-type transformers shall be used which are provided with earthed screens between the windings of high and low voltages.

18.8.2 Tripping of transformers on the higher-voltage side should trip the switch connected on the lower-voltage side.

18.8.3 When the lower-voltage side of the transformer has an insulated neutral point, the spark gap shall be inserted between the neutral point of the transformer and ship's hull. The spark gap shall be rated for not less than 80 per cent of the minimum testing voltage of appliances fed through the given transformer.

18.8.4 It is permitted that the apparatus for the insulation monitoring of the lower-voltage installation and for detection of the insulation damage should be connected in parallel to the spark gap. These apparatus shall not interfere with reliable operation of the spark gap.

18.8.5 Effective means are to be provided, such as heating, to prevent the accumulation of moisture and condensation within the transformers, when de-energized.

18.9 CABLING

18.9.1 For the three-phase cable systems triple-core cables with multiwire cores shall be used.

18.9.2 The cross-sectional area of the cable conductor for power circuits shall be not less than 10 mm^2.

18.9.3 The construction type and permissible current loads of the cables used are subject to the special consideration by the Register in each case.

18.9.4 The cables should be laid separately from cables for voltages below 1000 V.

18.9.5 When installing the cables, the following conditions shall be met:

.1 combined installation of cables intended for electrical power supply with different voltages is permitted provided that insulation of all the cables laid together is designed for the largest voltage;

.2 cables shall not run through accommodation spaces;

.3 the distance between the outer sheaths of cables designed for different voltages shall be equal to at least double outside diameter of the thicker cable, but not less than 50 mm;

.4 cables laid outside special electrical spaces shall be installed in earthed metallic pipes or conduits and shall be protected by earthed metallic enclosures.

Open installation of these cables is permitted in case they have continuous metallic armour which shall be reliably earthed.

18.9.6 Installation of junction boxes or other types of connection is not permitted for the purpose of elimination of cable breaking or lengthening (splicing).

19 REQUIREMENTS FOR ELECTRICAL EQUIPMENT PROCEEDING FROM SHIP PURPOSE

The present requirements are additions and amendments to the relevant requirements of Sections 1 to 18 of this Part of the Rules.

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 should be supplied directly from the main and the emergency distribution boards through separate feeders. The feeders should be connected to an automatic switch fitted near the pump of the sprinkler system. Normally, the switch is to be connected to the feeder from the main distribution board, and in case of supply failure it should 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 should be clearly marked off and are to be permanently in the "on" position. No other switches should 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 should 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 should be supplied through two independent feeders at least (see also 6.2.3).

19.1.1.4 The supply systems of essential ship gear should 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 should consist of two independent groups: one for passengers and the other for the crew.

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.

19.1.2 Supply from emergency sources of electrical power.

19.1.2.1 In passenger ships of unrestricted service and of restricted area of navigation I, the emergency sources of electrical power should 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 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;

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 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 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 other systems whose 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 hrs.

For ships of restricted navigation area II and IIСП, the period of 36 hrs may be reduced to 18 hrs, and for ships of restricted navigation area IIIСП and III, it may be reduced to 12 hrs.

19.1.2.2 Emergency sources of electrical power should ensure the supply of steering gear in accordance with 5.5.6.

19.1.2.3 Emergency sources of electrical power should 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 should be:

.1 driven by an internal combustion engine (see 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 should be automatically supplied from the emergency generator. The total time for starting and carrying the board by the generator should not exceed 45 s;

.3 for an emergency, a transitional source of electrical power is to be provided which should be activated immediately upon de-energizing.

19.1.2.5 Where an accumulator battery serves as the emergency source of electrical power, it should:

.1 operate without recharging and with voltage across its terminals within 12 per cent of rated voltage during the whole discharge period;

.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 should be used which should operate without recharging and with voltage across its terminals within 12 per cent of rated voltage during the whole discharge period.

19.1.2.7 The capacity of the battery serving as transitional source of electrical power is to be sufficient for supplying the services listed below during 30 min:

.1 lighting 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.

Services listed under 19.1.2.7.2 to 19.1.2.7.4 may be supplied from their own accumulator batteries which are to 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 should 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 should activate an audible and visual alarm in the main control station and at the navigating bridge.

19.1.4 Electrically powered low-location lighting (see 8.5.5, Part III "Equipment, Arrangements and Outfit").

19.1.4.1 The low-location lighting system should 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 should function at all times.

19.1.4.2 Where an accumulator battery is the emergency source of electrical power, its capacity should 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 should ensure the following standards of luminance:

.1 the active parts of the system should have a minimum luminance of 10 cd/m^2;

.2 the point sources of miniature incandescent lamps should provide not less than 150 mcd mean spheric intensity with a spacing of not more than 100 mm between lamps;

.3 the point sources of light emitting diode systems should have a minimum peak intensity of 35 mcd. The angle of half intensity cone should be appropriate to the track directions of approach and viewing. Spacing between lamps should 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) should be provided with a minimum degree of ingress protection of IP55.

19.2 OIL TANKERS AND OIL RECOVERY SHIPS

19.2.1 General provisions.

The requirements of this Chapter cover the electrical equipment of oil tankers intended for the carriage of liquids having a flash point 60°C or below and liquids having a flash point 60°C and above for which heating is required up to a temperature not more than 15°C below the flash point and also the electrical equipment of ships intended for the recovery and transporting of oil spilt on the sea surface.

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

.1 Zone 0: in which an explosive gas/air mixture is continuously present or present for long periods.

.2 Zone 1: in which an explosive gas/air mixture is likely to occur in normal operation.

.3 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 other spaces adjoining cargo compartments and tanks;

.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;

areas in way of pressure/vacuum valve outlets and vent pipe outlets in accordance with 10.2.7 — 10.2.9, Part VIII "Systems and Piping";

.7 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;

.8 storage spaces for cargo hoses and equipment for collecting spilt oil (oil collectors);

.9 enclosed and semi-enclosed spaces having direct access or other openings into one of the above areas and spaces;

.10 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:

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).

19.2.3.2.4 Spaces and areas not included in Zones 0, 1 and 2 are considered safe.

19.2.3.3 Spaces below the upper deck having direct access to or other openings into spaces on the main deck listed under 19.2.3.2.2.7 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 should not be located more than 6 m below the deepest waterline and, under all circumstances, should be outside dangerous zones.

Entrances to safe spaces lying more than 6 m below the deepest waterline or within dangerous zones should be provided with air locks. In such spaces, openings more than 6 m below the waterline should 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 (*Exi*).

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 3.7.4.6, Part V "Navigational Equipment" of 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 (see 4.2.5, 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 (see also 9.1.4, Part VIII "Systems and Piping").

19.2.4.6 In enclosed and semi-enclosed spaces above the deck on which cargo compartments, tanks and areas are located whose 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 should 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 are to be arranged on at least two independent supply circuits with fuses and switches which are to 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 should 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 — 19.2.3.2.2.10. The design of electrical equipment operable during the above operations, i.e. of lighting fixtures, winches, electrical equipment installed in wheelhouse wings, etc., should be such that no arcs or sparks are formed, and the surfaces of equipment do not heat up to dangerous temperatures during normal service.

19.2.5 Portable electrical equipment used for collecting spilt oil.

19.2.5.1 Portable equipment for collecting and transfer of oil should be of safe type.

19.2.5.2 Distribution boards and socket outlets for supplying portable oil-collecting and transfer equipment on deck should 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 should 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 used for portable electrical equipment intended for collecting spilt oil should have a sheathing made of oil-resistant material. The cable structure should include a wire braiding (screen) protected by a proof sheathing.

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) or pipes. Where the flying bridges are inside the spaces specified in 19.2.3.2.2.7, 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 within the zone specified in 19.2.3.2.2.7 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 is to be at least the cross-sectional area of a conductor.

The structure of such cables is subject to the special consideration of the Register.

19.3 SHIPS INTENDED FOR CARRIAGE OF MOTOR VEHICLES WITH FUEL IN THEIR TANKS, TANK CARS AND TANK WAGONS FOR FLAMMABLE LIQUIDS

19.3.1 General requirements.

19.3.1.1 The requirements of this Chapter are applicable to electrical equipment of holds and other spaces and zones intended for the carriage of motor vehicles with fuel in their tanks and of tank wagons and tank cars for flammable liquids on board the ships.

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 should be protected against mechanical damage. Cables installed horizontally should be positioned at a distance not less than 450mm above the continuous deck or platform preventing a free propagation of gases in the downward direction. The sealings where cables penetrate bulkheads and deck should 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 propagation of gases in downward direction, electrical equipment may be installed with the degree of protection not lower than IP55 provided that the ventilation system ensures at least 10 air changes per hour.

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 should be provided in all public spaces and corridors, that is to serve for 3 hrs at least under any heel of the ship and when all other electrical power sources fail.

This lighting is to make the escape routes clearly visible (or ensure an illumination intensity of 0,5 lx). Any damage to a lighting fixture is to be clearly visible.

19.3.3.2 As electrical power sources for this additional lighting, accumulator batteries should serve fitted in lighting fixtures, continuously recharged from the emergency distribution board and replaced within the period established by the Manufacturer with regard for 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) should 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.

19.3.3.4 In accordance with the requirements of 7.16, Part III "Equipment, Arrangements and Outfit", the following signalling equipment should be provided on the navigating bridge:

.1 indication of cargo port doors being closed and properly secured (a green lamp);

.2 indication of cargo port doors being open and not properly secured (a red lamp);

.3 audible signals actuated when cargo port doors are transferred from the closed and properly secured condition into the open condition. Provision should be made for the acceptance of the audible signal.

The visual signalling equipment indicating the position of cargo port doors should be so designed that the signal would comprise two indicators (two lamps or a coiled-coil filament). Alternatively, a device should be provided to control the serviceability of signalling lamps.

The signalling system is to be based on the fail-safe concept.

The power supply to the signalling equipment is to be independent of the supply of the cargo port door closing and securing drives.

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, spaces and zones more than 450 mm above the cargo deck or platform preventing a free propagation of gases in the downward direction, it is permitted to install electrical equipment with the degree of protection not below IP55 on condition that the ventilation system ensures at least 10 air changes per hour.

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 should 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 should comply with 9.3.

Ships having a length above 50 m should 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 should 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.

19.5 CONTAINER SHIPS

19.5.1 General provisions.

The requirements of this 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 (see also 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.

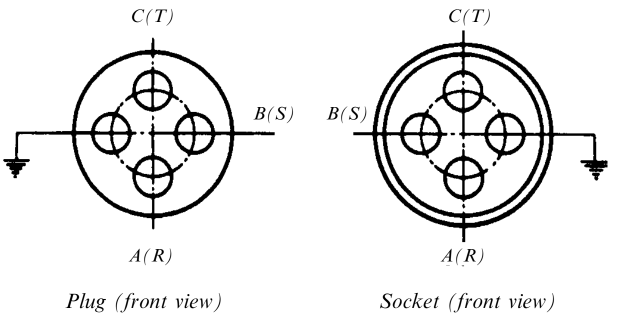


Fig. 19.5.4.3

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 is to be provided.

19.6.2 In each hull of the ship, a main distribution board should be installed. One of the boards may be installed above the bulkhead deck.

19.6.3 The busbars supplying the ship hulls should be sectioned.

19.6.4 The emergency services of each hull should 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 should 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 this Section deemed necessary by the Register.

19.7.2 For self-driven floating cranes, the capacity of the main source of electrical power is to 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 should be fitted on the crane, activated from the operator's cabin.

19.8 FLOATING DOCKS

19.8.1 General provisions.

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 Supervision 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 supervision 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 supervision 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 supervision.

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 (see also 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 should 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.

19.8.8.1 In addition to provisions of 6.6.1, socket outlets for portable lighting fixtures are to 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 is to 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 be not 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 should 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 is to 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 is to 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 should be effected in conformity with 19.1.1.1-19.1.1.4.

The side, bow and stern lights may be supplied from lighting switchboards.

19.9.6 Each floating hotel or hostel should 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 hrs, 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 19.1.2.4-19.1.2.7 should be complied with.

19.10 FISHING VESSELS

19.10.1 Supervision of vessel's electrical equipment.

In addition to the requirements of 1.3.2.1 the following kinds of equipment, systems and devices are subject to supervision on board the vessel:

.1 electrical equipment of fishing machinery;

.2 electrical equipment of processing machinery (catch processing).

19.10.2 Supervision during manufacture of electrical equipment.

The electrical equipment specified in 19.10.1 is subject to supervision in addition to that listed in 1.3.3.1. Use of electrical equipment specified in 19.10.1.2, 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 are to 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, manoeuvrability 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 50V, 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.

20 REQUIREMENTS FOR ELECTRICAL EQUIPMENT OF REFRIGERATING PLANTS

20.1 GENERAL PROVISIONS

20.1.1 The requirements of this 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 (see 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 should 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 an enclosure not below IP55 type.

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 GENERAL REQUIREMENTS

21.1.1 Each ship shall have a store of spare parts in an amount not less than specified in the present Section.

For ships of restricted areas of navigation, the amount of spare parts to be stored on board may be reduced on agreement with the Register.

21.1.2 For electric propulsion plants, electric slip couplings, self-excitation and voltage regulation systems of generators and automation systems in icebreakers and ships with ice strengthening of category **ЛУ7**, as well as in ships having electrical equipment of a type not specified in Table 21.2, the list and amount of spare parts are subject to special consideration by the Register in each case.

21.1.3 Spare parts shall be ready for use without additional processing or adjustment.

21.1.4 Spare parts shall comply with the requirements of the present Part of the Rules.

Completed spare parts shall be subjected to tests.

21.1.5 Spare parts shall be secured in accessible places, duly marked and reliably protected against environmental effects.

21.1.6 Each ship shall be provided with a set of special tools and fixtures such as required for disassembling and reassembling electrical equipment under service conditions.

It is recommended that the ship should be provided with necessary materials for maintenance of accumulator batteries (distilled water, acid, alkali),

Table 21.2

Required minimum spare parts for ship's electrical equipment

Nos	Equipment	Spare parts		Number of spare parts	Remarks
1	Rotating generators and exciters	Brushes		1 set	For 3 generators and 3 exciters of the same type
		Brush holders		1 pc	
		Bearings		1 set	
2	Static exciters	Power thyristors and diodes		1 pc of each type	For 3 exciters of the same type It is recommended to provide one spare exciter in assembly instead of spare parts
		Resistors, condensers and inductances of power circuit		1 pc of each type	
3	Electric motors	Brushes		1 set	For 6 motors of the same type
		Brush holders		1 pc	
		Bearings		1 set	
4	Steering gear	Brushes		1 set	For each motor
		Brush holders		1 pc	
		Bearings		1 set	
		Armature with shaft and half-coupling		1 unit	Additional spare parts for d.c. steering gear with one motor
		Field coils of each type		1 pc	
		Complete electric motor		1 unit	For a.c. steering gear with one motor only
5	V-belt drives	V-belts		1 set	For each drive
6	Main emergency and auxiliary switchboards, control desks, etc. (for the whole ship)	Knife-switches, rotary switches, and circuit breakers for current up to 63 A		2 pcs	Of each type
		Circuit breakers for current over 63 A	Contacts subject to wear	1 set	
			Voltage coil	1 pc	
			Arc chute	1 pc	
		Fuses in assembly		2 pcs	
7	Starting and control apparatus and contactors	Contacts subject to wear		1 set	Of each type per 6 identical devices
		Voltage coil		1 pc	
8	Emergency lighting	Incandescent lamps		1 set	If lighting supply voltage differs from voltage of ship's mains
9	Navigation lanterns	Incandescent lamps		See 2.2.6.2, Part III "Signal Means" of the Rules for the Equipment of Sea-Going Ships	—
10	Navigation lights switchboard	Relay		2 pcs	—
		Pilot lamps		1 set	
11	Portable measuring instruments	Insulation resistance measuring instrument		1 unit	A multi-purpose multi-range instrument is recommended
		Ammeter		1 unit	
		Voltmeter		1 unit	
		Ohmmeter		1 unit	
12	Fans for cooled spaces of classed refrigerating plants	Complete armature		1 unit	Per 6 d.c. motors of the same type where no spare motors are available
		Set of coils		1 set	
		Complete stator		1 unit	Per 6 a.c. motors of the same type where no spare motors are available

cables and wires, fuse links of all sizes for fuses, insulating materials, as well as such materials as may be required for eliminating faults in electrical equipment.

21.1.7 Spare parts are not considered indispensable for the electric drives of auxiliaries where such auxiliaries are provided in duplicate, used in accordance with their direct functions, and the capacity of each of them is sufficient.

Spare parts are not compulsory for the generators of the ship's electric generating plant provided it is equipped with generators of adequate power in number exceeding the requirements of the present Part of the Rules.

21.2 REQUIRED MINIMUM OF SPARE PARTS

21.2.1 Each ship shall be provided with spare parts in the amount specified in Table 21.2.

PART XII. REFRIGERATING PLANTS

1 GENERAL

1.1 APPLICATION

1.1.1 The present Part of the Rules applies to stationary marine refrigerating plants and their equipment in compliance with 4.1, Part I "Classification".

1.1.2 Classed refrigerating plants are to comply with all the requirements of this Part of the Rules.

1.1.3 Unclassed refrigerating plants are to comply with the requirements of this Part, set forth in 1.3.2.1, 1.3.2.2, 1.3.2.5 (only for heat exchangers and vessels subject to a pressure of a refrigerant), 1.3.2.6 (only for refrigerant systems), 1.3.2.7 (only for the automatic 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, 2.2.2, 3.1.1, 3.1.3 —3.1.7, 3.2.1 — 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, 5.2.1, 6.1.1, 6.1.2, 6.2.1 (only for refrigerant piping), 6.2.2, 6.2.3, 6.2.5 — 6.2.8, 7.1.2, 7.2.3, 7.2.4.2, 7.2.4.3, 7.2.8, 8.2.3, 8.2.4, 12.1.2 (only for equipment working under a pressure of a refrigerant), 12.1.3, 12.1.6, 12.2.1, 12.2.4.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to general terminology of the Rules are given in General Regulations for the Supervision.

For the purpose of the present Part of the Rules the following 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 holds and 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 SUPERVISION AND TECHNICAL DOCUMENTATION

1.3.1 General provisions covering the procedure of classification, supervision during construction and classification surveys as well as the amount of technical documents for the refrigerating plant which should be submitted to the Register for consideration and approval are specified in General Regulations for the Supervision, 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 should be submitted to the Register for consideration 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 machinery and apparatus which are to be manufactured under the supervision of the Register are:

.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 automatic 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 technical supervision of 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 — 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 is to be supervised 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 PROVISIONS

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 are to be installed and secured on board the ship in accordance with the requirements of 4.4.1, 4.4.4, 4.4.6 and 4.4.7, 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 R134A	CHF_2 Cl CF_3 — CH_2F	2,0 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 are to be calculated for compliance with hydraulic test pressure (see 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 is to 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 of ships of unrestricted service is to 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 is to 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 at least 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 as quickly as may be required for the intended cargo.

2.3.8 Pipe systems 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 The distribution of cooling grids is to provide uniform cooling of the space concerned.

The grids are to be arranged in not less than two independent sections, with means permitting shut-off of each section.

2.3.10 When pumping for liquid refrigerant circulation is used, at least two circulating pumps are to be fitted, one of which is to 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 chambers or units capacity is not reduced in excess of 20 per cent.

2.3.11 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 is to have at least one circulating pump; a common standby pump may be admitted provided it has adequate capacity and pressure head.

2.3.12 Cooling water supply to the refrigerating plant is to be provided from at least two circulating pumps, one of which is to be used for standby purpose. Any of sea water pumps with adequate capacity and pressure head may be accepted as standby means.

2.3.13 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 are to 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 are to 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 and their solutions, lubricating oils, 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 $-50\,^{\circ}C$ are to comply with the requirements of 3.5, Part XIII "Materials" and 1.2, Part II "Hull";

.4 materials used for the manufacture of parts of equipment working at temperatures below $-50\,^{\circ}C$ 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 are to 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 are to be protected against galvanic corrosion.

2.4.3 Steel piping of refrigerant, secondary refrigerant and connecting pieces of these pipes made of steel other than stainless steel are to be galvanized on the outside or treated in some other way ensuring equivalent antirust protection. Surfaces in contact with refrigerant or secondary refrigerant are not to be galvanized.

In manufacturing pipes the requirements of 2.4.1 and 2.4.2 are to 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 are to comply with adequate requirements of Part XI "Electrical Equipment".

2.5.2 Driving motors of compressors, pumps and fans are to meet the requirements of Sections 5 and 10, Part XI "Electrical Equipment".

3 SPACES FOR REFRIGERATING PLANTS, REFRIGERATED CARGO, PROCESS SERVICES

3.1 REFRIGERATING MACHINERY SPACES

3.1.1 The refrigerating machinery spaces are to meet the requirements of 4.5.1 and 4.5.2, Part VII "Machinery Installations" as well as the requirements of this Chapter.

Refrigerating equipment working with Group II refrigerants is to be arranged in isolated gastight compartments.

The possibility of installation of a refrigerating machine using a Group II refrigerant in the common machinery space of the ship of less than 55 m in length is subject to special consideration by the Register in each case.

Drainage of the refrigerating machinery space is to be provided as required by 7.4.10, Part VIII "Systems and Piping".

3.1.2 The machinery, apparatus and piping are to be so arranged in the refrigerating machinery space as to permit easy access for maintenance and to enable the parts to be renewed, if necessary, without dismantling the machinery and apparatus from foundations. Care should 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 is to 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 is to 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 are not to lead in accommodation, public and service spaces or spaces in communication therewith. One of the means of escape is to lead to the open deck.

Where the escape routes pass through corridors and casings, these are to be fitted with supply and exhaust ventilation, forced air supply being obligatory. The starting arrangements of the ventilation are to 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 are to be provided with water-screen arrangements. The starting means of water screens are to 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 of the water fire main system and 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 is to 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 is to 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, should the switchboard of the refrigerating units be de-energized.

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 are to be provided at the exits of the refrigerating machinery space.

3.2 REFRIGERANT STOREROOMS

3.2.1 Refrigerant storerooms are to be separated from other spaces, with location in the ship and construction of boundaries, as well as refrigerant storage cylinders for the refrigerating plants chosen in compliance with the requirements of 6.4.5, Part X "Boilers, Heat Exchangers and Pressure Vessels".

The spaces intended for storage of the refrigerant are to 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.

3.2.2 The refrigerant storage cylinders are to be secured in place in such a way that they will not shift in adverse weather conditions.

Non-metallic pads are to 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 should 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 are to 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 are to be provided with condensate tray. For the refrigerated spaces with the ambient air temperature being negative the condensate trays are to be provided with the heating system.

3.3.3 Where the air cooling system is adopted, the air coolers are to 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 is to 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 are to be fitted. The sluice valves are to be designed as strong as the bulkhead. The sluice valves are to 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 is to have an arrangement to permit being closed airtight.

3.3.7 Air ducts passing through refrigerated cargo and other spaces are to 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 is to 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 is to be met.

3.3.9 The refrigerated spaces are to be fitted with telethermometric arrangements.

3.3.10 Drainage of refrigerated spaces is to conform to the requirements stated in 7.8, Part VIII "Systems and Piping".

3.3.11 Piping passing through refrigerated spaces is to comply with 5.4, Part VIII "Systems and Piping".

3.4 FREEZING AND COOLING APPARATUS

3.4.1 The arrangement of air coolers and fans in freezing apparatus is to comply with the requirements of 3.3.1.

3.4.2 Provision is to be made in the refrigerating machinery space for the devices for monitoring the operation of freezing and cooling apparatus.

3.4.3 Valves and fittings of the piping carried inside the freezing apparatus are to be located in the portion of the piping outside the chamber.

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 will require special consideration by the Register in each case.

3.5.2 Spaces containing the process equipment working under pressure of Group II refrigerant are to be provided with a fire hydrant and hose of the water fire main system.

3.5.3 Spaces containing the process equipment working under pressure of a refrigerant are to 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 are to 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 are to comply with the requirements specified in this Part of the Rules and also with those of 5.1.3 and 5.1.4.1, Part IX "Machinery".

4.1.2 Parts of compressors exposed to the action of dynamic loads and excessive pressure are to 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 are to have stop valves apart from the automatic valves.

4.1.4 Cavities in compressors reserved for refrigerant, lubricating oil and cooling water are to have drain arrangements, where necessary.

4.1.5 A pressure relief valve or more other self-operating safety device is to 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 is to be not less than the maximum volumetric capacity of the compressor stage protected.

The pressure rise 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.

4.2 PUMPS

4.2.1 Pumps are to comply with the requirements set out in 5.2, Part IX "Machinery".

4.3 FANS

4.3.1 Fans are to 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 are to 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 are to 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, is not to be less than determined by the following formula:

$$G = qS/r \tag{5.1.2}$$

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 is to 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 are to have suitable facilities for removing water, air, lubricating oil and secondary refrigerant.

5.1.4 Pressure vessels with Group II liquid refrigerants are to have suitable facilities for emergency dumping of the latter.

The rated time of refrigerant dumping shall be not 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.

5.2 AIR COOLERS

5.2.1 Air coolers working under pressure of a refrigerant are to 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 are to 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 is to be arranged in not less than two sections, each of which is to be capable of being disconnected, if necessary.

6 FITTINGS AND PIPING

6.1 FITTINGS AND SAFETY VALVES

6.1.1 The refrigerating plants are to be provided with shut-off, regulating and safety devices designed for pressure of not less than 1,25*p*, where *p* is the design pressure as given in 2.2.1.

As a rule, valves and fittings are to 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 safety valve springs are to 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 are to comply with the relevant requirements set out in Section 2 and Chapter 5.4, Part VIII "Systems and Piping" and also with the requirements of this Chapter.

In accordance with Table 1.3.2, Part VIII "Systems and Piping", piping conveying Group I refrigerant is Class II piping while piping conveying Group II refrigerant is Class I piping.

6.2.2 The piping of refrigerant and liquid secondary refrigerant is to be made of seamless pipes. The piping of the liquid secondary refrigerant is to be made of steel pipes. The joining of steel pipes carrying the refrigerant is, as a rule, to be made by welding and, where copper pipes are concerned, by welding or brazing. Where pipes are joined with fittings, machinery, heat exchangers and pressure vessels, detachable connections may be admitted.

6.2.3 The refrigerant delivery piping of the compressors and refrigerant pumps is to 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 are to be fitted on the liquid piping carrying the refrigerant slightly soluble in water. They are to be fitted together with gauze filters in the liquid lines to the regulators or structurally connected with them.

6.2.5 The pipes from safety devices (other than those referred to in 4.1.5) are to be led overboard below the waterline corresponding to the minimum draught. These pipes are to be provided with non-return valves fitted in proximity to the ship's side.

Refrigerant leak detectors are to 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.

The discharge of Group II refrigerants is subject to special consideration by the Register in each particular case.

6.2.6 The pipes for refrigerant dumping from heat exchangers and pressure vessels in emergency are to terminate into a header (see 5.1.4) located outside the refrigerating machinery space, but near the access thereto. Each dumping pipe is to be fitted with shut-off valves located near the header. These valves are to be protected from opening by unauthorized persons and must be so constructed as to be convenient for sealing when closed. The common main of the emergency dumping header is to have a non-return valve fitted in accordance with 4.3.2.10, Part VIII "Systems and Piping" and is to be led overboard below the waterline corresponding to the minimum draught of the ship. To permit purging of the common main, steam or compressed air connections are to be provided.

The inner diameters of the refrigerant emergency dumping pipes of separate heat exchangers and pressure vessels are not to be less than the diameter of the relief valve determined as required by 5.1.2. The cross-sectional area of the dumping main is to be not less than the total cross-sectional area of three largest dumping pipes communicating with the main.

6.2.7 For pipes led overboard in a place below the waterline according to 6.2.5 and 6.2.6, the minimum pipe wall thickness in all cases is not to be less than that specified in column 3 of Table 2.3.8, Part VIII "Systems and Piping".

6.2.8 Group II and Group III refrigerant piping is not to pass through accommodation and service spaces.

7 INDICATING AND MEASURING INSTRUMENTS AND AUTOMATIC DEVICES

7.1 INDICATING AND MEASURING INSTRUMENTS

7.1.1 The compressors and apparatus for the refrigerating plants are to be fitted with suitable devices to permit the working parameters being monitored. Besides, the arrangement should provide for the possibility of installing additional indicating and measuring instruments required when testing the plant.

7.1.2 Indicating and measuring instruments are to be placed in readily accessible and visible positions. The instruments are to bear clear marks indicating admissible values of the parameters controlled.

Indicating and measuring instruments are to be checked and accepted by competent bodies which are recognized by the Register.

7.2 AUTOMATIC DEVICES

7.2.1 Automatic systems as well as the elements and components constituting these systems are to comply with the requirements of Part XV "Automation".

7.2.2 Where automatic control of the refrigerating plant is used, facilities for local operation are also to be available.

7.2.3 The refrigerant compressors are to be provided with automatic 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 are to be fitted with automatic 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, should the level of refrigerant liquid rise inadmissibly.

7.2.5 Plants incorporating "shell and tube" type evaporators are to be fitted with automatic devices capable of:

.1 stopping the compressor, should the circulation of the secondary refrigerant inside the evaporator be impeded, or cutting off this evaporator from the refrigerant system;

.2 stopping the compressor, should the temperature of secondary refrigerant drop inadmissibly.

7.2.6 The refrigerating plants are to 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 — 7.2.5.

Provision is to be made at the local control station for decoding of the above signals.

7.2.7 In addition to the requirements of 7.2.6, the following shall be provided at the control stations of automated refrigerating plants of unattended operation:

.1 indication of the plant machinery operation and stopping showing temperature in refrigerated spaces;

.2 alarm to warn of temperature deviation in refrigerated spaces from that required for the cargo carried;

.3 alarm to warn breakdown of circulation fans of air coolers.

7.2.8 Spaces with equipment under refrigerant pressure are to be fitted with gas detection panel and signal devices of maximum allowable concentration of refrigerant (3000 mg/m^3 — freon, 20 mg/m^3 — ammonia), warning audible and visible alarm is to be mounted before entrance to this space. This warning signal shall be duplicated in main control station of the machinery installation as well as on the navigating bridge.

7.2.9 The system for temperature, humidity and atmosphere control inside the refrigerated spaces should 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 is to be efficiently insulated. The applied insulating materials should be of a type approved by the Register and should also comply with the requirements of the properly authorized Sanitary Inspection Authorities.

8.1.2 The insulating materials adopted for refrigerated cargo spaces are to have adequate resistance to adverse biological factors and are to 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 are to be coated with oil-resistant and inodorous material. The coating is to be applied before the insulation of these surfaces is arranged.

8.1.4 Care should 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 are to be provided.

8.1.5 The insulation of refrigerated cargo spaces is to be covered with suitable lining or other protective coating. In places where insulation linings may be crushed by cargo, they are to be suitably protected.

8.1.6 The insulation in freezing apparatus is to 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 carried through bulkheads and decks, no direct contact with surfaces they pierce is permitted to prevent heat exchange.

8.2.2 Provision is to be made for protecting the insulation of piping from dampness.

8.2.3 The insulating materials used for piping are to be non-combustible in accordance with 2.1.1.1, 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 2.1.1.1, Part VI "Fire Protection" provided they are kept to the minimum quantity and their exposed surfaces have low flame spread characteristics.

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 of the Rules.

9.1.2 The refrigerating plants should 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 should be consistent with transportation conditions of particular kinds of cargo.

The refrigerating capacity margin of the plant should be not 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 should meet the requirements of Part III "Thermal Containers" of Rules for the Construction of Containers.

9.1.4 The atmosphere control system inside the thermal containers should be capable of maintaining the required oxygen concentration in the containers.

9.1.5 The cooled air supplied to the thermal containers should be sufficiently dry to avoid ice formation in flexible couplings.

9.1.6 The thermal containers carried on board ship should comply with the requirements of Part III of Rules for the Construction of Containers and Guidelines on 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 "Г" (see 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 is to meet the requirements for operation with controlled atmosphere.

10.1.2 Equipment, leading of piping should 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 should be fitted with a safety device, whose pressure set point and pressure relieving capacity are to be such that the pressure in the space is not to exceed 0,5 kPa (50 mm water column) and not to be less than 0,2 kPa (20 mm water column).

10.1.4 Gas should be discharged from the safety device through vertical ducts whose outlets are to 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 should 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 should not be hostile to the cargo carried, insulating and structural materials of the refrigerated spaces.

10.1.7 Alarm is to be provided to automatically giving audible and visual warning at least 60 sec before the inert gas injection takes place.

The alarm should 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 should 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 should 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 is to 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 are to 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 should 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 should be provided on board ship.

10.1.13 The supply and exhaust ducts of the atmosphere control system are not to pass through the accommodation and service spaces.

11 REFRIGERATING PLANTS DESIGNED FOR COOLING OF LIQUEFIED GAS

11.1 GENERAL PROVISIONS

11.1.1 The refrigerating plants should ensure maintenance of temperatures and pressures as may be required for the carriage of liquefied gas in bulk.

11.1.2 The refrigerating plants should comply with the requirements of 4.2, Part VIII "Systems and Piping" of 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 should be indicated in the Classification Certificate for the refrigerating plant.

12 TESTS

12.1 TESTS AT MAKER'S WORKS

12.1.1 Tests of the refrigerating plant components listed in this Chapter are to 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 are to be carried out by a test pressure of not less than 1,5p in accordance with 2.2.1.

Components working under the pressure of secondary refrigerant or water are to be tested by a hydraulic pressure of 1,5 times the working pressure, but not less than 0,4 MPa, whereas box structures are to 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 are to 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 is to 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 in addition to the above-mentioned tests 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 are to be tested in accordance with the requirements of 1.4, Part IX "Machinery".

12.2 TESTING ON BOARD

12.2.1 After the refrigerating plant has been completely assembled on board, the entire refrigerant system is to be subjected to pneumatic leak tests at a test pressure of 1,0p in accordance with 2.2.1.

12.2.2 Pneumatic test on board may be carried out using nitrogen, carbon dioxide or dried air.

12.2.3 Upon completion of leak test the Group I refrigerant system is to be dried and tested for tightness by a vacuum-test at a residual pressure of not more than 1,0 kPa.

12.2.4 After the system has been filled with refrigerant all joints and fittings are to be checked for leak.

12.2.5 All pipes of secondary refrigerant and cooling water systems together with pertaining fittings are to be subjected to leak tests under operating conditions.

12.2.6 Air ducts to the thermal containers should 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 with design backpressure. Air flow (by amount of air) available at each thermal container should not differ by more than ± 5 per cent from the design one.

12.2.7 After the cooled air ducts have been completely fitted on board before installation of insulation, strength tests should be carried out by air pressure of not less than 1,5 times the design pressure and also leak tests should be carried out by a working pressure at the design backpressure.

12.2.8 After the insulation has been completely installed, tests of the refrigerating plant should be carried out under the programme agreed with the Register, to make sure that the requirements of 2.3, 8.1, 8.2 have been met.

13 SPARE PARTS

13.1 GENERAL REQUIREMENTS

13.1.1 Each refrigerating plant is to be provided with spare parts carried on board to an extent that is not less than required by this Section.

13.1.2 The spare parts are to 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 are to be supplied with spare parts according to the provisions of Section 10, Part VII "Machinery Installations".

Electric motors of compressors, pumps and fans are to 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 are to 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	Fan impeller with shaft for refrigerated spaces and freezing apparatus of each size used	1
6	Control refrigerant expansion valve of each size used	1
7	Assorted cocks, valves and fittings of each size used	1
8	Gaskets and packings of each size used	1
9	Thermometers, pressure gauges and vacuum gauges of each size used	1
10	Safety valve springs of each size used	2
11	Leak detector	1
12	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 present Part of the Rules applies to materials and products that are subject, in conformity with the other parts of the Rules, to the manufacture supervision of the Register.

Requirements pertaining to the choice and application of materials and products are to be found in the relevant Parts of the Rules.

1.1.2 In addition to the requirements of the present Part, materials and products are to 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 are to 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 Rules requirements 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 should be carried out taking into account the most strict requirements.

1.1.4 The materials and products subject to supervision that are listed below should be manufactured by works for which Manufacturer Recognition Certificates were issued by the Register:

.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 propeller castings of copper-based alloys;

.7 semi-finished products of aluminium alloys for hull structures;

.8 chain cables and ropes;

.9 chain steel.

1.1.5 The materials subject to supervision that are listed below should be manufactured by works having the Type Approval Certificate:

.1 materials for reinforced plastic structures;

.2 laminated textiles;

.3 retro-reflective materials;

.4 foam plastics;

.5 adhesive, polymer pastes and coats.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to the general terminology of the Rules are given in the General Regulations for the Supervision.

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.

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.

A semi-finished product is a casting, forging, sheet or tube and etc. intended for machining and technological treatment to acquire the finished state.

A sample is a portion of a semi-finished product or product or a specially fabricated blank of which test specimens are to be machined.

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 SCOPE OF SUPERVISION

1.3.1 General provisions.

1.3.1.1 The regulating provisions for the extent and procedure of supervision are to be found in General Regulations for the Supervision.

1.3.1.2 The supervision of materials and products, effected by the Register, is composed of the following:

.1 consideration of technical documentation containing technical requirements for manufacture;

.2 survey and recognition of material and product manufacturers;

.3 manufacture survey and testing of materials and products;

.4 issue of relevant documents on the basis of supervision.

1.3.2 Recognition of materials, methods of their manufacturing and of manufacturers.

1.3.2.1 Materials and products as well as methods of their manufacturing that are used for the first time and being different from or not regulated by the present Part should be recognized by the Register and manufactured at works recognized by the Register.

1.3.2.2 Before the start of manufacturing of materials and products, mentioned in 1.1.4 and 1.1.5, under the Register supervision the manufacturer should apply to the Register for recognition of their products as being in compliance with the Rules and for getting the Manufacturer Recognition Certificate or Type Approval Certificate.

1.3.2.3 Together with the application, the following should be enclosed: information on the purpose and manufacturing procedure of the material, technical documentation for manufacture with indication of chemical composition, mechanical, technological and special properties, results of earlier testing and data on application (if any) to confirm that the material can be used in accordance with its purpose.

Attached to the application should be information on the process of manufacture and the system of quality control of the items under supervision as well as a program of control testing.

The availability at the works of the quality assurance system, which complies with ISO standards 9002 and 9001, confirmed by the document issued by the authorized organisation, can be considered by the Register an evidence of the necessary level of control systems, implemented at the works, without any additional requirements in this field.

The control test program should be drawn up on the basis of the Rules and the Register's additional requirements, standards, or other technical documentation which aimed at testing the products quality stability at the particular manufacturer's works.

1.3.2.4 If, after consideration of the information submitted and technical documentation for manufacture of materials and approval of the test program, these are found acceptable, the works survey and testing are carried out.

Testing should be carried out at the manufacturer's works or in laboratories recognized by the Register. Tests according to the program approved by the Register should be conducted in the presence of the Register representative.

1.3.2.5 If the testing results are acceptable, the use of material in accordance with its purpose is permitted and the works is recognized as its manufacturer. According to 1.1.4 and 1.1.5 the Register issues the necessary documents. The validity of these documents can be extended on the basis of the acceptance test results under the continuous Register supervision at the works in the past period and if the terms of documents issuance are unchanged. The date of the next extention is pointed out in the Register documents.

1.3.2.6 If the steel for products and rolled stock manufacturing is delivered to the steel-rolling plant by other works, the Register should be given the full information about the method of this steel manufacturing, the documentation according to which it is delivered and about the supplier's works, and also the chance to survey the works. The Register can demand the steel supply only by works it recognizes.

1.3.3 Manufacture supervision.

1.3.3.1 Materials and products listed in 1.1.4 are subject to the manufacture supervision of the Register including surveys and testing prescribed by the relevant chapters of this Part or by standards and technical documentation.

Control of the surface, dimensions and mass of materials and products should be effected by the manufacturer. The availability of the Register certificate does not relieve the manufacturer of the responsibility if a material or product is subsequently found defective or does not comply with agreed standards or technical requirements as regards its dimensions, mass and surface finish.

Survey and testing of materials and products including the issue of relevant Register certificates is generally effected at the manufacturer's works, but in any case, after the final technological operation which substantially affects the properties of material (for instance, heat treatment).

1.3.3.2 Prior to survey and testing, the manufacturer is to submit the following information to the Register:

name, type or trade mark of material/product;

name and number of standard;

grades of or requirements for materials contained in the Rules or technical documentation;

condition of supply;

customer and order number, structure for which the material/product is intended (if known);

quantity;

number of cast, identification number;

numbers of samples/specimens prepared for testing.

The manufacturer is to confirm that the materials/products submitted are to the satisfaction of the

Register.

When steel is approved in accordance with 3.13, information concerning condition of supply, hot and cold forming and postheat treatment as well as welding recommendations should be submitted besides the information listed above.

1.3.4 Testing.

1.3.4.1 Testing should be conducted under the Register supervision.

1.3.4.2 If testing results are unsatisfactory, the tests may be repeated subject to the following conditions:

.1 where the test results are unsatisfactory due to local defects in the specimen material, faulty machining of specimens or faulty test equipment, the test should be repeated on the same number of specimens;

.2 where the test results are unsatisfactory, the test should be repeated on a double number of specimens machined from the same piece.

In case the results of re-testing are satisfactory, the product in question as well as the other products of the batch may be accepted. If, in the case of re-testing, at least one test yields unsatisfactory results the product is to be rejected and the rest of the batch may be accepted provided the test results obtained on specimens that are machined from two other products of the same batch prove satisfactory.

When the average impact energy value of three impact test specimens according to Fig. 2.2.3.1-2 fails to meet the required value, or the value for two specimens is below the required average value, or when the value for a single specimen is below 70% of specified average value, three additional specimens of the same material may be tested. Proceeding from the results of initial and additional testing the average impact value for six specimens is determined. If this average complies with the requirements and not more than two values are lower than the average or not more than one value is below 70% of it the piece or batch may be accepted;

.3 if the properties of material are improved as a result of heat treatment then after it the tests should be repeated and the extent of testing is to be similar to that of initial testing;

.4 when, to ensure required mechanical properties, the heat treatment has to be repeated one should be guided by agreed standards or should act on agreement with a Surveyor to the Register; the heat treatment may be repeated not more than thrice;

.5 when a batch of material is rejected the products comprising the batch may, at the manufacturer's discretion, be tested individually and the products for which the test results are satisfactory may be accepted.

1.3.4.3 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 the tests to be repeated in the presence of its representative.

1.3.4.4 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 consideration of the deviations by the Register and in case a relevant application from the manufacturer is available.

1.3.5 When the results of surveys and testing stated under 1.3.2, 1.3.3 and 1.3.4 are satisfactory the Register would issue forms relevant to the case.

Before the Surveyor to the Register signs the Certificates, the manufacturer should submit to him a confirmation in writing that the material is manufactured by an approved technological process and has satisfactorily withstood all the tests required by the Rules.

If inserted with a stamp or printed on each copy of test certificate or manufacturer's certificate containing the name of the manufacturer and the authorized person's signature, the following statement may be adopted by the Register: "We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules for the Classification and Construction of Sea-Going Ships of Russian Maritime Register of Shipping".

1.4 MARKING

1.4.1 The marking of materials is to be carried out in accordance with standards taking the following requirements into consideration:

.1 In the case of semi-finished products delivered in single pieces each one of them is to be marked. For shipments in bundles two weather-resistant labels containing the marking are to 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 are to be agreed with the Register.

Semi-finished products to undergo further machining are to be stamped, as far as possible, in spots not to be machined.

The stamp is to stand out clearly and be framed with a bright paint resistant to atmosphere.

.2 As a rule, the stamp is to 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 are to be removed or cancelled.

1.5 LABORATORIES ENGAGED IN TESTING

1.5.1 The present Chapter applies to laboratories engaged in testing of materials subject to the supervision of the Register.

1.5.2 Laboratories of metallurgical works and of other works and bodies engaged in manufacture of materials and testing 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 works and bodies may determine chemical composition and effect testing for the purpose of determining mechanical properties, etc. only after being recognized by the Register.

1.5.3 Laboratories engaged in non-destructive testing of materials (for instance, radiography, magnetic particle tests, etc.) need not be specially recognized by the Register. The documents issued by the above laboratories are to contain information about the testing method and other technical data necessary for assessing the test results.

1.5.4 Laboratories engaged in the ultrasonic testing of materials and products are to have a Recognition Certificate issued by the Register. In the Certificate, the scope and conditions of applying the ultrasonic testing are to be defined. To be recognized for applying the ultrasonic testing, an application is to 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 should be made to confirm reliability of the test results and the possibility of their reproduction.

The test program is to 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.) is to contain all the data necessary for the assessment of material quality and subsequent issue of certificate.

A report of the ultrasonic testing of products is to include at least the following information: kind of product, material and major dimensions of product, type of ultrasonoscope and finders, testing frequency, method of testing and type of unified reference block, size and position of defects, name of operator and date of testing.

2 PROCEDURES OF TESTING

2.1 GENERAL PROVISIONS

2.1.1 The requirements of the present Section cover the types and procedures of testing materials which are subject to the supervision of the Register during their manufacture. The need to conduct the tests and evaluation criteria of test results are defined in the relevant Sections of this Part or other Parts of the Rules.

2.1.2 This 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, are to 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 are to be met.

2.1.5 Test samples from which test specimens are cut are to have undergone the same treatment as the material from which they have been taken (e.g. heat treatment). Test specimens are to be prepared in such a manner that properties of the material are not affected.

2.1.6 All the tests are to 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 should be within ± 1 per cent. The machines should be regularly, as a rule at least once per year, checked and calibrated by the duly designated national authorities.

The results of regular checks are to be submitted to the Register.

2.2 TESTING PROCEDURES FOR METALS

2.2.1 Temperature.

The temperature of the ambient air during the tests is to comply with the requirements of the standards unless expressly provided otherwise in the subsequent sections and chapters of this 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 are to be determined:

.1 yield stress Re 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 should not exceed 30 N/mm^2 per second for steel and cast iron and 10 N/mm^2 per second for non-ferrous metals;

.2 when no well defined yield phenomenon exists, the 0,2% proof stress $R_{p0,2}$ is to be determined according to the applicable specification.

For austenitic and duplex stainless steel products the 1% proof stress R_{p1} may be determined instead of, or 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 is not to exceed that corresponding to a strain rate at maximum load of 40% of the gauge length per minute. For brittle materials, such as cast iron, the stress rate is not to 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 valid if the fracture occurs at least the following distance from the end marks of the gauge length:

for round test specimens — 1,25d;

for flat test specimens — $b+a$.

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 is to 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 are to be carried out on the test specimens of the following types (see 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.

Tests are to be carried out on the specimens according to Table 2.2.2.3.

Test specimens for a tensile test, as a rule, should 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 are to be used.

2.2.2.5 Tests across the thickness are to be carried out on the round specimens of the following dimensions:

$d = 6$ mm at 15 mm $< t <$ 25 mm,

$d = 10$ mm at $t >$ 25 mm,

$L_c \geqslant 2d$.

Where the product thickness does not allow to prepare specimens of sufficient length suitable for the gripping jaws of the testing machine, extension pieces may be attached for the plate surface by suitable welding methods in such a way as to ensure a minimal heat affected zone.

2.2.2.6 When wire is tested, its specimens of full cross-section are to be of the following dimensions:

Lo = 200 mm,

Lc = Lo + 50 mm.

2.2.3 Impact tests.

2.2.3.1 The impact toughness KCU is to 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.

Impact tests are to be carried out on Charpy machines having a striking energy from 150 to 300 J.

The impact energy KV and KU is to be determined on three test specimens and impact toughness KCU on at least two specimens. The impact energy KV and KU is to be determined as an average value obtained at testing three specimens according to Table 2.2.3.1-4; on individual value obtained is to be less than 70 per cent of the required minimum value. When the impact toughness KCU is determined on two specimens, each of the results obtained is not to be less than the required minimum value.

The impact toughness KCU on test specimens having a thickness equal to, or less than, 10 mm is to be determined only if required by the Register. The required minimum value is subject to agreement with the Register.

2.2.3.2 The dimensions of the test specimens without any notch used for impact tests are to be as shown in Fig. 2.2.3.2.

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 $d = 10$, preferable $L_0 = 5d$ $L_c = L_0 + d$ $R = 10$ $R = 20$ for materials having $A_5 \leqslant 10\%$, and nodular cast iron
	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 $b = 25$ $L_0 = 5{,}65\sqrt{S_0}$ $L_c = 2\sqrt{S_0}$ $R = 25$ or:
		Flat non-proportional test specimens
		a = rolled product thickness $b = 25$ $L_0 = 200$ $L_c = 225$ $R = 25$ 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 should be located at one-quarter of the rolled product thickness from the surface. The use of test specimens of the following dimensions is preferable: $d = 14$ $L_0 = 70$ $L_c = 85$ 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*	$L_0 = 5{,}65\sqrt{S_0}$ $L_c = L_0 + D$ $a = t$ $b \geqslant 12$ $L_0 = 5{,}65\sqrt{S_0}$ $L_c = L_0 + 2b$ 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

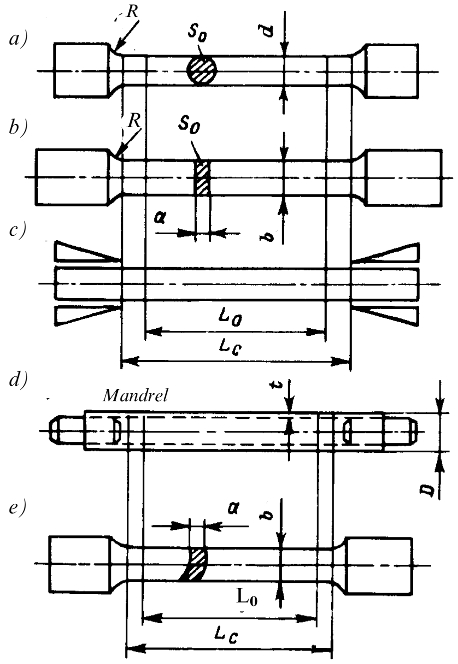


Fig. 2.2.2.3

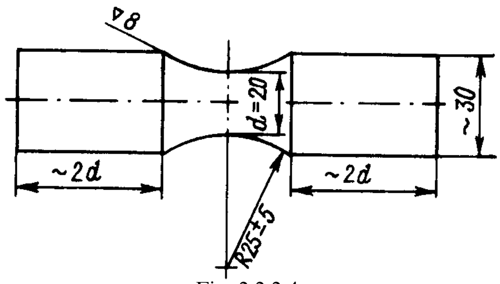


Fig. 2.2.2.4

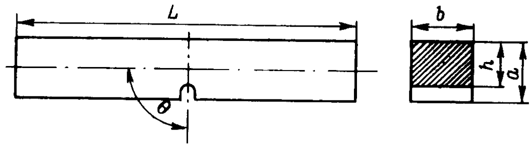


Fig. 2.2.3.1-1

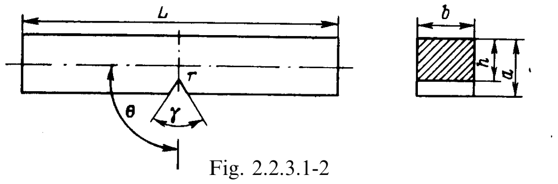


Fig. 2.2.3.1-2

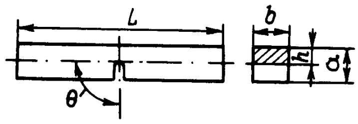


Fig. 2.2.3.1-3

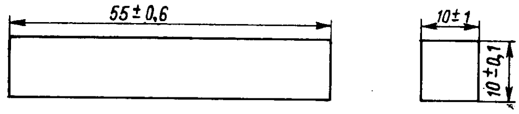


Fig. 2.2.3.2

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	±0,10
Thickness a, mm	10	±0,10
	7,5	±0,10
	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

Table 2.2.3.1-4

Dimensions of test specimen, mm	Average value of impact energy E, J
10×10×55	1E
10×7,5×55	5/6E
10×5×55	2/3E

2.2.3.3 Impact tests should be carried out on Charpy machines having a striking energy not less than 150J. The distance between the supports is to be (40±0,5) mm. The pendulum is to 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 are to be subjected to supercooling. When the tests are carried at a temperature down to −60°C, the test specimens are to be supercooled to − 4°C. Deviations from the required test temperature at the moment of breaking of the test specimen are not to exceed ±2°C.

2.2.3.4 The ageing resistance is to be proved by impact testing of specimens according to 2.2.3.1. Samples from which test specimens are prepared are to be pre-elongated to reach a 10 per cent permanent set, then heat treated for at least 30 min at (250±5)°C. When machined, the specimens are not to get heated above the said temperature. Unless specified otherwise, the aged specimens are to show the impact test value equal to 50 per cent of the minimum specified impact energy value KV or impact toughness value KCU obtained on non-aged specimens at 20°C; in no case, however, will the impact energy be below 27 J and the impact toughness below 20 J/cm^2.

2.2.4 Hardness testing.

Hardness is to 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 are to be used for bend test.

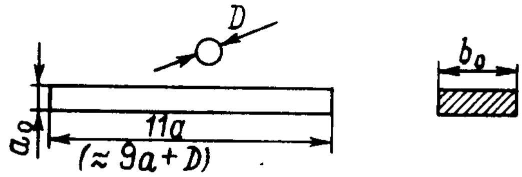


Fig. 2.2.5.1

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 this Part.

The bend test of plates and sections is to 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 is to be on the compression side of the bend test specimen.

The bend tests of forgings, castings and similar semi-finished products are to be carried out on the specimens having the following dimensions: $a_0 = 20$ mm, $b_0 = 25$ mm.

2.2.5.2 The flattening test is carried out on the pipes with an external diameter $D \leqslant 400$ mm and wall thickness $t \leqslant 15$ per cent of the external diameter.

The length of the specimen (pipe length) is to be equal to 1,5 times the external diameter, but is to be not less than 10 mm or greater than 100 mm. Unless otherwise provided in the Rules or standards, the distance H, in mm, between the platens is to be determined by the formula:

$$H = \frac{(1+c)t}{c+(t/D)}, \qquad (2.2.5.2)$$

where c = constant dependent on the material and assumed on agreement with the Register;
t = specified thickness of the pipe, mm;
D = external diameter, mm.

The test specimens are to be flattened until the distance between the platens is equal to 2,25t.

For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

2.2.5.3 The drift expanding test is carried out on tubes having an external diameter less than, or equal to 150 mm and a wall thickness up to 9 mm. A conical mandrel is to be forced into the test specimen vertically to the longitudinal axis until the required degree of expansion is reached. An angle of drift is to be 30°; 45°; 60° or 120°.

The length of the test specimen L is to be equal:

for steel tubes:

$L = 2D$ when $\alpha = 30°$;

$L = 1{,}5D$ when $\alpha = 45°$, 60° or 120°, but not less than 50 mm;

for copper and aluminium alloys:

$L = (2-3)D$.

2.2.5.4 The ring expanding test is to be made on steel tubes with an external diameter of 110 to 508 mm and a wall thickness not more than 30 mm. The wall thickness to the external diameter ratio is not to exceed 0,13.

Length of the ring is to be between 10 and 15 mm.

The test specimen is to be expanded until it breaks, using two mandrels with a diameter equal to 3 times the tube wall thickness.

For welded tubes, the weld is to be placed at 90° to the direction of expansion.

2.2.6 Dropweight tests.

Where required by the Rules, the dropweight test and evaluation of results are made according to the standards. The test specimens are to have the following dimensions:

25 × 90 × 360 mm;

19 × 50 × 130 mm;

16 × 50 × 130 mm.

When the test specimens are made using flame cutting, their dimensions are to be increased by at least 25 mm, but not less than a plate thickness.

The machining of the plate to prescribed specimen thickness is to be on one side only.

If not otherwise specified, the specimens may be of any orientation.

2.2.7 Macro- and microstructural analysis.

Where required by this or other Parts of the Rules, macro- and microstructural analysis of metals is to be made in compliance with 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 are to be recorded in the form of radiographs with a summary of test evaluations attached.

2.2.9.2 Ultrasonic testing is to 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 are to be regularly checked.

The method for determination of a defect size is selected in compliance with relevant standards, otherwise it is to 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 is to 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 is to have appropriate intensity of the field.

A need in demagnetization of the product after completion of the test is to 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 are to be agreed with the Register.

2.2.9.5 The evaluation of non-destructive testing results is to be made only by the works responsible for the results submitted to the Register. Records of testing are to 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 are to be conditioned at an ambient air temperature (23 ± 2)°C and relative humidity (50 ± 5)%. Unless expressly provided otherwise, the duration of conditioning is to be at least 16 h. Testing is to 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 is to 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 whose shape and dimensions differ from those required by this Chapter.

2.3.1.4 Testing conditions other than those specified in this Chapter are to comply with the relevant standards.

2.3.2 Tensile tests.

2.3.2.1 Tensile strength of glass-reinforced plastics is to 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.

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	—

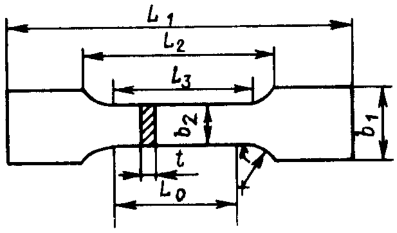


Fig. 2.3.2.1-1

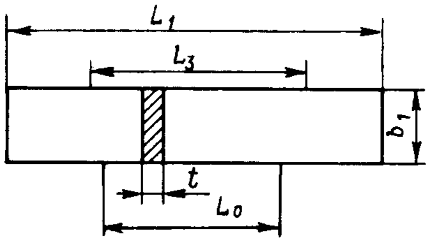


Fig. 2.3.2.1-2

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 should 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 should 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.

Notches out to the cloth

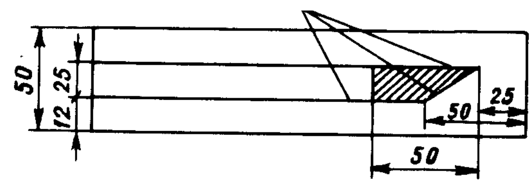


Fig. 2.3.2.4

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% of the lowest peak values to be found in the graph as measured on the central section of the specimen length making up 50% 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 should 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 is to 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 is to 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 is to be not in excess of 5 mm/min.

2.3.4 Determination of modulus of elasticity for glass-reinforced plastics.

The modulus of elasticity in tension is to 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 is to 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 is to 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 is to 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 should equal 16 times the specimen thickness. The load applied to the midlength of the specimen should 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) (25 ± 5) 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 is to be 30 mm.

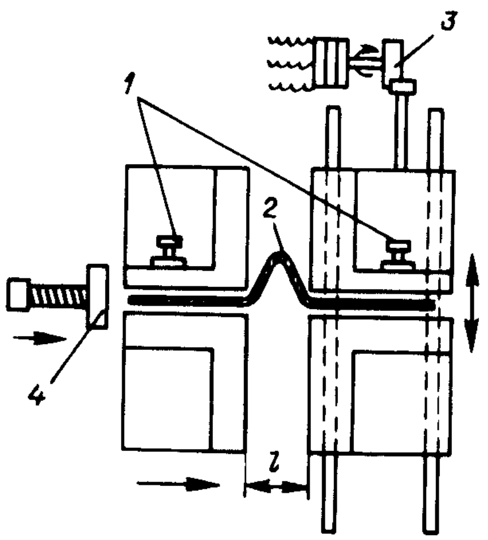


Fig. 2.3.5.3:
1 — grip; 2 — test specimen; 3 — motor; 4 — load

The test specimen being fixed, the grips are brought together until they touch each other. At this time, the load upon the test specimen must 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 is to 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 is to 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 are to 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 $(100 \pm 1) \times \times (100 \pm 1) \times (15 \pm 0{,}5)$ mm is conditioned at the appropriate temperature during 48 h.

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 is to be determined on test specimens having the dimensions $(50 \pm 1) \times (50 \pm 1)$ mm and a thickness equal to the thickness of the product, but not more than (50 ± 1) mm.

Before testing the specimens are to 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 is to 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 whose 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 is to 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 whose 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 retroreflective 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.

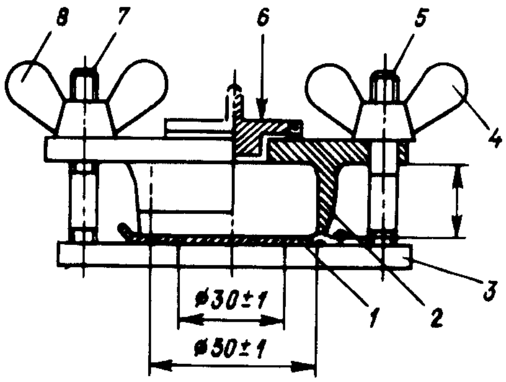


Fig. 2.3.11:
1 — test specimen; 2 — cylindrical chamber; 3 — base plate with a hole of 30 mm diameter; 4, 8 — wing nuts; 5, 7 — bolts; 6 — plug

The arrangement is filled up to the level of 20 mm with a mixture of oils in the following proportion:

30% of 2, 2, 4 — trimethylethane,

50% of toluene,

15% of diisobutylene,

5% 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 should be dried a little bit, the wet surface folded in two and the halves pressed to each other.

The wet surfaces should not stick to each other, nor should the fingers be stained when the surfaces are touched.

2.3.11.2 A sample whose 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 whose 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 whose 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 whose 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 should be conditioned in salty water with salt concentration 3,3 — 3,8% 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 $(70 \pm 5) \times (150 \pm 5)$ 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 semisubmersed condition during 16 h in enclosed volume.

After conditioning, the salt residues on the specimen surface should be washed off.

2.3.12.4 Specimens of retro-reflective material measuring $(70 \pm 5) \times (150 \pm 5)$ mm which are secured on an aluminium panel are sprayed with 5% 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.

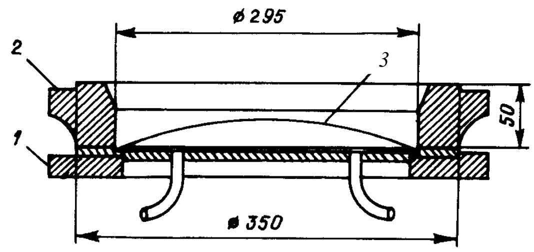


Fig. 2.3.13:
1 — base plate; 2 — clamping ring; 3 — specimen

From below, a positive air pressure of 27.5 kPa acts upon the test specimen. In 10 — 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 should remain on the specimen surface. Within the following 5 min, no bubbles should rise to the surface.

2.3.14 Cold resistance test.

The cold resistance test of laminated textiles is effected on rectangular specimens measuring $(100 \pm 5) \times (50 \pm 5)$ 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. By the end of the test the distance between the parallel parts of the test specimen should equal four times its thickness.

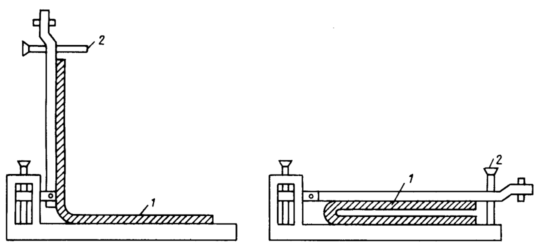


Fig. 2.3.14 Sketch of testing machine
1 — specimen; 2 — regulating screw

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%.

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 $(150 \pm 5) \times (75 \pm 5)$ 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 is to be found in Fig. 2.3.18.2. Measurements are taken at the observation angle of 0,2° and entrance angle of 5°.

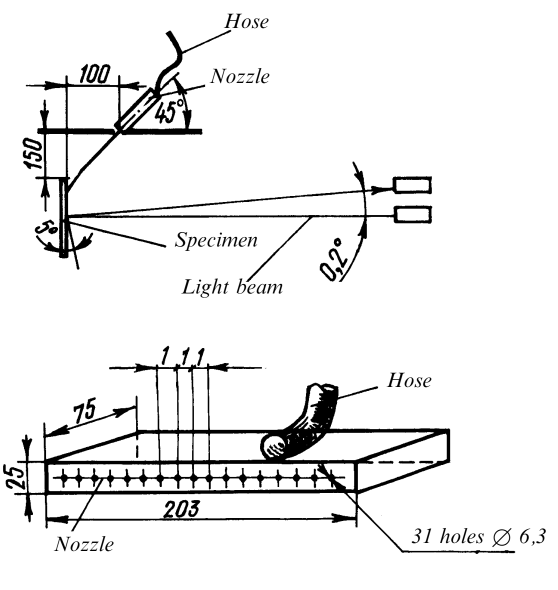


Fig. 2.3.18.2

2.3.19 The bend test of retro-reflective materials is made on specimens measuring $(25 \pm 5) \times (150 \pm 5)$ 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 are to 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% 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 400-475 g/m^2 must not be less than 50% of the initial value.

2.3.22 The abrasion-resistance test of retro-reflective material is made on specimens measuring $(150 \pm 5) \times (425 \pm 5)$ 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 $(90 \pm 5) \times (40 \pm 5) \times \times (12.5 \pm 5)$ mm and having a total weight of 450 ± 15 g. The bristles are to 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% solution of a detergent and rinsed in water.

The contaminant used for testing should 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 is to be examined in the course of approval tests by using the same welding methods that would be applied when producing structures subject to the supervision of the Register. The welding methods are indicated in the approval documentation for the material.

2.4.3 During the weldability test the following is to 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 are to 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 standards approved by the Register.

3 STEEL AND CAST IRON

3.1 GENERAL PROVISIONS

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.

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 is to be melted in open hearth or electric furnaces or in converters with top blowing of high purity gaseous oxygen. Cast iron is to be melted in cupolas or electric furnaces.

Use of other methods of steel and cast iron making is to be agreed with the Register.

When steel is not produced at the works where it is rolled, forged or drawn, a certificate is to 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 is to have access to the works at which the steel was produced.

3.2 HULL STRUCTURAL STEEL

3.2.1 General provisions.

The requirements of this Chapter apply to weldable heat-rolled steel plates, strips and sections up to 50 mm in thickness as well as to steel bars intended for hull structures and items subject to the Register supervision during their manufacture.

The present Chapter also includes additional requirements for hull structural steel plates and broad-strip steel of Grades E and E36, 50 through 100 mm thick.

Steel with different chemical composition, deoxidation method, heat treatment or mechanical properties, clad steel included, may be accepted subject to the special approval of the Register. Such steel is to have a special identification mark, namely, the letter S added to the grade symbol.

3.2.2 Chemical composition.

The chemical composition of steel is to 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 is to 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 should be at least 0,020%.

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 is not to exceed 0,30 per cent each.

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 × 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			
	Upper 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% 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%.
6. Grade D steel exceeding 25 mm in thickness should be killed, fine-grained and should contain A1 ≥ 0,015%.
7. When the tensile properties of standard full thickness non-proportional specimens with $L_0 = 200$ mm are determined the minimum elongation should 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 normal strength carbon steel the total carbon content plus 1/6 of the manganese content is not to 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 is not to 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 should 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 is not to be greater than grain size No.5.

For higher strength steel subjected to the thermo-mechanical controlled processing (TMCP), the carbon equivalent should 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

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) Mn Si (max) P (max) S (max) Cu (max) Cr (max) Ni (max) Mo (max) Al (min) Nb V Ti (max)	0,18 0,90 — 1,60 0,50 0,035 0,035 0,35 0,20 0,40 0,08 0,015 0,02 — 0,05 0,05 — 0,10 0,02 } $\leqslant$0,12								
Tensile properties	Tensile strength, R_m, MPa	440...590			490...620			510...650		
	Upper yield stress R_{eH}, min, 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%.
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 is to 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

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 should 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.

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	—

3.2.3 Mechanical properties.

The mechanical properties of normal strength steel are to comply with the requirements given in Table 3.2.2-1 while the mechanical properties of higher strength steel are to 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.

At the option of the manufacturer and on agreement with the Register, the impact energy at impact testing may be determined either on longitudinal (KV_L) or transverse (KV_T) specimens. Requirements for impact energy, when higher strength steel is concerned, are given in Table 3.2.3.

Table 3.2.3

Steel grade	Tempe-rature, °C	Average impact energy, 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	not applicable			
D40	-20	41	27	not applicable			
E40	-40	41	27	not applicable			

3.2.4 Condition of supply.

As far as the condition of supply is concerned, the steel is to be in agreement with Tables 3.2.4-1 and 3.2.4-2, and the condition of supply should be indicated in the certificate and the manufacturer's document.

When controlled rolling or thermo-mechanical controlled processing is permitted as an alternative to normalising (N), these procedures may be used subject to the special approval of the Register. These rolling procedures are defined as follows:

.1 Controlled rolling (CR) is a procedure in which generally the final rolling temperature is controlled within the range used for normalising heat treatments so that the austenite completely recrystallises.

.2 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 or below the Ar3 transition temperature and may involve rolling towards the lower end of the temperature range of the intercritical duplex phase region thus permitting little if any recrystallisation of the austenite.

Before subjecting these steels to further heating for forming or stress relieving, or using high energy input welding, consideration must be given to the possibility of a consequent reduction in mechanical properties.

The use of accelerated cooling on completion of rolling may also be accepted subject to the special approval of the Register.

3.2.5 Sampling.

Unless otherwise specified, the test samples are to be taken as follows.

The test samples of plates and flats wider than 600 mm are to be taken from one end so that the sample axis is located midway between the longi-tudinal 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

Table 3.2.4-1

Condition of supply for normal strength steels

Grades	Thickness, mm	Condition of supply
A	$t \leqslant 50$ $50 < t \leqslant 100$	Not regulated (any) Normalised (N), controlled rolled (CR) or thermo-mechanical controlled processed (TMCP)
B	$t \leqslant 50$ $50 < t \leqslant 100$	Not regulated (any) Normalised (N), controlled rolled (CR) or thermo-mechanical controlled processed (TMCP)
D	$t \leqslant 50$ $50 < t \leqslant 100$	Not regulated (any) Normalised (N), controlled rolled (CR) or thermo-mechanical controlled processed (TMCP)
E	$t \leqslant 100$	Normalised (N), or thermo-mechanical controlled processed (TMCP)
Note: Subject to the special approval of the Register, sections in Grade D steel may be supplied in the as rolled condition provided satisfactory results are consistently obtained from impact tests. Similarly sections in Grade E steel may be supplied in the as rolled condition or after CR.		

Table 3.2.4-2

Condition of supply for higher strength steels

Grades	Grain refining elements used	Thickness, mm	Condition of supply
A32, A36	Nb and/or V	$t \leqslant 12,5$ $12,5 < t \leqslant 100$	Not regulated (any) N, CR, TMCP
A32, A36	Al or Al and Ti	$t \leqslant 20$ $20 < t \leqslant 35$ $35 < t \leqslant 100$	Not regulated (any) Not regulated (as rolled subject to special approval of the Register) N, CR, TMCP
A40	Any	$t \leqslant 12,5$ $12,5 < t \leqslant 50$	Not regulated (any) N, CR, TMCP
D32, D36	Nb and/or V	$t \leqslant 12,5$ $12,5 < t \leqslant 100$	Not regulated (any) N, CR, TMCP
D32, D36	Al or Al and Ti	$t \leqslant 20$ $20 < t \leqslant 25$ $25 < t \leqslant 100$	Not regulated (any) Not regulated (as rolled subject to special approval of the Register) N, CR, TMCP
D40	Any	$t \leqslant 50$	N, CR, TMCP
E32, E36	Any	$t \leqslant 50$ $50 < t \leqslant 100$	N, TMCP N, TMCP
E40	Any	$t \leqslant 50$	N, TMCP or Q+T

Notes: 1. The requirements for impact tests are to be found in 3.2.6.2.

2. Subject to the special approval of the Register, sections in Grade A32, A36, A40, D32, D36 and D40 steels may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from impact tests. Similarly sections in Grade E32, E36 and E40 steels may be supplied in the as-rolled condition or after CR. The frequency of impact tests is to be in accordance with 3.2.6.3.

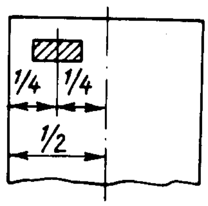


Fig. 3.2.5-1 Plate and flat

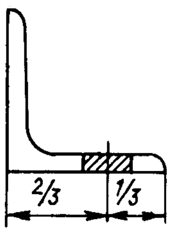


Fig. 3.2.5-2 Angle

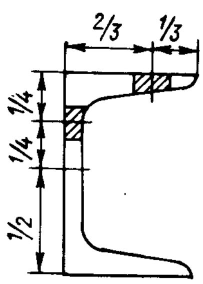


Fig. 3.2.5-3 Channel and beam

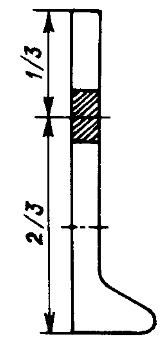


Fig. 3.2.5-4 Bulb bar

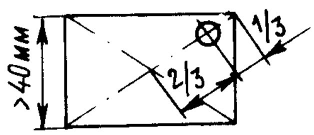


Fig. 3.2.5-5 Rectangular bar

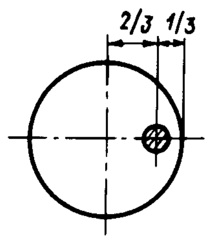


Fig. 3.2.5-6 Cylindrical bar

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).

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 are to 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 are to 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* is to be determined should 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 is to be cut perpendicular to the rolled surface and not closer than 25 mm to the flame cut or sheared edge.

3.2.6 Number of tests.

3.2.6.1 Rolled material is presented for tests in batches. A batch is to 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 is to 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 is to be made for each 50 t or fraction thereof. An additional test is to 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.

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 is to 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 should be as follows:

for plates and wide flats each piece is to be tested;

for sections and bars one set is to 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 is to be tested from each batch of 15 t or fraction thereof.

3.2.7 Inspection.

Allowable under-thickness tolerances of shell plates and wide flats for hull structures are not to exceed −0,3 mm. For steel less than 5 mm thick, the under-thickness tolerances should 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 are to be in accordance with Table 3.2.7.

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 are to be in accordance with standards.
2. The thickness measurements are to be taken not less than 10 mm from the plate edge.

The steel is to be reasonably free from segregations and non-metallic inclusions. The semi-finished products are to be free from cracks, slag inclusions and other defects prejudicial to the use of the material for its intended application. The semi-finished products are also to have workmanlike surface and are not to have been hammer dressed.

The manufacturer must guarantee complete elimination of piping which is to be verified by check tests. The methods of testing are to 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 is not to 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 Surveyor's consent and under his 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, and that the welded area is ground smooth to the correct nominal thickness. The area of a single welding is not to exceed 25 cm^2. The total welded area is not to 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.

The steel maker is to adopt a system for identification of ingots, slabs and semi-finished products which would enable the material to be traced to its original cast, and the Surveyor is to be given full facilities for so tracing a material when required.

Every semi-finished piece is to be clearly marked in a specified place and in a specified manner with the Register's stamp or brand and at least the following particulars:

name or initials to identify the steelworks;

number or initials to identify the piece;

number of cast;

unified identification mark for grade of steel and strength level (e.g. A, D36).

When required by the Register, material supplied in the thermo-mechanically controlled processed condition is to have the letters TMCP added after the identification mark (e.g. E36TMCP).

3.3 STEEL FOR BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

3.3.1 General provisions.

3.3.1.1 The present requirements are applicable to rolled steel for marine boilers, heat exchangers and pressure vessels manufactured under the supervision of the Register.

3.3.1.2 The steel is to be manufactured 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 is to 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 is not to 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 is to 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 is to 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 is not to 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 are to be in accordance with standards.

The properties of steel are to 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 are to 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 are to be submitted.

3.3.4 Heat treatment.

The steel is to be manufactured as normalized, normalized and tempered or quenched and tempered. The method of heat treatment is to 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 is to be carried out in accordance with 3.2.5.

Tensile test specimens and those for determining the impact toughness *KCU* are to 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 is to 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 should 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 is to 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 are to be cut out on both ends.

3.3.7 Inspection.

The rolled steel is to be free from defects prejudicial to the use of the material for the intended application. Freedom from non-allowable defects is to 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.

The marking is to be effected in accordance with 1.4.

3.4 STEEL TUBES AND PIPES

3.4.1 General provisions.

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 supervision of the Register during manufacture.

3.4.1.2 The steel pipes and tubes are to be manufactured in accordance with standards or technical requirements agreed with the Register.

3.4.1.3 Pipes and tubes that are manufactured and tested in accordance with the present requirements are intended for operation at room or elevated temperatures.

3.4.1.4 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 is to 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 is not to 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 is to 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 is not to 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 is to 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 are to be in accordance with standards for pipes and tubes.

3.4.3.2 In the process of manufacture the pipes and tubes are to 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 are to 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 are to be submitted.

3.4.4 Heat treatment.

The pipes and tubes are to 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 are in any case to be heat treated, normalized, normalized and tempered or quenched and tempered. The method and conditions of heat treatment are to be chosen by the manufacturer, reported to the Register and stated in the certificate.

3.4.5 Sampling.

Unless stated otherwise, sampling for specimens is to 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 are to be tested by batches. A batch is to 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 is not to 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 is to be included in a relevant batch and one which is half and over — to 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 is to be in the tension zone), one specimen for the expanding test is to be cut.

All the pipes and tubes are to be tested by hydraulic pressure. The test pressure is to be in accordance with standards for pipes and tubes or with documentation agreed with the Register, but in any case it is not to be less than that stated in 15.2, 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 are to undergo the ultrasonic testing.

3.4.7 Inspection.

All the pipes and tubes are to undergo visual examination.

The surface of the pipes and tubes is to 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 under-thickness tolerances.

3.4.8 Marking.

The marking is to be in accordance with 1.4.

3.5 STEEL FOR STRUCTURES INTENDED FOR LOW TEMPERATURE SERVICE

3.5.1 General provisions.

3.5.1.1 Steel plates and sections up to 50 mm thick, steel forgings and castings intended for hull structures, ship equipment and machinery cooling up to minus 50°C at low ambient temperatures are to be manufactured in conformity with the requirements below and tested in the presence of a Surveyor to the Register.

Unless expressly provided otherwise, the requirements for the manufacture, testing, survey and marking of steel plates and sections, contained in 3.2 "Hull structural steel", of steel forgings and round rolled billets, contained in 3.7 "Steel forgings", and of steel castings, contained in 3.8 "Steel castings", should be complied with.

3.5.1.2 Steel having its chemical composition, heat treatment and mechanical properties different from those required below may be approved by the Register provided it shows no tendency to brittle fracture, as determined by drop-weight test in accordance with 2.2.6, at design (service) temperature and provided adequate weldability is ensured where necessary.

For rolled steel more than 50 mm thick, a special agreement of the Register is necessary.

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 are to ensure the welded joint resistance to cracking.

For weld metal, the mechanical properties and impact energy obtained at impact test at prescribed temperature are not to be lower than those required for the base metal.

3.5.1.4 The impact testing of steel is to be made on specimens complying with Fig. 2.2.3.1-2 for steel plates and sections at the temperature in accordance with Table 3.5.2.3, for steel forgings and castings, in accordance with standards and technical require-

Table 3.5.2.2

Chemical composition of hull structural steel

Steel grade	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	0,09 where Al = 0,12
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%.

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 is to be in accordance with the Table; if treated with a combination of elements, the content of at least one of them is to be in accordance with the Table.

ments, but in any case at a temperature at least by 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 is to 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 is not to exceed the ultimate values of Table 3.5.2.2. The steel is to 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, are to comply with Table 3.5.2.3.

Table 3.5.2.3

Mechanical properties of hull structural steel

Steel grade	Yield stress R_{eH}, MPa, min	Tensile strength R_m, MPa	Elongation A_5, min	Impact test: Test temperature, °C	Impact energy, in J, min: transv.	Impact energy, in J, min: longit.
F32	315	440-590	22	−60	31	22
F36	355	490-620	21	−60	34	24
F40	390	510-650	20	−60	41	27

The mechanical properties of steel more than 50 mm thick should be agreed with the Register. In any case, the impact energy of such a steel must comply with Table 3.5.2.3 for the respective grade.

3.5.2.4 Condition of supply.

Steel plates may either be normalized (N) or quenched and tempered (QT), or supplied in the thermo-mechanically controlled processed condition (TMCP). The condition of supply is to be agreed with the Register and is stated in the certificate.

3.5.2.5 Scope of testing.

Impact tests of steel plates are made on longitudinal and transverse specimens on the following scale: in the case of steel as normalized and thermo-mechanically treated, one set of specimens from each feed is tested, and in the case of steel as quenched and tempered, one set of specimens from each furnace charge is tested.

The impact test of transverse specimens may be waived by the Register. This test is, however, mandatory in case of steel or manufacturer approval (see also 1.3.2 and 1.3.3 respectively).

3.5.3 Steel forgings.

3.5.3.1 Chemical composition.

The chemical composition of steel for forgings is to be chosen on the basis of standards agreed with the Register proceeding from the required properties at room temperature and low temperatures and is to conform to 3.7.2.

The content of sulphur and phosphorus in carbon and carbon-manganese steel is not to exceed 0,025% and 0,030%, accordingly, and in alloy steel — 0,025% of each element.

3.5.3.2 Mechanical properties.

The mechanical properties of forged steel and the results of impact testing at room temperature are to be in accordance with 3.7.3.

Besides, the steel forgings are to be impact tested at the temperature determined proceeding from 3.5.1.4. The required impact energy value is to be chosen on the basis of standards or technical requirements, but in any case it is not to 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 is not to be less than 50%.

For the approval of steel to be used for important forgings which are to operate at minus 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 is to be chosen on the basis of standards agreed with the Register proceeding from the required properties at room temperature and low temperatures and is to conform to 3.8.2. The content of sulphur and phosphorus is not to exceed 0,025% and 0,030%, accordingly.

3.5.4.2 Mechanical properties.

The mechanical properties of steel castings and the results of impact testing at room temperature are to be in accordance with 3.8.3.

Besides, the steel is to be impact tested at the temperature determined proceeding from 3.5.1.4. The required impact energy value is to be chosen on the basis of standards or technical requirements, but in any case it is not to 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 is not to be less than 50%.

For the approval of steel to be used for important castings which are to operate at minus 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 WELDED CHAIN CABLE LENGTHS

3.6.1 General provisions.

3.6.1.1 The present requirements apply to rolled steel used for manufacture of anchor chain cable lengths subject to the Register supervision.

3.6.1.2 The rolled steel (rolled bars) should be approved by the Register and manufactured by the works recognized by the Register.

3.6.1.3 The manufacturer of rolled products should submit specifications of the material to the Register for approval.

Stated in the specification should 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 this Chapter are subject to the special approval by the Register.

3.6.2 Chemical composition.

3.6.2.1 The chemical composition of rolled steel bars, based on ladle analysis for grades 1 and 2 chain cables should comply with Table 3.6.2.

3.6.2.2 For chain cables of grades 3, R3, R3S and R4 the chemical composition of steel should 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 should contain not less than 0,2% of molybdenum.

Table 3.6.2

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	0,40min	0,040	0,040	-
2[2]	0,24	0,15 — 0,55	1,60max	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.

3.6.2.3 The rolled bars should be made of killed steel, and the steel for chain cables of grades 2, 3, R3, R3S and R4 should be deoxidized and fine grain treated.

3.6.3 Mechanical properties.

The mechanical properties of rolled bars should ensure the properties of finished chain cable as stipulated by Table 3.6.3.

3.6.4 Supply condition.

3.6.4.1 Rolled bars may be supplied in as-rolled condition.

3.6.4.2 When the rolled products manufacturer is recognized, the chain cables of grades 3, R3, R3S and

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] KV		
			min		Test temperature, oC	Base material	Weld joint
						Impact energy, J, min	
1	-	490 max	25	-	-	-	-
2	295	490 - 690	22	-	0	27	-
3	410	690 min	17	40	0(-20)	60(35)	-
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 cab-les 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 $R_{eH}/Rm \leqslant 0{,}92$.
[4] When the material susceptibility to hydrogen embrittlement for chain cables of grades R3, R3S and R4 is determined, Z/Z' $\geqslant$85, where Z and Z' are the sample percentage reduction of area under tension before and after heating respectively.

R4 should 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 should 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 should be taken from the test sample in the longitudinal direction according to Fig.3.6.5.2.

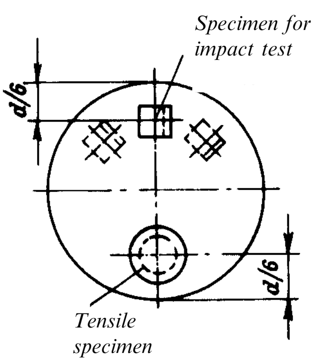


Fig. 3.6.5.2

3.6.5.3 For each steel casting for chain cables of grades R3S and R4, one sample each of two ingots is taken. From the central part of those samples, two test specimens at a time are machined for testing steel susceptibility to hydrogen embrittlement.

When one ingot is manufactured by the continuous casting method, samples are taken from the beginning and the end of an ingot.

3.6.5.4 Mechanical tests results should meet the requirements of Table 3.6.3.

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 should be confirmed by following procedures approved by the Register.

3.6.6 Inspection.

3.6.6.1 The admissible tolerances of rolled bars diameter for chain cables of grades 1, 2 and 3 are set down in standards and stated in the specification, but should be according to Table 3.6.6 for chain cables of grades R3, R3S and R4.

3.6.6.2 Rolled bars must 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 to the even outline.

Table 3.6.6

Specified diameter, mm	Tolerance for diameter, mm	Tolerance for ellipticity, $(d_{max}-d_{min})$, mm
51 — 80	- 0; + 2,0	1,50
81 — 100	- 0; + 2,6	1,95
101 — 120	- 0; + 3,0	2,25
121 — 160	- 0; + 4,0	3,00

N o t e: On agreement with the Register the plus tolerance for rolled bars diameter may be increased if requirements for tolerances for finished chain cable diameter are met.

3.6.7 Non-destructive testing.

Rolled bars for chain cables of grades R3, R3S and R4 should be subjected to 100% 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.

Marking is inserted upon each bar according to 1.4.

3.7 STEEL FORGINGS

3.7.1 General provisions.

3.7.1.1 Steel forgings subject to supervision of the Register when produced in conformity with the relevant parts of the Rules, are to be manufactured and tested in accordance with the requirements stated below.

3.7.1.2 The present requirements apply to forgings used in hull and ship machinery construction the purpose of which is established proceeding from the properties determined at room temperature.

3.7.1.3 The requirements apply also to rolled billets used as substitutes for forgings and for rolled steel the diameter of which does not exceed 250 mm used for manufacturing (by means of machining only) of shafts, bolts and similar items simple in shape.

3.7.1.4 The requirements for forgings to be used at low or high temperature, as well as for forgings of alloy steel 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 agreement are to contain detailed information on the chemical composition, mechanical and special properties, the methods and scope of testing the forgings.

3.7.1.5 In the case of established manufacturing process where uniform forgings are produced alternative testing methods and scope can be adopted on agreement with the Register provided the stable character of the technological processes and the quality of forgings are confirmed.

3.7.1.6 When two or more forgings are joined by welding to form a composite component, details of the chemical composition of steel and welding procedure are to be agreed with the Register. Welding procedure tests may be required.

3.7.1.7 The forging ratio is to be such as to ensure freedom from defects, uniformity of structure and the required mechanical properties after the heat treatment, and as a rule it is to be in conformity with Table 3.7.1.7.

Table 3.7.1.7

Method of manufacture	Total forging ratio
From ingot or forged billet	3:1 for $L > D$ 1,5:1 for $L \leqslant D$
From rolled billet	4:1 for $L > D$ 2:1 for $L \leqslant D$

Notes: 1. L and D are the length and diameter of a forging or its part respectively.
2. The forging ratio is to be calculated with reference to the average cross-sectional area of the ingot. The initial upsetting of the ingot may be also taken into consideration.
3. For rolled bars used as a substitute for forgings the reduction ratio is to be not less than 6:1.

Where disc-type forgings such as gear wheels are made by upsetting, the thickness of any part of the disc is to be not more than one half of the length of the billet from which it was formed provided that this billet has received an initial forging reduction of not less than 1,5:1. Where the piece used has been cut directly from an ingot or where the billet has received an initial reduction of less than 1,5:1, the thickness of any part of the disk is to be not more than one third of the length of the original piece.

Rings and other types of hollow forgings are to be made from hollow billets by expanding or drawing on a suitable mandrel. Alternatively, hollow cast billets may be used. The wall thickness of the forging is to be not more than one half of the wall thickness of the hollow billet. Where this is not practicable, adequate working is to be given to the billet prior to expanding or drawing, and the reduction is to be not less than 2:1.

3.7.1.8 For certain components, 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 to be agreed with the Register. During the manufacture of the forgings tests may be required by the Register to demonstrate that a satisfactory structure and grain flow are obtained.

3.7.1.9 Unless otherwise agreed, flame cutting, scarfing, and arc gouging are to be carried out before the final heat treatment. Pre-heating is to be employed when necessitated by the chemical composition of the steel and/or thickness.

3.7.2 Chemical composition.

3.7.2.1 The chemical composition of steel for forgings is to be chosen for the particular type of steel and the required mechanical and special properties of the forgings being manufactured.

The forgings are to be made from killed steel.

3.7.2.2 For carbon and carbon-manganese steel forgings the chemical composition of ladle samples is to be within the following overall limits in per cent:

carbon - 0,60 (max), silicon - 0,45 (max), manganese - 0,30 . . . 1,50, sulphur - 0,04 (max), phosphorus - 0,04 (max), copper - 0,30 (max), chromium - 0,30 (max), molybdenum - 0,15 (max), nickel - 0,40 (max).

3.7.2.3 For alloy steel forgings the chemical composition of ladle samples is to be in accordance with standards or with other technical requirements agreed with the Register and is to comply with the following overall limits in per cent:

carbon - 0,45 (max), silicon - 0,45 (max), sulphur - 0,035 (max), phosphorus - 0,035 (max).

3.7.2.4 If not otherwise stated, grain refining elements may be added at the option of the Manufacturer. The content of such elements is to be reported in the ladle analysis.

3.7.3 Mechanical properties.

3.7.3.1 Proceeding from the tensile strength required, yield stress, elongation, reduction of area and the results of impact testing for forgings of

Table 3.7.3.1-1

Tensile strength R_m, MPa	Yield stress R_{eH} or $R_{p\,0,2}$, MPa	Elongation A_5, %	Reduction of area Z, %	Impact testing results			Brinell hardness
				Impact energy KV, J	Impact energy KU5, J	Impact toughness KCU2, J/cm^2	
minimum							
360	180	$\frac{28}{20}$	$\frac{50}{35}$	$\frac{32}{18}$	$\frac{30}{20}$	$\frac{60}{40}$	95...135
400	200	$\frac{26}{19}$	$\frac{50}{35}$	$\frac{32}{18}$	$\frac{30}{20}$	$\frac{60}{40}$	110...150
440	220	$\frac{24}{18}$	$\frac{50}{35}$	$\frac{32}{18}$	$\frac{30}{20}$	$\frac{60}{40}$	125...160
480	240	$\frac{22}{16}$	$\frac{45}{30}$	$\frac{32}{18}$	$\frac{30}{20}$	$\frac{60}{40}$	135...175
520	260	$\frac{21}{15}$	$\frac{45}{30}$	$\frac{25}{15}$	$\frac{25}{17}$	$\frac{50}{34}$	150...185
560	280	$\frac{20}{14}$	$\frac{40}{27}$	$\frac{25}{15}$	$\frac{25}{17}$	$\frac{50}{34}$	160...200
600	300	$\frac{18}{13}$	$\frac{40}{27}$	$\frac{18}{12}$	$\frac{20}{15}$	$\frac{40}{30}$	175...215
640	320	$\frac{17}{12}$	$\frac{40}{27}$	$\frac{18}{12}$	$\frac{20}{15}$	$\frac{40}{30}$	185...230
680	340	$\frac{16}{12}$	$\frac{35}{24}$	$\frac{18}{12}$	$\frac{20}{15}$	$\frac{40}{30}$	200...240
720	360	$\frac{15}{11}$	$\frac{35}{24}$	$\frac{18}{12}$	$\frac{20}{15}$	$\frac{40}{30}$	210...250
760	380	$\frac{14}{10}$	$\frac{35}{24}$	$\frac{18}{12}$	$\frac{20}{15}$	$\frac{40}{30}$	225...265

Notes: 1. In the numerator requirements for testing longitudinal specimens are to be found, in the denominator — for testing transverse specimens.

2. The tensile strength values obtained at tensile testing are not to exceed the specified values by more than:
120 MPa for specified R_m below 600 MPa,
150 MPa for specified R_m from 600 to 900 MPa,
200 MPa for specified R_m 900 MPa and over.

3. If not specially provided for by the Register, impact energy KV and KU or impact toughness KCU is to be determined by means of impact testing at the option of the manufacturer. These are determined on specimens in accordance with Fig. 2.2.3.1-2, Fig. 2.2.3.1-3 and Fig. 2.2.3.1-1, respectively.

4. For intermediate tensile strength values the minimum values of yield stress, elongation reduction of area and impact energy KV or impact toughness KCU may be obtained by interpolation.

5. The requirements given in these tables relate to specimens taken with their axes at a distance up to 10% of the diameter or thickness from the surface.

6. Where more than one tensile test specimen is taken from a forging, the variation in tensile strength is not to exceed:
70 MPa for specified R_m below 600 MPa,
100 MPa for specified R_m from 600 to 900 MPa,
120 MPa for specified R_m 900 MPa and over.

7. The variation in hardness for an individual forging or in a batch of forgings is not to exceed:
25 HB for specified R_m below 600 MPa,
35 HB for specified R_m from 600 to 900 MPa,
42 HB for specified R_m 900 MPa and over.

carbon and carbon-manganese steel are to conform to Table 3.7.3.1-1, for forgings of alloy steel after quenching and tempering — to Table 3.7.3.1-2 and for forgings of alloy carburizing steel — to Table 3.7.3.1-3.

3.7.4 Heat treatment.

3.7.4.1 All the forgings are to be suitably heat treated to obtain the required structure of metal and mechanical properties. The procedure of heat treatment is to be chosen by the manufacturer proceeding from chemical composition of steel, the purpose and dimensions of the forgings. The following conditions are to be observed:

the tempering temperature is to be not less than 550°C;

if for any reasons a forging is heated for further hot working, it is to be reheat treated;

where a forging is intended for surface hardening, full details of the proposed procedure and specification are to be agreed with the Register. For this purpose the manufacturer may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel;

Table 3.7.3.1-2

Tensile strength R_m, MPa	Yield stress R_{eH} or $R_{p\,0,2}$, MPa	Elongation A_5, %	Reduction of area Z, %	Impact testing results			Brinell hardness
				Impact energy KV, J	Impact energy KU5, J	Impact toughness KCU2, J/cm^2	
minimum							
600	420	18/14	50/35	41/24	35/24	70/48	175...215
650	450	17/13	50/35	32/22	30/23	60/46	190...235
700	480	16/12	45/30	32/22	30/23	60/46	205...245
750	530	15/11	45/30	32/20	30/22	60/44	215...260
800	590	14/10	40/27	32/20	30/22	60/44	235...275
850	640	13/9	40/27	27/18	26/20	52/40	245...290
900	690	13/9	40/27	27/18	26/20	52/40	260...320
950	750	12/8	35/24	25/16	25/18	50/36	275...340
1000	810	12/8	35/24	25/16	25/18	50/36	290...365
1050	870	11/7	35/24	21/13	23/15	46/30	310...375
1100	930	11/7	35/24	21/13	23/15	46/30	320...385

See Notes to Table 3.7.3.1-1.

Table 3.7.3.1-3

Mechanical properties of alloy carburizing steel

Diameter or thickness of sample, mm	Tensile strength R_m, MPa	Yield stress R_{eH} or $R_{p\,0,2}$, MPa	Elongation A_5, %	Reduction of area Z, %	Impact test results		
					Impact energy KV, J	Impact energy KU5, J	Impact toughness KCU2, J/cm^2
		minimum					
30	800 — 1100	600	10/8	35/25	22/16	24/18	48/36
	1000 — 1300	680	8/6	35/25	18/14	20/15	40/30
	1050 — 1350	780	8/6	35/25	18/14	20/15	40/30
60	650 — 950	450	11/9	40/27	22/16	24/18	48/36
	800 — 1100	550	10/8	35/27	22/16	24/18	48/36
	950 — 1250	680	8/6	35/27	18/14	20/15	40/30

See Notes to Table 3.7.3.1-1.

where induction hardening, carburizing or nitriding is to be carried out after machining, forgings are to be heat treated (generally either by full annealing or by normalizing and tempering) to a condition suitable for this subsequent surface hardening;

if any straightening operation is performed after the final heat treatment a subsequent stress relieving heat treatment should be carried out.

The method of heat treatment is to be reported to the Register and indicated in the certificate.

The method and regime of heat treatment shall be agreed upon with the Register. The method of heat treatment shall be specified in the Register Certificate.

3.7.5 Sampling.

3.7.5.1 Test material sufficient for the required tests and for possible re-test purposes is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging except where specially provided otherwise. The specimens are to be taken with their axes at a distance up to 10% of the diameter or thickness from the surface.

3.7.5.2 Except for components which are to be carburized or as otherwise specially agreed, test material is not to be cut from a forging until all heat treatment has been completed.

3.7.5.3 Generally, a tensile test specimen and a set of impact test specimens are to be machined from a sample.

3.7.6 Scope of testing.

3.7.6.1 Forgings are to be submitted for testing individually or in batches. Except where specially provided otherwise, the number and direction of tests are to be as follows:

.1 *Forgings for rudder stocks, pintles, shafting, connecting rods, etc.*

One sample is to be taken from the end of each forging in a longitudinal direction according to Figs 3.7.6.1.1-1, 3.7.6.1.1-2 and 3.7.6.1.1-3 (position *A*).

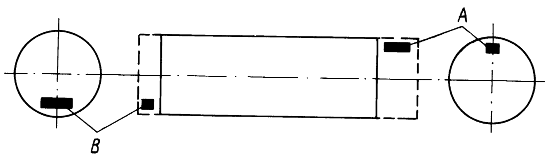


Fig. 3.7.6.1.1-1

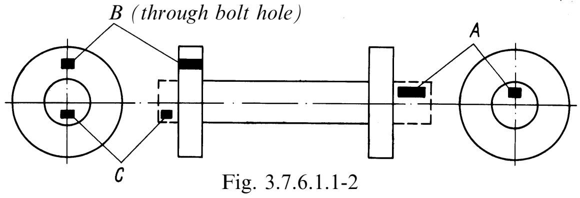


Fig. 3.7.6.1.1-2

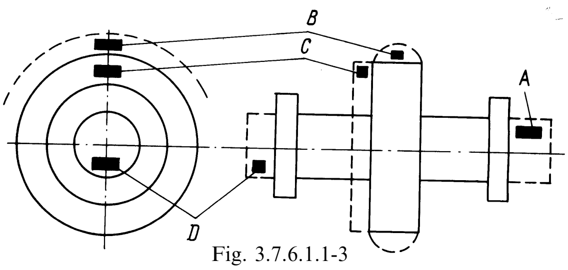


Fig. 3.7.6.1.1-3

On agreement with the Surveyor a sample may be taken in the transverse direction according to the positions *B*, *C* and *D*. Where a forging exceeds both 4 t in mass and 3000 mm in length, one sample is to be taken from each end.

The mass and length of a forging to be quenched and tempered are to be those of the forging prior to heat treatment.

.2 *Pinion forgings*

Where the finished machined diameter of the toothed portion of the forging exceeds 200 mm, one sample is to be taken from each forging in the transverse direction according to Fig. 3.7.6.1.2

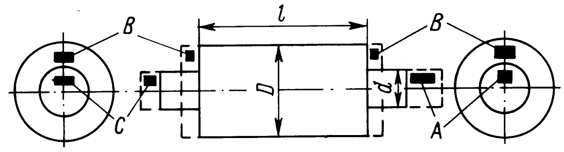


Fig. 3.7.6.1.2

(position *B*). Where the dimensions preclude sampling from this position, a sample in the transverse direction is to be taken according to Fig. 3.7.6.1.2 (position *C*). If however, the diameter is 200 mm or less, samples are to be taken in the longitudinal direction according to Fig. 3.7.6.1.2 (position *A*). Where the finished length of the toothed portion exceeds 1250 mm, one sample is to be taken from each end.

.3 *Gear wheel forgings*

One sample is to be taken from each forging in the transverse direction according to Fig. 3.7.6.1.3 (position *A* or *B*).

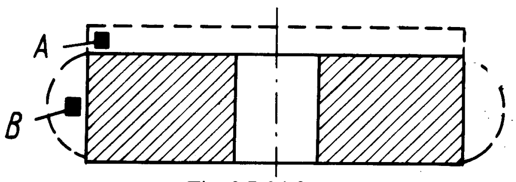


Fig. 3.7.6.1.3

.4 *Gear wheel rim forgings (made by expanding)*

One sample is to be taken from each forging according to Fig. 3.7.6.1.4 (position *A*). Where the finished diameter exceeds 2500 mm or the mass exceeds 3 t, two samples are to be taken according to Fig. 3.7.6.1.4 (positions *A* and *B*).

.5 *Pinion sleeve forgings*

One sample is to be taken from each forging in the transverse direction according to Fig. 3.7.6.1.5 (position *A* or *B*). Where the finished length exceeds 1250 mm, one sample is to be taken from each end (positions *A* and *B*).

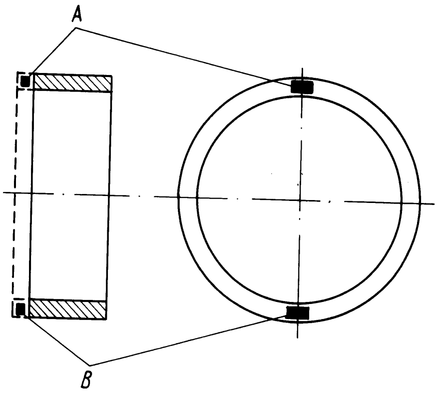


Fig. 3.7.6.1.4

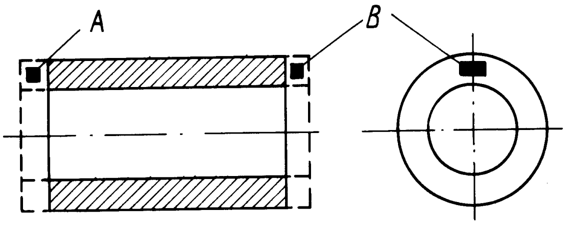


Fig. 3.7.6.1.5

.6 *Crankweb forgings*

One sample is to be taken from each forging in the transverse direction.

.7 *Solid-forged crankshafts*

One sample is to be taken in the longitudinal direction from the coupling end of each forging according to Fig. 3.7.6.1.7 (position *A*). Where the mass exceeds 3 t samples in the longitudinal direction are to be taken from each end (positions *A* and *B*). Where, however, the crankthrows are formed by machining or flame cutting the second sample is to be taken in the transverse direction (position *C*).

A (from coupling end)

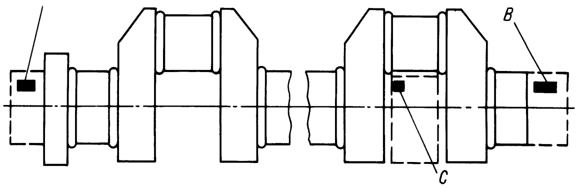


Fig. 3.7.6.1.7

.8 *Crankshaft and other forgings with grain flow in the most favourable direction*

The number of samples and the areas for sampling are, in each case, to be specially considered by the Register.

.9 *Forgings subject to carburizing*

Unless stated otherwise by the Register, for both preliminary tests after forging and for final tests after completion of carburizing, duplicate samples are to be taken from positions as detailed above for appropriate forgings, except that irrespective of the dimensions or mass of the forging the samples are to be taken in one direction only. The samples are to 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 forging the samples are to be given a blank carburizing and heat treatment cycle simulating that which will be subsequently applied to the forging. For the final acceptance tests, the second set of samples is to be blank carburized and heat treated along with the forgings which they represent.

At the discretion of the manufacturer of forgings or gear manufacturer, test samples of larger cross-section may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and stress relieving heat treatment.

Alternative procedures for the testing of forgings which are to be carburized may be specially agreed with the Register.

3.7.6.2 Unless expressly provided otherwise, smaller forgings are to be submitted for testing in batches made up of items having approximately the same dimensions and mass, coming from the same heat and heat-treated in the same furnace charge. Test specimens may be prepared either from one of the forgings of the batch or from a separately forged sample the degree of deformation of which is equal to the reduction ratio of the forgings in the most stressed area and which has been heat-treated together with the forgings.

The scope of testing is set down in accordance with Table 3.7.6.2.

Table 3.7.6.2

Scope of testing for smaller forgings

Mass of forging, in kg	Number of forgings (batch) for the first set of specimens for tensile and impact testing
≤25	200
>25≤50	100
>50≤100	50
>100≤200	25
>200≤500	10
>500≤1000	5

Note: Where the number of forgings exceeds the specified number by 50% or more, a new batch should be formed.

3.7.6.3 When a forging is subsequently divided into a number of components, then the number of tests required is to be related to the total length and mass of the original multiple forging provided that the components thus obtained are heat treated together in the same furnace charge.

3.7.6.4 A batch testing procedure may also be used for hot rolled bars, not exceeding 250 mm in diameter, used instead of forgings. A batch is to consist of:

either material from the same rolled length provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge;

or rolled bars of the same diameter and cast, heat treated in the same furnace charge and with a total mass not exceeding 2,5 t.

3.7.6.5 The Register may require hardness tests on the following:

gear forgings after completion of heat treatment of the gear teeth. The hardness is to 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 2500 mm, the above number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1250 mm, the hardness is to be determined at eight positions at each end of the forging;

small crankshaft and gear forgings which have been batch tested. In such cases the hardness test is to be carried out on each forging;

forgings which have undergone induction hardening, nitriding or carburizing.

The results of such tests are to comply with the approved specification.

3.7.7 Inspection.

3.7.7.1 All forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces.

The forgings are to 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 Register approved technical documentation, the forgings, including those to be welded are to undergo appropriate non-destructive testing according to the procedure approved by the Register.

Magnetic particle or dye penetrant testing is to be carried out when the forgings are in the finished condition. Acceptance standards for defects are to be to the satisfaction of the Register and in accordance with Register approved technical documentation.

Ultrasonic examination, when required by the relevant parts of the Rules or Register approved technical documentation, is to be carried out in accordance with 3.7.8 following the final heat treatment and at the stage when the forgings have been machined to a condition suitable for this type of examination (including the final machining).

3.7.7.3 Surface imperfections are permitted within machining allowances only. Small surface imperfections revealed through visual examination or by non-destructive testing may be removed by local grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination.

3.7.7.4 In general, repairs by welding should be restricted to the rectification of defects of the minor nature in areas of low working stresses. Full details of the proposed repair and subsequent inspection procedures are to be approved by the Register. After welding the location of all repairs and the results of inspection are to be shown in a drawing or sketch of the forging.

3.7.8 Ultrasonic testing.

3.7.8.1 The ultrasonic testing of the forgings is to be carried out in accordance with 2.2.9.2.

3.7.9 Marking.

3.7.9.1 The marking of steel forgings is to be in accordance with 1.4.

3.8 STEEL CASTINGS

3.8.1 General provisions.

3.8.1.1 Steel castings subject to supervision of the Register, when produced in conformity with the relevant parts of the Rules, are to 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 is to 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 are to 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.

3.8.2 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 are to be made from killed steel.

3.8.2.2 For carbon and carbon-manganese steel castings the chemical composition of ladle samples is to comply with the following overall limits in per cent:

carbon - 0,40 (max), silicon - 0,60 (max), manganese - 0,50... 1,60, sulphur - 0,04 (max), phosphorus - 0,04 (max), copper - 0,30 (max), chromium - 0,30 (max), nickel - 0,40 (max), molybdenum - 0,15 (max).

Table 3.8.3.1

Tensile strength R_m, MPa	Yield stress R_{eH} or $R_{p\ 0,2}$, MPa	Elongation A_5, %	Reduction of area Z, %	Impact testing results		
				Impact energy KV, J	Impact energy KU5, J	Impact toughness KCU2, J/cm^2
minimum						
400	200	$\frac{25}{28}$	$\frac{40}{45}$	$\frac{25}{32}$	$\frac{25}{30}$	$\frac{50}{60}$
440	220	$\frac{22}{26}$	$\frac{30}{45}$	$\frac{20}{28}$	$\frac{22}{27}$	$\frac{44}{54}$
480	240	$\frac{20}{24}$	$\frac{27}{40}$	$\frac{18}{25}$	$\frac{20}{25}$	$\frac{40}{50}$
520	260	$\frac{18}{22}$	$\frac{25}{40}$	$\frac{15}{20}$	$\frac{17}{22}$	$\frac{34}{44}$
560	300	$\frac{15}{20}$	$\frac{20}{35}$	$\frac{12}{18}$	$\frac{15}{20}$	$\frac{30}{40}$
600	320	$\frac{13}{18}$	$\frac{20}{35}$	$\frac{10}{18}$	$\frac{12}{17}$	$\frac{24}{34}$

Notes: 1. The elongation, reduction of area, impact energy and impact toughness mentioned in the denominator are established for castings of main components (crankshafts, turbine parts, propellers, etc.). The application of those norms is regulated by the relevant Parts of the Rules.

2. The tensile strength values obtained at tensile testing are not to exceed the required minimal values by more than 150 MPa and for castings mentioned in Note 1, by more than 120 MPa.

3. If not specially required by the Register, impact energy KV and KU or impact toughness (KCU) is to be determined by means of impact testing at the manufacturer's discretion. These are determined on specimens in accordance with Fig. 2.2.3.1-1, 2.2.3.1-2 and 2.2.3.3-1 and Tables 2.2.3.1-1, 2.2.3.1-2 and 2.2.3.1-3, respectively.

4. For intermediate tensile strength values the minimal values of yield stress, elongation, reduction of area and impact energy or impact toughness may be determined by linear interpolation.

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 is to be reported in the ladle analysis.

3.8.3 Mechanical properties.

3.8.3.1 Proceeding from the minimal tensile strength required, the yield stress, elongation, reduction of area and the results of impact testing for carbon and carbon-manganese steel castings are to conform to Table 3.8.3.1.

3.8.4 Heat treatment.

3.8.4.1 To ensure the required structure and mechanical properties the castings are to undergo heat treatment. The procedure of heat treatment is to be chosen by the manufacturer proceeding from the chemical composition of steel, the purpose and shape of the castings. The following conditions are to be observed:

the tempering temperature is to be not 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, is to 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.

3.8.5 Sampling.

3.8.5.1 Sampling may be effected directly from the casting or the test samples may be cast to it. They are to have a thickness not less than 30 mm.

The use of separately cast samples is permitted in which case the dimensions of the sample are to correspond to the casting dimensions.

3.8.5.2 Where two or more test samples are to be provided for a casting they are to be cast at locations as widely separated as possible.

3.8.5.3 The samples are to be heat treated together with the castings which they represent.

3.8.6 Scope of testing.

3.8.6.1 At least one test sample is to be provided for each casting. Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more test samples are to be provided corresponding to the number of casts involved.

Where the casting is of complex design or where the finished mass exceeds 10 t, at least two test samples are to be provided.

3.8.6.2 A batch testing procedure may be adopted for castings. A batch is to consist of castings of approximately the same size and shape made from one cast and heat treated in the same furnace charge. For batch testing separately cast test samples may be used or one of the castings out of those comprising the batch.

3.8.6.3 At least one tensile test specimen and one set of impact test specimens are to be taken from each test sample.

3.8.7 Inspection.

3.8.7.1 The castings submitted for inspection and control testing are to be cleaned, de-gated, free of risers and burrs, etc.

The castings are to be free from defects which would be prejudicial to their proper application in service.

3.8.7.2 Where relevant requirements are to be found in other parts of the Rules or following the instructions of a Surveyor the castings are to undergo non-destructive testing. The testing procedure and the allowances for defects are to 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 2.12.3, Part XIV "Welding". Prior to carrying out weld repairs of large-sized defects, alloy steel castings, castings for crankshafts and for other main components are to be pre-heated in accordance with 3.8.4; if required by the Surveyor, the welded spots should be subjected to non-destructive testing.

3.8.8 Marking.

3.8.8.1 The marking of steel castings is to be in accordance with 1.4.

3.9 SPHEROIDAL OR NODULAR GRAPHITE IRON CASTINGS

3.9.1 General provisions.

3.9.1.1 As defined in the relevant parts of the Rules, all spheroidal or nodular graphite iron castings subject to supervision of the Register during their manufacture are to be manufactured and tested in accordance with the requirements of the following paragraphs. If agreed with the Register and 3.1.2 of this Part is followed, castings may be manufactured according to national standards or works specifications.

3.9.1.2 These requirements are applicable to spheroidal or nodular graphite iron castings used in hull and ship machinery construction. The purpose of the castings is to 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 is to 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 supervision of the Register should be manufactured at works recognized by the Register as mentioned in 1.3.2 of this Part.

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 must be free of defects unfavourably effecting their use and should 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 is to 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 is to be reported.

3.9.3 Mechanical properties.

3.9.3.1 The mechanical properties of the castings are to conform to Table 3.9.3.1.

Table 3.9.3.1

Mechanical properties and structure of nodular graphite iron

Minimum tensile strength [1], Rm, MPa		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% of the given value.

[4] Data for consideration.

While effecting the tensile test of the casting material the tensile strength and elongation are to be determined.

The minimum required tensile strength is to 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.

3.9.3.2 Where impact testing is required, the standards and type of specimen are to be approved by the Register.

3.9.3.3 The microstructure of the castings is to 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 are to be supplied in either as the cast or heat treated condition.

The necessity of heat treatment and the relevant procedure is to 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 is to 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 should 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 are to be submitted to the Register for consideration. Special quality castings having the tensile strength 350 and 400 MPa and the relevant necessary impact energy value should undergo ferritizing.

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, are to be in accordance with Figs 3.9.5.1-1, 3.9.5.1-2 and 3.9.5.1-3; the sample length *l* is to be chosen proceeding from the type of the machine for tensile testing.

Subject to approval by the Register, the samples may have alternative dimensions or they may be taken

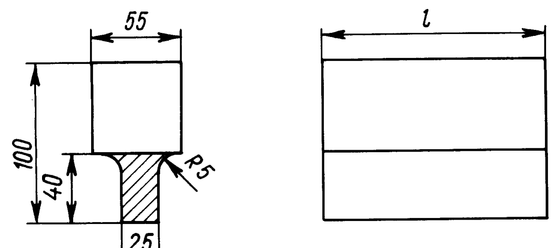


Fig. 3.9.5.1-1

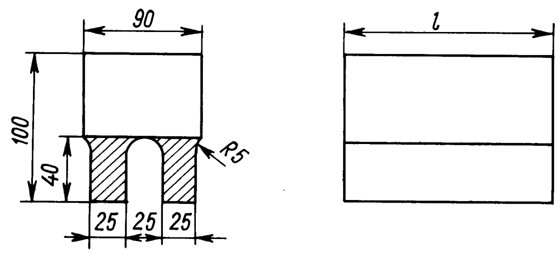


Fig. 3.9.5.1-2

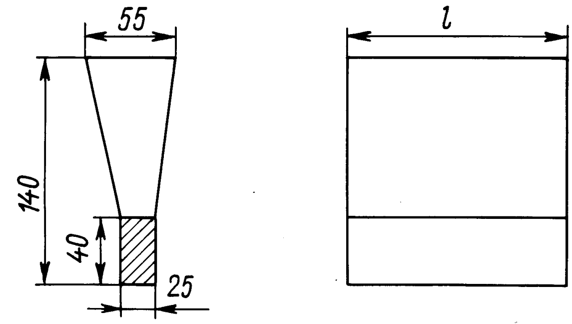


Fig. 3.9.5.1-3

directly from one of the castings forming the batch.

Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are not to 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 are to 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 is to be taken from each casting. If metal from several ladles is used for a casting, one sample is to 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 are to be of similar type and dimensions, cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2 t of fettled castings in the batch.

3.9.6.3 At least one tensile test specimen, should 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 is to be stated in the technical documentation.

3.9.7 Inspection.

3.9.7.1 The castings are to be submitted for inspection and control testing in cleaned and de-gated condition, free from risers, etc.

The castings are to 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 should undergo magnetic particle testing and metallographic examination.

3.9.8 Marking.

3.9.8.1 The marking of spheroidal or nodular graphite iron castings is to be in accordance with 1.4.

3.10 GREY IRON CASTINGS

3.10.1 General provisions.

3.10.1.1 All grey iron castings subject to supervision of the Register, as defined in the relevant parts of the Rules, are to 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 supervision should be manufactured at works recognized by the Register, as stated in 1.3.2.

3.10.2 Chemical composition.

3.10.2.1 The chemical composition is left to the discretion of the manufacturer, who is to 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 is to be reported.

3.10.3 Mechanical properties.

3.10.3.1 When carrying out the tensile test of the casting material (according to 2.2.2.4) the tensile strength is to be determined. The specified minimum tensile strength is to be stated in the technical documentation for the casting, but in no case shall it be less than 200 MPa. Any additional requirements of the relevant parts of the Rules are also to be complied with.

3.10.4 Heat treatment.

3.10.4.1 Castings may be supplied in either as the cast or heat treated condition.

The necessity of heat treatment and the relevant procedure is to 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 is to follow the heat treatment for structure refining and to precede the machining.

3.10.5 Sampling.

3.10.5.1 The test samples may be separately cast and are to have the form of cylindrical bars 30 mm in diameter.

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.

Separately cast test samples are to be cast in moulds made from the same type of material as used for the castings and are not to 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 should be not less than 50 mm.

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 should 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 are to be heat treated together with the castings which they represent.

3.10.5.3 One tensile test specimen is to be prepared from each sample.

3.10.6 Scope of testing.

3.10.6.1 From each casting at least one sample is to be taken. Where metal from several ladles is used for a casting, one sample is to be taken from each ladle.

3.10.6.2 All castings in the batch should be of similar type and dimensions, and cast from the same ladle of metal. As rule, the batch mass should 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 is to be stated in the technical documentation.

3.10.7 Inspection.

3.10.7.1 The castings are to be submitted for inspection and control testing in cleaned and de-gated condition, free from risers, etc.

The castings are to 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.

3.10.8.1 The marking of grey iron castings is to be in accordance with 1.4.

3.11 MALLEABLE CAST IRON

3.11.1 General provisions.

Malleable cast iron may be used for the manufacture of parts for hull and ship machinery construction that are subject to supervision of 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 are to be agreed with the Register in each case.

3.12 STEEL CASTINGS FOR PROPELLERS

3.12.1 General provisions.

The requirements apply to castings for all-cast propellers blades and hubs of propellers with detachable blades and controllable-pitch propellers manufactured of carbon, low-alloy and alloy steel. Applicable requirements of 3.8 are also to be fulfilled.

Alloy steel the chemical composition and mechanical properties of which differ from those required by 3.12.2 and 3.12.3 is to be approved by the Register, and the corrosion fatigue test results are to be submitted for the steel. The corrosion fatigue limit on the basis of 10^8 cycles is to be not less than 75 MPa.

3.12.2 Chemical composition.

The chemical composition is to be in accordance with Table 3.12.2.

For all the steel grades the S and P content is not to exceed 0,035% of each element.

3.12.3 Mechanical properties.

The mechanical properties of steel for propellers are to be determined during the testing of specimens machined, on the option of the Register, either from separately cast samples or samples cast to the hub or the flange portion of the blade, and they are to be in accordance with Table 3.12.3.

3.12.4 Heat treatment.

Propeller castings are to be heat treated in conformity with Table 3.12.3.

The heat treatment for stress relieving is not to detrimentally affect the mechanical properties of the casting metal and its corrosion resistance.

Table 3.12.2

Grade	Material	Content of elements, %						
		C	Si	Mn	Cr	Ni	Mo	Cu
1	Carbon steel	According to 3.8						
2	Low-alloy steel							
3	Alloy steel (martensite-ferrite class)	0,22	0,5	2,0	0,9	2,0	—	1,5
4	Alloy steel (martensite-austenite class)	0,12	0,6	1,0	13,0 — 17,0	2,0	0,2	1,5
		0,08	0,6	2,0	13,5 — 17,0	3,0	1,0	1,5
5	Alloy steel (austenite class)					5,0		
		0,12	2,0	1,6	16,0 — 20,0	8,0 — 11,0	0,5	—

Table 3.12.3

Grade	Tensile test				Impact test		Condition of supply
	R_m, MPa	R_{eH} or $R_{p\ 0,2}$, MPa	A_5, %	Z, %	Impact energy, KV, J	Temperature, °C	
1	According to 3.8						Normalization and tempering
2	450	350	20	45	—	—	Normalization and tempering or quenching and tempering
3	550	380	19	40	21	— 10	
4	750	600	17	45	21	— 10	
5	450	175	30	50	—	—	Austenitization

The heat treatment procedure should be chosen by the manufacturer.

3.12.5 Sampling.

Separately cast samples are to be taken from the same ladle as the casting and heat treated in the same furnace charge.

For each casting or batch of castings one sample should be taken for specimen machining purposes, and for propeller castings of more than 4,0 m diameter two samples should be taken.

3.12.6 Number of tests.

Each propeller casting is to be submitted for testing.

Castings of less than 1,0 m diameter made from metal of one and the same cast and heat treated in the same furnace charge may be submitted in batches. A batch is to include not more than five castings.

For a casting or batch of castings the following tests should be made:

tensile test at least on one specimen;

impact test at least on one set of specimens.

When required by the Register, microstructure should be controlled.

3.12.7 Inspection.

The castings are to be submitted for the survey with their surface prepared both for the visual inspection and non-destructive testing.

The surface of the castings is to undergo dye penetrant or magnetic particle testing. The pressure and suction surfaces of the blade as well as the transition zone between blade and hub or between blade and flange is to undergo compulsory testing by one of the above methods. When required by the Register, the castings should undergo non-destructive testing to reveal internal defects.

The number of test and the testing procedure as well as dimensions of permissible defects are to be in accordance with technical documentation agreed with the Register.

Defects that are revealed may be removed by machining or welding. The dimensions, number and location of defects that need not be removed, defects that are to be machined away and those that are to be welded should be determined on agreement with the Register. Defect elimination and the areas welded are subject to non-destructive testing.

The dimensions and location of the welded defects should be indicated in the drawing attached to the propeller casting certificate.

3.12.8 Marking.

The marking of steel castings for propellers is to be in accordance with 1.4.

3.13 HIGH STRENGTH STEEL FOR WELDED STRUCTURES

3.13.1 General provisions.

The present requirements apply to weldable plates and wide flats of high strength steel up to 70 mm thick subject to the manufacture supervision of the Register 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 above is subject to special consideration by the Register.

3.13.2 Chemical composition.

The chemical composition of steel is to be determined by the manufacturer from each cast or ladle in an adequately equipped laboratory with competent staff. The chemical composition of steel should be in accordance with specification approved by the Register and the limiting values to be found in Table 3.13.2.

The steel is to be fully killed and fine grain treated.

The content of alloying and grain-refining elements is to 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 should 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} is to be agreed with the Register and included in Register-approved specification.

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

3.13.3 Mechanical properties.

For the purpose of tensile and impact testing, the mechanical properties of steel should 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 is to exceed that stated in Tables 3.13.3-1 and 3.13.3-2 by 2%.

3.13.4 Condition of supply.

The steel is to 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 should be perpendicular to the direction of the last

Table 3.13.3-1

Mechanical properties with maximum thickness of 70 mm

Steel grade	Tensile test			Impact test		
	Yield stress R_{eH} or $R_{p0.2}$, min, MPa	Tensile strength R_m, MPa	Elongation A_5, min, %	Test temperature, °C	Impact energy KV, min, J	
					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 must 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, in 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

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 should 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 should 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 is to 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 should be effected on longitudinal specimens.

3.13.6 Scope of testing.

Each plate (rolled length) should 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 specification approved by the Register, after special consideration.

Out of each test sample, at least one tensile specimen and three impact test specimens should be machined.

If required by the Register, tensile testing should be made on specimens with their longitudinal axes perpendicular to the plate surface and the reduction of cross-sectional area should be determined.

3.13.7 Inspection.

Rolled products are to 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 should not exceed permitted tolerances. When required by the Rules, the rolled products should undergo the ultrasonic examination in conformity with standards approved by the Register.

3.13.8 Marking and documentation.

The marking of rolled products should be effected in conformity with 1.4 and 3.2.8. The Register Surveyor should be provided with documentation in the necessary number as per 1.3.4.2.

If required by the Register, the documentation is to be provided separately for each steel grade and strength level.

3.14 Z-STEEL

3.14.1 General provisions.

3.14.1.1 Z-steel intended for the manufacture of hull-structural components subject to the manufacturer supervision of the Register is to be produced and tested under the Register supervision and in conformity with the requirements below.

The requirements of 3.2, 3.5 and 3.13 pertaining to manufacture, testing, survey and marking should also be complied with.

3.14.2 Chemical composition.

3.14.2.1 In carbon and carbon-manganese steel, the content of basic elements and impurities is to be in accordance with standards approved by the Register or with other technical documentation and the maximum values given in Table 3.14.2.1.

Z-steel should be fully killed and fine grain treated. The content of grain refining elements should be determined on the basis of standards approved by the Register or other technical documentation.

The chemical composition of steel may be adopted according to 3.2.2, 3.5.2.1 or Table 3.13.2 provided the content of phosphorus and sulphur complies with Table 3.14.2.1.

Table 3.14.2.1

Content of elements, %, max				
C	Si	Mn	P	S
0,18	0,5	1,6	0,01	0,01

3.14.3 Mechanical properties.

3.14.3.1 After a tensile test of Z-steel specimens the longitudinal axis of which is transverse to the direction of rolling, the reduction of area (Z_z) should not be less than 25%.

3.14.3.2 The mechanical properties of steel and impact test results should comply with the requirements of Tables 3.2.2-1, 3.2.2-2, 3.5.2.2 or 3.13.3.

3.14.4 Z-steel should comply with the requirements of 3.2.4, 3.5.2.3 or 3.13.4.

3.14.5 Sampling and testing.

3.14.5.1 For the purpose of Z-steel testing, samples should be taken from each end of the feed, and from these samples tensile test specimens, a set of impact test specimens and a set of specimens for tensile testing in the through-thickness direction should be prepared.

The procedure of specimen preparation and tensile testing in the through-thickness direction is subject to the approval of the Register.

For the reduction of area (Z_z), the average of three tensile tests is adopted which must not be lower than the required value.

3.14.5.2 In the case of pieces having the thickness 50 mm and above, an additional set of three impact specimens should be prepared and tested, the specimens being cut out in such a way that their longitudinal axis would coincide with the middle of the piece thickness.

3.14.6 Inspection.

Z-steel pieces must undergo the ultrasonic examination. The examination procedure and the acceptable type and size of defects are subject to the approval of the Register.

3.14.7 Marking.

The identification mark of the particular Z-steel should be branded, e.g. D32 Z, where D32 is the identification mark of steel with guaranteed properties in the through-thickness direction.

3.15 WIRE ROPES

3.15.1 General provisions.

3.15.1.1 The present requirements apply to ropes, subject to the Register supervision, which are intended for cargo-handling gear, life-saving appliances and other ship appliances.

3.15.1.2 The ropes should be manufactured and tested in conformity with standards approved by the Register and by works recognized by that body.

3.15.2 Manufacture.

3.15.2.1 For the manufacture of ropes, wire of round cross-section should be used with a coating to protect it from corrosion and a tensile strength of 1180 — 1770 MPa.

3.15.2.2 The organic fibre core of ropes is to be manila, sizal, hemp or synthetic fibre. Ropes with the diameter more than 12 mm should have a core of three strands.

3.15.2.3 The wires of a finished rope should be covered with a lubricant.

Cores of organic fibre should 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 should 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 is to be taken, and from ropes longer than 2000 m a sample length should be taken from both ends. The sample lengths are to be long enough to make all the required testing possible.

3.15.4 Scope of testing.

3.15.4.1 After manufacture, each rope should 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% of the total number of wires in a group of wires of a particular diameter should be tested.

3.15.4.2 Testing should be conducted in accordance with approved standards.

The breaking test of the rope as a whole should 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 is to be repeated.

3.15.4.3 The test results are to 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:

$$F = c\sum_{1}^{i}[(\sum_{1}^{m}F_m)\,n/z]\ ,$$

where c = wire efficiency factor for the rope which is to 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% 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 is to 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 should 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 should be determined on a slack rope at right angles to the axis between two opposite strands in two positions.

The rope diameter should not exceed the design value by more than 6%.

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.

The marking of the ropes is effected in conformity with standards.

The test results should be entered in the Certificate of Test the contents of which are to be agreed with the Register.

4 COPPER AND COPPER-BASE ALLOYS

4.1 SEMI-FINISHED PRODUCTS OF COPPER AND COPPER-BASE ALLOYS

4.1.1 General provisions.

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 supervision.

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 are to meet the requirements of appropriate standards or specifications approved by the Register.

When selecting copper-base alloys, one should 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 is to be reported to the Register and stated in the material certificate.

Rolled products made of CuZn alloys (brasses) are to 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 are to 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 are to 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 are to be cut after the final heat treatment (in the supply condition).

4.1.5 Scope of testing.

If not otherwise specified, the following samples are to 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) should be determined according to standards recognized by the Register.

CuZn alloy tubes for heat exchangers should 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 are to be subjected to hydraulic testing; the test pressure should be determined by standards or specifications.

The test pressure for heat exchanger tubes is to be 5 MPa, and for tubes (bushes) on the propeller shaft lining, 2 MPa.

Substitution of non-destructive inspection 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 should not have defects which are detrimental for their intended use.

4.1.7 Marking.

The marking of products is to be in accordance with 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 are to be cast by foundries approved by the Register in compliance with 1.1.4 and 1.3.2. The application for approval is to be accompanied by specifications of

Table 4.2.2.1

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 — 6.0	max 0.1	max 0.03
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
Note: Chemical composition is to be determined for the metal of each ladle.								

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 are to be carried out in compliance with 1.3.5 under the programme approved by the Register. The purpose of the tests is to verify that the castings and their quality, including chemical composition and mechanical properties, comply with these requirements.

4.2.1.4 The foundry is to 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 is to be made for NDT inspection. If these test facilities are not available, details are to 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 must be carried out into dried moulds using degassed liquid metal. The pouring is to be controlled as to avoid turbulences of flow. Special devices and/or procedures must 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 is to submit a specification containing the details of the heat treatment to the Register for approval (see Tables 4.2.8.5.1-1 and 4.2.8.5.1-2).

4.2.2 Chemical composition and structure characteristics.

4.2.2.1 The chemical composition of typical copper propeller alloys is to comply with the requirements of Table 4.2.2.1.

Note: 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 is to be kept low. The concept of the zinc equivalent should 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 must contain an alpha phase component of at least 25%. The content of alpha phase is to be measured by the manufacturer. The zinc equivalent defined by the following formula is not to exceed a value of 45%.

$$\text{Zinc equivalent (\%)} = 100 - \frac{100\%\ \text{Cu}}{100 + A}\ ,\ \%$$

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 are to 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% 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 4.2.3

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 are to be taken from each ladle and are to 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.

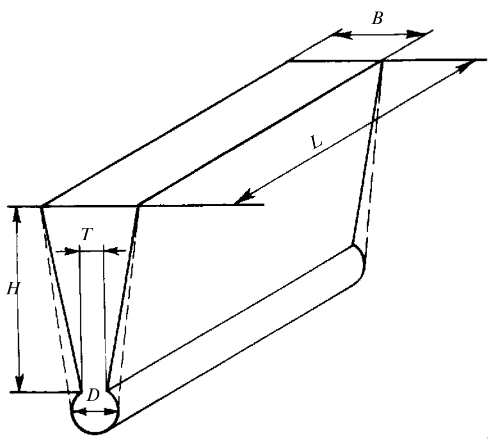


Fig. 4.2.4
Separately cast sample with dimensions in mm:
$H = 100$; $B = 50$; $L > 50$; $T = 15$; $D = 25$

4.2.5 Scope of tests.

Out of each sample at least one cylindrical specimen is machined to undergo the tensile test (see Table 2.2.2.3). The tensile strength, 0.2% proof stress and elongation are to be determined by tensile test.

Generally, the specimens are to be taken from separately cast sample pieces (see 4.2.4). The test samples are to be cast in moulds made of the same material as the mould for propeller. They must be cooled down under the same conditions as the propeller. If propellers are subjected to a heat treatment the test samples are to be heat treated together with them. Where use of integrally cast test specimens is approved by the Register, they must, 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 is to 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 is to be taken from each heat. The proportion of alpha phase is to be determined as the average value of 5 counts. The requirements of 4.2.2.1 are to 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 (see 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 (see Fig. 4.2.6.1).

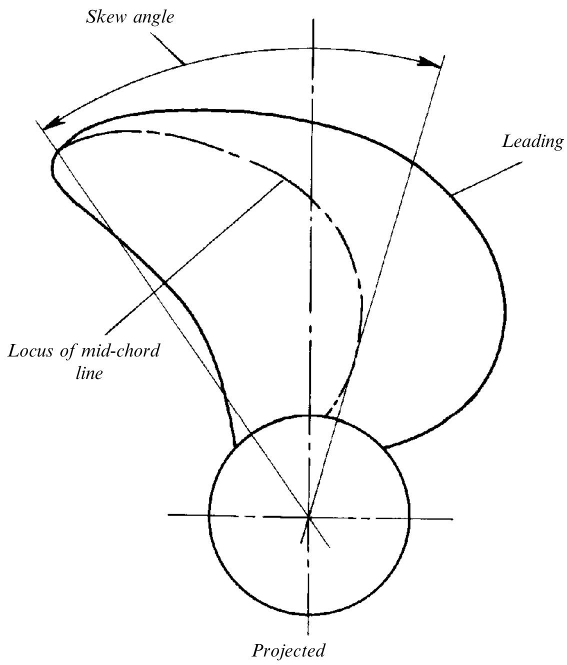


Fig. 4.2.6.1 Definition of skew angle

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 is to 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.

Z o n e B is the area on the pressure and suction sides of the blade. On the pressure side zone B is the

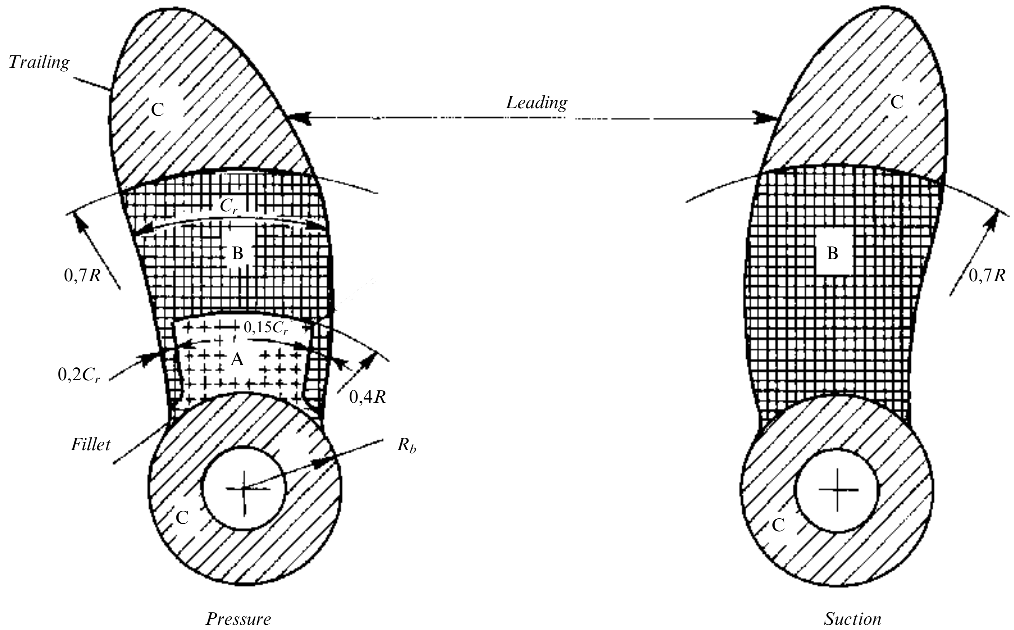


Fig. 4.2.6.2-1 Severity zones for integrally cast low skew propellers

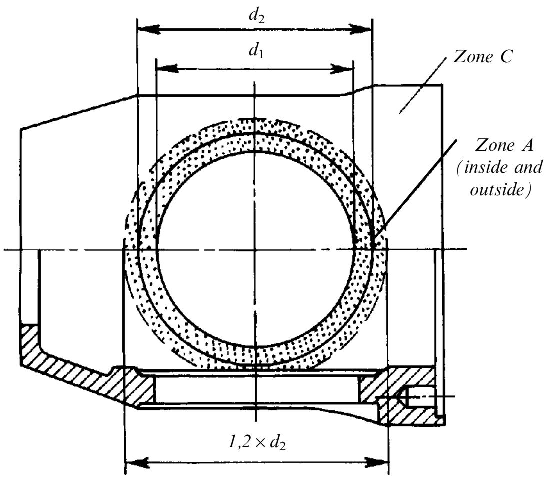


Fig. 4.2.6.2-2 Severity zones for controllable pitch propeller boss

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.

Z o n e 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.

Z o n e 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.

Z o n e 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.

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 should 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.

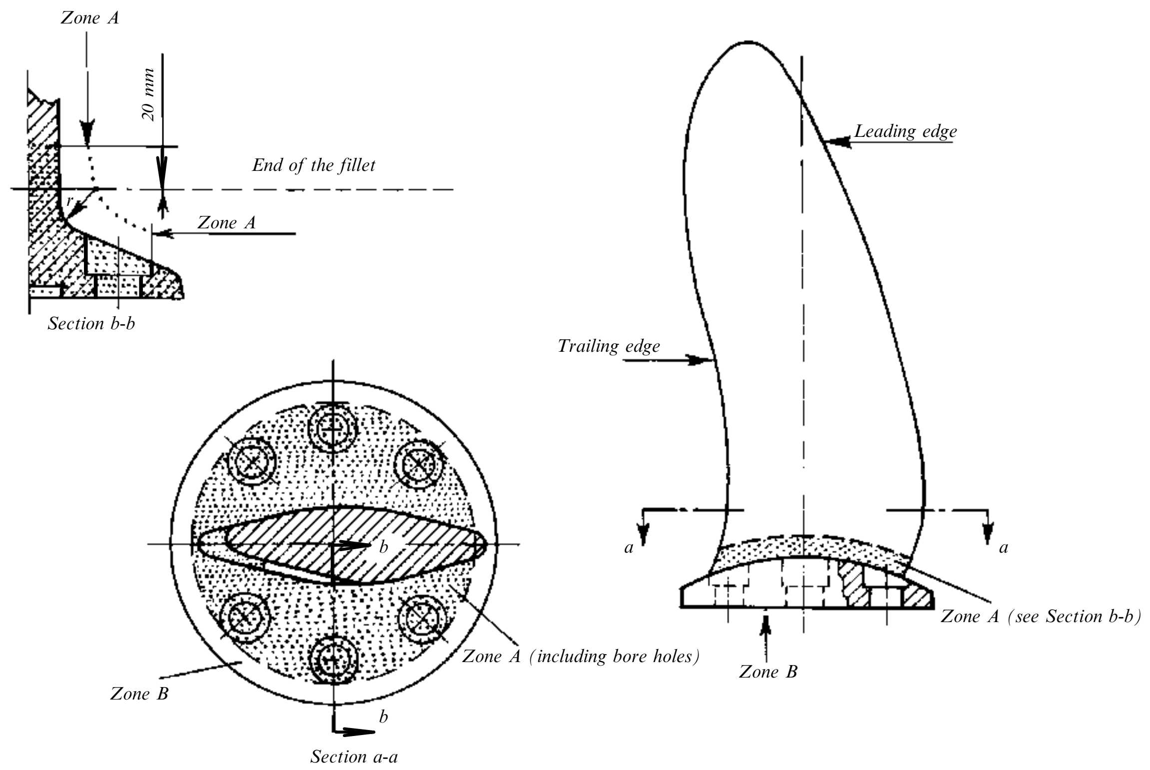


Fig. 4.2.6.2-3 Severity zones for controllable pitch and built-up propeller

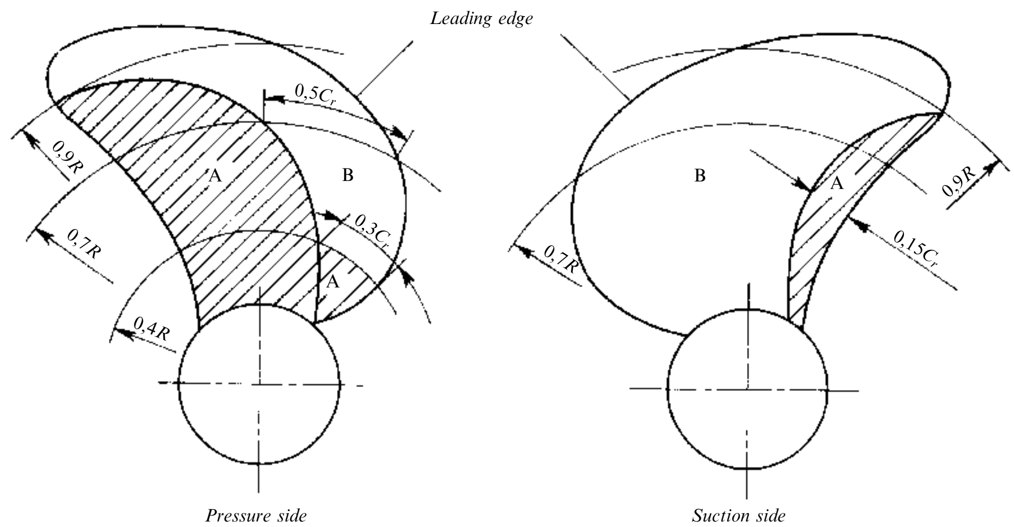


Fig. 4.2.6.3 Severity zones in blades with skew angles greater than 25°

4.2.7 Inspection.

4.2.7.1 Propeller castings are to be visually inspected at all stages of manufacture. The castings are to 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 is to include the bore. The castings subject to inspection are to be fettled and their surface prepared for visual inspection and non-destructive testing. The surface is to 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

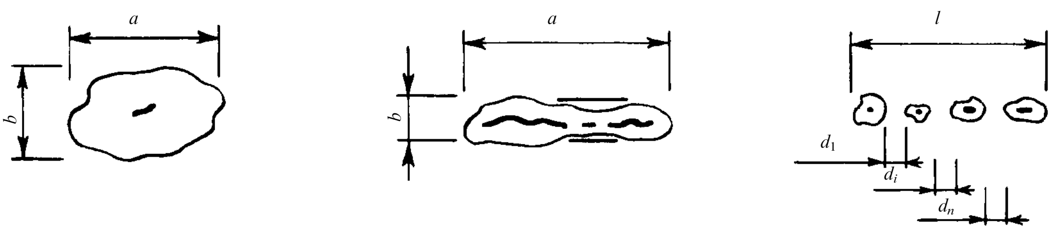


Fig. 4.2.7.3.1 Shape of indications: 1 - circular; 2 - linear; 3 - aligned

description and documentation must be presented to the Surveyor to the Register before commencement of works.

4.2.7.2 The dimensions and the dimensional and geometrical tolerances are to 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 are to 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 is to 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 inspections.

4.2.7.3.1 Dye-penetrant inspection.

The severity zones A (see 4.2.6) are to 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 is to 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 are additionally to be subjected to the dye-penetrant inspection independent of their location and/or severity zone.

The dye-penetrant inspection is to be carried out in accordance with a standard or specification approved by the Register. The following definitions are to 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 is to 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 is to be divided into reference area. The area is to 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, not to exceed the values given in Table 4.2.7.3.1.

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

N o t e s: 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 aligned indications retaining the total number of allowable indications.

Areas which are prepared for welding are, independent of their location, always to 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 are to be carried out upon request of the Register. The evaluation and acceptance criteria are to be agreed between the manufacturer and the Register in accordance with the standards approved by the Register.

It should be noted 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 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 must be eliminated or welded.

Dimensions, number and location of defects allowable without repairs, as well as of those subject to repair are to be determined on agreement with the Register.

In general the repairs are to 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 is to be applied for such defects which are not to be welded. Grinding is to 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 is to be avoided.

4.2.8.2 Repair of defects in zone A.

In zone A, repair welding is not allowed.

Grinding is to 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 is to 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) are to 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.

4.2.8.5.1 The welding procedure and welding consumables used in repair welding are to be recognized by the Register as required by Part XIV "Welding".

Defects are to be repaired by welders of adequate qualification, allowed by the Register to perform such works.

The approval of the welding procedure is to be based on welding of test samples as shown in Fig. 4.2.8.5.1-1, which are to be subjected to a non-destructive testing (dye-penetrant inspection and radiography).

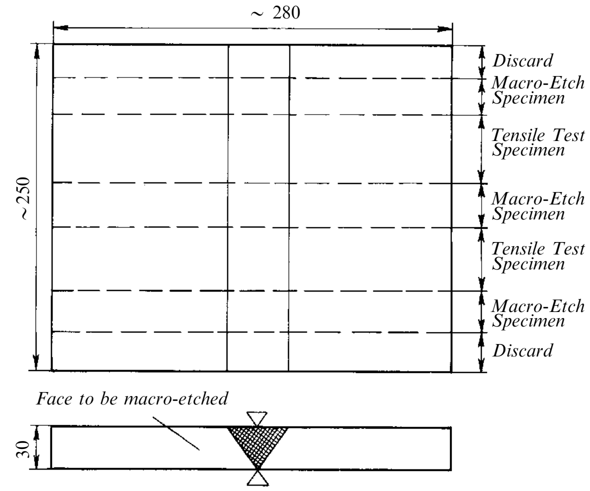


Fig. 4.2.8.5.1-1

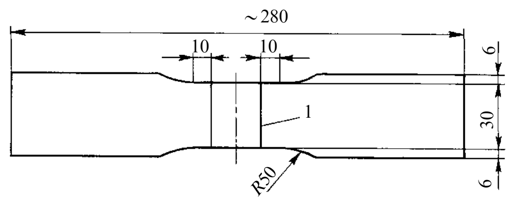


Fig. 4.2.8.5.1-2 Tensile test specimen: 1 - weld edge

Two transverse tensile test specimens are to be taken from test samples as shown in Fig. 4.2.8.5.1-2 and three macro-etch specimens are to be prepared. Test results are to meet the requirements of Table 4.2.8.5.1-3.

The above works are to be performed by the manufacturer before commencement of welding operations.

Welding specification to be submitted to the Register for approval is to be made taking into account the following requirements and recommendations:

defects are to 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 are to be made in compliance with the requirements of Table 4.8.5.1-1. It should be noted that with the exception of alloy CU3 all weld repairs are to be stress relief heat treated, in order to avoid stress corrosion cracking;

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 is to be either stress relief heat treated in the temperature 450 to 500°C or annealed in the temperature range 650-800°C, depending on the extent of repair (see Table 4.2.8.5.1-1);

the defects are to 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 is to 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 4.2.8.5.1-2. The cooling rate is not to exceed 50°C/h until the temperature of 200°C is reached.

Table 4.2.8.5.1-1

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

Notes: [1] Ni-Al-bronze and Mn-Al-bronze are acceptable.
[2] Stress relieving is not required.

Table 4.2.8.5.1-2

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 4.2.8.5.1-3

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 is to be used.

Straightening of a bent propeller blade or pitch modification is to be carried out after heating the bent region and approximately 500 mm wide zones on either side of it. The temperature range is to comply with the requirements of Table 4.2.8.5.1-1; the heating is to be slow and uniform.

The concentrated flame such as oxy-acetylene and oxy-propane is not to be used.

Cold straightening is to be used for minor repairs of tips and edges only. Cold straightening on CU1 and CU2 as well as CU4 bronze is to be always followed by a stress relieving heat treatment in accordance with Table 4.2.8.5.1-1.

4.2.9 Identification and marking.

4.2.9.1 Identification.

The manufacturer's must 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 is to be given to the Surveyor to the Register at his request.

4.2.9.2 Marking.

Marking is to be made in compliance with the requirements of 1.4. Besides, marking is to 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 is to 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 provisions.

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 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 1.3.2.1.

All aluminium alloys shall be manufactured under the supervision of the Register at the enterprises recognised by the Register in accordance with 1.3.2. 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 supervision 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):* 5083,5086,5784;

temper conditions: O/H111/H112,H116,H32/H321;

national alloys:1530,1550,1561,1561H,1575;

temper conditions: O/H111/H112, H32/H321;

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	—
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)
1561n	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] Exact content of admixtures is not specified.

N o t e : Slight variations in the content of some elements indicated in the Table may be accepted on agreement with the Register.

.2 *pressed sections (full sections, hollow sections, angles and bars etc.):*

5083,5086;

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, 5.1.3-2 and 5.1.3-3.

5.1.4 Temper conditions.

Temper conditions shall be specified in accordance with EN515. National aluminium wrought alloys shall be delivered with indication of temper conditions in accordance both with EN515 and applicable national standards.

The parameters of thermal and thermomechanical treatment providing alloys properties are determined by semi - finished products manufacturer.

Temper conditions are 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.

Specimens undergo elongation test in accordance with 2.2.2.

Flat tensile test specimens shall be used for thicknesses of 12,5 mm and less. Specimens shall maintain both rolled surfaces without cleaning. For thicknesses exceeding 12,5 mm round tensile test specimens are made blanked from the middle of the semi - finished product (the specimen longitudinal axis shall be in the centre part of the semi - finished product) . For thicknesses over 40 mm specimens shall be blanked at a distance of one quarter of the semi - finished product thickness.

5.1.6 Scope of testing.

Semi - finished products of wrought aluminium alloys are submitted for testing in batches.

A batch is to 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.

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 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 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 methods of examination is not required if not specially indicated. Still it is supposed that manufacturers use the

Table 5.1.3-1

Mechanical properties of rolled products

Grade	Temper conditions	Yield strength, R_{p02}, min, MPa	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
5083	H112	125	⩾275	⩽12,5	12	—
				> 12,5	—	10
5083	H116	215	⩾305	⩽12,5	12(10 ? t⩽6)	—
				> 12,5	—	10
5083	H32/H321	215	305 — 380	⩽12,5	10	—
				> 12,5	—	9
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 ? 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·n111/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	—
Note: The values are applicable for longitudinal and transverse tensile test specimens as well.						

Table 5.1.3-2

Mechanical properties of pressed semi - finished products

Grade	Temper conditions	Yield strength, R_{p02}, min, MPa	Tensile strength, R_m, MPa	Elongation, %, min		
				t, mm	A_{50mm}	A_{5d}
5083	H111	110	⩾270	⩽12,5	10	—
				> 12,5	—	12
5083	O/H112	125	⩾270	⩽12,5	10	—
				> 12,5	—	12
5086	O/H111	95	240 — 320	⩽12,5	15	—
				> 12,5	—	18
5086	H112	95	⩾240	⩽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.

Note: The values are applicable for longitudinal and transverse tensile test specimens as well.

Table 5.1.3-3

Mechanical properties of pressed hollow sections

Grade	Temper conditions	Yield strength, R_{p02}, min, MPa	Tensile strength, R_m, min, MPa	Elongation, A_{5d}
6061	t5/t6	205	245	4
6005	t5/t6	215	250	5
6082	t5/t6	240	290	5

Note: The values are applicable for transverse tensile test specimens.

required non-destructive methods of examination 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.

The manufacturer of material is responsible for the size of semi - finished products and respective allowed tolerances , the minimum values of which are given in Tables 5.1.8-1, 5.1.8-2. 5.1.8 -3.

Table 5.1.8-1

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⩽*t*⩽4	0,10	0,15	0,15
4<*t*⩽8	0,20	0,20	0,25
8<*t*⩽12	0,25	0,25	0,25
12<*t*⩽20	0,35	0,40	0,50
20<*t*⩽50	0,45	0,50	0,65

Table 5.1.8-2

Ultimate negative tolerances for pressed semi - finished products

Nominal thickness, *t*, mm	Ultimate tolerances, mm		
	⩽250	>250 ⩽400	>400
3⩽*t*⩽6	0,25	0,35	0,40
6<*t*⩽50	0,30	0,40	0,45

Table 5.1.8-3

Ultimate negative tolerances for pressed hollow sections

Nominal thickness, *t*, mm	Ultimate tolerances, mm
3⩽*t*⩽6	0,25
6<*t*⩽50	0,30

5.1.9 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.

5.1.10 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 project 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 allow 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 buyer.

5.2 CAST ALUMINIUM ALLOYS

5.2.1 General provisions.

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 supervision of the Register.

5.2.2 Chemical composition and mechanical properties.

The chemical composition and mechanical properties of items cast of aluminium alloys are to 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 are to 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.

5.2.4 Sampling.

The samples may be cast on to the castings or cast separately. The sample thickness is to be not 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 is not to be

Table 5.2.2

Chemical composition and mechanical properties of cast aluminium alloys

Grade	Chemical composition, %		Condition of supply	Mechanical properties			
	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

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

less than the thickness of the highest loaded zone of the castings and it is to be specified in the drawing.

5.2.5 Scope of testing.

Depending on their application the castings of aluminium alloys are to 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 is to 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 are to be submitted for inspection in the fettled condition with sprues, heads and burrs removed. They are to 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 is to be agreed with the Register.

If the material of the castings is tested for soundness by hydraulic pressure, the casting drawing is to 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.

The marking of the castings is to be in accordance with 1.4.

6 PLASTICS AND MATERIALS OF ORGANIC ORIGIN

6.1 GENERAL PROVISIONS

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 supervision of the Register.

The requirements of the present Section apply also to plastics and organic materials used for structures and items which are not subject to supervision of the Register, if their application has considerable effect on the safety of the ship as a whole.

6.1.2 General requirements.

All plastics and materials of organic origin are to satisfy the following requirements unless there are special provisions regarding them in the chapters of this Section:

.1 Their combustibility, flame spread and ignitability is to be assessed in conformity with 1.6, Part VI "Fire Protection".

.2 When they give off explosion-hazardous or harmful vapours, their concentration is not to exceed maximum permissible values even at temperatures above those at which they are efficient.

.3 They are to 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.

.4 They are to resist embrittlement and reduction of mechanical properties in service by more than 30 per cent in comparison with the original values.

.5 They are to resist decay and destruction by fungi and not to affect adversely the materials with which they come into contact.

6.2 MATERIALS FOR REINFORCED PLASTIC STRUCTURES

6.2.1 General provisions.

The present requirements cover materials for the manufacture of glass-fibre reinforced ship structures and systems, and of other items subject to the Register supervision.

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 which are approved by the Register and produced by Register-approved manufacturers.

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 should 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 should have a diameter of 5 to 15 μm.

6.2.2.5 The moisture content in the reinforcement material is not to exceed 0,2% of the mass of the material.

6.2.2.6 Cloths of reinforcement material should 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 should be well soluble in the resin without any adverse effect on its properties. A rapid solution of the adhesive is not to result in the mat collapsing while it is impregnated with the resin.

6.2.2.8 The mechanical properties of reinforcement materials are to be in compliance with Register-approved documentation.

6.2.2.9 Each batch of reinforcement material should 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 Adhesives.

6.2.3.1 When manufacturing reinforced plastic structures, polyester resins approved by the Register and produced by Register-approved manufacturers should 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 must be in accordance with the requirements of Table 6.2.3.3.

Table 6.2.3.3

Gelation time, in min., min	Minimal temperature of thermal deformation for resin in solid condition, in °C, min	Modulus of elasticity in bending, in MPa, min	Water absorption in 24 h, in %, 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 must not exceed 15% 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 must not deteriorate by more than 25% 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 is not to 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 should 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 should be indicated.

6.2.3.8 Each batch of resin is to be provided with the maker's certificate stating the following:

manufacturer,

mark,

test results.

6.3 LAMINATED TEXTILES

6.3.1 General provisions.

6.3.1.1 The present requirements apply to textiles subject to the Register supervision which have a rubber or plastic watertight coating and are intended for structures that are under pressure during their service.

6.3.1.2 Laminated textiles must be approved by the Register.

6.3.1.3 Laminated textiles are to be manufactured and tested in conformity with standards agreed with the Register, at works approved by that body.

6.3.2 Properties.

6.3.2.1 Laminated textiles must be air-tight and are to 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

Note: 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 must not be more than 10% of that before ageing, and the difference of dimensions along the warp and weft before and after ageing must not be more than 2%.

When the adhesive joints of laminated textiles are tensile-tested before and after ageing, the rupture must occur in the base material.

6.3.2.3 No stickiness, cracks, delaminations or colour modifications should 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 should not detrimentally affect the properties of the base material.

6.3.3 Sampling.

Sampling for test specimens should be effected from each batch of laminated textiles 0,1 m from the edge and at least 1 m from the roll end. Samples are to 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 are to be effected, and the material mass is to 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 2.3.5.3.1, 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, sea water resistance test in accordance with 2.3.12, cold resistance test in accordance with 2.3.14 and ozone resistance test in accordance with 2.3.15 are to be effected in addition to those mentioned under 6.3.4.2.

6.3.4.4 The test results must 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 is to be stated.

6.4 FOAM PLASTICS

6.4.1 General provisions.

6.4.1.1 The present requirements apply to foam plastics used for the manufacture of items subject to the Register supervision.

6.4.1.2 Foam plastics are to be approved by the Register and should be produced by Register-approved manufacturers.

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 should chiefly have closed-cell structure.

6.4.2.3 The shrinkage of grades 1 and 2 foam plastics is not to result in poor adhesion to boundary surfaces.

6.4.2.4 The physical and mechanical properties of grade 1 foam plastics are to be in accordance with Table 6.4.2.4.

Table 6.4.2.4

Apparent density, in g/cm^3, min	Bending strength, in MPa, min	Modulus of elasticity in bending, in MPa, min	Compression strength, in MPa	Modulus of elasticity in compression, MPa, min	Water absorption in 24 h, in 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 are to be in accordance with Register-approved documentation.

6.4.2.6 Under the effects of sea water and petroleum products, the mechanical properties of grade 1 foam plastics must not deteriorate by more than 25% 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 must not be reduced by more than 5% of the initial value.

6.4.2.8 When approving foam plastics of grade 2, they should 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 is not to be reduced by more than 10%, and if they come additionally under the effects of diesel oil in conformity with 2.3.11.3, it is not to be reduced by more than 16% of the initial value.

6.4.2.10 The cyclic effects of temperature, oil products and fresh water are not to bring about a deterioration of the mechanical properties of grades 2 and 3 foam plastics.

6.4.3 Sampling.

Samples are to be cut out in the middle of a foam-plastic block, and a section with the most uniform cell structure is to 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 is to 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 should 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 are to 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 should be entered in the Certificate of Test.

6.5 ADHESIVES, POLYMER PASTES AND COATS

6.5.1 The present requirements apply to adhesives, polymer pastes and coats used for items subject to the Register supervision.

6.5.2 Adhesives, polymer pastes and coats are to be approved by the Register, and all operations where they are used should be effected by Register-approved enterprises.

6.5.3 Proceeding from their purpose, adhesives and polymer pastes are subdivided into two grades:

grade 1 is used for joining the load-bearing members of hull structures, load-bearing elements of machinery, systems and arrangements, and for the installation of machinery and arrangements;

grade 2 is used for the sealing of systems and machinery, fixing and locking of fasteners, as well as for repairing casting defects.

6.5.4 The physical and mechanical properties of adhesives, polymer pastes and coats are to comply with Register-approved documentation.

6.5.5 The technical documentation of adhesives and polymer pastes should contain data on the service range of temperatures and, proceeding from service conditions:

for grade 1 — compression strength, uniform-separation strength and shear strength;

for grade 2 — unscrewing moment, maximum gap in joints with indication of maximum pressure.

6.5.6 When adhesives, polymer pastes and coats are approved by the Register, the instructions for their application and storage, which, among other things, must mention their resistance to the attack by corrosive media at ambient conditions, should also be submitted.

6.5.7 To verify the service properties of adhesives, polymer pastes and coats, the Register may require the sea water test in accordance with 2.3.12.1, oil resistance test in accordance with 2.3.11.2, vibration resistance test in accor-dance with 2.3.17 and 10-time cyclic exposure to tempera-tures in accordance with 2.3.16 to be conducted. In this ca-se, the deterioration of mechanical properties of the mate-rial is not to exceed 25% as compared to the initial value.

6.6 ROPES OF NATURAL AND SYNTHETIC FIBRE

6.6.1 The present requirements apply to ropes, subject to the Register supervision, which are intended for cargo handling gear, life-saving appliances and other ship appliances.

6.6.2 The ropes should be manufactured and tested in conformity with standards approved by the Register and by works recognized by that body.

The breaking load on a rope is determined by testing the rope as a whole. Testing should be conducted in conformity with standards.

6.6.3 The breaking load on a rope F, in kN, may be determined by the following formula:

$$F = c(\sum_{1}^{m} F_m)n/z\ ,$$

where c = yarn efficiency factor for the rope which is to 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 — 115 mm in diameter and $0{,}1n$ for ropes over 115 mm in diameter.

6.6.4 A rope of synthetic fibre should 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:

$$\sigma_{cp} = (l_p - l_0)/l_0 100,$$

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 is to be found in the standard, cm.

6.6.5 The compliance of the structure diameter and other parameters of the rope to the standard is to 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 should be detectable.

The colour of the rope should be uniform along its whole length and should 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 standards.

6.6.7 The test results should be entered in the Certificate of Test the contents of which are to be agreed with the Register.

6.7 RETRO-REFLECTIVE MATERIALS FOR LIFE-SAVING APPLIANCES

6.7.1 General provisions.

6.7.1.1 The present requirements apply to the retro-reflective materials of life-saving appliances subject to the Register supervision.

6.7.1.2 Retro-reflective materials must be approved by the Register and are to be produced and tested in accordance with Register-approved standards by Register-approved manufacturers.

6.7.1.3 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 must 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 $lx^{-1} \cdot m^{-2}$, should 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% as compared to Table 6.7.2.2, and after the abrasion test, it may be lowered by not more than 50%.

6.7.2.4 Exposure to sea water, mildew, salt fog and ultimate temperatures should 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 is not to be less than 16 N/25 mm.

6.7.2.6 Exposure to ultraviolet irradiation, sea water and distilled water should 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 h.

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 should 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 should be conducted at least on three specimens.

6.7.4.5 The test results are to 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 are to be observed on the surface of retro-reflective materials, and their size is to be the same.

6.7.5 Examination.

The surface of retro-reflective materials is to 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 should be effected in conformity with 1.4.

The test results should be entered in the Certificate of Test.

6.8 PLASTIC PIPES AND FITTINGS

6.8.1 General requirements.

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 condtions:

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 100000 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 following requirements.

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 to 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 shall be manufactured by enterprises the quality systems of which are certified by the Register.

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 Register surveyor's supervision.

7 ANCHOR AND MOORING CHAIN CABLES

7.1 ANCHOR CHAIN CABLES AND ACCESSORIES

7.1.1 General provisions.

7.1.1.1 The present requirements apply to the materials, design, manufacture and testing of anchor chain cables and accessories used for ships.

7.1.1.2 Chain cables and accessories must be manufactured and tested by works recognized by the Register according to technical documentation it approved.

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 and studless link chain cables are subdivided into grades 1 and 2.

7.1.2 Materials for chain cables and accessories.

7.1.2.1 The rolled steel bars used for the manufacture of chain cables must comply with the requirements of 3.6.

7.1.2.2 Unless otherwise specified, the material of forged chain cables and accessories must comply with the requirements of 3.7, and that of cast chain cables, with the requirements of 3.8.

7.1.2.3 The studs are to 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 are to 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 must comply with specifications approved by the Register bearing in mind Figs 7.1.3-1 — 7.1.3-7 (dimensions on all figures are given multiple to the nominal diameter of the usual link), and length of chain cable must comprise an odd number of links.

Where designs do not comply with this and where accessories are of welded construction, relevant drawings must be submitted to the Register, and the specification must 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 are to be supplied in one of the conditions specified in Table 7.1.3.4.

The heat treatment is to be performed before

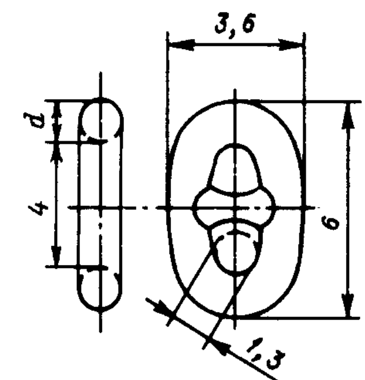


Fig. 7.1.3-1
Common link

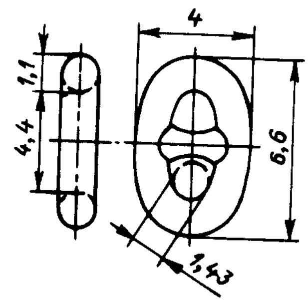


Fig. 7.1.3-2
Enlarged link

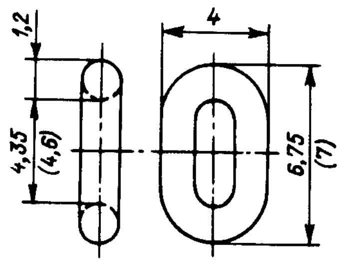


Fig. 7.1.3-3
Studless link

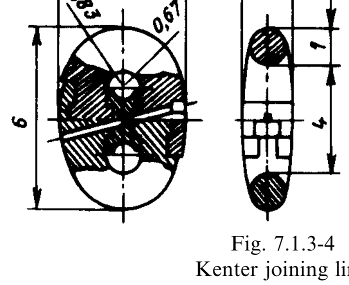


Fig. 7.1.3-4
Kenter joining link

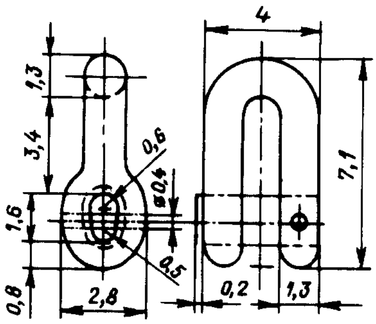


Fig. 7.1.3-5
Joining shackle

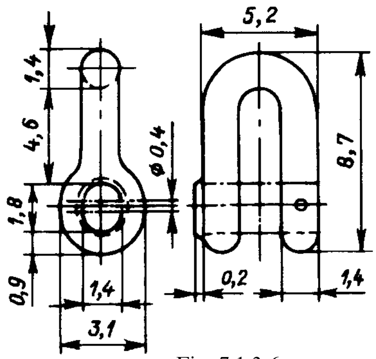


Fig. 7.1.3-6
End shackle

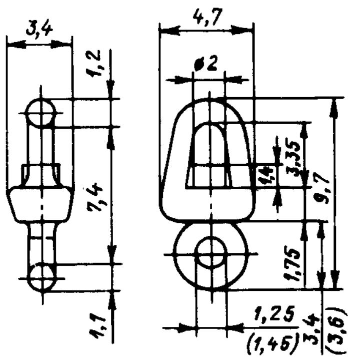


Fig. 7.1.3-7
Swivel

Table 7.1.3.4

Heat treatment of finished chain cables and accessories

Grade	Condition of supply
1	Not regulated (any)
2[1], 3	Normalized, normalized and tempered or quenched and tempered condition

[1]On agreement with the Register, a chain may be supplied without heat treatment provided the results of testing in conformity with 7.1.4.3 are satisfactory.

breaking load or proof load testing.

7.1.3.5 The mechanical properties of the material of a finished chain cable and accessories are to be in accordance with Table 7.1.4.3.3.

7.1.3.6 Chain cables and accessories are to 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 must 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 must 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% of the nominal link diameter or item thickness may be permitted.

7.1.3.8 The dimensions of stud chain links and accessories must comply with Figs 7.1.3-1 — 7.1.3-7 and with approved specifications.

The dimensions of studless links must 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 must 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 are not to exceed 5% of the nominal diameter.

7.1.3.9.2 The cross-sectional area of the elbow must 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 is not to exceed +2.5% of the nominal length (measured with the chain under tension after proof load test).

7.1.3.9.4 Studs must 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

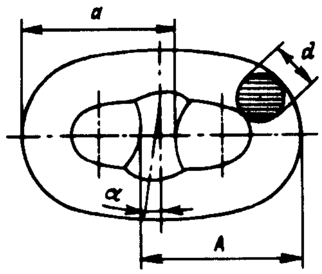


Fig. 7.1.3.9.4:

$$X = \frac{A-a}{2}$$

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% of the nominal diameter d;

maximum deviation α from the 90°-position: 4°.

The tolerances are to be measured in accordance with Fig. 7.1.3.9.4.

7.1.3.10 The following tolerances are applicable in accessories:

nominal diameter $+5\%$ ± 0;

other diameter -2.5%.

7.1.3.11 The welding of studs is to be in accordance with procedure approved by the Register subject to the following conditions.

The studs must be of weldable steel in accordance with 7.1.2.3.

The studs are to be welded at one end only, i.e. opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.

The welds, preferably in the downhand position, should be executed by qualified welders using suitable welding consumables.

All welds must be carried out before the final heat treatment of the chain cable.

The welds must be free from defects liable to impair the proper use of the chain cable. Undercuts, end craters and similar defects should, where necessary, be ground off.

If required by the Register, a procedure for the welding of chain studs is to 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 are to be subjected to the tests specified below in the presence of a Surveyor to the Register. For this purpose, the chain cables must be free from paints and anti-corrosion media.

7.1.4.1.2 Each chain cable length (27,5 m) is to be subjected to a loading test at the proof load appropriate to the particular chain cable as shown in Tables 7.1.4.1.2-1 and 7.1.4.1.2-2.

7.1.4.1.3 For breaking load testing in accordance with Tables 7.1.4.1.2-1 and 7.1.4.1.2-2, sample lengths are taken from the chain cables in conformity with Table 7.1.4.1.3 which comprise at least three stud links or five studless links. The links concerned shall be made in a single manufacturing cycle together with the chain cable and must be welded and heat treated together with it. Only after this may they be separated from the chain cable in the presence of a Surveyor to the Register.

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 Should 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 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 Should a proof load test fail, the defective link (links) is (are) to be replaced, a local heat treatment to be carried out on the new link (links) and the proof load test is to be repeated. An investigation is to 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 In accordance with Table 7.1.4.1.3, tensile and impact test specimens are taken from every fourth length of grade 3 chain cables and non-heat-treated grade 2 chain cables.

The specimens are cut out as shown in Fig. 3.6.6 on the link side opposite to the weld.

The Register may require the weld-cut specimens to be subjected to tensile testing across the weld and to impact testing with a notch through the weld.

7.1.4.3.2 For the purpose of test specimen preparation, provision should be made for an additional link (or where the chain diameter is small, several links) in a length of chain cable. The additional link is to 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 must comply with the requirements of Table 7.1.4.3.3.

7.1.4.4 Chain cables are to be marked at both ends of each length, and the marking is to include

Table 7.1.4.1.2-1

Test loads for stud link chain cables

Chain diameter, mm	Test loads, in kN, for chain cable grades					
	1		2		3	
	proof load	breaking load	proof load	breaking load	proof load	breaking load
11	36	51	51	72	72	102
12,5	46	66	66	92	92	132
14	58	82	82	116	116	165
16	76	107	107	150	150	216
17,5	89	127	127	179	179	256
19	105	150	150	211	211	301
20,5	123	175	175	244	244	349
22	140	200	200	280	280	401
24	167	237	237	332	332	476
26	194	278	278	389	389	556
28	225	321	321	449	449	642
30	257	368	368	514	514	735
32	291	417	417	583	583	833
34	328	468	468	655	655	937
36	366	523	523	732	732	1050
38	406	581	581	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	981	981	1400
44	538	769	769	1080	1080	1540
46	585	837	837	1170	1170	1680
48	635	908	908	1270	1270	1810
50	686	981	981	1370	1370	1960
52	739	1060	1060	1480	1480	2110
54	794	1140	1140	1590	1590	2270
56	851	1220	1220	1710	1710	2430
58	909	1290	1290	1810	1810	2600
60	969	1380	1380	1940	1940	2770
62	1030	1470	1470	2060	2060	2940
64	1100	1560	1560	2190	2190	3130
66	1160	1660	1660	2310	2310	3300
68	1230	1750	1750	2450	2450	3500
70	1290	1840	1840	2580	2580	3690
73	1390	1990	1990	2790	2790	3990
76	1500	2150	2150	3010	3010	4300
78	1580	2260	2260	3160	3160	4500
81	1690	2410	2410	3380	3380	4820
84	1800	2580	2580	3610	3610	5160
87	1920	2750	2750	3850	3850	5500
90	2050	2920	2920	4090	4090	5840
92	2130	3040	3040	4260	4260	6080
95	2260	3230	3230	4510	4510	6440
97	2340	3340	3340	4680	4680	6690
100	2470	3530	3530	4940	4940	7060
102	2560	3660	3660	5120	5120	7320
105	2700	3850	3850	5390	5390	7700
107	2790	3980	3980	5570	5570	7960
111	2970	4250	4250	5940	5940	8480
114	3110	4440	4440	6230	6230	8890
117	3260	4650	4650	6510	6510	9300
120	3400	4850	4850	6810	6810	9720
122	3500	5000	5000	7000	7000	9990
124	3600	5140	5140	7200	7200	10280
127	3750	5350	5350	7490	7490	10710
130	3900	5570	5570	7800	7800	11140
132	4000	5720	5720	8000	8000	11420
137	4260	6080	6080	8510	8510	12160
142	4520	6450	6450	9030	9030	12910
147	4790	6840	6840	9560	9560	13660
152	5050	7220	7220	10100	10100	14430
157	5320	7600	7600	10640	10640	15200
162	5590	7990	7990	11170	11170	15970

Table 7.1.4.1.2-2

Test loads for studless link chain cables

Chain grade	Test load, kN	
	proof load	breaking load
1 2	0,185 d^2 0,260 d^2	0,370 d^2 0,520 d^2

Note: d is the nominal chain diameter, in mm.

Table 7.1.4.1.3

Scope of chain cable testing

Grade	Manufacturing method	Heat treatment	Number of test specimens taken from every fourth length or 100 m of chain cable				
			Breaking load test	Tensile test		Impact test	
				base metal	welded joint	base metal	welded joint
1	Welding	Not required	1	—	—	—	—
2	Welding	Normalizing	1	—	—	—	—
		Not required	1	1	1[1]	3	3[1]
3	Welding	Normalizing, quenching and tempering	1	1	1[1]	3	3[1]
2	Casting or forging	Normalizing	1	1	—	3	—
3	Casting or forging	Normalizing, quenching and tempering	1	1	—	3	—

[1]The Register requirements of 7.1.4.3.1 are to be complied with.

Table 7.1.4.3.3

Mechanical properties of finished chain cables

Grade	Base metal	Welded joint		
		Tensile test[1]	Impact test KV[2]	
		Elongation A_5, %, min	Test temperature, °C	Impact energy J, min
1	The requirements of Table 3.6.3 are applicable	25	—	—
2		18	0	27
3		14	0 (−20)	50 (27)

[1]For the tensile and yield strength the requirements of Table 3.6.3 are applicable. A reduction of area is not specified.
[2]On agreement with the Register the impact test of grade 3 materials may alternatively be carried out at −20°C.

certificate number, chain cable grade and the Register stamp.

The arrangement of symbols comprising the marking should be in accordance with Fig. 7.1.4.4.

7.1.5 Testing of accessories.

7.1.5.1 Proof and breaking load testing.

7.1.5.1.1 All accessories are to be subjected to tests described below in the presence of a Surveyor to

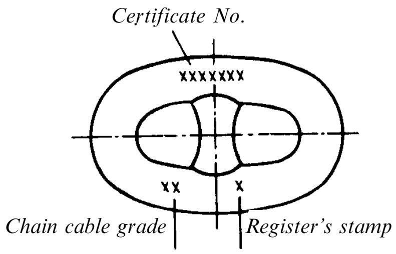


Fig. 7.1.4.4

the Register. For this purpose, the accessories must be free from paint and anti-corrosion media.

7.1.5.1.2 All accessories are to be subjected to the proof load test at the proof load specified in Table 7.1.4.1.2-1.

7.1.5.1.3 For breaking load test in accordance with Table 7.1.4.1.2-1, the accessories are to be submitted in batches.

A batch of shackles, swivels, swivel shackles, large links and end links should comprise not more than 25 items and one consisting of Kenter shackles should 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, the items which have been tested at the prescribed breaking load may be used in service if use is made in manufacture of materials having higher strength characteristics than those specified for the part in question.

7.1.5.2 Mechanical tests.

7.1.5.2.1 Out of each batch of accessories, one specimen is tensile tested and one set of three specimens is impact tested (KV), the specimens machined from an assembly or item specially taken for the purpose as shown in Fig. 3.6.6.

7.1.5.2.2 The results of the mechanical tests are to comply with the requirements of Table 7.1.4.3.3.

7.1.5.3 Each item of accessories is to be marked, and the marking is to include certificate number, grade and the Register stamp.

7.2 MOORING CHAIN CABLES AND ACCESSORIES

7.2.1 General provisions.

7.2.1.1 These requirements apply to the materials, design, manufacture and testing of mooring chain cables and accessories for mobile offshore drilling units, offshore loading systems and gravity based structures.

7.2.1.2 Chain cables and accessories must be manufactured and tested by works recognized by the Register according to technical documentation it approved.

7.2.1.3 Depending on the tensile strength of the chain cable steel, chain cables and accessories are subdivided into grades R3, R3S and R4.

7.2.2 Materials for chain cables and accessories.

7.2.2.1 The rolled steel bars used for the manufacture of chain cables must comply with the requirements of 3.6.

7.2.2.2 Unless otherwise specified, steel forgings and castings for chain accessories must 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 must 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% and down to 35% for grade R4.

7.2.2.4 Steel forgings and castings for chain accessories must undergo 100% ultrasonic testing according to the procedure approved by the Register.

7.2.2.5 The studs are to 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, must not exceed 0,25%.

7.2.3 Design and manufacture of chain cables and accessories.

7.2.3.1 The design of chain cable links and accessories must meet the requirements in 7.1.3.3.

The studs must be impressed in the chain link to secure their position. The shape and depth of the studs impression must not cause any harmful effect on links quality. Machining of kenter shackles must result in fillet radius not less than 3% of link diameter.

7.2.3.2 Chain cables must 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 The chain cable heat treatment is performed in a continuous furnace according to the normalization scheme before breaking load and proof load testing. Normalizing and tempering or quenching and tempering are carried out according to technical documentation approved by the Register.

The heat treatment of chain cable batches is not permitted.

7.2.3.4 The mechanical properties of the finished chain and accessories must meet the requirements of Table 3.6.3.

7.2.3.5 Depending on the grade, chain cables and accessories must withstand the proof and breaking loads given in Table 7.2.3.5.

Table 7.2.3.5

Test loads for chain cables

Chain diameter, mm	Test loads, in kN, for chain cable grades					
	R3		R3S		R4	
	proof load	breaking load	proof load	breaking load	proof load	breaking load
50	1480	2230	1800	2490	2160	2740
52	1590	2400	1940	3680	2330	2960
54	1710	2580	2080	2880	2500	3170
56	1830	2760	2230	3090	2680	3400
58	1960	2950	2380	3300	2860	3630
60	2090	3150	2540	3510	3050	3870
62	2220	3350	2700	3740	3240	4120
64	2360	3550	2870	3970	3440	4370
66	2500	3760	3040	4200	3640	4630
68	2640	3980	3210	4440	3850	4890
70	2790	4200	3390	4690	4060	5160
73	3010	4540	3660	5060	4390	5580
76	3240	4880	3940	5450	4730	6010
78	3400	5120	4130	5720	4960	6300
81	3640	5490	4430	6130	5320	6750
84	3890	5870	4730	6550	5680	7220
87	4150	6250	5050	6980	6060	7690
90	4410	6650	5370	7420	6440	8180
92	4590	6920	5580	7670	6700	8510
95	4860	7330	5910	8180	7100	9010
97	5050	7600	6140	8490	7370	9360
100	5330	8030	6480	8960	7780	9880
102	5520	8320	6710	9280	8050	10230
105	5810	8720	7060	9770	8480	10770
107	6000	9050	7300	10100	8760	11130
111	6400	9650	7790	10780	9350	11870
114	6710	10110	8160	11290	9790	12440
117	7020	10580	8540	11810	10240	13010
120	7330	11050	8920	12330	10700	13590
122	7540	11360	9170	12690	11010	13980
124	7750	11690	9430	13050	11320	14380
127	8080	12170	9820	13590	11790	14980
130	7950	12660	10220	14140	12270	15580
132	8620	12990	10490	14510	12590	15990
137	9180	13830	11160	15440	13500	17020
142	9740	14680	11850	16390	14220	18060
147	10310	15540	12540	17350	15050	10120
152	10890	16400	13240	18320	15890	20190
157	11470	17280	13950	19300	16740	21270
162	12060	18170	14660	20280	17600	22350

7.2.3.6 The dimensions of chain cable links and accessories must comply with Figs.7.1.3.1 to 7.1.3.7 or technical documentation approved by the Register.

7.2.3.7 The allowable tolerances of chain cables links and accessories must comply with the requirements in 7.1.3.9 and 7.1.3.10 respectively.

7.2.3.8 For grade R3 and R3S chain cables, the welding of studs is permitted according to 7.1.3.11.

The fillet weld sizes, depending on the diameter, *d*, must comply with Fig.7.2.3.8; the negative tolerance is not more than 10%.

7.2.3.9 Connecting common links.

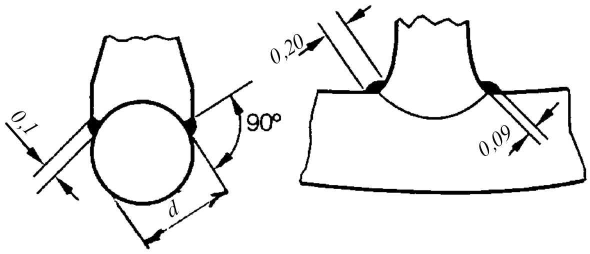


Fig. 7.2.3.8

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, must be agreed with the Customer.

7.2.3.9.2 The connecting common link material must 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 must not exceed 250°C.

7.2.3.9.4 In all other respects the connecting common links must comply with the requirements of 7.2.3.4-7.2.3.8.

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.

7.2.4 Testing of finished chain cables.

7.2.4.1 Following the final heat treatment, all finished chain cables are to be subjected to tests in the presence of a Surveyor to the Register. For this purpose, the chain cables must be free from paints and scale.

7.2.4.2 Breaking and proof load testing.

7.2.4.2.1 For each sampling length in Table 7.2.4.2, a break-test specimen consisting of 3 links is to be taken from rolled products of every cast.

Table 7.2.4.2

Sampling length of chain cable

Chain diameter, mm	Sampling length, m
min — 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

The tests results are considered to be acceptable if the test specimens withstand loading, given in Table 7.2.3.5, without fracture and cracking in welds during 30 seconds.

If the breaking load, due to insufficient loading capacity of the testing machine and large chain diameter, is unattainable, the Register may approve other test methods.

7.2.4.2.2 The entire length of chain cable must 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%.

If two or more chain links fail during proof load testing, the sampling length of a chain cable is rejected.

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, 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 must 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 1.3.5.2.

7.2.4.4.3 The lengths of chain cable failed during retesting are to be replaced.

The connecting common links used therewith are to be subjected to local heat treatment and proof load testing according to Table 7.2.3.5.

7.2.5 Testing of accessories.

7.2.5.1 Following the final heat treatment all accessories are to be subjected to tests described below in the presence of a Surveyor to the Register.

For this purpose, the accessories must be free from paint and scale. All non-machined surfaces of accessories are to be sand blasted.

7.2.5.2 Breaking and proof load testing.

7.2.5.2.1 For breaking load test according to Table 7.2.3.5, the accessories are to be submitted in batches. A batch must comprise not more than 25 items of the same grade and size which were manufactured from metal of the same heat and heat treated in the same furnace charge.

One item out of each batch is subjected to tests and after testing, the use of items according to its purpose is not permitted.

7.2.5.2.2 All accessories of each batch are to be subjected to the proof load test according to Table 7.2.3.5.

7.2.5.2.3 If a break load test fails, or if at least one accessory out of a batch during proof load testing has failed, and there is no confirmation that failure causes do not extend to remaining accessories, the entire batch of accessories is to be rejected.

7.2.6 Examination.

7.2.6.1 Following proof load testing chain cables and accessories are to 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 and non-destructive examination.

7.2.6.2.1 All chain links and accessories are to be subjected to a visual examination.

Links must be free from mill defects, surface cracks, dents and also from other defects preventing their use. Link studs must 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, must be subjected to 100% checking by dye penetrant and magnetic particles methods approved by the Register.

Weld surface must be free from cracks, lacks of fusion and large clusters of porosity.

If the results of weld surface 10% 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, must be subjected to 100% checking by ultrasonic method approved by the Register.

Results of inspection for defects must comply with the requirements of normative documentation approved by the Register.

7.2.6.2.4 The surface defects detected during visual or non-destructive examination may be removed by local grinding within tolerance for the given chain cable diameter. Dye penetrant or magnetic particles must be employed for checking the removal of all defects.

7.2.6.3 Dimensional inspection.

7.2.6.3.1 Checking of chain links dimensions according to 7.2.3 must be carried out on at least 5% of links for the lengths of chain specified in Table 7.2.4.2.

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) are to 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 must be examined.

7.2.6.3.2 Measurements on the five links lengths of chain must be carried out for the entire chain length with inclusion of two links from the previous five links set into the next one.

Measurements are to be taken while the chain is stretched by loading of 5-10% of the 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 must be approved by the Register.

7.2.6.3.3 At least one accessory out of each batch must 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 must 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 must be marked as follows:

chain grade,

certificate No.,

Register's stamp.

All detachable component parts must be marked with an ordinal number.

7.2.7.3 The marking is to 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 must be stated in certificates for the chain cable and accessories.

PART XIV. WELDING

1 GENERAL

1.1 APPLICATION

1.1.1 The present Part of the Rules applies to the following items which are subject to the supervision of 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 present Part is to establish requirements for welding consumables manufacture, welding procedures, and testing of welded structures stated in 1.1.1.

1.1.3 The present Part of the Rules is to be applied when designing, building and manufacturing items stated in 1.1.1.

1.1.4 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

Definitions and explanations pertaining to the general terminology of the Rules are to be found in General Regulations for the Supervision.

Besides, for the purpose of the present Part of the Rules the following 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 PROVISIONS

1.3.1 Welding of items stated in 1.1.1 is to 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 is to be backed up by the results of testing conducted in accordance with a program agreed with the Register.

Welding consumables are to be approved in compliance with the requirements of Section 4.

1.3.2 Welding operation on structures subject to the Register supervision should be performed by those welders only who stood the tests prescribed by Section 5.

1.4 SCOPE OF SUPERVISION

1.4.1 General provisions concerning manufacture of materials and equipment are to be found in General Regulations for the Supervision.

1.4.2 As far as structures stated in 1.1.1 are concerned, the following is subject to the supervision of 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 is to be agreed as part of the ship design is set out in Part I "Classification". Technical documentation on items specified in 1.1.1 is to 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 is to be determined proceeding from 4.1.5.

2 TECHNOLOGICAL REQUIREMENTS FOR WELDING

2.1 GENERAL PROVISIONS

2.1.1 The present technological requirements are to 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 the Register supervision the works is to have adequate equipment.

2.1.2 Where welding is performed at low temperature, working conditions should be provided to enable the welder to produce sound welds. The welding site is to be protected from draught and precipitation.

2.1.3 When welding is performed at low temperature, the weld, if necessary, should 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 is to 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 should be preheated at least to 20 °C over a width of 75 mm to either side of the joint at ambint air temperature:

.1 below -15 °C when forgings and castings used for ship hull are to be welded;

.2 below -10 °C when semi-killed or rimming steel is welded;

.3 below -5 °C when low alloy boiler steel is to 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 is to operate at temperatures above 350 °C should not be conducted at temperatures below zero.

2.1.6 The structural requirements for welds aimed at ensuring their strength are to be found in the relevant Parts of the Rules.

2.1.7 The edge preparation of the parts to be welded should be effected in conformity with standards or with drawings approved by the Register.

2.1.8 The edges of parts to be welded are to 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 are to be removed.

Steel parts coated with a primer may be welded without removing it; in this case, the primer is to 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 should be free from snow, hoar-frost, ice and be dry.

2.1.11 When structures are welded, the sequence of welding operations is to 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 is to 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 are to be specially considered by the Register.

2.1.14 When plates, sheets and the like are to be welded into a rigid contour, technological measures should 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 is not to exceed 650 °C, but in no case should 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 is to be determined by the manufacturer proceeding from the properties of material, and it is to 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 is to be equal to at least the triple thickness of the plate.

2.1.18 Welding consumables with controllable hydrogen content in the deposited metal are to 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 are to be assembled in such a way that the stresses arising during assembly and welding are as low as possible. Tack welding is to be performed only by persons possessing the necessary qualifications. Tack welding is to be carried out using welding consumables of the grades required for welding structural components. Tack welds are to be free from any defects which could impair the quality of welded joints.

If required by the Surveyor to the Register, the tack welds are to be checked for freedom from cracks or other defects. When cracks occur in way of tack welds, they are to be cut out to sound metal and rewelded. Temporary fittings used for assembly are to 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 are to 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 is not to 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 are to be removed and then dressed (the permissible reinforcement is not to 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 is to 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 should 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 are to 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 D and E32 grade 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 D32 and E32 grade 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, should be used. Other welding consumables may be used only on the special permission of the Register for steels having the carbon equivalent (see 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 grade 1Y welding consumables, the material thickness should not exceed 25 mm;

.6 the welding consumables in Table 2.2.4 may also be used for welding of steel other than that shown in Table if the mechanical properties and chemical composition of such a steel are equivalent to

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
I, IS, IT, IM, ITM, IV	+	–	–	–	–	–	–	–	–	–	–	–
IYS, IYT, IYM, IYTM, IYV	+	–	–	–	+[1]	–	–	–	–	–	–	–
2, 2S, 2T, 2M, 2TM, 2V	+	+	+	–	–	–	–	–	–	–	–	–
2Y, 2YS, 2YT, 2YM, 2YTM, 2YV	+	+	+	–	+	+	–	–	–	–	–	–
2Y40, 2Y40S, 2Y40T, 2Y40M, 2Y40TM, 2Y40V	See 2.2.4.4				+	+	–	–	+	+	–	–
3, 3S, 3T, 3M, 3TM, 3V	+	+	+	+	–	–	–	–	–	–	–	–
3Y, 3YS, 3YT, 3YM, 3YTM, 3YV	+	+	+	+	+	+	+	–	–	–	–	–
3Y40, 3Y40S, 3Y40T, 3Y40M, 3Y40TM, 3Y40V	See 2.2.4.4				+	+	+	–	+	+	+	–
4Y, 4YS, 4YT, 4YM, 4YTM, 4YV	+	+	+	+	+	+	+	+	–	–	–	–
4Y40, 4Y40S, 4Y40T, 4Y40M, 4Y40TM, 4Y40V	See. 2.2.4.4				+	+	+	+	+	+	+	+

[1] See 2.2.4.5.

the same of the steel for which the given welding consumable was approved;

.7 rutile electrodes should 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);

.8 oxide-coated electrodes should 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 should 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 are to 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;

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	–	–	–	–	+	+

.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 consumables, having the classification indices HHH or HH, according to Table 4.2.1.4, should 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 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;

.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 should 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 should 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 are to be followed including the following additions:

.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 4Y46 and 5Y46 grades welding consumables, intended for high strength steel welding, is subject to additional agreement with the Register.

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] See 2.2.6.1.
[2] See 2.2.6.2.

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 of the Rules. Manufacturing of structures from materials not regulated by the Rules is to be effected on agreement with the Register.

2.3.2 Welding consumables for machinery and machinery installations are to be chosen on the basis of steel grades used for the manufacture bearing the requirements of 2.2.4, 2.2.5 and 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 should 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 are to be applied which would guarantee the cold cracking resistance of the weld, or the manufacturer is to 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 are to be exposed to dynamic loads should be executed with full penetration. The transition from the base metal to the weld should be smooth.

2.3.6 When shafts for ship shafting or crankshafts are fabricated, the application of welding is to 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 are to 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 is not to be over 15 mm.

2.4 WELDING OF STEAM BOILERS AND PRESSURE VESSELS

2.4.1 Welded joints of boilers are to be so marked as to make it possible to identify the operator having performed the welding.

Longitudinal and circumferential welds of boiler shells are to 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 should 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 will be specially considered by the Register in each case.

The longitudinal and circumferential joints of headers, boiler shells and pressure vessels are to be butt-welded. If butt welding cannot be applied, the type of weld is to be specially considered by the Register.

2.4.2 Welding consumables for boilers and pressure vessels are to be chosen on the basis of steel grades used for the manufacture bearing the requirements of 2.2.4, 2.2.5 and 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 (see 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 is to 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 is to 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 should 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 is not to exceed 500 cm^2, and its depth is not to be over 30 per cent of the plate thickness. If these conditions cannot be met, the faulty area is to 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 (see 1.3.1.2, Part X "Boilers, Heat Exchangers and Pressure Vessels"), test samples are to 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 are to be prepared, if required by the Register.

2.4.8 The test samples are to 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 is to be the same as employed in the welding of the boiler or pressure vessel joint.

A test assembly thus prepared is to 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 are to be prepared, if required by a Surveyor to the Register. The requirements for cutting specimens from the test assembly and for testing them are to 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 is to comply with standards.

2.5.2 Welding consumables for pipelines are to be chosen on the basis of steel grades used for the manufacture bearing the requirements of 2.2.4, 2.2.5 and 2.2.6 in mind.

2.5.3 In the welded butt joints of pipes complete root penetration is to 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 are not to be used for flange-to-pipe butt joints.

2.5.5 The welded joints in pipes are to 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 should be preheated to a temperature 200 to 230 °C. This temperature is to be maintained during welding.

2.5.7 Before welding, the edges of copper pipes with a wall thickness 5 mm and over are to be heated to a temperature 250 to 350 °C. Nickel-copper pipes are to 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 is to be effected with preheating, or other technological measures are to 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 **ЛУ4 — ЛУ7** (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 is to 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 for the service conditions of the cast or forged part.

Repairs of faults by welding are generally to 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 is to 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 are to be ground to sound metal so as to provide for full penetration throughout the welded area.

The surfaces of areas to be rewelded are to be gently sloped and are not to 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 are to be approved in accordance with 1.3.1, the welding consumables — in accordance with Section 4.

The edge preparation for welding is to be in accordance with national standards or drawings approved by the Register.

Preparation of the edges is to be effected by machining or grinding. The edges of parts to be assembled are to fit each other closely and not to be out of alignment on the clad surface.

2.8.2 The corrosion resistance of weld metal on the clad side is to be equal to that of the cladding. The thickness of the corrosion-resistant layer of the weld is not to be less than that of the cladding.

The chemical composition of weld metal on the clad size (except the root zone) should correspond to the chemical composition of the cladding metal.

2.8.3 As a rule, the weld is to 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 is to be so done that no melting of the cladding layer occurs. Prior to welding on the clad side the root of an unalloyed weld is to be cut out to sound metal by machining or grinding. For a back-sealing run the same welding consumables are to be used as for welding the cladding layer. The cladding layer is to 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 are to be used. The welding is to be carried out, as far as possible, at a low rate of energy input. The weld on the clad surface is to 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 is to be deposited in several runs, the last run should 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 is to be welded with the use of welding consumables suitable for the cladding material. When welding clad sheet steel, the entire joint is also to 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 the supervision of the Register. They are to 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 should 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 are to be located in areas exposed to the lowest stresses.

As a rule, welding should be effected in the down-hand 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 should 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 is to be brushed before the next run is applied.

2.10.4 Welding consumables of aluminium and aluminium alloys must 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 are to be of stainless steel. The backings that are not removed must 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 is to 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 is to be within the limits corresponding to the properties of the alloy.

2.10.8 Where a flux is used, it should, as a rule, be neutral. If, by way of an exception, the flux used was not neutral, it is to be carefully removed after welding.

2.10.9 On riveted structures made of aluminium alloys, all major welding operations are to 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 should 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 are to 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 are to be approved by the Register after fabrication testing by an agreed program. For this, the manufacturer of welded structures must submit the documented preheating temperature, linear power comsumption during welding, postweld heat treatment, and temperature between runs.

The manufacturer is to 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 are to be made by multirun welding.

Single-run welding may be permitted only on agreement with the Register.

Each run is to 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 should be followed by the machining of the remaining part and by dressing.

2.12.5 The edges prepared by gas cutting are to be machined after such cutting. Roots are to 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 are to be ensured.

3 INSPECTION OF WELDED JOINTS

3.1 GENERAL REQUIREMENTS

3.1.1 Inspection of welding operations and welded joints during fabrication of structures and components is to be performed by the inspection authorities of the works. The results of the inspection are to 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 is to 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 is to be carried out upon its completion.

For welding of high strength steels and complex shape structures, non-destructive testing should be performed not earlier than 72 hours after welding is completed.

Non-destructive testing of welded joints is to be effected by laboratories recognized by the Register.

The personnel effecting inspection of welds and evaluation of their quality should 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 is to 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 should go on along both sides of the area in question until satisfactory results are obtained. In addition, the Register Surveyor 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 are to 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 is to be additionaly tested along its whole length.

Unacceptable defects must 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 are to be examined on each side of the butt as shown in Fig. 3.1.6-2.

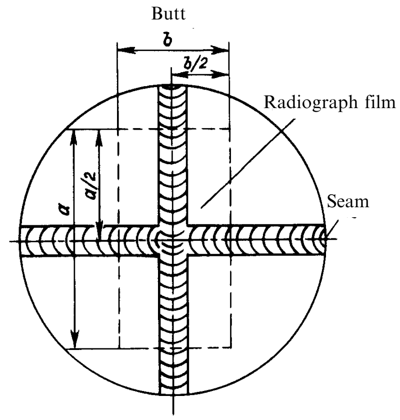


Fig. 3.1.6-1:
a -length of radiograph film equal to ≈500 mm;
b - width of radiograph film equal to ≈100 mm

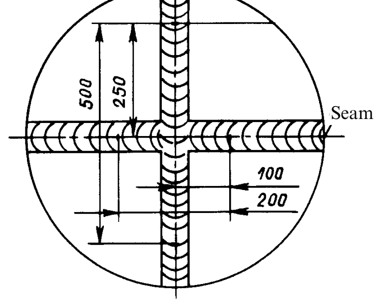


Fig. 3.1.6-2

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 should 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 is to be determined by the following formula:

$$N = \frac{L(B+D)}{45} T$$

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 $60 \text{ m} \leqslant L < 80$ 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 mounting 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 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) should undergo testing.
[3] The number of weld lengths undergoing testing should be up to 20 per cent of the lengths specified for the area 0,4L amidships.
[4] Where ice strengthened, the ice belt butts should mainly be controlled.
[5] Intersections between seams and butts should 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 are to be subjected to non-destructive testing within the scope specified in Table 3.2.2 depending on the class of structure (see 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", are to 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	⩽75	100	10[2]
	> 75		100
II	⩽ 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, 3.2.2 and 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 are to 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 should 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 is to be determined by the following formula:

$$K = 100l/s$$

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 are to be adopted according to standards recognized by the Register.

The assessment criteria by the three-mark system are to be determined as specified in 3.3.3.

The quality assessment using other methods of control should be performed with regard for 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 should not exceed $t/2$, the total length of undercuts at each controlled weld length not exceeding 5% of this weld length.
[2] The maximum length of a single defect should not exceed t, the total length of defects at each controlled weld length not exceeding 5% of this weld length.
[3] For locations with high stresses or vibration, the mark may be raised.
Note: 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 should not exceed $t/2$, the total length of undercuts at each controlled weld length not exceeding 5% of this weld length.
[2] The maximum length of a signle defect should not exceed t, the total length of lacks of fusion at each controlled weld length not exceeding 5% of this weld length.
Note: t is the thickness of the welded metal, in mm.

After the inspection has been completed, a protocol is to 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 is not to 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.

Table 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.

Table 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 are to be found in 3.4.2.

Quality assessment of welded joints by other examination procedures should 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 is to be uniform, free of craters, arc-striking areas, tolerances should be observed and a smooth transition to the base metal ensured.	

[1] The maximum length of an individual undercut is not to exceed the base metal thickness, and on each weld length controlled, the total extent of undercuts is not to exceed 20% of the weld length.

[2] The extent of a defect is not to exceed the base metal thickness, and on each weld length controlled, the total extent of poor fusion is not to exceed 10% of the weld length.

[3] The maximum permissible area of surface imperfections is to be reduced to 100 mm of the controlled weld length, and the diameter of gas inclusions is not to 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 is not to 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 is not to 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 are to 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 is to 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 PROVISIONS

4.1.1 Welding consumables intended for welding the structures referred to in 1.1.1 are to 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 are to 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 are to be witnessed by the Surveyor to the Register.

During the tests the manufacturer is to 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 is to 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's 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 (see also 4.1.4.1, 4.1.4.2).

4.1.2.6 The manufacturer must state in their catalogues and on packaging (label, tag) the information on the Register's 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 is to 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 is to 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 are to 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 is to be made in the Certificate of Approval for Welding Consumables. The properties are to 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 is to 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, should 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 (see Section 6) the User of the welding consumables is to be authorized by the manufacturer to perform such works (combination of tests).

The welding process approval test programme is to be extended and is to 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's 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 is to be appended to the request for the Register's approval.

The scope and results of the tests are to comply with the requirements of this 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 are to be carried out at a yearly interval, and re-approval relates to the year when the tests are conducted. The tests are to 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 the Register's supervision.

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 certified 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 are to be conducted under 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 supervision by the Register, the approval certificate loses its validity. The Register's 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 is to 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 are to 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 is to be agreed upon with the Register in each particular case.

4.2 WELDING CONSUMABLES FOR HULL STRUCTURAL STEEL

4.2.1 General provisions.

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 are to 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 are to be chosen in accordance with Table 2.2.4.

4.2.1.4 Depending on the diffusible hydrogen content in the deposited metal which is determined from 4.2.2.3, the indices H, HH and HHH may be assigned to welding consumables by the Register in accordance with Table 4.2.1.4. The method of determining the hydrogen content should be indicated for approval purposes. The diffusible hydrogen content calculation should 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 % and over or for welding such steel to other steels, or for welding higher strength steel, are to 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 is not to exceed 0,03 % 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 **ЛУ5 — ЛУ7** and icebreakers) are to be tested to determine the weld corrosion resistance in sea water, the welds being of steel grades adopted for the structures.

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	
		Tensile strength, *Rm*, MPa	Yield stress, *Re*, 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	400 — 560	305	22	45	+20	47	+20	34
2	strength steel	400 — 560	305	22	45	0	47	0	34
3		400 — 560	305	22	45	−20	47	−20	34
1Y	For higher	490 — 660	375	22	45	Not subject to classification		+20	34
2Y	strength steel	490 — 660	375	22	45	0	47	0	34
3Y	with	490 — 660	375	22	45	−20	47	−20	34
4Y	$Re \leqslant 355$ MPa	490 — 660	375	22	45	−40	47	−40	34
2Y40	For higher	510 — 690	400	22	45	0	47	0	41
3Y40	strength steel with	510 — 690	400	22	45	−20	47	−20	41
4Y40	$Re \leqslant 390$ MPa	510 — 690	400	22	45	−40	47	−40	41

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, Rm, 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 $Re \leqslant 355$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 $Re \leqslant 390$MPa	510	120	0	47	41	0	41
3Y40		510	120	−20	47	41	−20	41
4Y40		510	120	−40	47	41	−40	41

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
H	15	10
HH	8	5
HHH	5	Not to be used

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 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 multi-run 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 electro-slag 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 is to 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 Part of the Rules or at the option of the manufacturer the following is to be determined when approving the welding consumables:

diffusible hydrogen content in the deposited metal (see 4.2.1.4 and 4.2.2.2);

weld metal and welded joint resistant to cold cracking during welding (see 4.2.1.5 and 4.2.2.4);

corrosion resistance of welded joint in sea water (see 4.2.1.6 and 4.2.2.5).

4.2.2.2 When annual re-approval tests for welding consumables are conducted in compliance with 4.1.4.1, the scope of the appropriate welding consumable tests is to 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 Determination of hydrogen content, when required, may be effected by the vacuum method and in one of the two ways:

according to the procedure described in Collection of Regulating Documents of the Register (book 3) using vacuum non-mercury equipment;

according to a procedure providing for the use of vacuum mercury equipment.

On agreement with the Register, it is permitted to determine the hydrogen content by the glycerine method.

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 are to 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 are to 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 are to be prepared from steel of the highest grade.

Welding of test assemblies is to be carried out at normal temperature and the subsequent run is to be made after the preceding one has cooled to at least 250 °C but not less than to 100 °C; welded test assemblies are not to be heat treated.

Before being cut to test specimens, butt weld test assemblies must undergo radiographic inspection the results of which are to confirm freedom from impermissible defects.

Welding of test assemblies is to be made in the presence of a Surveyor to the Register or a person authorized by that body.

4.2.3.2 Specimen preparation.

4.2.3.2.1 For the weld metal test, longitudinal cylindrical test specimens are to be used in accor-

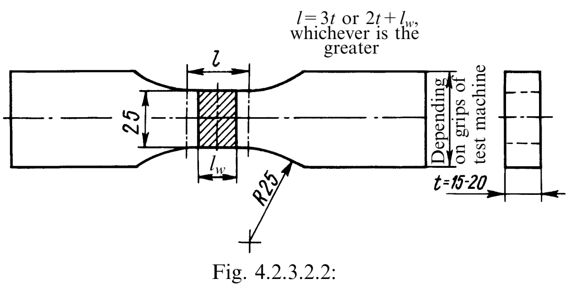


Fig. 4.2.3.2.2:
l_w - utmost weld width (upper side of weld)
$l = l_w + 12$ mm

dance with Fig. 2.2.2.3*a*, Part XIII "Materials" with dimensions: $d = 10$ mm, $L_o = 50$ mm, $L_c = 60$ mm, $R \geqslant 5$ mm.

The longitudinal axis must coincide with the centre of the weld and:

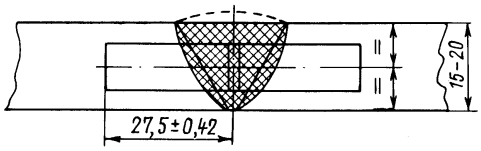


Fig. 4.2.3.2.4-1

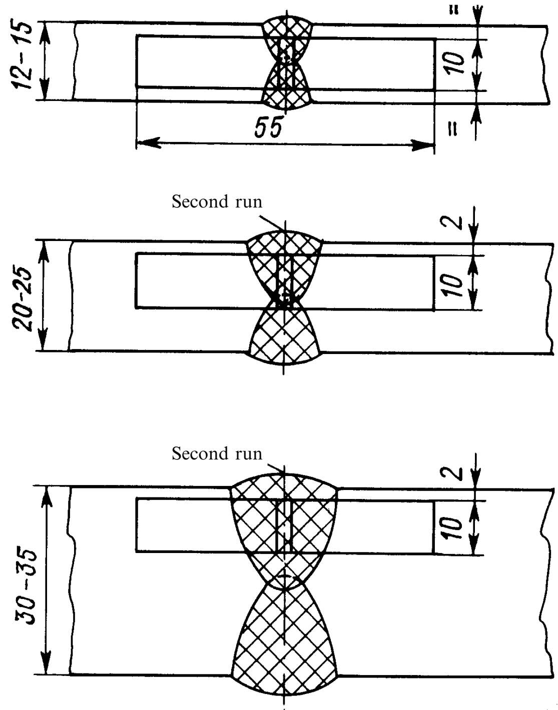


Fig. 4.2.3.2.4-2

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 are to be used in accordance with Fig. 4.2.3.2.2. The upper and lower surfaces of the weld are to 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.

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 are to 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 25mm by machining on the compression side of the bend specimen.

While side bend testing of transverse specimen, specimen dimensions are to 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 i$\geqslant$ 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 are to 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 is to 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 is to meet requirements of 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.

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 should be ignored.

4.2.3.3.2 Where the tensile and bend test results do not agree with the requirements, the tests should be repeated on a double number of specimens.

4.2.3.3.3 For impact testing, three specimens should be chosen. The average impact energy value obtained should 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 % of that value. During the tests, the temperature of the specimens being tested should be maintained within ± 2 °C.

4.2.3.3.4 Where the results of impact testing do not agree with the requirements, an additional set of three specimens may be tested. Re-tests may be effected if not more than two of the values obtained are below the average value required, and out of those values not more than one is less than 70 % of the required value.

The average values obtained as a result of testing the three specimens and three additional specimens should comply with the standard. Out of six values obtained, only two may be below the required value and out of those not more than one may be less than 70 % of the required value.

4.2.3.3.5 The hot cracking test results will be considered satisfactory if no surface or internal cracks nor considerable porosities are to be found in the welds of the tee-joint test assembly.

4.2.3.3.6 The cold cracking test results are to 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 will be determined. The ratio of corrosion rates of welded joints components should be 0,9 — 1,1.

4.2.4 Testing of electrodes for manual arc welding.

4.2.4.1 Deposited metal tests.

Two test assemblies are to 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 should be as shown in Fig. 4.2.4.1.

The weld is to be made by several runs, the direction of each subsequent run being opposite to that of the preceding one. The thickness of each run is to be between 2 and 4 mm.

The test results should 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 should 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 are to be prepared in that position.

Butt weld test assemblies for electrode testing should be as shown in Fig. 4.2.4.2.

For particular positions, preparation of test assemblies should be effected taking the following into consideration.

Downhand position. The first run should be made with 4 mm diameter electrode. Remaining runs (except the last two layers) should be made with 5 mm diameter electrodes or larger.

The runs of the last two layers should be made with the largest diameter of electrode manufactured.

Downhand position (where a second downhand test is required). The first run should 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.

Horizontal position. The first run should be made with 4 mm or 5 mm diameter electrode, subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead positions. The first run should 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.

Vertical-downward position. Electrode diameter and the sequence of welding the test assembly should be those recommended by the manufacturer.

Back sealing runs are to be made with 4 mm diameter electrodes after cutting out the root run to clean metal in the same welding position as the weld runs.

The test results should comply with Table 4.2.1.2-2.

4.2.4.3 Hot cracking test of weld metal and weld as a whole.

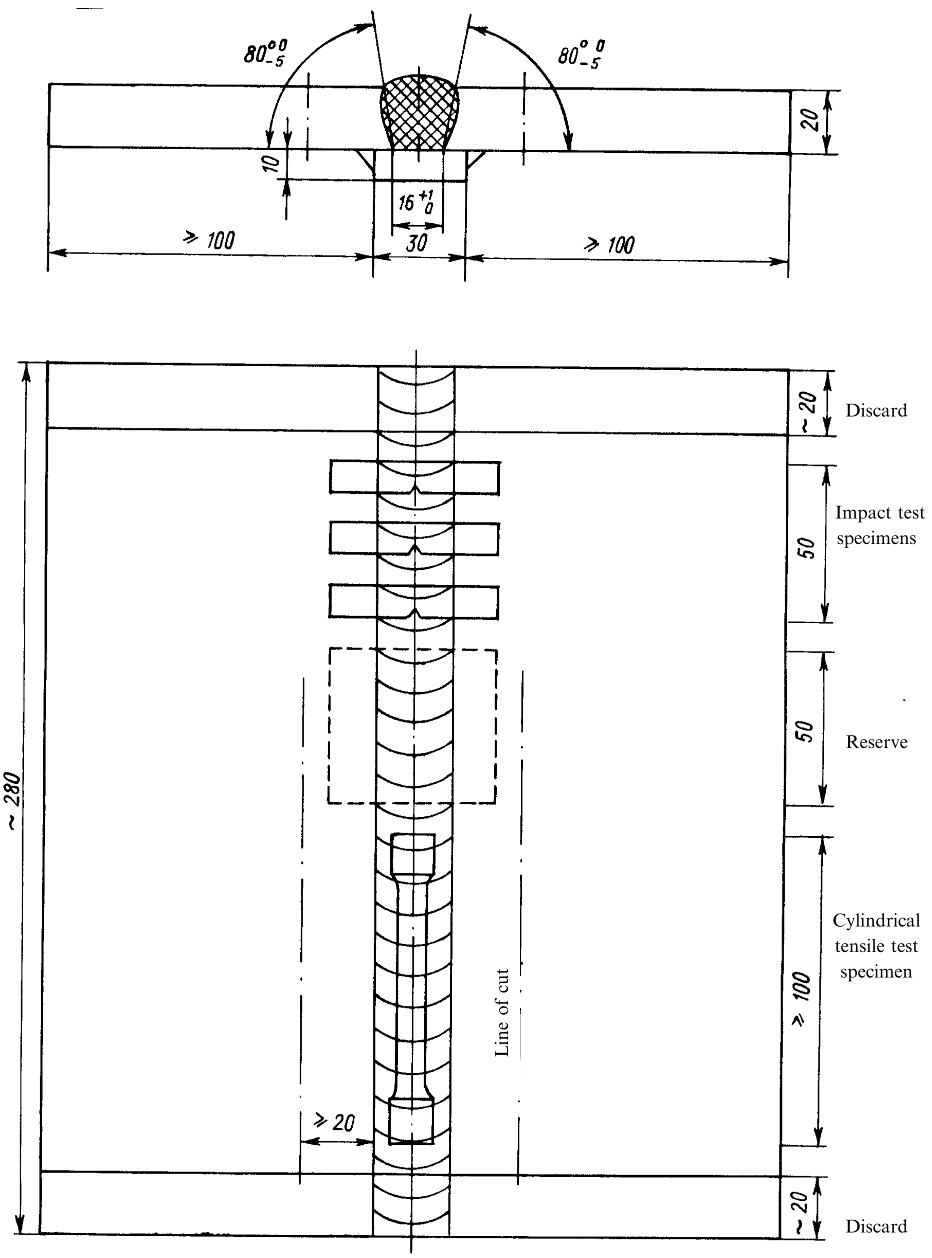


Fig. 4.2.4.1

To determine hot cracking resistance, three tee-joint test assemblies are to be prepared as shown in Fig. 4.2.4.3.

As far as possible, the test assemblies are to be welded with electrodes of different diameters.

The lower edge of the vertical plate is to be smooth and to fit closely to the lower plate surface. Uneven spots should be removed before welding. Tack welds should be made on the butt ends of the plates. The lower plate is to be stiffened additionally by welding three transverse ribs to it to protect it against deformation.

Welding is to be carried out in the gravity position. The fillets are to be signle-run welds joined at the maximum current recommended for the particular type and size of electrodes by the manufacturer.

The second fillet should be welded immediately after the first one and is to end at that side of the test assembly where the first one was started. Both the fillets should be executed at a constant speed and without weaving.

The length of electrode necessary to make a weld (see Fig. 4.2.4.3) is specified in Table 4.2.4.3.

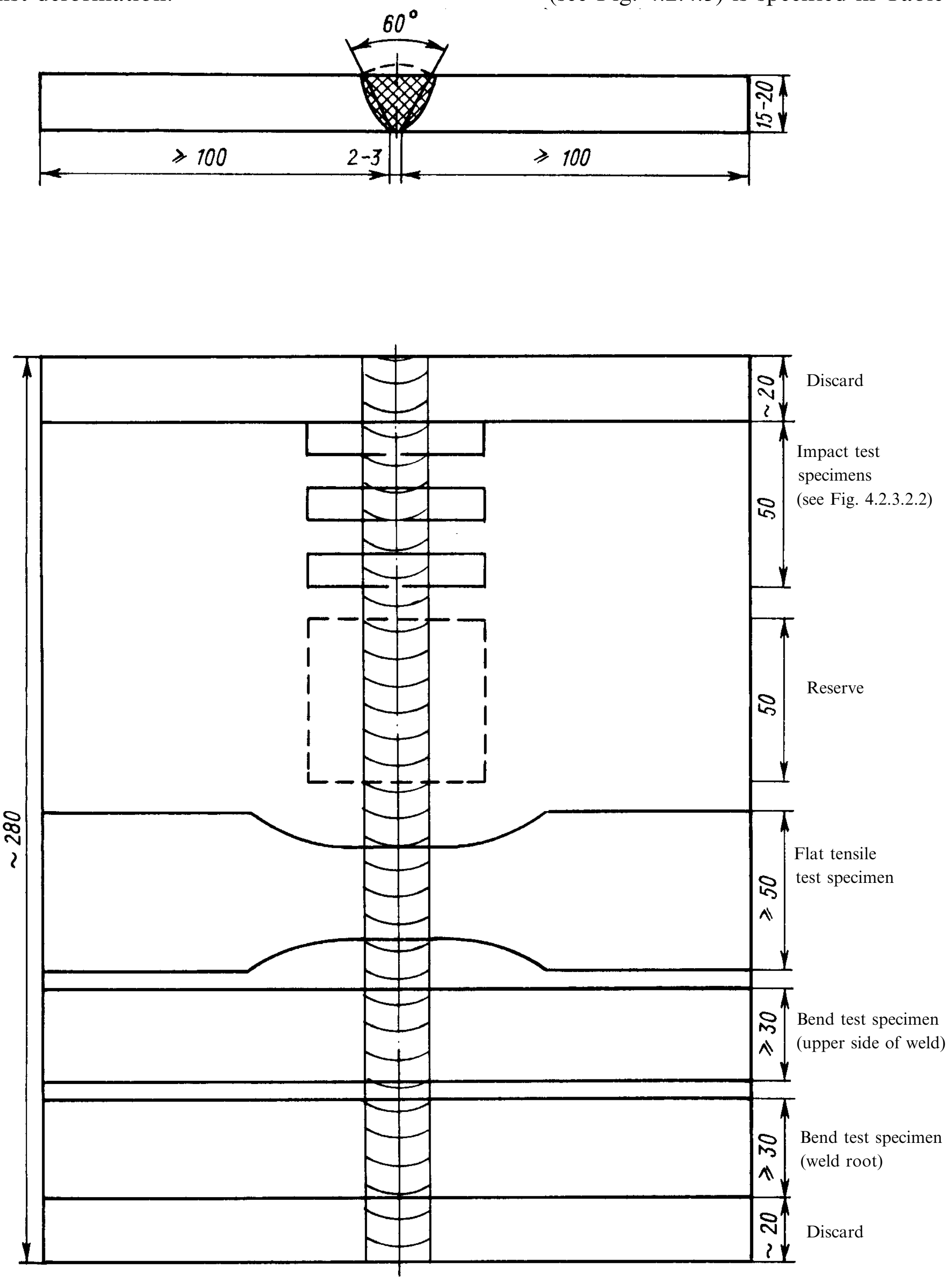


Fig. 4.2.4.2

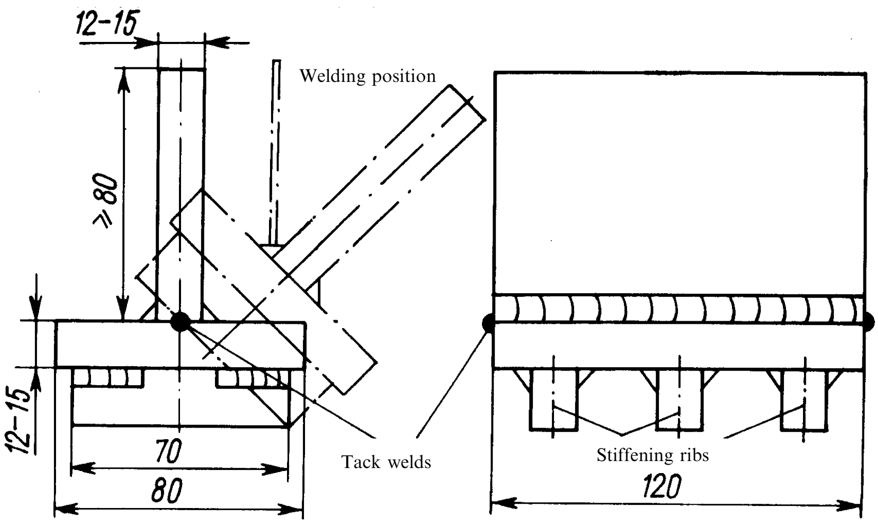


Fig. 4.2.4.3

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

After welding, the slag is to be removed from the fillets, and after complete cooling they are to 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 are to 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 is to 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.

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 are to be required, in addition to the normal annual re-approval tests of welding consumables in compliance with 4.2.4.4.1. One must 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 are to 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 is to 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 should 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 is to be carried out as shown in Fig. 4.2.5.

Tee-joint test assemblies are to be prepared for each welding position for which the electrode is recommended (downhand, vertical-upward, vertical-downward, overhead). The test assemblies are to be prepared using electrodes of the diameter recommended by the manufacturer for the particular welding position. The length of test assembly is to be sufficient to allow at least the deposition of the entire length of the electrode being tested. The first weld on the test assembly is to be made with an electrode of the largest diameter manufactured, and

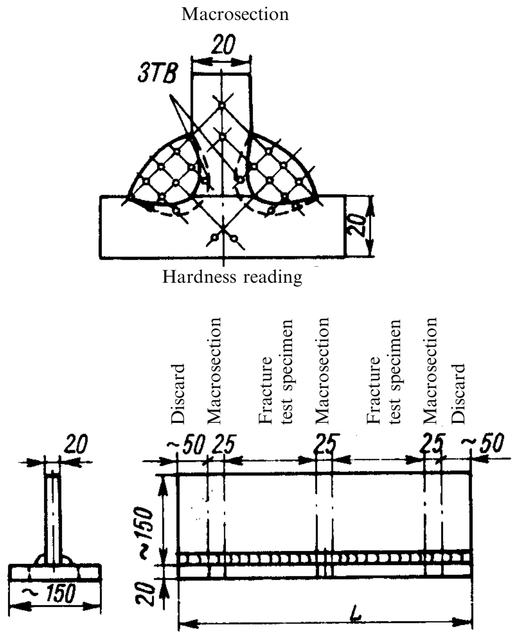


Fig. 4.2.5

the second one with an electrode of the smallest diameter manufactured.

From three sections about 25 mm wide, three macrosections should be prepared.

On the macrosections, the hardness of weld metal, heat-affected zone and base metal should 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 must not exceed 350 HV (Vickers hardness, load 100 N).

After one of the welds has been gouged or machined, the fracture test is to be carried out submitting the root of the remaining weld to tension. The fractured surface is to be free of cracks and considerable porosity.

In re-approval of welding consumable annual tests of the electrodes intended for fillet welding are to 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 are to be conducted in the following way:

where the requirements for the impact test temperature only change the deposited metal tests are to 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 is to 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 should 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 is to 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 is to be opposite to that of the preceding one. The thickness of each run should 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 should comply with Table 4.2.1.2-1.

4.2.6.2.2 Butt weld test.

A test assembly is to 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 should comply with Table 4.2.1.2-2.

4.2.6.3 Combinations for two-run welding.

Two test assemblies are to 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 are to 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 are to be in accordance with Table 4.2.6.3.

The root gap should not exceed 1 mm. The test assembly is to be welded in two runs. After completion of the first run and before the next one, the assembly is to 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 are to comply with Tables 4.2.1.2-1 and 4.2.1.2-2.

4.2.6.4 The welding consumable re-approval tests are to be carried out according to the programme, having regard to the following:

.1 for combinations intended for multi-run welding one deposited metal test assembly is to be welded, and one tensile specimen and three impact specimens are to be tested;

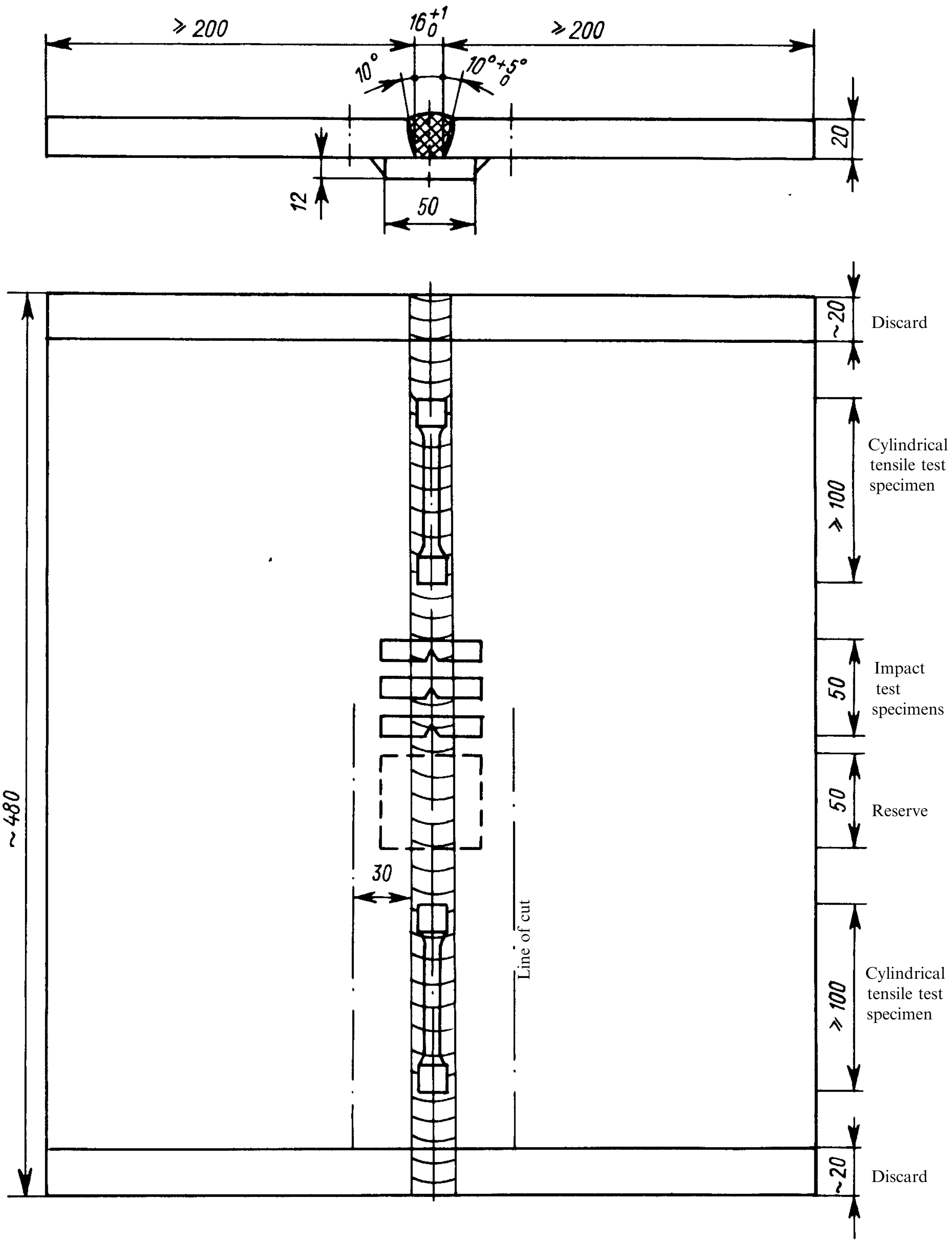

≥ 200
16^{+1}_{0}
≥ 200
10°
$10^{\circ}{}^{+5^{\circ}}_{0}$
20
12
50
~20
Discard
≥ 100
Cylindrical tensile test specimen
50
Impact test specimens
50
Reserve
~480
30
Line of cut
≥ 100
Cylindrical tensile test specimen
~20
Discard

Fig. 4.2.6.2.1

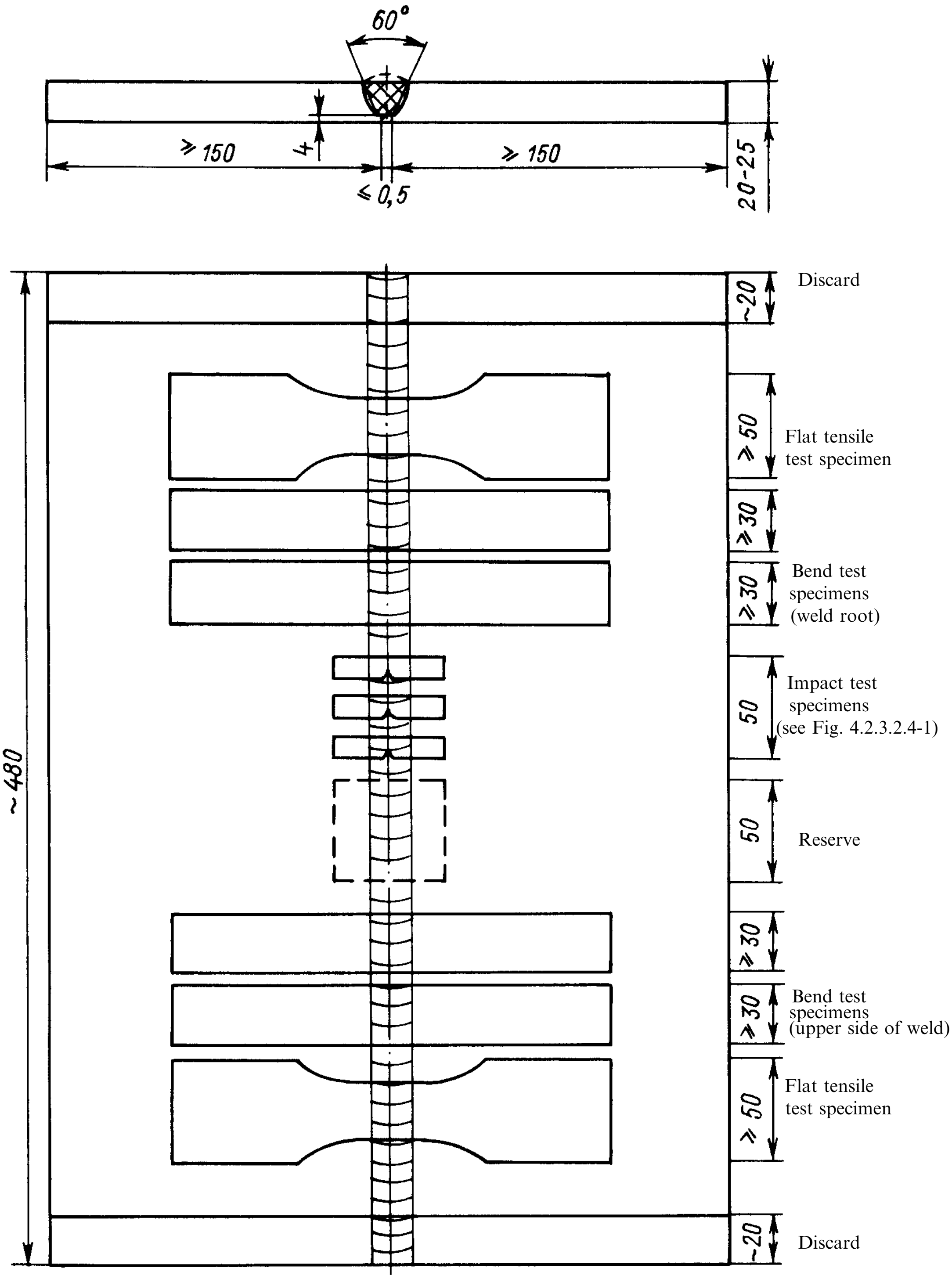

60°
≥ 150
4
≥ 150
≤ 0,5
20-25
~20
Discard
≥ 50
Flat tensile test specimen
≥ 30
≥ 30
Bend test specimens (weld root)
50
Impact test specimens (see Fig. 4.2.3.2.4-1)
50
Reserve
≥ 30
≥ 30
Bend test specimens (upper side of weld)
≥ 50
Flat tensile test specimen
~20
Discard
~480

Fig. 4.2.6.2.2

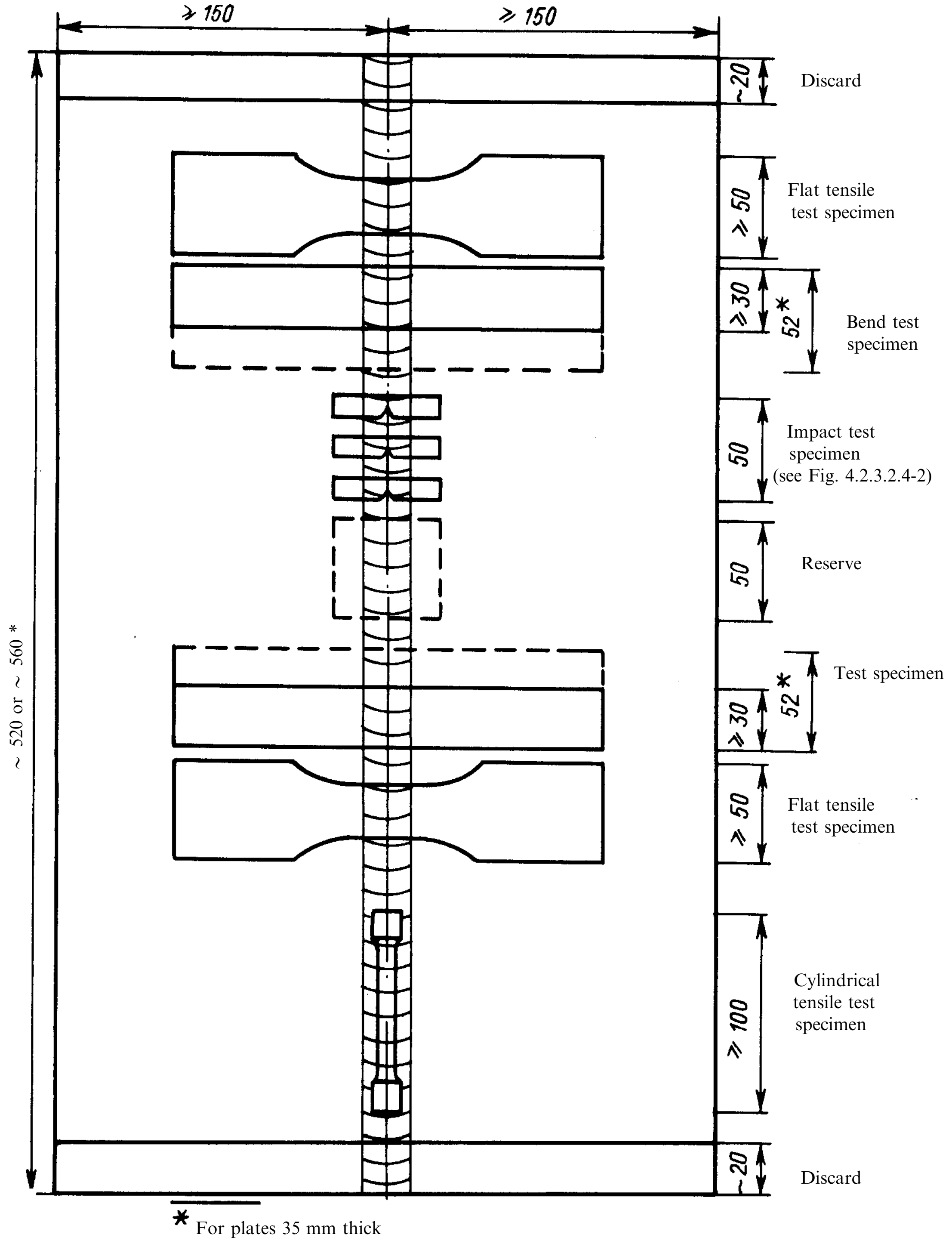
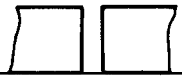
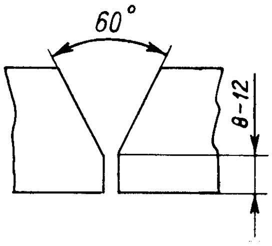
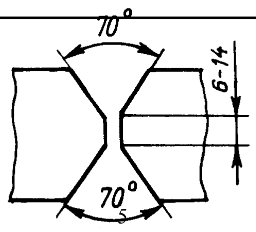

≥ 150
≥ 150
~20
Discard
≥ 50
Flat tensile test specimen
≥ 30
52*
Bend test specimen
50
Impact test specimen (see Fig. 4.2.3.2.4-2)
50
Reserve
52*
Test specimen
≥ 30
≥ 50
Flat tensile test specimen
≥ 100
Cylindrical tensile test specimen
~20
Discard
~ 520 or ~ 560 *
* For plates 35 mm thick

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	higher strength steel
12 —15			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

.2 for combinations intended for two-run welding one butt joint not less than 20 mm in thickness is to be welded, and one transverse tensile test specimen, two transverse bend test specimens and three impact test specimens are to be tested.

In case the combination is approved only for two-run welding one longitudinal cylindrical tensile test specimen is to be also tested.

4.2.6.5 For the purpose of the tests for upgrading the welding consumables one must 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 is to 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 is to be reported in Certificate of Approval 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 should be complied with.

When approving combinations for automatic multirun welding, the requirements of 4.2.6.2 should be complied with and when the deposited metal assembly is prepared the thickness of a layer should 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 are to 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 is to be prepared.

The thickness of each layer of weld metal is to 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 are to 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 are to be prepared for each welding position for which the combination is recommended by the manufacturer.

The assembly is to 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 is to 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 is to be prepared.

The results of testing specimens cut out of the test assembly as shown in Fig. 4.2.4.2 are to comply with the requirements of Table 4.2.1.2-2.

4.2.7.3 Combinations for automatic two-run welding.

Approval tests are to be carried out in accordance with the requirements of 4.2.6.3 taking the following into consideration.

Two test assemblies are to be prepared as shown in Fig. 4.2.6.3, using plates 12-15 mm and 20-25 mm in thickness.

If approval is requested for welding plates thicker than 25 mm, one assembly is to 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 is to be as shown in Fig. 4.2.7.3.

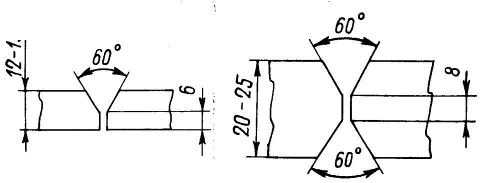


Fig. 4.2.7.3

4.2.7.4 The welding consumable re-approval tests are to be carried out according to the programme, having 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 is to be made in accordance with Fig. 4.2.4.1, and one tensile test specimen and three impact test specimens are to be tested. The diameter of the welding wire is to 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 is to be made in accordance with Fig. 4.2.6.2.1, and one tensile test specimen and three impact test specimens are to be tested. The diameter of the welding wire is to 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 is to 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 are to be tested. The diameter of the welding wire is to 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 must 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 is to 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 should be considered.

4.2.8.2 Two test assemblies are to 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 35-40 mm thick. The grade of steel to be used for each one of these assemblies must be selected according to the requirements given in Table 4.2.6.3.

For specimens cut out of the test assemblies as shown in Fig. 4.2.8, the test results should 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 are to 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;

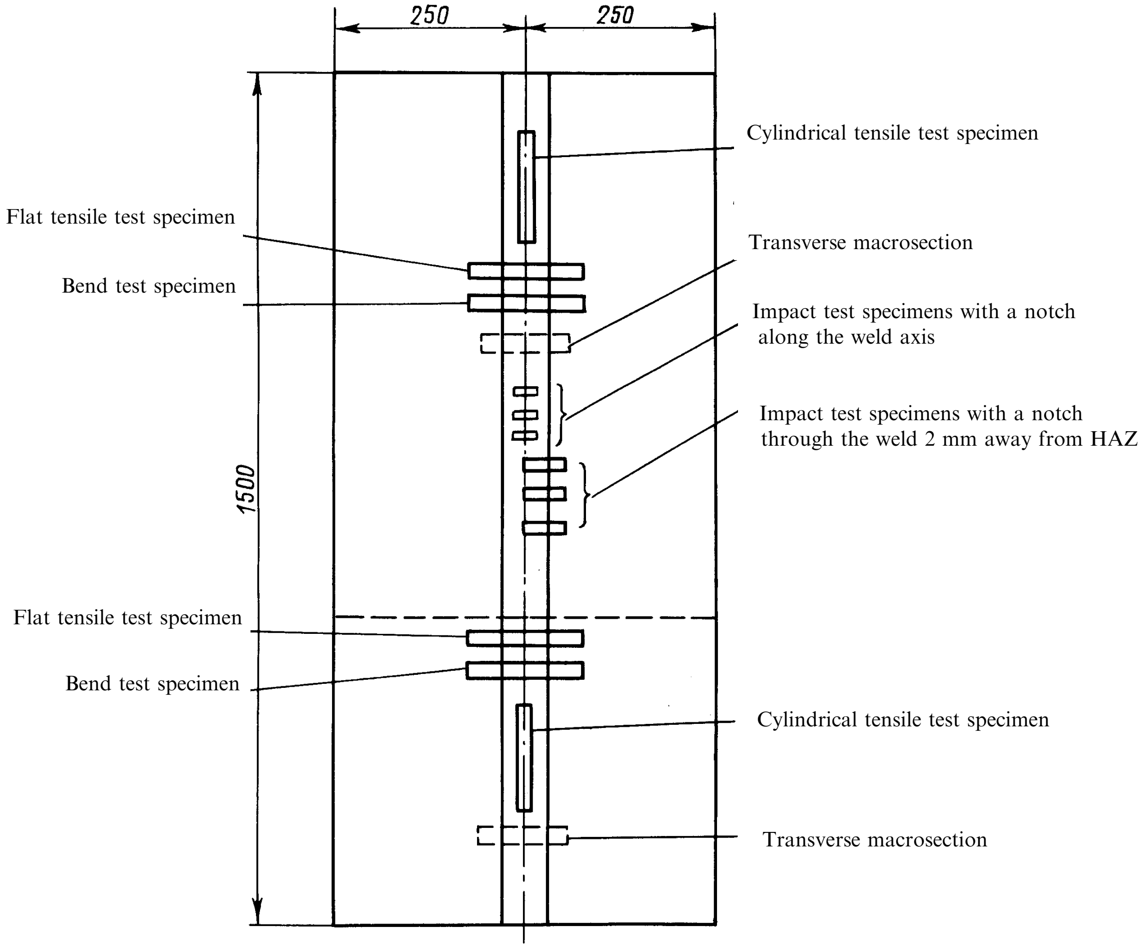


Fig. 4.2.8.2-1

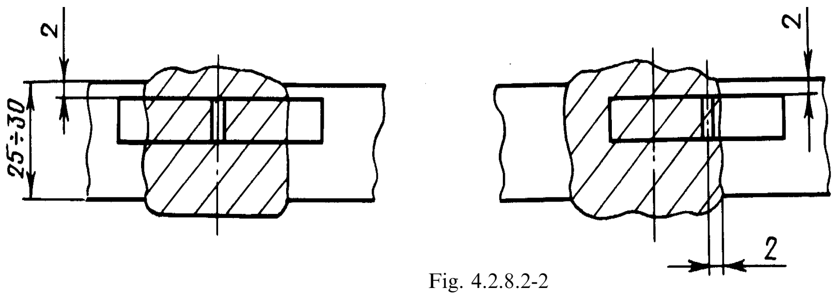


Fig. 4.2.8.2-2

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 (see Fig. 4.2.8.2-2);

macro section.

4.2.8.4 In upgrading of welding consumables all the tests required for approval of electrogas and electroslag welding are to 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 are to 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 should 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 maxi-mum thickness should be prepared as shown in Fig. 4.2.9.

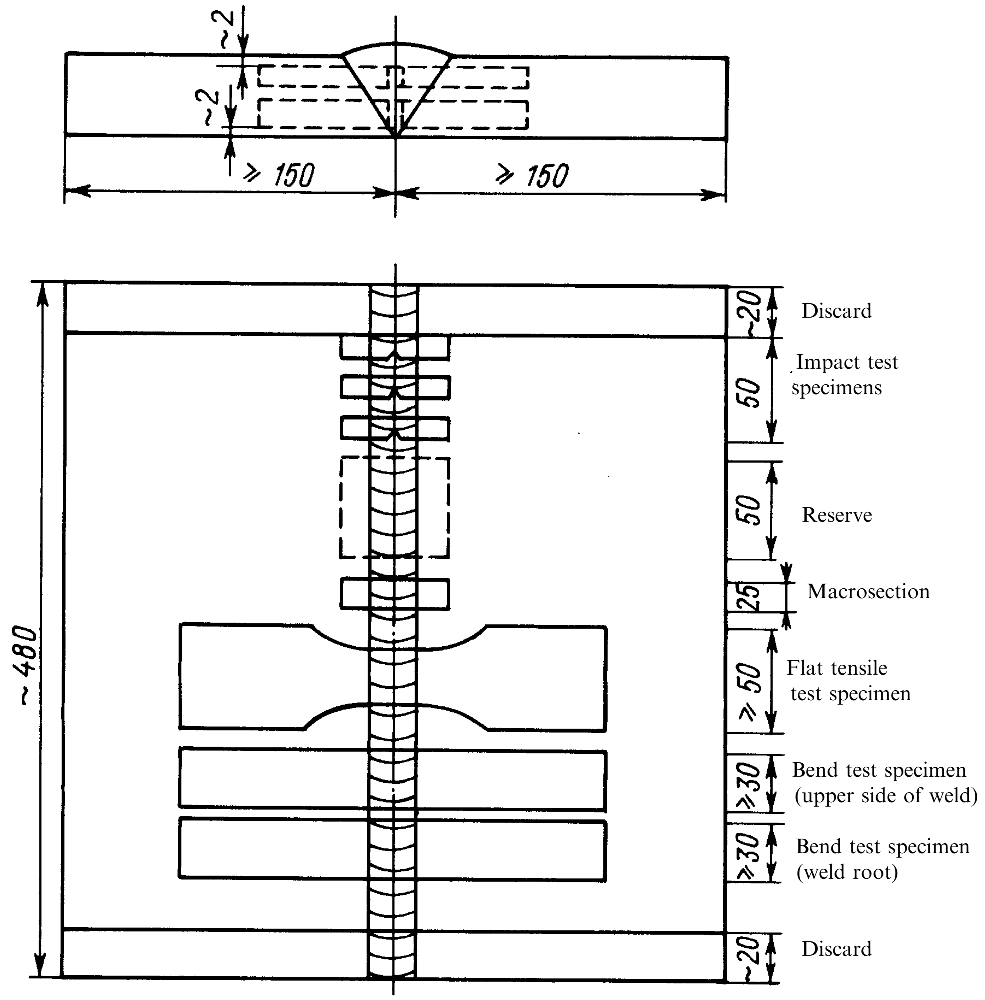


Fig. 4.2.9

Edge preparation, gap dimensions and welding methods should be those recommended by welding consumables manufacturer.

The mechanical properties of deposited metal should 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 is to be prepared.

Welding consumable re-approval tests are to 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 (see 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 is to be additionally welded.

In upgrading welding consumables for single-pass welding the full tests (with regard to annual re-approval tests) are to 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" is to 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 ($R_{p0,2/t}$) is to be determined.

Testing and considering of the test results is to 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 are to be tested on steels for the welding of which they are intended. The tests are to 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" are to 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 should meet 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 °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 are to be obtained at a testing temperature not less than 5 °C lower than the lowest design temperature.

4.5.4 The lowest permissible design temperature is to be stated in the type approval certificate for the welding consumables and in the accompanying documentation of the manufacturer.

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, *Rm*, MPa	Yield stress, *Re*, 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	41

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, *Rm*, 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
		minimum			downhand, horizontal and overhead positions	vertical position		
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	41

4.5.5 The programme for welding consumable re-approval tests of grades 5Y and 5Y40 is to 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 are to 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 are to comply with the requirements of Table 4.6.1.

4.6.2 Weld tests.

Preparation of test assemblies, their size and number, and testing of welds are to 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 are to be made of high strength steels with a minimum tensile strength complying with the specified grade.

The results of specimen tests are to comply with the requirements of Table 4.6.2.

4.6.3 Welding consumables should 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 should 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 is to 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 is to 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.

Table 4.6.1

Requirements for mechnaical properties of deposited metal

Grade of welding consumables	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, *Rm*, MPa [1]	Elongation, A_5, %	Test temperature, °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% 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.

Table 4.6.2

Requirements for mechnaical properties of welded joints

Grade of welding consu-mables	Tensile strength, *Rm*, 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.

4.7 WELDING CONSUMABLES FOR ALUMINIUM AND ALUMINIUM ALLOYS

4.7.1 Welding consumables approved for welding a particular alloy are to be tested on that alloy. For testing purposes, three butt-weld and three tee-joint test assemblies are to be prepared.

4.7.2 Butt-weld test assemblies should be prepared by welding plates of the following thickness:

one assembly - 5 mm thick or less;

one assembly - about 10 mm thick;

one assembly - more than 10 mm thick.

Test assemblies are to be prepared in the down-hand position. The edge preparation should be effected in accordance with normal practice adopted for the welding procedure to be applied.

The size of test assemblies should be sufficient for preparing all the necessary specimens taking possible re-testing into account. The following specimens are to be cut out of each butt-weld assembly and tested:

three flat transverse specimens for tensile test. The weld reinforcement is not to be removed prior to testing;

three transverse specimens for bend test.The weld reinforcement should be removed prior to testing. The specimen is to be bent in such a way that the run made in the last turn is in tension;

three cylindrical specimens for the tensile test of weld metal to be cut out in the longitudinal direction. The specimens should be prepared of test assemblies 10 mm or more in thickness.

4.7.3 The test results obtanied on above specimens should comply with the requirements of Table 4.7.3.

4.7.4 Tee-joint test assemblies are to be prepared in accordance with 4.2.4.3 and subjected to fracture test for checking the weld metal for fracture, porosities, cracks and other flaws.

One of the three tee-joint test assemblies is to be welded with the wire of the smallest diameter, the other with the wire of the largest diameter and the third one with the wire of the medium diameter.

The number of flaws in the fracture should not exceed that permitted by 3.4.2.2.

Table 4.7.3

Specimens					
Weld		Weld metal			
R_m, MPa	Angle of bend	R_m, MPa	$R_{p\,0,2}$, MPa	A_5, %	Z, %
Not lower than R_m of base metal in mild condition	Not less than 120° over a mandrel having a diameter four times the specimen thickness	Subject to special consideration by the Register			

5 APPROVAL TEST FOR WELDERS

5.1 GENERAL

5.1.1 The requirements of this Section set down the general conditions of the approval test for welders (operators) who are to weld structures listed under 1.1.1.

5.1.2 Upon compliance with the requirements of this Section, a Certificate of Approval Test for Welder (see Annex to this Section) 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 the Register supervision.

5.1.3 Welders approved for the welding of structures subject to the Register supervision are not to be under 18, they should be adequately qualified and trained, and are to have practical experience.

5.1.4 An application for welder approval test must contain the following particulars: surname, name, patronymic, year of birth, place of work, date and place of issue of the qualification certificate.

5.1.5 The approval test of a welder by the Register may be conducted simultaneously with qualification tests at the place of the welder's work or training.

5.1.6 The basic materials for the preparation of test assemblies are to be approved by the Register, and relevant certificates are to be issued for them.

Test assemblies are to be welded using welding consumables and procedures approved by the Register.

5.1.7 If malfunction of equipment (voltage drop, de-energizing, etc.), peeling of electrode coat or other defects which do not depend on the welder occur during the preparation of test assemblies, the same number of test assemblies is to be prepared once more.

5.2 WELDER APPROVAL TEST

5.2.1 The conditions of the welder approval test should provide for the welder's qualifications and training to be verified.

5.2.2 The approval test for manual and semi-automatic welding is to be conducted in conformity with Table 5.2.2 and Figs 5.2.2-1 to 5.2.2-8.

5.2.3 The approval test for automatic welding is to be conducted in conformity with Table 5.2.3.

5.3 CERTIFICATE VALIDITY

5.3.1 The period of the certificate validity is up to two years.

When this period is over, the certificate is withdrawn, and the welder is to be tested in accordance with 5.2.

However, the certificate may be renewed without testing provided that, while the certificate was still valid, the welder effected the welding of structures mentioned under 1.1.1 and no remarks were made to him proceeding from the results of weld examination (including non-destructive testing).

5.3.2 The certificate becomes invalid in the following cases:

if the welder was not engaged in the welding operations mentioned in the certificate for more than six months on end while the certificate was valid;

if the welds made by the welder while the certificate was valid do not comply with the requirements of this Part.

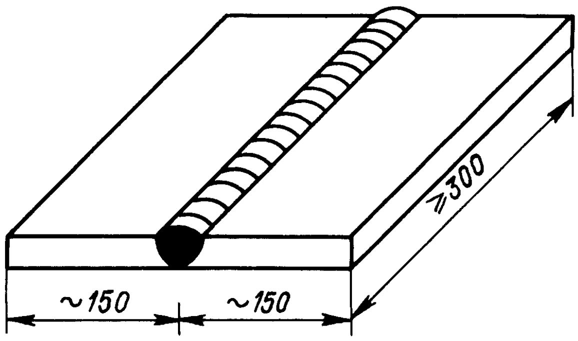


Fig. 5.2.2-1 Test assembly P_1

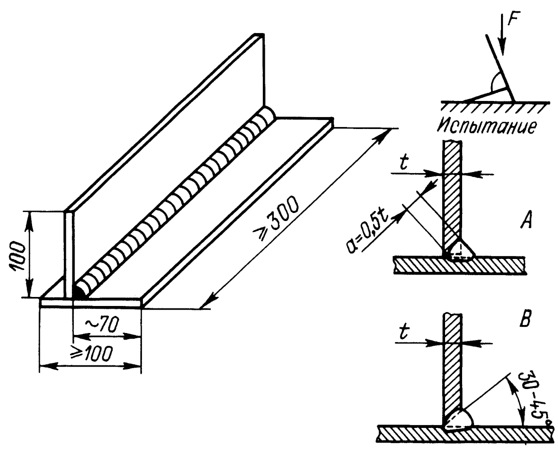


Fig 5.2.2-2 Test assembly P_2

Table 5.2.2

Item	Thickness, mm	Welding position	Type of test assembly [2]	Type of examination and quality grade: visual [3]	radiographic (ultrasonic)	destructive testing[4]
Plates	≤5	Horizontal	$P_{1d}+P_{2h}$	According to Table 3.3.2-1	According to 3.3.3.1 - grade III	Two specimens for fracture test from each fillet, joint according to 4.2.5. Four specimens for bend test according to 4.2.3.2.3 for butt welds performed using slag-free procedure, including: for thickness below or equal to 12 mm - two specimens with root tension and weld surface; for thickness above 12 mm - four specimens for side bend.
		Horizontal [1]	P_{2h}		—	
		All positions	$P_{1v}+(P_{1d}, P_{1h\text{-}v}, P_{10})+P_{2v}$		According to 3.3.3.2 - grade II	
		All positions [1]	$P_{2v}+(P_{2h}, P_{20})$		—	
	6 — 25	Horizontal	$P_{1d}+P_{2h}$		According to 3.3.3.1 - grade III	
		Horizontal [1]	P_{2h}		—	
		All positions	$P_{1v}+(P_{1d}, P_{1h\text{-}v}, P_{10})+P_{2v}$		According to 3.3.3.2 - grade II	
		All positions [1]	$P_{2v}+(P_{2h}, P_{20})$		—	
	> 25	Horizontal	$P_{1d}+P_{2h}$		According to 3.3.3.1 - grade III	
		Horizontal [1]	P_{2h}		—	
		All positions	$P_{1v}+(P_{1d}, P_{1h\text{-}v}, P_{10})+P_{2v}$		According to 3.3.3.2 - grade II	
		All positions [1]	$P_{2v}+(P_{2h}, P_{20})$		—	
Pipes [5]	≤5	Horizontal	$P_{1v}+P_3$	According to Table 3.3.2-2	According to 3.3.2-2 - grade II	Four specimens for bend test according to 4.2.3.2.3.
		All positions	P_4+P_5			
	> 5	Horizontal	$P_{1v}+P_3$			
		All positions	P_4+P_5			
		All positions [6]	P_6+P_7			
Pressure vessels (plates)	$(0{,}5-1{,}5)/t^7$	All positions	$P_{1v}+(P_{1h\text{-}v},P_{10})$		According to 3.3.3-1 - grade II	Four specimens for bend test according to 4.2.4.2.
Pressure vessels (pipes)	$(0{,}5-1{,}5)/t^{5,7}$	All positions	P_6			
Welding up of defective forgings and castings	—	Horizontal	P_8	According to Table 3.3.2-1	According to 3.3.2-2 - grade II	Two specimens for fracture test according to 4.2.5 and two specimens for fracture test according to 4.2.3.2.3.

[1] Fillet welds only.
[2] According to drawings to be found below:
P_{1d} - butt welds in horizontal position;
P_{1v} - butt welds in vertical position;
$P_{1h\text{-}v}$ - horizontal butt welds in vertical bulkhead;
P_{10} - overhead butt welds;
P_{2h} - fillet welds in horizontal position;
P_{2v} - fillet welds in vertical position;
P_{20} - overhead fillet welds.
[3] Eventually supplemented by dye penetrant or magnetic particle method.
[4] The Register Surveyor is to determine areas from which test specimens would be machined.
[5] The test assembly diameter is determined proceeding from the structural type.
[6] For the approval of welds in pipe constructions.
[7] t = test assembly thickness.

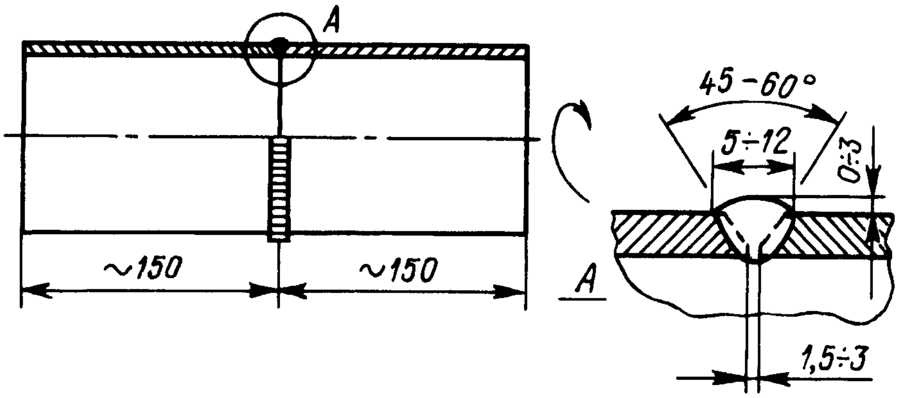


Fig 5.2.2-3 Test assembly P_3

Table 5.2.3

<table>
<tr><th rowspan="2">Item</th><th rowspan="2">Thickness or diameter, mm</th><th rowspan="2">Welding position</th><th rowspan="2">Type of test assem-bly</th><th colspan="3">Type of examination and quality grade</th></tr>
<tr><th>visual [2]</th><th>radiographic (ultrasonic)</th><th>destructive testing [3]</th></tr>
<tr><td>Plates</td><td>(0,5 - 2)t[1]</td><td rowspan="2">Welding position is chosen proceeding from welding procedure and the output of automatic welding equipment.</td><td>P_1</td><td>According to Table 3.3.2-1</td><td rowspan="2">According to 3.3.3 - grade III</td><td>Four bend test specimens according to 4.2.3.2.3.</td></tr>
<tr><td>Pipes</td><td>$\geqslant 0,5D$; (0,5 - 2)t[1]</td><td>$P_3(P_6)$</td><td>According to Table 3.3.2-2</td><td>Four bend test specimens according to 4.2.3.2.3.</td></tr>
</table>

[1] t = test assembly thickness, D = test assembly diameter.
[2] Eventually supplemented by dye penetrant or magnetic particle method.
[3] The Register Surveyor is to determine areas from which test assemblies would be machined.

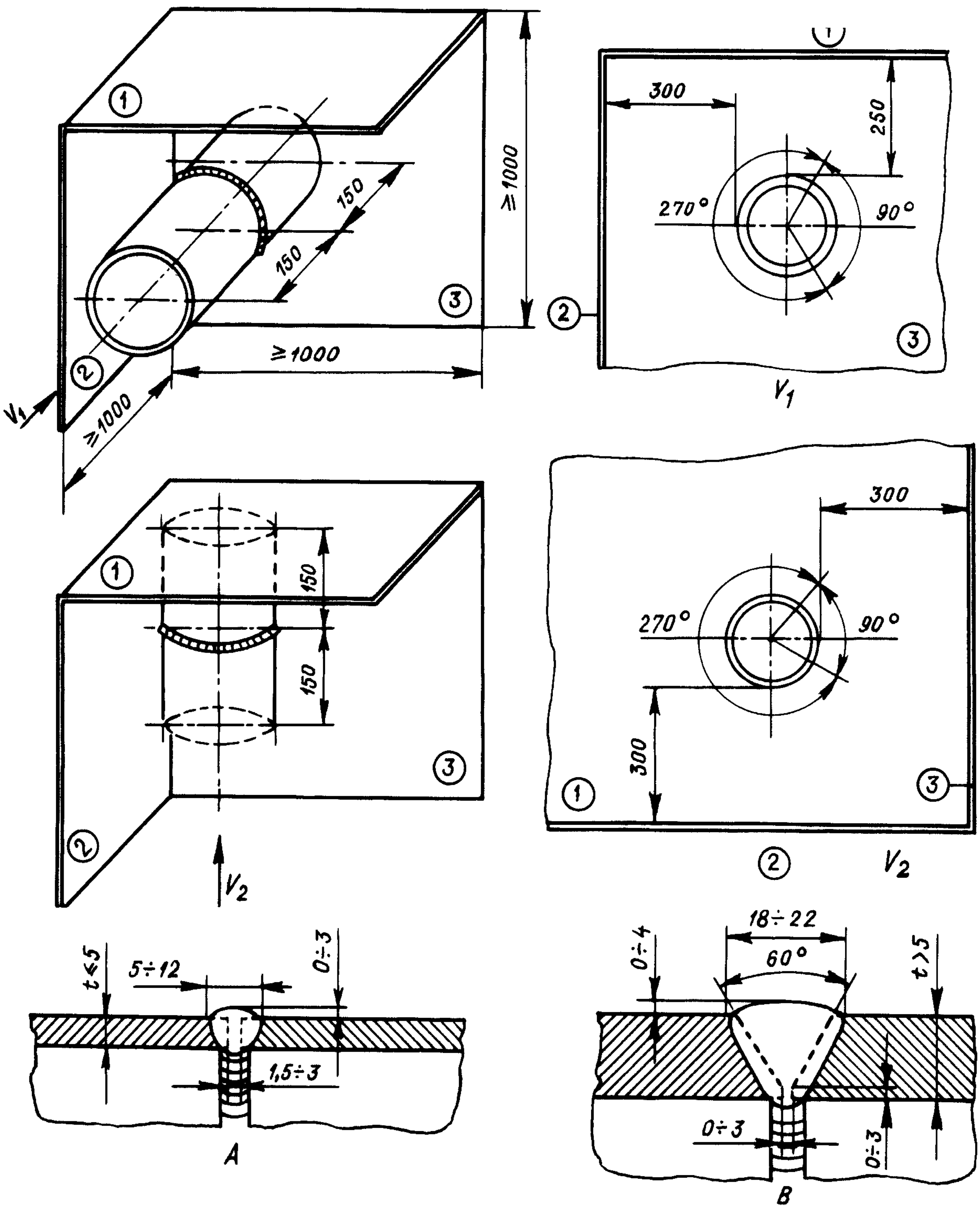


Fig 5.2.2-4 Test assembly P_4

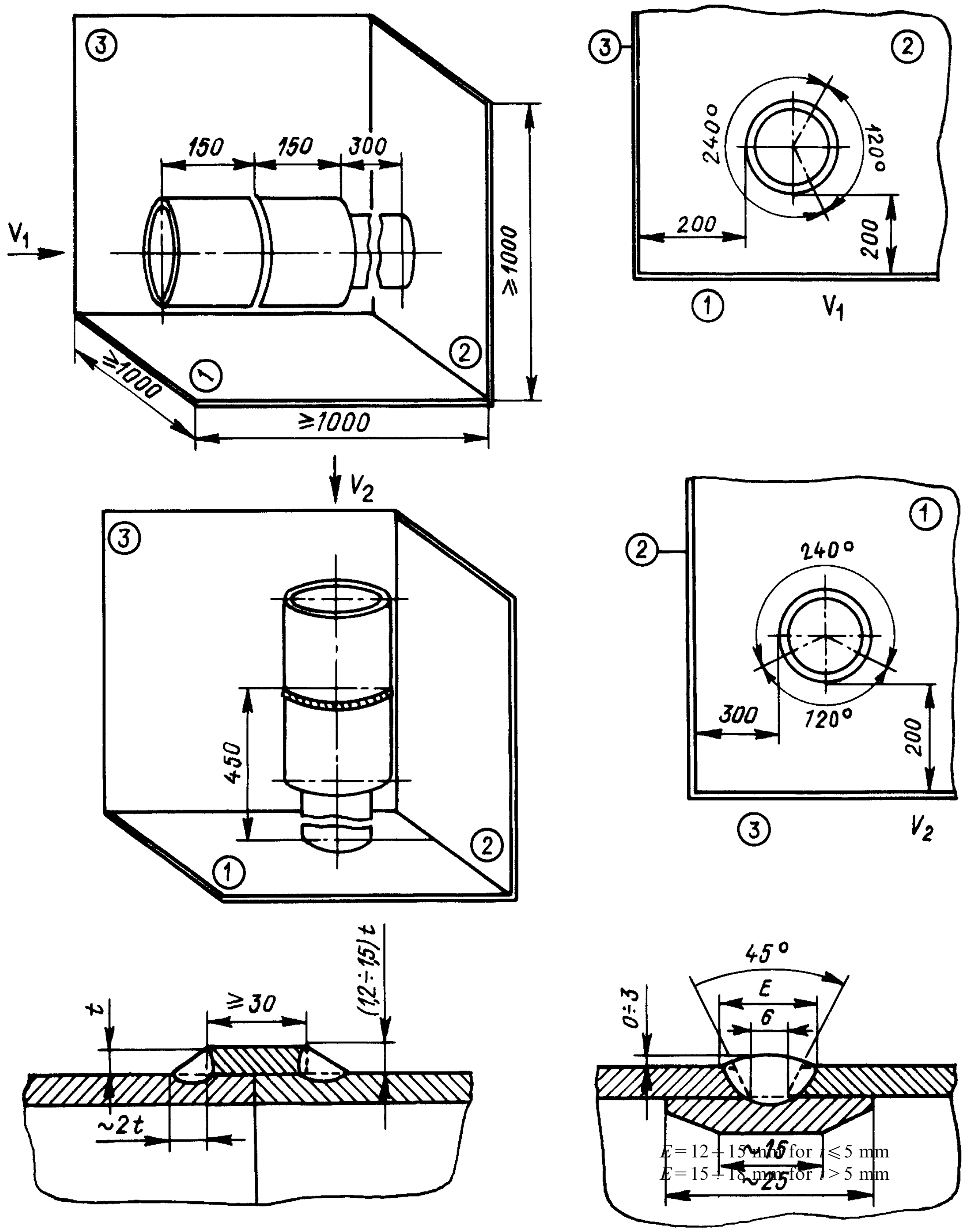
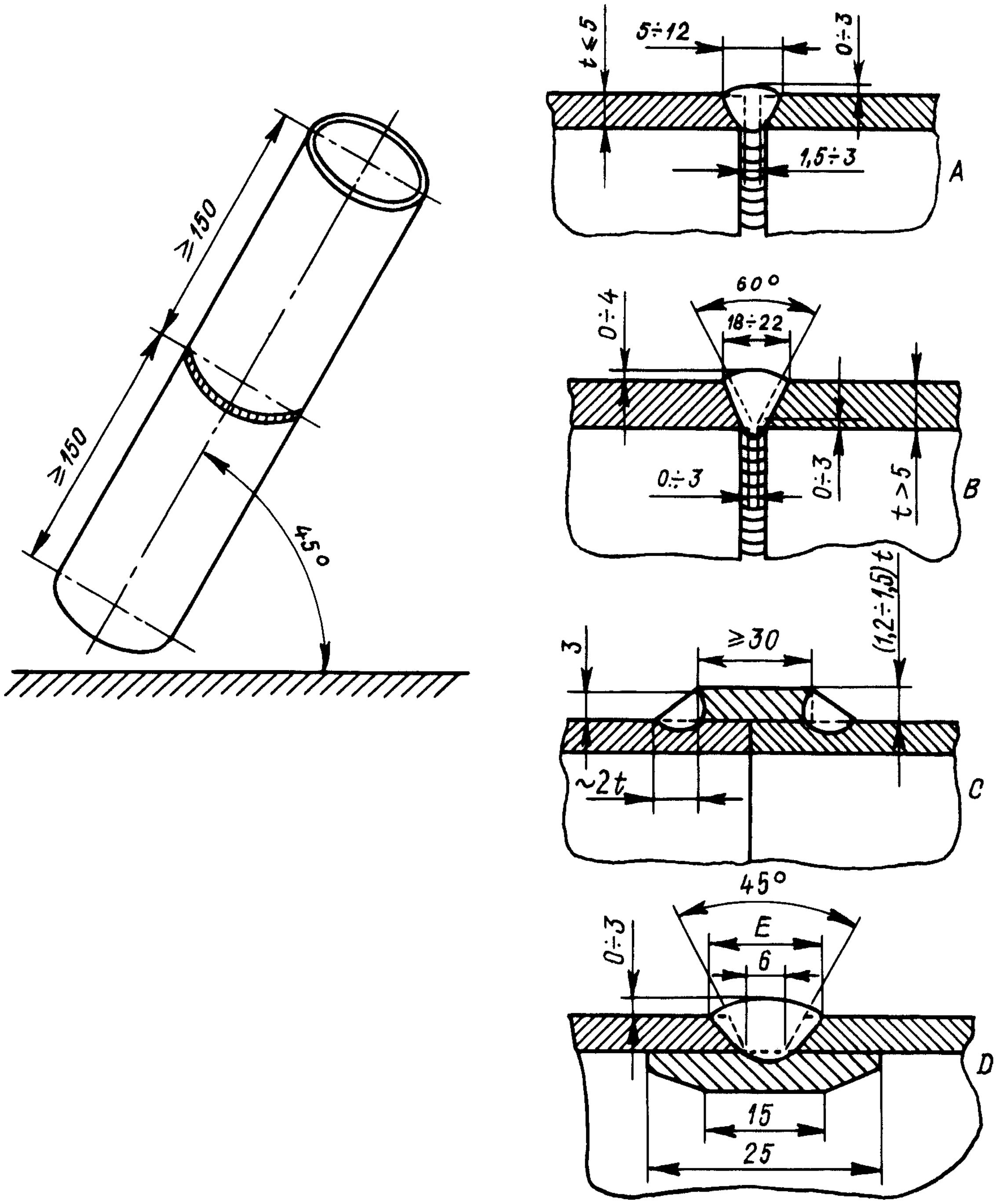


Fig 5.2.2-5 Test assembly P_5



$E = 12 \div 15$ mm for $t \leqslant 5$ mm
$E = 15 \div 18$ mm for $t > 5$ mm

Fig 5.2.2-6 Test assembly P_6

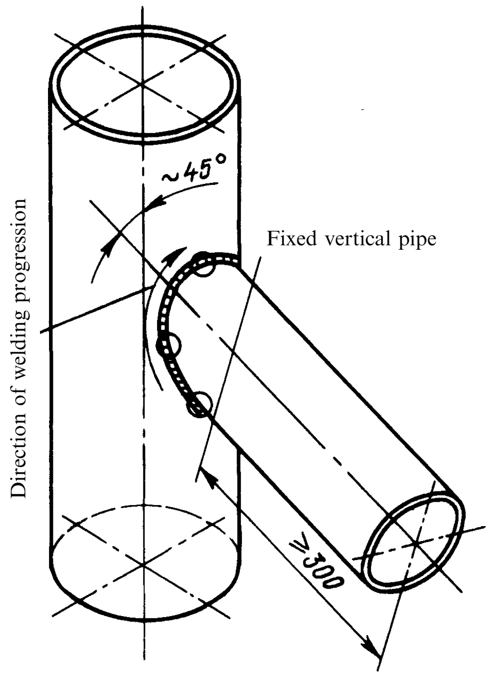
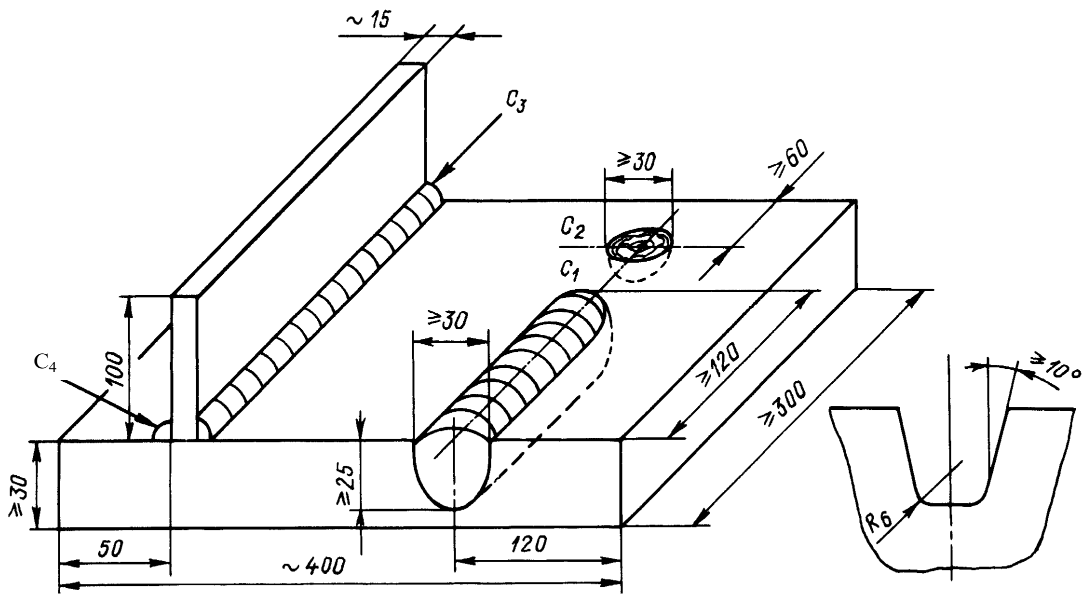


Fig. 5.2.2-7. Test assembly P_7



Groove preparation (recommendation) for C_1 and C_2 welds

C_1, C_2, C_3 - horizontal welding position
C_4 - vertical welding position

Fig. 5.2.2-8 Test assembly P_8

6 APPROVAL OF WELDING PROCESS

6.1 GENERAL

6.1.1 Welding processes adopted for the manufacture of structures subject to the Register supervision which are mentioned in 1.1.1 are to be approved by the Register and should comply with the requirements below.

6.1.2 Welding processes may be approved by the Register after consideration of relevant documentation and proceeding from the results of testing conducted in accordance with a program agreed with the Register. The documentation and the program are to be attached to the application of the manufacturer seeking the Register approval.

6.1.3 Documentation submitted to the Register is to contain the following information to characterize the welding procedure adopted:

principal materials used for the manufacture of structures (brand, grade, condition of supply, type of semi-finished product, dimensions, etc.);

types of structures, their purpose and service, sequence of assembly;

welding process (including welding techniques);

equipment (brief description, examination periods, etc.);

welding consumables (type, brand, grade, conditions of supply and storage);

welding positions and, where necessary, welding direction, types of joints, preparatory work necessary, primer, order of metal depositions, polarity of current, etc.;

requirements concerning backings and other fixtures, tacking techniques;

conditions of welding (temperature, protection from the weather, pre-heating, post-weld heat treatment, etc.).

6.1.4 Besides the above, the documentation is to contain information on the quality control system applied to the welding procedure in question by the works. Requirements for materials and operations should be stated, as well as the sources of quality assessment criteria.

6.1.5 Documentation which contains technical requirements for welding operations and for methods and criteria of assessment is to have relevant, unique identification (number) and is to be approved by the Register.

6.2 TESTING

6.2.1 Testing is to be conducted in accordance with a program approved by the Register. The purpose of the tests comprising the program is to verify that the materials, methods and procedures mentioned in the documentation submitted, which are applied for the manufacture of structures subject to the Register supervision, comply both with the requirements of the present Rules and with the requirements imposed by the procedure the approval of which is sought.

6.2.2 Test assemblies should be prepared by qualified welders (operators) whose qualification should, as a minimum, be confirmed by a certificate issued by a competent body.

If the results of assessing the welds made by the welders (operators) in accordance with the above program are satisfactory, the welders (operators) will be qualified by the Register in conformity with the requirements of Section 5 of this Part, with a relevant certificate being issued.

6.2.3 All the materials used during testing are to be (type) approved by the Register (have Certificate of Approval for Welding Consumables), and are to have a relevant quality certificate. If the material does not comply with one of these conditions, relevant tests may be held at the works. The scope of the tests is determined proceeding from the requirements of this Part and of Part XIII "Materials".

The above also refers to coats not removed before welding, if these are applied. As an alternative to the application of primers, they may be removed before welding, with relevant amendments to the documentation.

6.2.4 If, as a result of the tests below, a procedure for which approval is sought cannot be approved by the Register, it may be submitted for approval anew only after a corresponding analysis of the mishap and introducing relevant amendments to the documentation.

6.2.5 The tests are conducted on test assemblies and specimens bearing the Register brand. The test results including retesting should be entered in the protocol of the testing laboratory, and a relevant report should be issued.

6.2.6 Scope of approval.

6.2.6.1 Butt welds.

Proceeding from metal thickness or test assembly diameter, the approval of a welding procedure may be extended to the welding of rolled sheets and pipes the thickness and diameter of which are in compliance with Tables 6.2.6.1-1 and 6.2.6.1-2.

6.2.6.2 Fillet welds.

Proceeding from the design throat thickness *a* of fillet welds in the assemblies being tested (see 1.7.5.1, Part II "Hull"), a welding procedure approval covers welds having throat thicknesses from 0,75*a* through 1,5*a* with $a < 10$ mm.

Table 6.2.6.1-1

Thickness of test assemblies, t, mm [4]	Range of approval, mm [1, 2, 3, 4]
$3 \leqslant t < 12$	3 through $2t$
$12 \leqslant t \leqslant 100$	6 through $2t$, but not over 110

[1] For single-run welds, the thickness range of approval is $0{,}9t$ through $1{,}1t$.
[2] For double-run welds, the thickness range of approval is up to and including $1{,}0t$.
[3] For vertical downward welds, the thickness range of approval is $0{,}5t$ through $1{,}1t$.
[4] Where welds of different thickness are concerned, the maximum metal thickness should be adopted as the base metal thickness.

Table 6.2.6.1-2

Thickness of test assemblies, D, mm	Range of approval, mm
$D < 25$	D through $2D$
$25 \leqslant D < 150$	$D/2$ through $2D$, but not less than 25 mm
$D \geqslant 150$	$D/2$ and above

For welding test assemblies with $a \geqslant 10$ mm, a welding procedure approval covers welds with design throat thicknesses of fillets from 10 mm through $1{,}5a$.

For vertical downward fillets, a welding procedure approval covers thicknesses from $0{,}75a$ through $1{,}1a$.

Besides granting approval on the basis of a, provisions for approval proceeding from the thickness of the base metal t, similar to those of 6.2..6.1, are also valid for fillet welds.

6.2.7 When welding test assemblies, the working conditions are to be similar to those described in the documentation stipulated by 6.1.

As a rule, the mechanical properties of the weld metal and the results of bend testing are not to be lower than those required for the base metal.

6.2.8 Provided the results of tests in accordance with 6.3 are satisfactory and the other requirements of this Part are complied with, a Welding Procedure Qualification Certificate will be issued by the Register.

6.3 PREPARATION OF TEST ASSEMBLIES AND TEST SPECIMENS, AND CRITERIA FOR ASSESSMENT OF TEST RESULTS

6.3.1 Test assemblies for approval of welding procedure for butt welds.

6.3.1.1 Welding of test assemblies and cutting out of test specimens from plates and/or pipes should be carried out in accordance with Figs 6.3.1.1-1 and 6.3.1.1-2.

Note. Fig. 6.3.1.1-1 is applicable to pipes with the external diameter over 800 mm.

The dimensions of test assemblies are to be such as to allow for the tests to be repeated if necessary, but in any case they should not be less than:

for manual or semi-automatic welding of plates

l = 300 mm,

L = 350 mm;

for automatic welding of plates

l = 400 mm,

L = 1000 mm;

for pipe welding

L = 400 mm.

6.3.1.2 Assemblies from rolled plates should be welded with regard for the direction of the last rolling and for the orientation of the impact specimen axis. The test results for the specimens are to be found in the base material certificates.

In the case of rolled plates impact-tested in longitudinal direction (KV_L), the assemblies are welded with the butt weld perpendicular to the rolling direction.

When rolled plates are impact-tested in transverse direction (KV_T), the butt weld is to be parallel to the rolling direction.

6.3.1.3 When an assembly is tested which is made of hull steel plates of different grades, the test results are to comply with the requirements for the lower steel grade.

6.3.1.4 The test assemblies are prepared for each welding position mentioned in the welding procedure documentation submitted in accordance with 6.1.

For a welding procedure classification by welding position, see Table 6.3.1.4.

6.3.1.5 If necessary, each test assembly is to undergo a visual examination and an ultrasonic or radiographic inspection along the whole weld length after welding and heat treatment. The criteria for assessing the inspection results must be in conformity with the requirements of the manufacturer's documentation to be submitted in accordance with 6.1, and with the relevant requirements of this Part.

Defects may be rectified on agreement with the Register and on the basis of documentation to be submitted in accordance with 6.1.

6.3.1.6 For the purpose of weld testing in accordance with Figs 6.3.1.1-1 and 6.3.1.1-2, the following specimens are cut out from the test assembly:

2 prismatic tensile specimens (a) and 1 tensile cylindrical specimen (e) for testing deposited metal, if required;

2 face bend specimens and 2 root bend specimens (b);

9 impact specimens (c).

For the precise position of the notch in each group of three specimens, see Fig. 6.3.1.6.

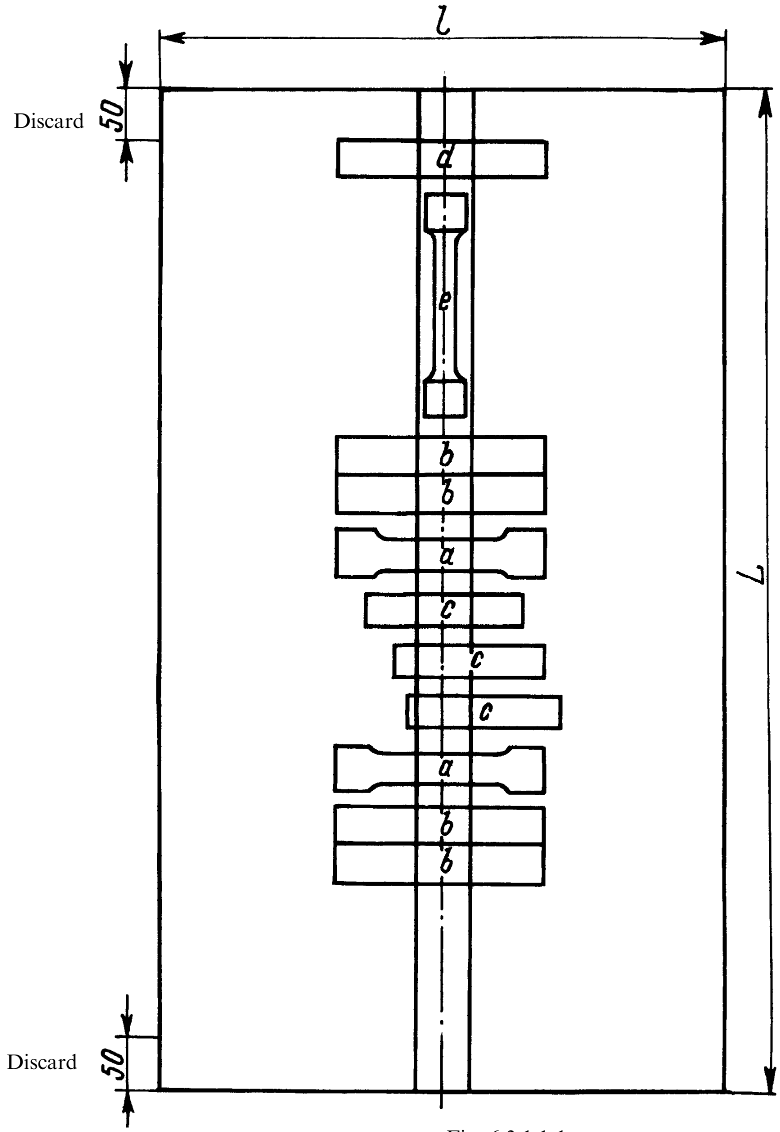


Fig. 6.3.1.1-1

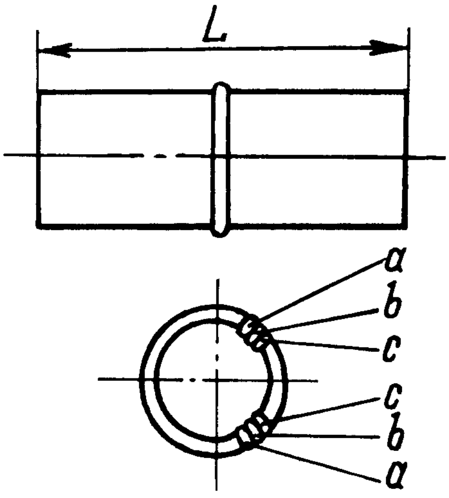


Fig. 6.3.1.1-2

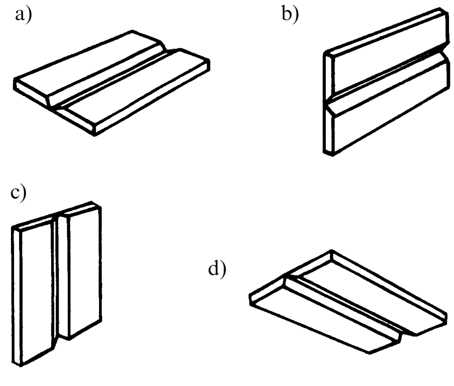


Fig. 6.3.1.4-1

Table 6.3.1.4

Welding procedure classification by welding position

Welding position	Designation	Type of semi-finished product	Butt weld	Fillet weld
Downhand	*D*	Plate	Fig.6.3.1.4-1(a)	Fig.6.3.2.2-1(a)
		Pipe	Fig.6.3.1.4-2(a)	Fig.6.3.2.2-2(a)
Horizontal	*H*	Plate	Fig.6.3.1.4-1(b)	Fig.6.3.2.2-1(b)
		Pipe	Fig.6.3.1.4-2(b)	Fig.6.3.2.2-2(b or c)
Vertical (On plate assemblies, a direction is to be indicated, e.g. downward, upward)	*V*	Plate	Fig.6.3.1.4-1(c)	Fig.6.3.2.2-1(c)
		Pipe	Fig.6.3.1.4-2(c)	Fig.6.3.2.2-2(e)
Overhead	*O*	Plate	Fig.6.3.1.4-1(d)	Fig.6.3.2.2-1(d)
		Pipe	Fig.6.3.1.4-2(c) or Fig.6.3.1.4-2(a)	Fig.6.3.2.2-2(d)
Downhand, vertical and overhead	*D+V+O*	Pipe	Fig.6.3.1.4-1(c)	Fig.6.3.2.2-2(e)
Downhand, vertical, horizontal and overhead	*D+V+H+O*	Pipe	Fig.6.3.1.4-2(d)	Fig 6.3.2.2-2 e+(b or c)

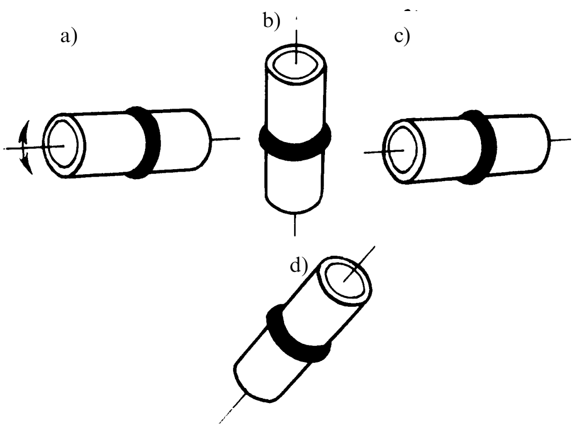


Fig. 6.3.1.4-2

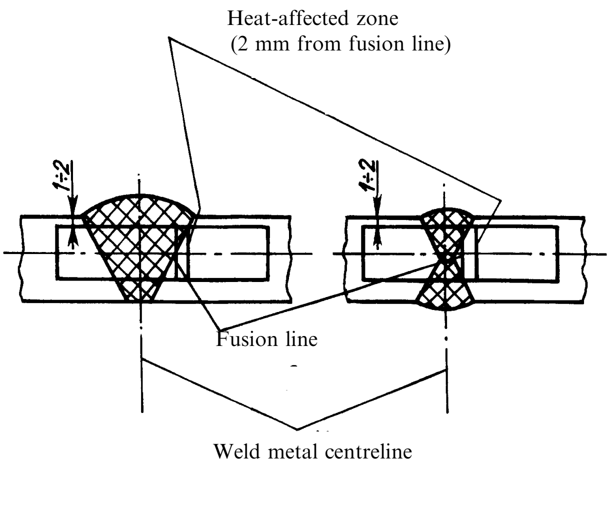


Fig. 6.3.1.6

Alternative location of the notch in the heat-affected zone (HAZ) of impact specimens may be required at the discretion of the Register, and the number of the specimens may be increased.

6.3.1.7 The specimens are prepared in accordance with 4.2.3.1.

6.3.1.8 For hull steel classed in accordance with these Rules, the test results are to be in compliance with 4.2.3.3, Table 4.2.1.2-2, Table 4.6.2 or 4.5.2-2.

6.3.1.9 The retest procedure is to be found in 4.2.3.3.2 and 4.2.3.3.4.

6.3.1.10 When welding higher and high strength steel, hardness must be determined in all cases. Hardness is determined on the specimens (d) for metallographic analysis (see Fig. 6.3.1.1-1). The Vickers method HV5 or HV10 is applied in conformity with Fig. 6.3.1.10. As a minimum, three measurings should be made in each of the weld, the heat-affected zone (both sides) and the parent metal (both sides). The hardness values are to be in compliance with national or international standards, or with these Rules.

6.3.1.11 Metallographic analysis is carried out in conformity with national or international standards.

6.3.2 Test assemblies for welding procedure approval for fillet welds.

6.3.2.1 The test assembly length for rolled plates (Fig. 6.3.2.1) is to be sufficient for eventual retesting, but in any case it must not be less than:

for manual and semi-automatic welding

L = 350 mm;

for automatic welding

L = 1000 mm.

Test assemblies are welded on one or both sides with no clearance, the throat thickness of the weld being not less than 4,5 mm. During welding, a stop/

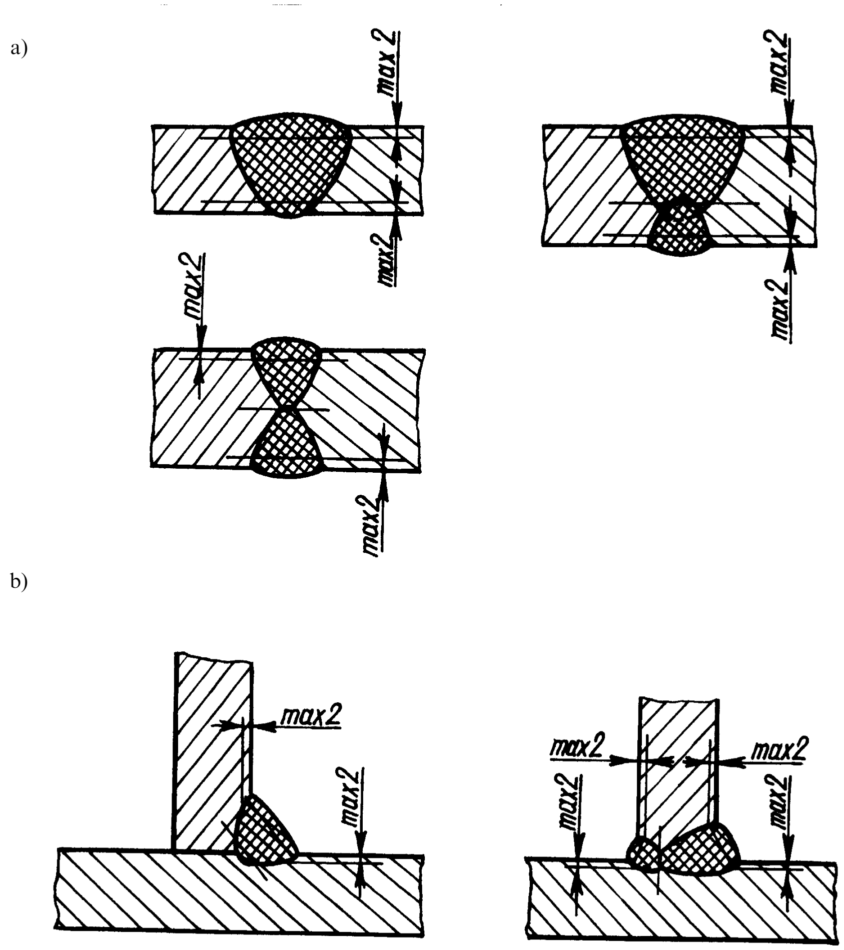


Fig. 6.3.1.10

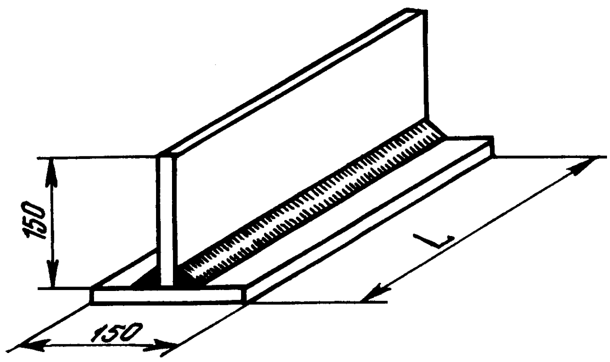


Fig 6.3.2.1

restart is permitted in conformity with the welding procedure under consideration.

6.3.2.2 Test assemblies are prepared in conformity with Figs 6.3.2.2-1 and 6.3.2.2-2 for each welding position stated in the documentation to be submitted in accordance with 6.1, and are classed on the basis of Table 6.3.1.4.

6.3.2.3 If required, each assembly is to undergo a visual examination, magnetic particle or dye penetrant testing after welding and heat treatment. The assessment criteria should be in compliance with the requirements of the manufacturer's documentation submitted for the Register approval in accordance with 6.1, and with the relevant requirements of this Part.

Removal and rectification of defects may be carried out on agreement with the Register and on the basis of the documentation to be submitted in accordance with 6.1.

6.3.2.4 Vickers hardness (HV5 or HV10) is determined proceeding from Fig.6.3.1.10. The hardness values are to be in compliance with national or international standards, or with these Rules.

6.3.2.5 Metallographic analysis is carried out in conformity with national or international standards.

6.3.2.6 Breaking test is conducted with the weld root in tension. An inspection is to be made for cracks and porosity.

6.3.2.7 If an assembly is rejected as a result of visual examination or non-destructive testing, an extra test assembly is to be welded. If this additional test assembly does not comply with the relevant requirements, the procedure must be regarded as

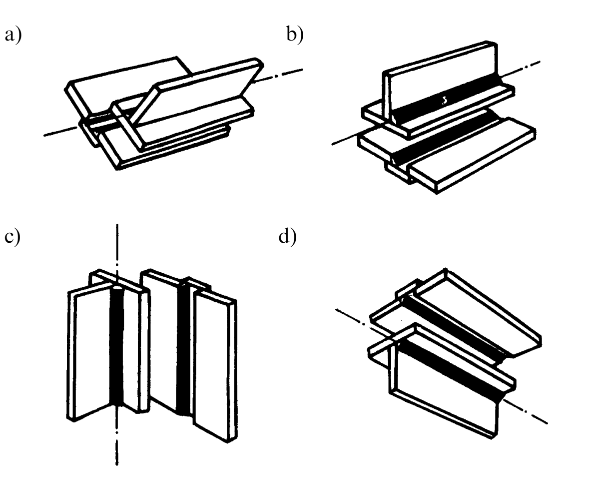


Fig 6.3.2.2-1

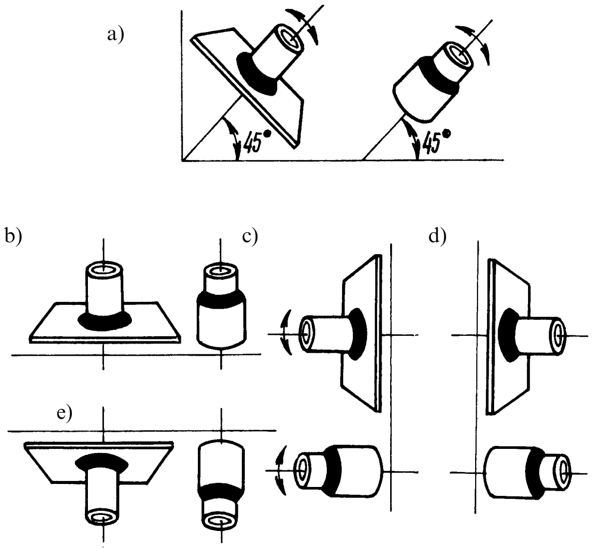


Fig 6.3.2.2-2

unable to meet the requirements without modification.

If any test assembly fails to comply with the requirements for the breaking test, hardness test or marco-examination, two extra test specimens must be obtained for each one that failed.

If out of the new test assembly at least one specimen fails to comply with the relevant requirements, an extra test assembly is to be welded.

If test specimens out of this new assembly are rejected due to the same reasons (geometric weld imperfections, porosity, cracks, slag inclusion, etc.), the procedure must be regarded as unable to meet the requirements without modification.

PART XV. AUTOMATION

1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of Sections 1 — 4 apply to automation equipment subject to supervision irrespective of whether the ship has an automation mark in the class notation or not.

The requirements of Sections 5 — 7 also apply to ships which have an automation mark added to the character of classification in conformity with 2.2.6, Part I "Classification".

The requirements of Section 6 apply to ships as well with the main machinery and propellers remotely controlled and having a main control station, which have no automation mark in the class notation.

1.1.2 The present Part of the Rules contains technical requirements for the automation equipment and ships mentioned under 1.1.1 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.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to the general terminology of the Rules are to be found in General Regulations for the Supervision.

For the purpose of this Part, the following definitions have been adopted:

Automated machinery plant is a complex of machinery and equipment fitted up with an automation system.

Call is the request for contact, assistance and/or action from an individual to another person or group of persons, i. e. the complete procedure of signalling and indicating this request.

Grouping is the combining of individual alarms to provide one generalized alarm at the remote-control position of machinery or systems.

Acknowledgement is manual acknowledgement of receipt of an alarm or call.

Standby power source - is a source of electric power independent of the ship main and emergency power sources intended for provision of the uninterrupted power supply of certain kinds of automation equipment. Uninterrupted power supply is provided by means of combined operation of the main and reserve power sources according to the diagram to enable maintenance power supply in case of one of the power sources failure.

Remote automated control system 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.

Alarm system 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.

Safety system 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.

Indication system is equipment providing information on the values of certain physical parameters of or the fluctuations of certain conditions in machinery.

Automation system is equipment intended for an automatic (automated) performance of certain functions of control, regulation, monitoring, signalling and protection of machinery or systems.

Automation device is a part of automation system comprising elements which form a structural and functional unity.

Automation element is a structurally independent item (e.g. relay, logic element, sensor, amplifier, etc.) used in control devices and automation systems.

1.3 SCOPE OF SUPERVISION

1.3.1 General provisions concerning classification, procedure, supervision of ships being designed or constructed, manufacture of equipment and items, surveys and requirements for technical documentation to be submitted to the Register for consideration and approval of the ship as a whole are to be found in Part I "Classification" and General Regulations for the Supervision.

1.3.2 Subject to supervision during manufacture are automation elements, apparatus and control devices of the following:

.1 main machinery and propellers,

.2 electric power stations,

.3 auxiliary machinery,

.4 main and auxiliary boilers,
.5 refrigerating plants,
.6 alarm system,
.7 logging devices,
.8 other systems as required by the Register.

1.3.3 Subject to supervision on board is the automation equipment supervised by the Register and mentioned in the relevant Parts of the Rules.

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 is as follows:

.1 functional description including technical parameters, operating conditions and reliability data;
.2 general arrangement and layout;
.3 specification including materials used;
.4 schematic diagram and functional diagram;
.5 test program;
.6 list of spare parts.

1.4.2 The technical documentation of equipment mentioned under 1.3.3 is to be submitted for the Register consideration prior to ship construction in the number as stipulated by 4.1.9, Part I "Classification".

2 DESIGN OF AUTOMATION SYSTEMS, AUTOMATION ELEMENTS AND CONTROL DEVICES

2.1 GENERAL REQUIREMENTS

2.1.1 The design of automation elements and control devices shall ensure an average operating life of automation systems between repairs of at least 5000h.

2.1.2 Reliable operation of automation systems, automation elements 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 elements and devices to be built in distribution boards, control panels or enclosures shall reliably operate at ambient temperatures up to 55°C.

No damage to automation systems, automation elements and control devices shall be caused by temperatures up to 70°C.

2.1.3 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.

2.1.4 Reliable operation of automation systems shall be ensured at vibrations having a frequency of 2 to 100 Hz, namely, with a 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 ±4,0g where the frequency is between 25 and 100 Hz.

Besides, automation equipment is to operate reliably under shocks having an acceleration of ±5,0g and frequency between 40 and 80 shocks per minute.

2.1.5 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.

2.1.6 The protection of automation systems, automation elements and control devices shall be chosen in accordance with 2.4, Part XI "Electrical Equipment" proceeding from their location.

2.1.7 Electrical and electronic elements and devices shall operate reliably in case of deviation of the power parameters listed in Table 2.1.7 from nominal values.

Table 2.1.7

Parameter	Deviation from nominal value		
	long-term	short-term	
	%	%	s
Voltage Frequency	+6 −10* ±5	±20 ±10	1,5 5
* For direct current - ±10 %			

Automation equipment supplied from accumulator batteries is to operate reliably with the following voltage variations from the nominal value:

from +30 to −25% — for the equipment which is not disconnected from the battery during battery charging;

from +20 to −25% — for the equipment which is disconnected from the battery during battery charging.

The operability of automation systems shall not be affected by a loss of power supply repeated three times at an interval of 30 s.

2.1.8 Pneumatic and hydraulic elements and devices shall be operable under variations of the working medium pressure within ±20 per cent of the nominal value.

2.1.9 Provision shall be made to ensure the electromagnetic compatibility of automation equipment (see 2.2, Part XI "Electrical Equipment") and to keep the radio interference from it to a permissible level.

2.1.10 Automation equipment shall operate reliably in the case of harmonic distortions of the supply voltage curve as specified under 3.2.1.5, Part XI "Electrical Equipment".

2.1.11 Elements and devices to be installed in locations with specific operating conditions (extremely high or low temperature, excessive mechanical loads, etc.) shall be designed and tested with regard for the conditions.

2.2 ELEMENTS AND DEVICES

2.2.1 The elements and devices of automation systems shall additionally comply with applicable Parts of the Rules.

2.2.2 Pneumatic and hydraulic elements and devices are not to be damaged by momentary overloads due to a working medium pressure rise equal to 1,5 times the working pressure.

2.2.3 The contacting surfaces of electric plug-in-socket connections shall be so designed and positioned as to prevent the increase of contact resistance restricting their performance.

2.2.4 At cable and wire inlets, especially in way of connections to movable elements and devices, provision shall be made to avoid tension effects.

2.2.5 Printed circuit boards shall be coated with insulating varnish over the connecting wire line.

2.2.6 Regulating elements intended for initial setting shall be protected against spontaneous change of setting.

A reset and fixing of the regulating elements shall be possible.

2.2.7 Servomotors shall be so constructed that no spontaneous change of their setting is possible.

2.2.8 For logging equipment, special paper should be provided. The ends of paper rolls are to be specially marked.

2.3 AUTOMATION SYSTEMS

2.3.1 Replaceable and adjustable elements as well as check-up points (terminals, monitoring jacks) are to be so arranged that easy access is possible at any time.

2.3.2 Provision shall be made to prevent incorrect mounting while replacing removable items (modules) having plug-in-socket connections and to ensure their efficient fixing in the working position. Where necessitated by the operating or structural features of elements or devices, their position assuring proper mounting is to be clearly marked or, alternatively, they are to be so constructed that the possibility of being mounted in a wrong position is excluded.

2.3.3 The devices are to be so constructed as to permit check measurements to be taken while in operation.

2.3.4 Automation systems are to be so constructed that the replacement of elements and devices by others of the same type would not affect the operation of the systems or require additional adjustment. The adjustment, if necessary, shall be possible with simple means.

2.3.5 Automation systems shall comprise arrangements to preclude false alarms from momentary changes of parameters due to roll motions of the ship, machinery switch-on and switch-off, etc.

2.3.6 Electrical and electronic automation systems shall be fitted up with protective devices capable of a selective disconnection of that part of the system where a fault occurs.

2.3.7 Automation systems shall be based on the "fail-safe" principle.

2.3.8 Where machinery or units are stopped by safety devices, they are not to be restarted automatically or remotely before a manual reset has been carried out.

2.3.9 The analog transducer range is to be at least 20 per cent greater than the variation range of the parameter being measured.

2.3.10 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 for the equipment reliability and the requirements of 2.1.1.

2.3.11 The fluids of hydraulic systems shall maintain their physical properties for a long time under all possible operating conditions, shall possess good lubricating properties and a vapour flash point not less than 60°C, shall not cause the damage to elements and piping and not be toxic.

The viscosity of the fluid shall not be affected by ambient temperature.

2.3.12 It should be possible to clean the filters while in operation.

2.3.13 Hydraulic automation systems shall not communicate with other systems and are to be supplied from separate tanks. In exceptional cases and on agreement with the Register, the use of fluid from other systems may be permitted for actuating systems subject to the provision of cleaning arrangements.

2.3.14 Filling pipes shall be brought down sufficiently below the working fluid level in the tanks to allow for a level variation due to the consumption of fluid and rolling of the ship.

2.3.15 Pneumatic automation systems shall have arrangements to ensure the required degree of cleanliness and dryness of the air.

2.3.16 Pneumatic automation systems of the main power plants and electric plants shall generally have two devices for cleaning and drying the air so interconnected 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 sets is possible without interrupting the air supply.

2.3.17 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, are to be duplicated.

2.3.18 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 or from the connections of same would not damage such elements and devices.

Desks, cabinets and cubicles containing hydraulic equipment shall be fitted up with appliances for the retrieval of the leaks.

2.3.19 A partial or full loss of power in automatic or remote control circuits shall not result in dangerous situations.

2.3.20 The operation of air-cooled control devices shall not be impaired owing to an eventual contamination of cooling air.

Where forced cooling is applied provision shall be made to prevent failure of the air-cooled equipment in case the cooling system is damaged and to give a proper alarm signal.

2.3.21 Provision shall be made that in the case of failure of visual or audible alarm devices in one circuit of the automation system the functioning of the other circuits would not be affected.

2.4 ALARM, PROTECTION, INDICATION AND RECORDING 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 is not to be affected by malfunction or failure of such devices.

Possibility of partial connection 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 is to be applied in the case of at least such typical faults as short-circuits, circuit break-off and earth fault.

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 is to be provided. The reception of one signal shall not prevent the reception of another. The failure of one element (device) of the system shall not cause the failure of the alarm system in general. When general monitors are applied instead of individual light signalling devices, at least two monitors shall be provided.

2.4.1.4 The visual signals must indicate the fault condition and are generally given as flashing lights.

After being accepted, the flashing light shall change to steady light, and the audible signal is to be disconnected.

Cancelling of a visual signal shall only be possible after the fault has been repaired or the faulty part of the system disconnected.

2.4.1.5 For all alarm systems, a common audible signal device may be used which shall be silenceable and, after being silenced, open to forthcoming signals even though the previous faults might not yet be attended to. If on the bridge and in the accommodation spaces the sound signal is silenced, this should not bring about a silencing of the sound signal in the machinery space.

2.4.1.6 Self-eliminating faults shall be indicated by the alarm system in such a way that the signal remains applied until it is accepted.

2.4.1.7 The signal indicating a complete or partial disconnection of the alarm system shall be readily distinguishable from other signals.

2.4.1.8 Checking of the alarm system for good working order shall be possible while in operation.

2.4.1.9 Momentary power failure in the alarm system shall not bring about the loss of signals applied at the moment.

2.4.1.10 Irrespective of the extent of automation and the surveillance procedure adopted for the machinery, the alarm system shall give warning signals at:

.1 parameters reaching predetermined limit values;

.2 operation of protective 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 this Part of the Rules.

Alarms for machinery faults shall be provided on the panels from which the machinery is remotely controlled.

2.4.1.11 The alarm system should be so arranged that signals not pertinent to navigation and navigational situation are in the first place directed to the panels in machinery spaces and main control stations, as well as to generalized signal and indication blocks in the accommodation, service and public spaces in which the personnel attending to the machinery installation might be staying. Then, if the signals are not accepted within a specified period of time (e.g. 2 min), they should be directed to the navigating bridge.

2.4.1.12 Provision should be made for a signalling system to call the engineers to the machinery space (main machinery control room), put into operation:

.1 manually from the main machinery control room or from a local control station of main machinery;

.2 automatically where an alarm for the machinery plant is not acknowledged, i. e. not heeded at the place of its destination within a specified period of time (e.g. 2. min).

This signalling system should be led to the genera-lized signal blocks in the accommodation, service and public spaces in which the personnel attending to the machinery installation might be staying.

2.4.1.13 Provision should be made for an alarm "Personnel in machinery space" by which the safe and efficient condition of the engineer on duty is confirmed on the navigating bridge, who is in the machinery space alone.

Unless reset in a period not exceeding 30 min, this alarm system is to be put into operation:

.1 manually by the engineer on duty when attending machinery spaces on routine checks to be disconnected after leaving the machinery space;

.2 automatically when the engineer on duty has to attend machinery space in case of a machinery alarm. Disconnection of the alarm "Personnel in machinery space" should not be possible before the engineer has acknowledged the alarm in the machinery space.

A pre-warning signal should be provided in the machinery space, which operates 3 min before the above alarm is given, concerning the necessity of acknowledgement the above alarm to be effected by the end of a specified (e.g. 30 min) period during the whole time the engineer on duty is staying in the machinery space.

2.4.2 Safety systems.

2.4.2.1 The safety systems of automated machinery should be provided for those parameters only the deviation of which could lead to serious damage, complete breakdown or explosion. A safety system is to include an indicator to show the parameter for which the system was put into operation.

2.4.2.2 Safety systems should 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 should be such as to preclude inadvertent operation. Light signal should be provided on the machinery control panels 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, circuit break-off and earth fault an alarm signal shall be activated.

2.4.2.4 The safety systems of particular machinery and units are to be independent of each other so that a failure in the safety system of certain machinery or unit would not affect the operability of the safety systems of the rest of the machinery and units.

2.4.2.5 The safety system is to 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 (by reducing the load upon the machinery);

.3 protect machinery and boilers from emergency condition by stopping the machinery and shutting off fuel supply to the boilers.

An alarm signal must be given before the safety has been automatically activated.

2.4.3 Indication and logging systems.

2.4.3.1 Indication and logging systems are to be independent of any other systems so that their failure would not affect such other systems.

2.4.3.2 When logging systems fail, an alarm signal shall be activated.

2.4.3.3 Provision shall be made for easy reading of indicated data with regard for the illuminance at the locations of indicators.

2.4.3.4 Provision shall be made for displaying the readings of indication systems in units normally used for the parameters, i.e. without recalculation.

3 SUPPLY OF AUTOMATION SYSTEMS

3.1 GENERAL

3.1.1 Where electrically driven units are to be supplied from both main and emergency power sources, the automation systems shall also be supplied from two energy sources independent of each other.

3.1.2 The control systems of main engines shall be supplied by two separate feeders, one of which is to 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 change-over from the main feeder to the standby one shall be effected automatically with appropriate signal activated at the control station.

3.1.3 Where the automation systems of particular auxiliary machinery are supplied by the same feeders as the corresponding electric motors, provision shall be made for a start of standby machinery in the case of a blackout in the power circuit of the running machinery.

3.1.4 Hydraulic and pneumatic automation systems shall be supplied from two sources. The second source shall be connected automatically at 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 2.3.15 and 2.3.16 are complied with.

3.1.5 Alarm and safety systems shall be supplied from both a main and a standby source. The standby power source is to be an independent source (e.g. an accumulator battery) which shall come into operation automatically when the main source fails, with an alarm activated on change-over.

The capacity of the standby source of power is to be sufficient for servicing automation and protection systems during 30 min.

3.1.6 The driving machinery of generators must be supplied independently of the main switchboard busbars.

4 AUTOMATED MACHINERY AND UNITS

4.1 GENERAL

4.1.1 Machinery and units shall be constructed in conformity with the requirements of the relevant Parts of the Rules, and provision shall be made for local control stations and indicators.

4.1.2 Machinery and units 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 shall still be possible.

4.1.3 Change-over from local control to automatic or remote control is to be possible from local control stations only. Change-over from remote to automatic control may be effected from remote control stations.

4.1.4 If the preset sequence of operations is disturbed the automated control system is to stop performing the program and shall bring the machinery to a safe condition with an alarm given in all cases at the control station where continuous watch is kept.

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 rotation frequency, and value direction of thrust within the whole operating range of the main propulsion plant.

4.2.2 Remote automated control systems shall meet the following requirements:

.1 in the case of quickly alternating commands, the last one in a sequence shall be fulfilled irrespective of the operating condition;

.2 setting of the rotation frequency, and of the thrust value and direction, shall be effected by means of one and the same control unit;

.3 when setting the rotation frequency of the main propulsion plant, provision should be made for an automatic passing of the critical rotation frequency ranges irrespective of the operation mode;

.4 remote automated control systems and engine telegraph systems shall be independent of each other so that faults in one of the systems would not affect the operation of the other; for both the systems, one and the same control unit may be used;

.5 provision shall be made for signalling to indicate power loss and malfunction of the remote automated control system;

.6 for main macvinery which are serviced by independent auxiliary electric machinery and which stop when the ship is deenergized, provision shall be made for remote starting when the feed is restored;

.7 if the remote automated control system fails, the preset mode of operation of main machinery and propellers shall be maintained until change-over to local control;

.8 remote automated control system shall ensure emergency manoeuvring whereby a change in ship speed and in the direction of movement for the opposite is to be achieved within shortest time possible. Besides, power limitations, if set below the nominal value, shall automatically be removed.

4.2.3 Where there are several control locations, the one in the main machinery control room should predominate over the one on the navigating bridge.

The same is true in respect of the control location in the main machinery space as compared to that in the main machinery control room.

The transfer of control to a predominant location and back should be possible from a predominant location only irrespective of whether the controls at the locations under consideration are matched or not.

The transfer of control is to be accompanied with visual and audible signals at all the control locations. At the locations, provision should be made for visual signals (indicators) showing from which location control is effected.

The possibility of simultaneous control from different locations is to be ruled out. Where several controls are provided at the locations (e.g. at bridge wings and in the centre), they should either be unswitchable, but rigidly coupled or switchable, but without zero position.

At all the control locations including disconnected ones, provision should be made for non-disconnectable indication of commands transmitted by engine telegraph.

4.2.4 The main engine emergency stop device required by 3.2.1.6, Part VII "Machinery Installations", if electrically operated, is to be independent of remote automated control system, alarm and protection systems, and of the ship mains.

4.2.5 With regard to the protection system, provision shall be made for an automatic power reduction in case of faults not involving direct damage to the driving unit.

4.2.6 In the case of main internal combustion machinery plants, to be automatically kept within the prescribed limits is the temperature of the working liquids as listed below:

cylinder coolant,

piston coolant,

nozzle coolant,

lubricating oil,

fuel oil if heavy fuel is used and viscosity regulation is not available.

As far as main machinery plants having driving units of other types are concerned, the automatic regulation of working liquid temperature is to be agreed with the Register.

4.2.7 A number of successful automatic starts made by the remote automated control system of the main machinery shall not be less than required in 16.1.3, Part VIII "Systems and Piping", and normal functioning of the remote automated control system shall not be limited in case of the starting air pressure drop or the capacity of starting accumulator batteries decrease lower than the limits of alarm system actuation.

However, the number of ineffective attempts of automatic starting shall be limited so that, after the last ineffective attempt, the starting air store or accumulator battery capacity are sufficient to effect manually a half number of starting attempts as required in 16.1.3, Part VIII "Systems and Piping" or 13.7.2, Part XI "Electrical Equipment".

4.2.8 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.

4.2.9 Controlled parameters of automated main machinery plants, measuring points, limiting values of parameters and types of automated protection and indication are to be found in Table 4.2.9.

Table 4.2.9

Nos	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection[1]	Indication at main control station	Notes
1	**Internal combustion engines (low-speed)[2]**					
1.1	Lubricating oil pressure	At engine inlet	Min	Shutdown	Continuous	In case of several lubricating oil systems (for camshaft, valve rockers, etc.), the requirement is applicable to each system
1.2	Lubricating oil pressure differential	Filter	Max	-	On call	-
1.3	Lubricating oil temperature	At engine inlet	Max	-	On call	See Note to 1.1
1.4	Cylinder flow of lubricating oil	At outlet of each lubricator	Min	Slowdown	-	-
1.5	Turbo-blower oil pressure	At inlet of bearing	Min	-	-	If independent lubricating oil pump is fitted

Table 4.2.9 — continued

Nos	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection[1]	Indication at main control station	Notes
1.6	Turbo-blower oil temperature	At outlet of bearing	Max	-	-	For sliding bearings
1.7	Lubricating oil level in oil circulation system	In sump circulation tank	Min Max	-	-	Maximum level alarm only where indication is not fitted. See Note to 1.1
1.8	Lubricating oil level in turbo-blower lubrication system	In gravity tank	Min		-	-
1.9	Oil mist concentration or bearing temperature	At each crank or bearing	Max	Slowdown	-	For engines having a power in excess of 2250 kW or cylinder diameter over 300 mm
1.10	Cylinder coolant pressure	At inlet of mains	Min	Slowdown	Continuous	Monitoring of flow rate may be substituted for pressure monitoring
1.11	Cylinder coolant temperature	At outlet of each cylinder	Max	Slowdown	On call	-
1.12	Presence of oil in fresh cooling water	In cooling water pipe at heat exchanger outlet	Max	-	-	When cooling water is used in fuel oil and lubricating oil heat exchangers
1.13	Piston coolant pressure	At inlet of mains	Min	Slowdown	-	No slowdown is required where circulation oil is the coolant
1.14	Piston coolant flow	At outlet of each piston	Min	Slowdown	-	-
1.15	Piston coolant temperature	At outlet of each piston	Max	Slowdown	On call	-
1.16	Fuel valve coolant pressure	At inlet of mains	Min	-	Continuous	Monitoring of flow rate may be substituted for pressure monitoring
1.17	Fuel valve coolant temperature	At outlet of mains	Max	-	On call	-
1.18	Cylinder coolant level	Expansion tank	Min	-	-	-
1.19	Piston coolant level	Expansion tank	Min	-	-	-
1.20	Fuel valve coolant level	Expansion tank	Min	-	-	-
1.21	Sea water pressure	At pump outlet	Min	-	Continuous	-
1.22	Scavenging air temperature	At cooler outlet	Max	-	On call	-
1.23	Scavenging air pressure	Manifold	-	-	Continuous	-
1.24	Water level	Scavenging air manifold	Max	-	-	-
1.25	Fuel oil pressure	At inlet of fuel injection pump	Min	-	On call	-
1.26	Fuel oil pressure differential	Filter	Max	-	-	-
1.27	Fuel oil viscosity (temperature)	At engine inlet	Max Min	-	On call	When heavy fuel oil is used
1.28	Fuel oil temperature	Settling tank and daily service tank	Min Max	-	-	If heated
1.29	Fuel oil level	Daily service tank and settling tank	Min	-	-	-
		Overflow tank	Max	-	-	-
1.30	Fuel oil leakage	High-pressure piping	Presence of fuel oil	-	-	-
1.31	Exhaust gas temperature	At outlet of each cylinder	Max	Slowdown	On call	-
		Deviation from average value	Max	-	-	-
1.32	Exhaust gas temperature	At inlet and outlet of turbo-blower	Max	-	On call	-
1.33	Temperature in the scavenging and sub-piston spaces (fire)	Scavenging and sub-bearing spaces	Max	Slowdown	-	-
1.34	Starting air pressure	At inlet of master starting valve	Min	-	Continuous	-
1.35	Control air pressure	Engine control system	Min	-	On call	-
		Emergency engine shutdown system	Min	-	-	-
1.36	Engine load	-	Max	Slowdown	-	-

Table 4.2.9 — continued

Nos	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection[1]	Indication at main control station	Notes
1.37	Engine speed	-	Max	Shutdown	Continuous	-
1.38	Direction of engine rotation	-	Opposite to prescribed	-	Continuous	-
1.39	Turbo-blower speed	-	-	-	Continuous	-
1.40	Power supply to control, safety and alarm system	-	No power supply	-	-	-
2	**Steam turbines**					
2.1	Lubricating oil pressure	At outlet of cooler	Min	Shutdown	Continuous	-
2.2	Lubricating oil pressure differential	Filter	Max	-	On call	-
2.3	Lubricating oil temperature	At outlet of each bearing	Max	-	Continuous	-
2.4	Lubricating oil level	Gravity tank	Max	Shutdown	On call	-
2.5	Steam temperature	At inlets of manoeuvring valves	Max Min	-	On call	Where re-heating is used, an additional alarm is required at turbine inlet
2.6	Steam pressure	At inlets of manoeuvring valves	Max	-	Continuous	-
2.7	Steam pressure	Condenser	Max	Shutdown	Continuous	-
2.8	Pressure	Deaerator	Max Min	-	On call	-
2.9	Water level	Deaerator	Max Min	-	On call	-
2.10	Water level	Condenser	Max Min	Shutdown	On call	-
2.11	Water pressure	At outlet of condensate pump	Min	-	On call	-
2.12	Condensate salinity	At outlet of condenser	Max	-	-	-
2.13	Turbine vibration	Turbine casing	Max	Shutdown	-	-
2.14	Axial displacement of rotor	-	Max	Shutdown	-	-
2.15	Steam pressure	End glands	Max	-	Continuous	-
2.16	Sea water pressure	At outlet of circulating pump	Min	-	Continuous	-
3	**Gas turbines**					
3.1	Lubricating oil pressure	At inlet	Min	Shutdown	Continuous	-
3.2	Lubricating oil temperature	At inlet	Max	-	On call	-
3.3	Bearings temperature	-	Max	-	On call	-
3.4	Cooling water pressure	-	Min	-	Continuous	-
3.5	Cooling water temperature	At inlet and outlet of turbine	Max	-	On call	-
3.6	Gas temperature	At turbine outlet	Max	Shutdown	On call	-
3.7	Air temperature	At inlet of high-pressure compressor	Max	-	On call	-
3.8	Lubricating oil pressure differential	Filter	Max	-	-	-
3.9	Fuel oil pressure	At inlet of pilot burners	Min	-	On call	-
3.10	Fuel oil temperature	At inlet of pilot burners	Max	-	On call	If heated
3.11	Pressure differential	Air intake	Max	-	-	-
3.12	Pilot burner flame	-	Flame failure	Shutdown	-	-
3.13	Turbine vibration	-	Max	Shutdown	-	-
3.14	Axial displacement of rotor	-	Max	Shutdown	-	-
3.15	Turbine speed	-	Max	Shutdown	Continuous	-

Table 4.2.9 — continued

Nos	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection[1]	Indication at main control station	Notes
4	**Shafting**					
4.1	Temperature of bearing (or of lubricating oil)	Thrust bearings, including those built in the engine or reduction gear	Max	Slowdown	-	-
4.2	Temperature of bearing (or of lubricating oil)	Tunnel bearings	Max	-	-	-
4.3	Temperature of bearing (or of lubricating oil)	Sterntube bearing	Max	-	-	See 2.5.3 of Part VII "Machinery Installations"
4.4	Lubricating oil level	Sterntube lubricating tank	Min	-	-	With sterntube closed
4.5	Water flow	Sterntube inlet	Min	-	-	If water-lubricated
5	**Controllable pitch propellers**					
5.1	Hydraulic oil pressure	At outlet of filter	Min	-	-	-
5.2	Hydraulic oil level	Sterntube oil lubricating tank	Min	-	-	-
5.3	Auxiliary power	Power supply to controls	Deenergizing	-	-	Bridge indication
6	**Reduction gear and couplings**					
6.1	Lubricating oil pressure	At inlet of reduction gear	Min	Shutdown	Continuous	Where a coupling is fitted, disengagement of coupling may be effected instead of engine shutdown
6.2	Lubricating oil temperature	Reduction gear	Max	Slowdown	On call	-
6.3	Temperature of bearing	Each sliding bearing	Max	-	-	For engines having a power above 2250 kW
6.4	Hydraulic oil pressure	At inlet of coupling	Min	-	Continuous	-

[1] On agreement with the Register, special visual and audible signals may be provided instead of slowdown where internal combustion engines are concerned.

[2] For medium- and high-speed internal combustion engines controlled parameters, limiting values, types of automatic protection and indication of parameters are to be provided as required in items 1.1 to 1.5, 1.9 to 1.11, 1.18, 1.21, 1.22, 1.25, 1.27,1.29 to 1.31, 1.34, 1.37, 1.40, 1.41 of this Table;
in item 1.9 in column "Automatic protection" "Shutdown" shall be indicated instead of "Slowdown";
in item 1.11 in column "Measuring point" "At engine outlet" shall be indicated instead of "At outlet of each cylinder";
item 1.3.1 is applicable for internal combustion engines with cylinder output of 500 kW and more.

4.3 AUTOMATED BOILER PLANTS

4.3.1 The requirements of this Chapter cover boiler plants with oil-burning installations.

4.3.2 Steam boilers shall be fitted up with automatic regulators of water level and steam pressure.

4.3.3 Automated boilers shall have at least two water level transducers independent of each other and connected to different output devices, one of which is to be used solely for low water level protection in compliance with 4.3.1, Part X "Boilers, Heat Exchangers and Pressure Vessels".

The second transducer may also be used for shutdown in case of low water levels, or for alarm and as part of the monitoring system.

4.3.4 Provision shall be made for a remote shutdown of automated boiler plants from the main control station or from the control station where continuous watch is kept.

4.3.5 Automated oil-burning installations shall be fitted up with interlocking devices to permit fuel oil being fed into the boiler furnace only 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 oil fuel viscosity (temperature) is such that adequate atomization is assured;

.2 boiler furnace is pre-ventilated with sufficient number of air changes;

.3 oil fuel supply to burners is set to minimum permissible quantity.

4.3.6 In addition to the requirements of 5.3.3, Part X "Boilers, Heat Exchangers and Pressure Vessels", the oil supply to the burners shall be cut off under the following circumstances:

.1 absence of flame for not more than 5 s from the moment the oil supply begins;

.2 oil fuel viscosity (temperature) being insufficient for atomization;

.3 decline of parameters of vapour or air intended for oil fuel atomization.

4.3.7 Starting of boiler plants from cold condition and after being shut down by the protection system

Table 4.3.9

Nos	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection [1]	Indication at main control station	Notes
1	**Main boilers**					
1.1	Steam pressure	Boiler drum	Max Min	— —	Continuous	—
1.2	Steam temperature	At superheater outlet	Max	—	On call	—
1.3	Steam temperature	At cooler outlet	Max	—	On call	—
1.4	Water level	Boiler drum	Min	Boiler shutdown	Continuous	—
1.5	Feed water pressure or pressure differential	At pump outlet	Min	Boiler shutdown	Continuous	—
1.6	Fuel oil pressure	At burner inlet	Min	—	On call	—
1.7	Pressure of air or steam used for atomization	At burner inlet	Min	—	—	—
1.8	Fuel oil viscosity (temperature)	At burner inlet	Max Min	—	On call	—
1.9	Air pressure	At furnace inlet	Min	—	On call	—
1.10	Feed water salinity	At feed pump outlet	Max	—	On call	—
1.11	Flame	—	Flame failure	Boiler shutdown	—	—
1.12	Fuel oil level	Daily service tank	Min	—	On call	—
1.13	Fuel oil temperature	Daily service tank	Max	—	On call	—
1.14	Power supply to controls	Power supply unit	Failure	Boiler shutdown	—	—
2	**Auxiliary boilers and thermal fluid boilers**					
2.1	Steam pressure	Boiler drum	Max Min	Boiler shutdown	Continuous	—
2.2	Water level	Boiler drum	Max Min	Boiler shutdown	Continuous	Two independent sensors
2.3	Feed water pressure	At circulating pump outlet	Min	Boiler shutdown	Continuous	—
2.4	Fuel oil pressure	At inlet of atomizer	Min	Boiler shutdown	On call	Except boilers with positional and proportional regulation of fuel supply
2.5	Fuel oil viscosity (temperature)	At inlet of atomizer	Max Min	—	—	Only when heavy fuel is used
2.6	Combustion air pressure	At furnace inlet	Min	Boiler shutdown	—	—
2.7	Flame	—	Flame failure	Boiler shutdown	—	—
2.8	Atomization air or steam pressure	At inlet of atomizer	Min	Boiler shutdown	—	—
2.9	Water level	Hot well	Min	—	—	—
2.10	Feed water salinity	At feed water pump outlet	Max	—	—	—
2.11	Power supply to controls	Power supply unit	Failure	Boiler shutdown	—	—
2.12	Thermal fluid pressure	At outlet of boiler	Max	Boiler shutdown	—	—
2.13	Thermal fluid temperature	At outlet of boiler	Max	Boiler shutdown	—	—
2.14	Thermal fluid flow	At outlet of boiler	Min	Boiler shutdown	Continuous	
2.15	Thermal fluid level	Expansion vessel	Min	Boiler shutdown	Continuous	

[1] At the main control station, common alarms may be used provided identification is possible at the local control station.

shall be possible from the local control station only.

4.3.8 If the ignition of oil fuel fails at the oil burning installation, re-ignition shall be possible from the local control station only.

4.3.9 Controlled parameters of automated boiler plants, measuring points, limiting parameter values and types of automatic protection and parameter indication are to be found in Table 4.3.9.

4.4 AUTOMATED ELECTRIC POWER PLANTS

4.4.1 The technical characteristics of an electric power plant shall ensure continuous power supply in conformity with the requirements below:

.1 On ships where the cruising load is taken up by one generator, control devices should be provided to ensure:

a) automatic starting of standby generator, automatic synchronization, taking over and distribution of load in case:

maximum permissible load is reached by the generator during operation (85%, for instance) or

there is malfunction of the operating unit which enables an automatic synchronization of generators to be carried out;

b) automatic starting of standby generator and its connection to the main switchboard busbars within 45 s if generator protection is activated and the main switchboard deenergized. In this case, the required sequence of automatic reconnection of important auxiliary machinery is to be observed which ensures propulsion, steerability and safety of the ship;

.2 In ships where electric power is normally supplied from two or more generators operating in parallel, provision shall be made (automatic disconnection of less important services, for instance) to prevent the overload of the remaining generators in case one of them fails while ensuring propulsion, steerability and safety of the ship.

4.4.2 When the voltage in the ship mains is restored after deenergizing, the start of important machinery essential for ship control shall be effected automatically in accordance with a specified program and in such a way that the electric power plant is not overloaded.

4.4.3 When, at load reduction on the power plant, the generators are to be disconnected automatically, provision shall be made to the effect this would not happen at momentary load variations.

4.4.4 The drives of generators started automatically shall be ready to start immediately.

When the drives are not ready to be started immediately, an indicator is to be provided to warn that automatic starting is impossible.

4.4.5 When the standby generators are to start automatically if the running ones are overloaded, provision shall be made for the following:

.1 automatic synchronizing and connection;

.2 automatic load distribution;

.3 preliminary determination of sequence in which the generators are to be started and connected to the collecting busbars of the main switchboard.

4.4.6 If the shaft rotational speed or the steam pressure at the exhaust-steam 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 automatically be started to ensure compliance with the provisions of 4.4.1.

4.4.7 Automated electric power plants shall ensure automatic and remote connection of electric generators including automatic synchronizing, placing on load and automatic load distribution.

4.4.8 Controlled parameters of automated electric power plants (exept emergency), measuring points, limiting values of parameters and types of automatic protection and parameter indication are to be found in Table 4.4.8.

Table 4.4.8

No.	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection	Indication at main control station	Notes
1	**Ship mains**					
1.1	Voltage	Main switchboard	Min	Disconnection of generator[1]	Continuous	Where the main switchboard is installed in engine control room, readings are to be displayed at the main switchboard only
1.2	Current frequency	Main switchboard	Min	-	Continuous	Ditto
1.3	Insulation resistance	Main switchboard	Min	-	Continuous	— " —
2	**Generators**					
2.1	Load (current)	Main switchboard	Max	Disconnection of non-essential consumers, disconnection of generator[1]	Continuous	— " —
2.2	Reverse power (current)	Main switchboard	Max	Disconnection of generator[1]	-	— " —
2.3	Winding temperature[2]	Generator	Max	-	-	— " —

Table 4.4.8 — continued

No.	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection	Indication at main control station	Note
3	**Internal combustion engines for driving generators**					
3.1	Lubricating oil pressure	At engine inlet	Min	Engine shutdown	On call	-
3.2	Lubricating oil temperature	At engine inlet	Max	-	On call	-
3.3	Coolant pressure or flow	At engine inlet	Min	-	-	-
3.4	Coolant temperature	At engine outlet	Max	-	On call	-
3.5	Engine speed	-	Max	Engine shutdown	-	-
3.6	Fuel oil level	Daily tank	Min	-	-	-
3.7	Fuel oil leakage	High pressure piping	Fuel oil presence	-	-	-
3.8	Exhaust gas temperature	Exhaust manifold	Max	-	On call	-
3.9	Sea water pressure or flow	In the sea-water cooling system	Min	-	-	-
3.10	Fuel oil pressure	At inlet of h.p. pump	Min	-	-	-
3.11	Fuel oil viscosity (temperature)	At engine inlet	Max, min	-	-	Only when heavy fuel is used
3.12	Cooling water level	Expansion tank	Min	-	On call	In case of independent cooling water system is used
3.13	Oil mist concentration or bearing temperature	Area of each crank, bearing	Max	Engine shutdown	On call	For engines with power output more than 2250 kW or with cylinder bore 300 mm and more
3.14	Starting air pressure	Before main starting valve	Min	-	On call	-
4	**Steam turbines driving generators**					
4.1	Lubricating oil pressure	At outlet of oil cooler	Min	Turbine shutdown	On call	-
4.2	Lubricating oil temperature	At outlets of bearings	Max	-	On call	-
4.3	Steam pressure	In condenser	Max	Turbine shutdown	On call	-
4.4	Steam pressure	Before turbine	Min	-	On call	-
4.5	Water level	In condenser	Max	-	-	-

[1] Effected by the protection system of the generators (see 8.2, Part XI "Electrical Equipment").

4.5 AUTOMATED COMPRESSOR PLANTS

4.5.1 In case of pressure fall below the lower limit at starting air cylinder outlet, compressors shall be started automatically.

4.5.2 For non-attached compressors, provision shall be made for regulating the starting pressure.

4.5.3 Compressed air systems shall be fitted up with automatic drainage devices.

4.5.4 Automated compressor plants shall keep up the starting air bottle pressure at a level which would suffice at least to comply with the requirements of 16.1.3 or 16.1.4 and 16.1.6, Part VIII "Systems and Piping".

4.5.5 Controlled parameters of automated compressor plants, measuring points, limiting values of parameters and types of automatic protection and parameter indication are to be found in Table 4.5.5.

4.6 AUTOMATED PUMPING PLANTS

4.6.1 Automated pump control system shall ensure automatic starting of standby pumps and change-over as necessary in systems in case of pump failure or upon reaching the highest permissible deviations of parameters in important circulation systems. The faulty pump shall be stopped and an alarm given only after the standby pump has been started.

Table 4.5.5

Nos	Controlled parameter	Measuring point	Alarms for limiting	Values of parameters	Automatic protection [1]	Indication at main control station
1	Lubricating oil pressure	At inlet of compressor	Min	Compressor shutdown	—	—
2	Coolant flow	At outlet of compressor	Min	Compressor shutdown	—	Instead of flow, maximum coolant temperature may be controlled
3	Air temperature	At outlet of cooler	Max	—	—	—
4	Starting air pressure	At outlet of air receiver	Min	—	Continuous	—
5	Air control pressure	At outlet of reducing valve	Min	—	—	—

[1] Common alarms is permitted at the main control station on condition provision is made for identification at the local control station.

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.

4.6.3 Provision is to be made in the engine control room and on the navigating bridge for alarms on the maximum hydrocarbon concentration in the pump rooms of tankers.

4.7 AUTOMATED BILGE PLANTS OF MACHINERY SPACES

4.7.1 Depending on the water level in the wells, the automated bilge plants shall put relevant bilge pumps in operation. A signal for pump operation should be provided.

4.7.2 If, after the bilge pumps have been started, the water goes on rising or does not fall, an alarm is to be given.

4.7.3 A separate sensor should be provided to signal the highest permissible level, which would be independent of the sensors fitted to control the bilge pumps.

4.7.4 The arrangement of sensors shall make it possible to determine the water level under conditions of heel and trim as stipulated by 1.6, Part VII "Machinery Installations".

4.7.5 The controlled parameters of automated bilge plants, measuring points, limiting values of parameters, types of protection and parameter indication are to be found in Table 4.7.5.

Table 4.7.5

Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection	Indication of parameters at main control station	Notes
Water level	Bilge wells	Max	—	—	
		Min	—	—	When remotely controlled
Water level in emergency	Bilge wells, shaft passages	Max	—	—	The 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 are to comply with the requirements of 7.2.

4.8.2 Provision should be made for indication of the automated refrigerating plant operation and for a common alarm of its malfunction and failure.

4.8.3 Controlled parameters of automated refrigerating plants, measuring points, limiting values of parameters, types of protection and parameter indication are to be found in Table 4.8.3.

Table 4.8.3

Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection	Indication of parameters at main control station	Notes
Condition of refrigerating plant	Compressor	Malfunction	—	—	Common alarm
	Ditto	Failure	Compressor Shutdown	—	Common signal of protection activated

5 REQUIREMENTS FOR SHIPS HAVING THE AUTOMATION MARK A1 IN THEIR CLASS NOTATION

5.1 GENERAL

5.1.1 Ships and floating facilities having the automation mark **A1** in their class notation are to 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 navigation (service) conditions without permanent attendance of personnel in machinery spaces and the main machinery control room.

5.1.2 To be automated are the following plants and systems at least (the requirements of sections 1 to 4 being complied with):

.1 main propulsion plants;

.2 important main and auxiliary boilers;

.3 electric power plants;

.4 compressor plants;

.5 auxiliary machinery and plants essential for the main propulsion plant operation;

.6 bilge plants in machinery spaces;

.7 refrigerating plants.

5.1.3 Provision shall be made for an alarm system to cover all the parameters and working conditions controlled, as mentioned in Section 4 and in this Section.

5.1.4 Provisions concerning fire protection are to be found in Part VI "Fire Protection".

5.1.5 All equipment installed in a machinery space is to be adapted to operation in an unattended machinery space and main control station. On agreement with the Register, some operations (replenishment of tanks, cleaning of filters, etc.) might be effected from local control stations, if carried out at certain intervals (not more than once in 24 h) and adequately serviced.

5.2 BRIDGE DEVICES

5.2.1 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".

Where there are several independent propellers, provision shall be made to control each propulsion plant from the bridge. Provision shall also be made for devices to reliably preclude the plant overloading.

5.2.2 An alarm device shall be fitted to give a common signal of malfunctions of machinery and plants in the machinery space to the effect:

main propulsion plant is shut down immediately;

main propulsion plant power is reduced;

main propulsion plant power is to be left unchanged.

5.2.3 Provision should be made for visual signalling (indication) for the case of signals required by 5.2.2 and 5.2.3 being acknowledged in the machinery space.

If the alarm is not acknowledged within due time, an alarm calling the engineers should be given automatically.

5.2.4 On the bridge, provision shall be made for the following alarms:

"water in machinery space";

"fire in machinery space";

"alarm system failure".

5.2.5 Provision should be made for an alarm device to apply a light and sound signal on the bridge or in engineers' accommodation if after the expiry of prescribed time (not exceeding 30 min) of the watchkeeping personnel stay in the machinery space the device is not shut down.

The alarm device should be activated:

automatically by the power plant alarm system operation;

manually by personnel on watch periodically attending the machinery space.

The alarm device should be disconnected by the watchkeeping personnel leaving the machinery space. Under the circumstances mentioned in 5.2.5.1, the disconnection is possible only after the alarm acknowledgement in the machinery space.

5.3 DEVICES IN MACHINERY SPACES

5.3.1 Main machinery control room, if provided, is to be fitted up with the following:

.1 devices required by 3.2, Part VII "Machinery Installations";

.2 alarm system and signals to indicate the safety systems are in operation;

.3 signals indicating the operation modes of machinery and plants that are essential for the reliable operation of machinery;

.4 disconnecting devices of the oil-burning installations of boilers, ventilators of machinery spaces, fuel oil pumps and lubricating oil pumps.

5.3.2 If agreed with the Register, the main machinery control room may be located outside the machinery space.

5.3.3 Where there is an enclosed main machinery control room, a call device is to be fitted connected to particular sections of machinery spaces and serviced from the main control station.

5.3.4 At the main machinery control room shall be provided the following separate signals:
"water in machinery space";
"fire in machinery space".

5.4 DEVICES IN ENGINEERS' ACCOMMODATION

5.4.1 In engineers' accommodation, alarm devices shall be fitted for the malfunctions of machinery and plants in accordance with 5.2.2 and signal devices in accordance with 5.2.4 and 5.2.5.

The acknowledgement of each signal from these devices should bring about the disconnection of the audible signal only.

5.4.2 Where there are several accommodation spaces the devices mentioned under 5.4.1 may be disconnected provided in one of the spaces at least the device remains connected.

5.4.3 In the engineers' accommodation (cabins, messrooms, etc.) and in spaces where watch is kept while in port, common alarm devices shall be fitted.

6 REQUIREMENTS FOR SHIPS HAVING THE AUTOMATION MARK A2 IN THEIR CLASS NOTATION

6.1 GENERAL

6.1.1 Ships and floating facilities having the automation mark **A2** in their class notation are to 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 navigation (operating) conditions without permanent attendance of personnel in machinery spaces if watch is kept at the main machinery control room.

The requirements of this Section may also be applied to ships which have no **A2** automation mark in their class notation, but on which a main machinery control room and a main machinery and/or propellers remote control is provided.

6.1.2 The automation systems installed are to comply with the requirements of Sections 1-3 and 4.1.

6.1.3 Provision shall be made for an automated main propulsion plant complying with 4.2 and an automated boiler plant complying with 4.3.

6.1.4 An integrated alarm system should be provided for all the controlled parameters and working conditions mentioned in Section 4 and in this Section.

6.1.5 All the equipment installed in the machinery space shall be adapted to unattended service. On agreement with the Register, certain operations (replenishing of tanks, cleaning of strainers, etc.) may be effected from local control stations if undertaken at definite intervals (not more than once in 12 hours) and carried out with adequate servicing.

6.1.6 Provisions concerning fire protection are to be found in Part VI "Fire Protection".

6.2 DEVICES ON THE BRIDGE

6.2.1 On the bridge, alarm devices as stipulated by 5.2.1 and signal devices as stipulated by 5.2.4 are to be fitted.

6.2.2 Provision shall be made for alarm which would enable to identify the reason of failure that has brought about an automatic shutdown of the main machinery.

6.2.3 Provision should be made for an alarm device in accordance with 5.2.5.

6.3 DEVICES IN MACHINERY SPACES

6.3.1 Provision shall be made for an enclosed main machinery control room fitted out in conformity with 5.3.1 and, additionally, with the following devices:

.1 remote controls of auxiliaries serving the main machinery if the latter is not automated;

.2 signalling devices to indicate which machinery and plants were in operation when the ship mains became deenergized that are to be started remotely as the voltage is restored;

.3 indicators and alarms stipulated in 4.8.

6.3.2 The requirements of 5.3.3 and 5.3.4 are to be complied with.

6.4 DEVICES IN ENGINEERS' ACCOMMODATION

6.4.1 In engineers' accommodation, alarm devices shall be fitted for the malfunctions of machinery and signal devices in accordance with 5.2.4. The acknowledgement of each signal of these devices should be indicated on the bridge only by audible alarm muting.

6.4.2 The requirements of 5.4.2 and 5.4.3 should also be complied with.

6.5 ELECTRIC POWER PLANTS

6.5.1 Where no provision is made for an automated electric power plant in conformity with 4.4, the following is to be available:

.1 generator drives must be kept ready to start;

.2 remote start and shutdown of generator drives from the main control station;

.3 remote synchronizing, connection and load distribution from the main machinery control room. Synchronizing, connection and load distribution may be effected from the main switchboard if installed at the main control station.

6.5.2 Where particular functions of the electric power plants are automatized, the relevant requirements of 4.4 are to be complied with.

6.6 BILGE SYSTEMS

6.6.1 Where no provision is made for an automated bilge system in conformity with 4.7, bilge wells in machinery spaces shall be remotely controlled from the main machinery control room.

6.6.2 For machinery spaces the requirements of 4.7.2 — 4.7.5 are to be complied with.

7 REQUIREMENTS FOR SHIPS HAVING THE AUTOMATION MARK A3 IN THEIR CLASS NOTATION

7.1 GENERAL

7.1.1 Ships and floating structures with the automation mark **A3** in the class notation the main machinery of which have the power up to 2250 kW should be fitted with machinery installation automation systems to the extent by which their steerability and safety would be ensured without permanent attendance of machinery spaces (as far as non-self-propelled ships and floating structures are concerned, the above power is the power of the prime movers of generators which ensure that the main purpose of the ship or floating structure is fulfilled).

7.1.2 Unless otherwise provided hereafter, the requirements of Sections 1 — 5 are to be complied with.

7.1.3 For plants and systems mentioned in 5.1.2.1 and 5.1.2.5, provision should be made for remote control from the bridge. On agreement with the Register, some operations (replenishment of tanks, cleaning of filters, etc.) might be effected from local control stations, if carried out at certain intervals (not more than once in 12 h) and adequately serviced.

7.1.4 The controlled parameters of plants and systems mentioned in 5.1.2, measuring points, limiting values of parameters and types of automatic protection and parameter indication are to be found in Table 7.1.4.

Table 7.1.4

Nos	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection[1]	Indication at main control station	Notes
1	**Main internal combustion engines**					
1.1	Lubricating oil pressure	At inlet of engine	Min	Shutdown	Continuous	-
1.2	Lubricating oil temperature	At inlet of engine	Max	-	Continuous	-
1.3	Lubricating oil flow	At outlet of lubricator	Min	Slowdown	-	-
1.4	Lubricating oil pressure differential	Filter	Max	-	On call	-
1.5	Turbo-blower lubricating oil pressure	Inlet of bearing	Min	-	-	When independent lubrication pump is available
1.6	Oil mist concentration or bearings temperature	At each crank or bearing	Max	Slowdown	-	For low-speed engines with cylinder diameter over 300 mm
				Engine Shutdown	-	For medium-speed engines with cylinder diameter over 300 mm
1.7	Coolant pressure or flow	Engine inlet	Min	Slowdown	Continuous	-
1.8	Coolant temperature	Engine outlet	Max	Slowdown	On call	-
1.9	Sea water pressure or flow	In the sea-water cooling system	Min	-	Continuous	-
1.10	Exhaust gas temperature	Exhaust manifold	Max	-	-	-

Table 7.1.4 — continued

Nos	Controlled parameter	Measuring point	Alarms for limiting values of parameters	Automatic protection[1]	Indication at main control station	Notes
1.11	Exhaust gas temperature	Each cylinder outlet	Max	Slowdown	On call	For engines with cylinder output above 500 kW
		Deviation from mean value for cylinders	Max	-	-	Ditto
1.12	Starting air pressure	At inlet of starting valve	Min	-	Continuous	-
1.13	Air pressure	Engine control system	Min	-	-	-
1.14	Scavenging air pressure	Scavenging air cooler outlet	Max	-	-	For engines having a power above 1500 kW
1.15	Fuel pressure	High-pressure fuel pump inlets	Min	-	On call	-
1.16	Fuel viscosity (temperature)	Engine inlet	Max Min	-	-	When working on heavy fuel
1.17	Fuel level	Daily service tank	Min	-	-	-
1.18	Fuel leakage	High-pressure piping	Fuel leakage	-	-	-
1.19	Engine speed	-	Max	Shutdown	Continuous	-
1.20	Power supply of control, signalling and protection system	At inlet of systems	Lack of power supply	-	-	-
2	**Auxiliary boilers and thermal fluid boilers**					See Table 4.3.9
3	**Internal combustion engines used as generator drives**					
3.1	Lubricating oil pressure	Engine inlet	Min	Shutdown	-	-
3.2	Coolant pressure or flow	Engine inlet	Min	-	-	-
3.3	Coolant temperature	Engine outlet	Max	-	-	-
3.4	Leakage of fuel	High-pressure piping	Presence of fuel	-	-	-
3.5	Engine speed	Limit regulator	Max	Engine shutdown	-	-
3.6	Stating air pressure	Before the main starting valve	Min	-	-	-
4	**Reduction gear**					
4.1	Lubricating oil pressure	Reduction gear inlet	Min	Engine shutdown	-	-
4.2	Lubricating oil temperature	Reduction gear	Max	-	-	-
5	**Starting air compressors**					
5.1	Lubricating oil pressure	Compressor inlet	Min	Compressor shutdown	-	-
5.2	Air temperature	Compressor outlet	Max	-	-	-
6	**Tanks**					
6.1	Lubricating oil level	Daily service tanks	Min	-	-	-
6.2	Oil leakage level	Oil leakage tank	Max	-	-	-
6.3	Fuel level	Daily service tank	Min	-	-	-
		Overflow tank	Max	-	-	-
6.4	Coolant level	Expansion tank	Min	-	-	-
7	**Ship mains**					
7.1	Voltage	Main switchboard	Min Max	-	Continuous	-
7.2	Load (current)	Main switchboard	Max	-	Continuous	-
7.3	Electrical frequency	Main switchboard	Min	-	Continuous	-
7.4	Insulation resistance	Main switchboard	Min	-	Continuous	-

[1] On agreement with the Register, special visual and audible signals may be provided instead of slowdown where internal combustion engines are concerned.

7.2 DEVICES ON THE BRIDGE

7.2.1 Provision shall be made for a remote control station for main machinery and propellers in conformity with 3.2, Part VII "Machinery Installations".

7.2.2 An alarm device shall be fitted to indicate malfunction of machinery and equipment in the machinery space in accordance with 5.2.2.

7.2.3 Signal devices shall be fitted to indicate acception of the common alarms as required in 7.2.2

7.2.4 On the bridge, provision shall be made for separate signals as follows:

.1 "water in machinery space";

.2 "fire in machinery space";

.3 "alarm system failure".

7.2.5 Provision shall be made for shutting down the oil burning installations of automated boiler plants.

7.2.6 Provision shall be made for remote control of bilge wells in machinery spaces. The requirements of 4.7.2 — 4.7.5 are to be complied with.

7.2.7 Provision should be made for an alarm device in accordance with 5.2.5.

7.3 DEVICES IN MACHINERY SPACES

7.3.1 Provision shall be made for a local control station for the main propulsion plant.

7.3.2 In the vicinity of the main propulsion plant control station, a panel shall be fitted for alarms and to indicate parameters as stipulated by Table 7.1.4.

7.3.3 It is recommended that the controls of auxiliaries (pumps, separators, boiler plants, generator drives) and the main switchboard be installed in close proximity to the main propulsion plant control station.

7.3.4 Where provision is made for an enclosed main control station, the requirements of 5.3.3 and 5.3.4 are to be complied with.

7.4 DEVICES IN ENGINEERS' ACCOMMODATION

7.4.1 In engineers' accommodation, alarm devices shall be fitted for the malfunctions of machinery and plants and also signal devices in accordance with 7.2.4. The acknowledgement of each signal of these devices should be indicated on the bridge only by audible alarm muting.

7.4.2 The requirements of 5.4.2 and 5.4.3 are also to be complied with.

7.5 MAIN PROPULSION PLANTS

7.5.1 Provision shall be made for a remote control system to control rotation speed, value and direction of thrust throughout the operation range of the main propulsion plant from the bridge.

Non-automated control systems are permitted.

7.5.2 If the main propulsion plant is controlled by means of an automated control system, the requirements of 4.2 are to be complied with.

7.5.3 For non-reversing engines with reverse-reduction gear, remote control systems may be used where the gear and the engine are operated by different controls.

7.5.4 Irrespective of remote control type, provision shall be made for automatic control of working liquids temperature in conformity with 4.2.6.

7.6 ELECTRIC POWER PLANTS

7.6.1 Provision should be made for an automated electric power plant in accordance with 4.4.

7.6.2 On agreement with the Register, diesel generators may be used fitted up with a device for remote starting and shutdown of prime movers, synchronization, connection and distribution of load from the bridge.

7.7 BOILER PLANTS WITH OIL-BURNING INSTALLATIONS

7.7.1 Boiler plants with oil-burning installations are to comply with 4.3.

8 REQUIREMENTS FOR COMPUTERS AND COMPUTER SYSTEMS

8.1 APPLICATION

8.1.1 The present requirements apply to computers and computer systems used as part of installations and systems subject to the Register supervision, and to computers not used as part of such installations and systems, but with which the safety calculations for the ship are made.

8.1.2 The instances of using computers and computer systems not covered by the present requirements are to be specially considered by the Register.

8.2 DEFINITIONS AND EXPLANATIONS

Computer is a programmable electronic device, including the input and output devices, intended for processing and storage of data in the digital form, making calculations or producing the logic for control functions.

Computer system is a monitoring/control system comprising one or several computers with the appropriate software, peripheral devices and interfaces, connected with sensors, controls and executive arrangements, performing the monitoring and control of the machinery plant.

Peripheral device is a device for the input/output of computer data.

R a n d o m a c c e s s m e m o r y (R A M) is a read/write memory losing its data when the electric power supply is disconnected.

R e a d - o n l y m e m o r y (R O M) is a memory for the storage of permanent data which are programmed by the manufacturer and retained when the electric power supply is disconnected.

S e l f - c o n t a i n e d m o d e is computer operation without direct influence upon other devices and installations.

C o n t r o l m o d e is computer operation with direct influence upon other devices and installations.

8.3 SCOPE OF SUPERVISION

8.3.1 General survey provisions are to be found in General Regulations for the Supervision.

Subject to survey during manufacture are:

computers,

peripheral devices,

interface modules.

8.3.2 Subject to on-board survey are computers and computer systems mentioned in this Part which belong to the automation equipment of devices, machinery and systems under the Register supervision and are described in the relevant Parts of the Rules.

8.4 TECHNICAL DOCUMENTATION

8.4.1 Prior to survey during manufacture, the manufacturer of computers and computer systems permitted for application is to submit documentation as follows:

mechanical structure,

technical description with a schematic diagram,

information on input and output and on interface possibilities,

description of self-checking system and behaviour in case of malfunction,

schematic diagram of feeder,

machinery control algorithm (user program),

maintenance manual,

test program,

information on the system reliability and on its stability under the operating conditions on board,

list of spare parts.

8.5 REQUIREMENTS FOR COMPUTER DESIGN

8.5.1 Computers and peripheral devices should operate reliably under the operating conditions described in this Part unless other service conditions are described in the relevant Parts of the Rules for machinery and plants serviced by the computers and peripheral devices.

8.5.2 Computers not forming a structural part of other installations, as well as peripheral devices, must have the degree of protection in accordance with Part XI "Electrical Equipment", but not lower than IP 22.

8.5.3 Computer design should be in compliance with the requirements of this Part.

8.6 GENERAL TECHNICAL REQUIREMENTS

8.6.1 The requirements of this Chapter are valid irrespective of the prescribed operation mode (self-contained or control) of the computer.

8.6.2 Any opportunity for program modifications by the ship personnel should be ruled out.

8.6.3 For computer-equipped plants, any modifications to user programs affecting the operation of the plant should be considered structural modifications and reported to the Register.

8.6.4 If peripheral devices are disconnected from the computer, this should not bring about an uncontrolled execution of commands which might involve critical conditions.

8.6.5 In case of operator input, control at input (for instance, a display, a printer) should be ensured.

8.6.6 Operator errors should not result in damage to computer, erasure or amendment of data in the RAM or ROM.

8.6.7 Programs and data essential for the faultless operation of the plant should be stored in the ROM or in external memories.

8.6.8 Where forced ventilation or conditioning is necessary for the operation of computers, an indicator or signal should be provided for exceeding the limiting values of climatic parameters.

8.6.9 Where colour monitors are used, the colour variation is not to detrimentally affect the reliability of information transmitted.

8.7 FUNCTIONAL TESTS, SELF-CHECKING AND MALFUNCTION SIGNALLING

8.7.1 Provision should be made for testing all the computer functions using special programs if need be.

8.7.2 The failure of a computer or an interruption of its functions should be signalled by an independent alarm system with a simultaneous indication of the point (unit) where the failure occurred or of the stage of a function execution.

8.7.3 Each computer is to be provided with self-checking. Self-checking is to cover peripheral devices as well. Self-checking is to be effected using relevant test programs (for instance, parity test, cycle length and frequency test).

8.7.4 Malfunction of computers and computer systems must not bring about an emergency condition of the plant serviced or the ship as a whole.

8.7.5 In case of peripheral devices failure, the operation of the rest of the peripheral equipment in the computer system is not to be affected. A malfunction alarm is to be provided.

8.7.6 Where it is necessary to preserve the data in the RAM intact in case of power supply failure, provision should be made for an immediate transfer of the RAM to battery supply.

8.8 ADDITIONAL REQUIREMENTS FOR COMPUTERS WHICH CONTROL AND MONITOR SHIP PLANTS

8.8.1 Computers or computer systems providing the monitoring and control of ship plants shall operate under all service conditions including emergency cases.

8.8.2 Multicomputer automation systems are to be so designed as to ensure a redundancy of all control functions (either by means of computers or by conventional automation equipment) for the case of malfunction of particular computers or their links.

8.8.3 Where a computer system may simultaneously execute more than one functional program, the execution of those programs should be coordinated. The priority (priority levels) of programs which ensure safe operation should be determined proceeding from their opportunities.

8.8.4 Using the functional units of one system including a computer as standby for another system including a computer is subject to a special agreement with the Register in each case.

8.8.5 Computers and computer systems may be incorporated in safety systems only provided the safety system would automatically function in the conventional way in case of the computer failure.

This requirement may be ignored if provision is made for computer redundancy.

8.8.6 Computers used for the control and/or monitoring of processes in ship plants should be capable of high-speed operation and of performing monitoring and safety functions in real-time.

8.8.7 The peripheral devices necessary for the system operation should be replaceable, in case of failure, with reserve devices having similar conditions of connection.

8.8.8 If screens are used to show the processes, the emerging signal of malfunction in plants or systems should immediately appear on the screen. It is not permitted that acknowledged signals would differ from non-acknowledged ones by their colour only.

8.8.9 Where a tube display is used for the visual signalling of emergency conditions, it is to be duplicated or equipment should be used to present such signals in another form (lamps, light-emitting diodes, etc.).

8.9 INSTALLATION OF COMPUTERS AND COMPUTER SYSTEMS ON BOARD SHIPS

8.9.1 The input/output arrangement is to facilitate maintenance. The routes of computer systems with permanent redundancy should be duplicated and located as far as practicable from each other.

8.9.2 The installation and design of computer equipment should be such as to ensure the electromagnetic compatibility of the computer system as assembled with the other systems at the place of installation.

If necessary, any instructions of the computer system or plant manufacturer and those of the finishing manufacturer should be taken into consideration which apply to specific operating conditions.

The measures to ensure electromagnetic compatibility should be agreed with the Register.

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

1 GENERAL

1.1 APPLICATION

1.1.1 This Part of the Rules applies 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 present Part of the Rules is also applicable to:

.1 displacement ships from (5)* 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

The definitions and explanations pertaining to the general terminology of the Rules are to be found in General Regulations for the Supervision.

The definitions of dimensions of ships comply with the provisions of Part II "Hull".

For the purpose of this Part of the Rules the following definitions are 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.

* References for ships below 12 m in length are shown in parentheses.

1.3 GENERAL PROVISIONS

1.3.1 The requirements of this 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 of the Rules.

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 are to 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 1.3.4.1 of General Regulations for the Supervision are met.

1.4 SCOPE OF SUPERVISION

1.4.1 The general provisions for supervision of the hull are set forth in General Regulations for the Supervision.

1.4.2 After consideration and approval of the technical design of a ship as a whole, the following items are to undergo supervision of 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 supervision 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" should be submitted to the Register for approval.

1.4.4 During construction the hull structures mentioned in 1.4.2 are subject to control 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 of the Rules 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 of the Rules 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, see 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 of the present Part of the Rules.

1.6.3 The frame spacing in the fore peak is not to 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 is to 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 are to 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 is to 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.

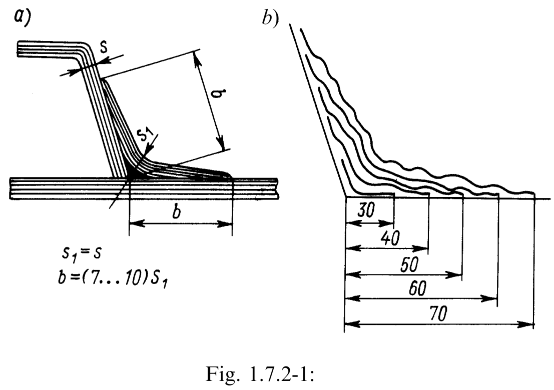


Fig. 1.7.2-1:
a - scantling of matting-in connection;
b - diagram of laying-up layers of glass mat or glass fabric strips

s_1, мм	3	4	5	6	8	10
b, мм	30	30	40	50	60	70

The width of the matting-in angle flange and the diagram of laying-up the reinforcement are to 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 is to be not less than 30 mm for stiffeners and 50 mm for transverse watertight bulkheads.

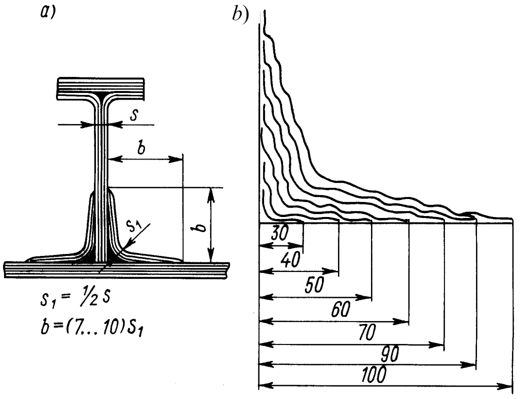


Fig. 1.7.2-2:
a - scantlings of matting-in connection; *b* - diagram of laying-up layers of glass mat or glass fabric strips

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 is to be equal to that of the bulkhead sheathing, platform planking, superstructure or deck-house side and end, respectively.

1.7.4 For bolted connections the following conditions are to be met:

.1 bolting is to be not less than three bolt diameters away from the edge of the laminate;

.2 the bolt diameter is to be equal to the thickness of the thickest laminate to be connected;

.3 bolts are not to be closer spaced than four diameters apart;

.4 parts of the bolted connections are to be protected with anticorrosive coating or made of corrosion-resistant materials;

.5 washers of not less than 2,5 times the bolt diameter are to 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 are to 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 are to 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 are to be connected along the

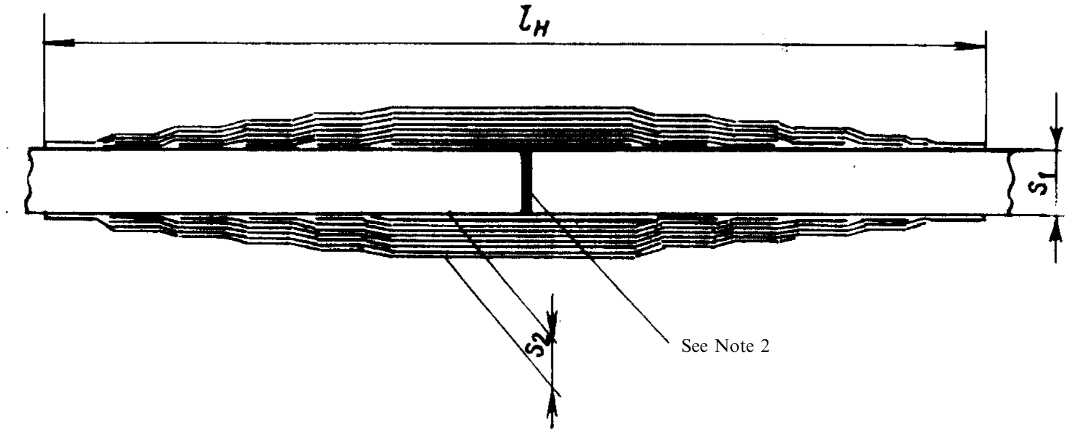


Fig. 1.7.6:
l_s — width of the matted-on strap: ($l_s = 200 + 15s_1$); ($s_2 = 0{,}5s_1$); s_1 — thickness of the laminates being connected; s_2— thickness of the matted-on strap

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 is to be oriented perpendicularly to the butts in the laminates.
2. The space between the laminates is to be 1-2 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 are to be moulded of glass-reinforced plastics of type III or IV for any length of the hull. The thickness s of each strap is to be 0,7 times the keel plate thickness s_k (see Table 2.2.1). The entire width of the matted-on straps is to be not less than 200 mm + 15 s_k.

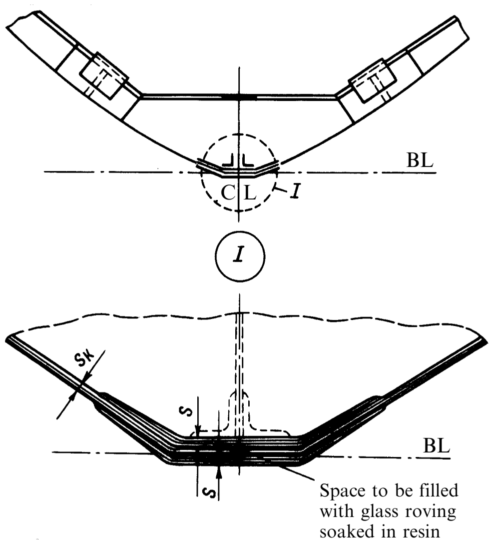


Fig. 1.7.7

1.7.8 The thickness of the matted-on straps is to 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

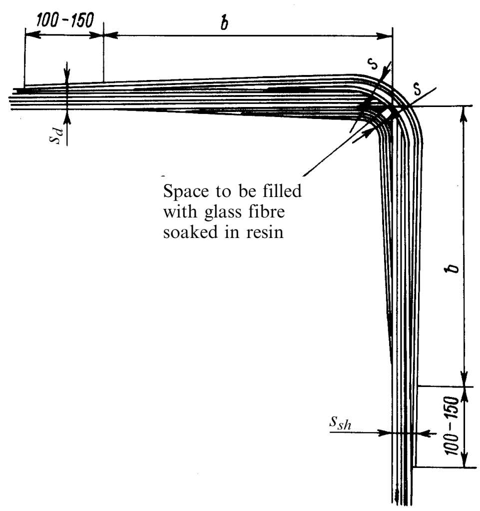


Fig. 1.7.9:
s_{sh} — sheerstrake thickness; s_d — deck laminate thickness;
s — thickness of the matting-in single angle; b — flange width of the matting-in angle

Note: 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 100-150 mm on each side, the direction of fabric warp being along the hull.

the number of one or from two to three at a time.

1.7.9 Deck-to-side connection is to be made by means of inner and outer matting-in angles (straps) in accordance with Fig.1.7.9. The angles are to be moulded of glass-reinforced plastics of type III or IV. The width of both flanges of the matting-in angles (2b) is to be not less than 200 mm + 15 s_{sh} (where s_{sh} is the sheerstrake thickness). The thickness of the matting-in angle is to be taken equal to 0,7 s_{sh}.

1.7.10 The layers in the matting-in angles are to be distributed as specified in 1.7.2.

2 HULL AND SUPERSTRUCTURES OF SHIPS

2.1 GENERAL PROVISIONS

2.1.1 The thickness of the shell and deck laminates as well as of the bulkhead and other laminates is to 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:

.1 the thickness of laminates with the glass content as specified in line No.1 of Tables 1 to 6 presented in Appendix 2 is to be determined from Fig. 2.1.1-1;

.2 the thickness of laminates with the glass content as specified in lines Nos 2 and 3 of the above-mentioned Tables is to be determined from Figs 2.1.1-2 and 2.1.1-3;

.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;

.4 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 are to be moulded and squeezed in special devices during manufacture.

2.1.2 This Part of the Rules 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,

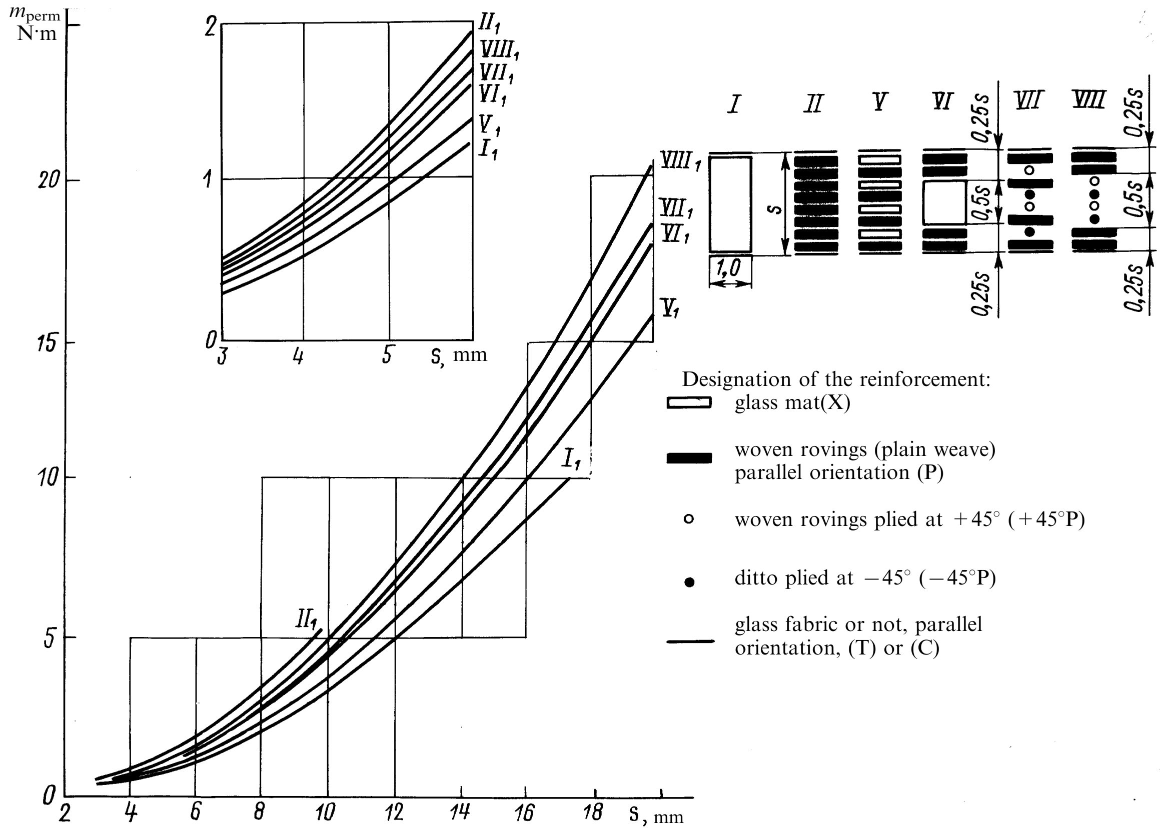


Fig. 2.1.1-1

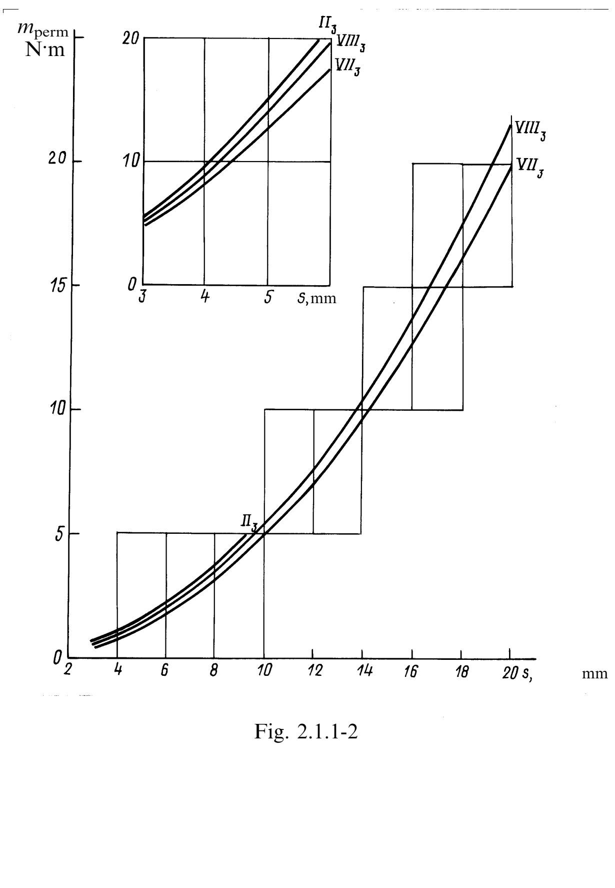


Fig. 2.1.1-2

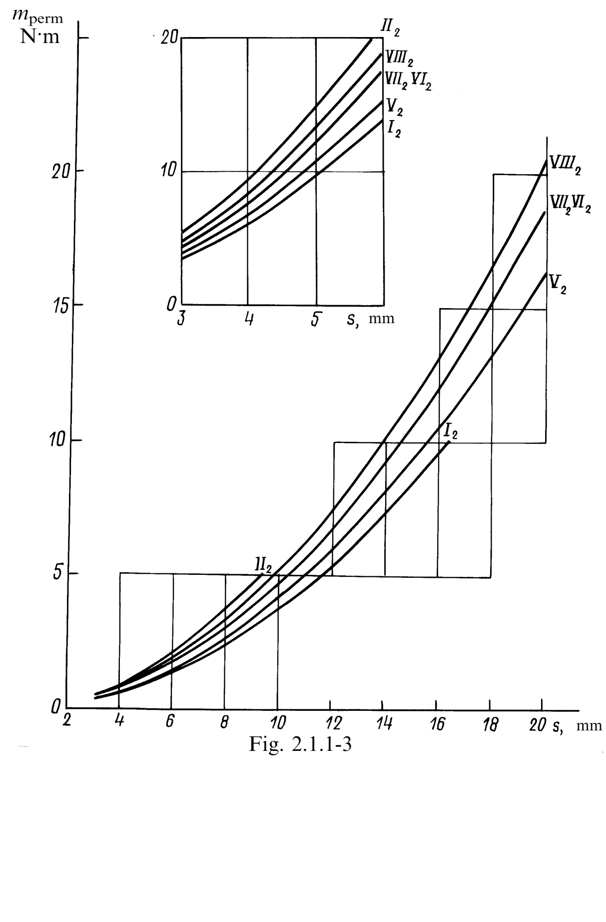


Fig. 2.1.1-3

type III_3, and the web of glass-reinforced plastics, type I_2.

2.1.3 The scantlings of framing members are to be determined from Figs 2.1.3-1, 2.1.3-2 and 2.1.3-3 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.

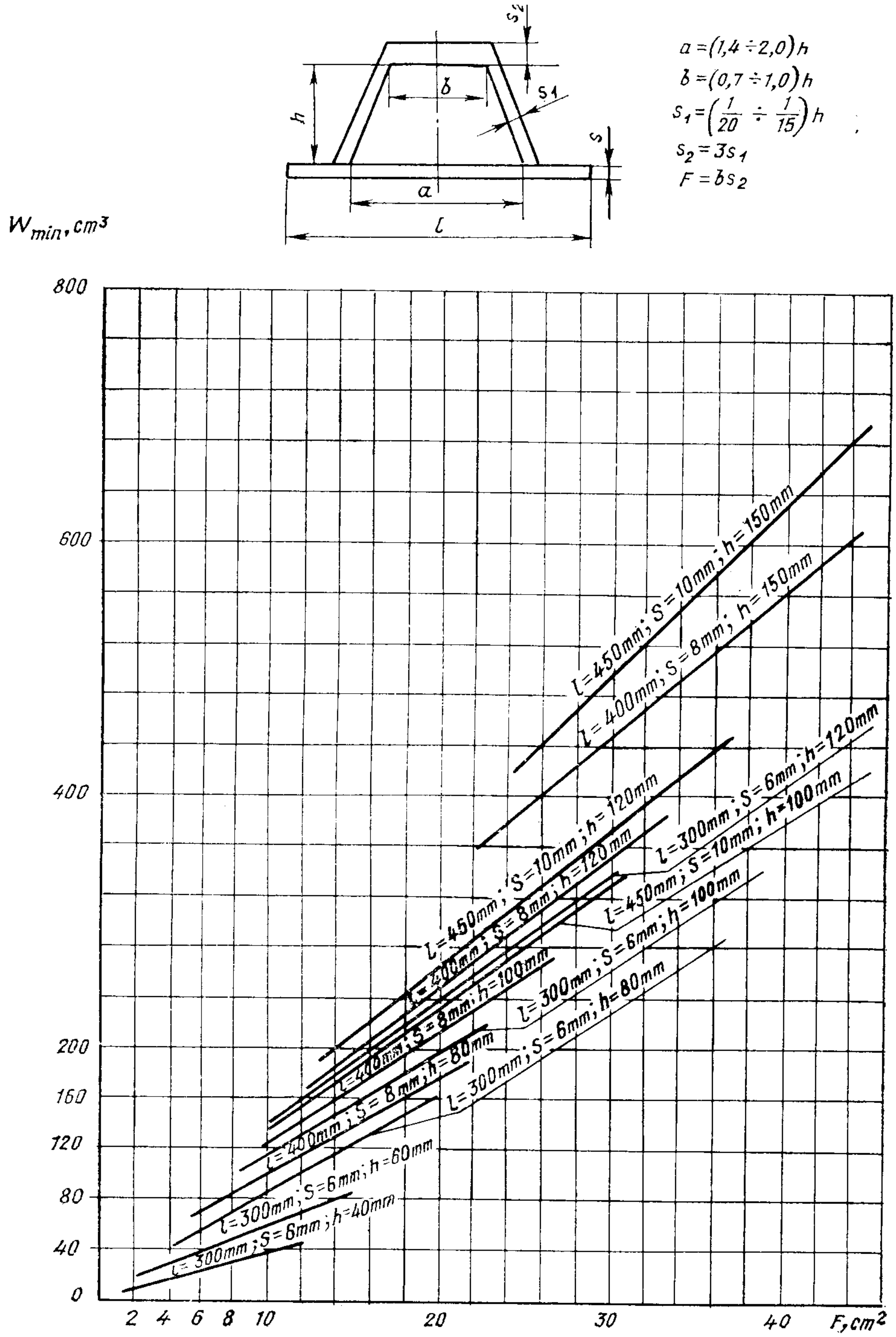


Fig. 2.1.3-1

Note: Stiffener with associated plate of glass plastic type I_2.

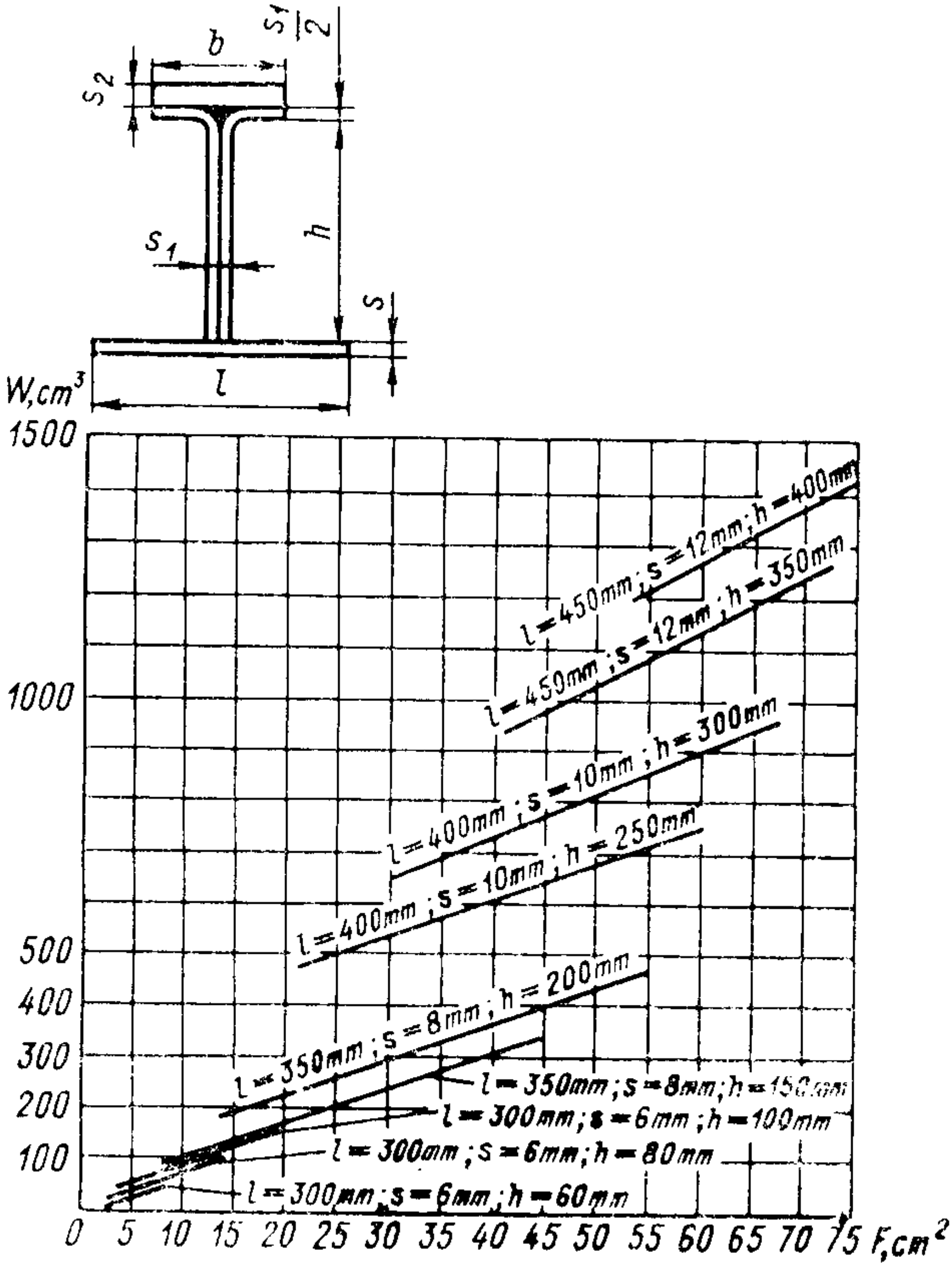


Fig. 2.1.3-2

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.

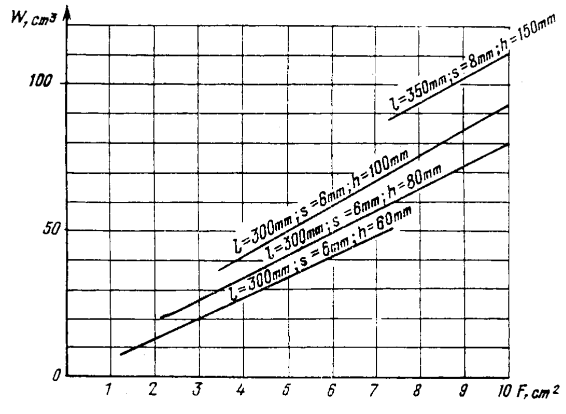


Fig. 2.1.3-3

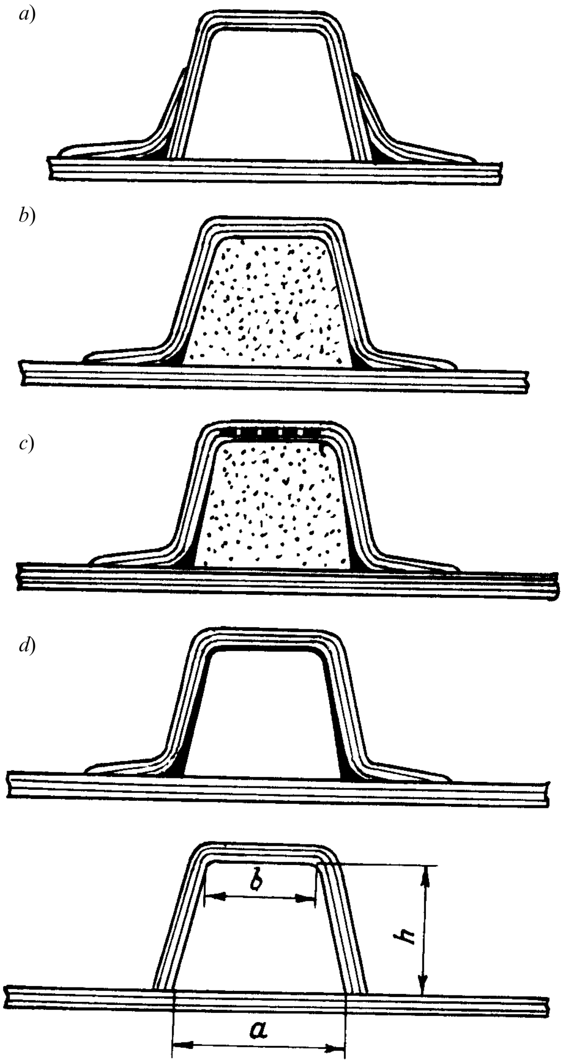


Fig. 2.1.3-4:
a - pre-moulded stiffener; *b* - stiffener moulded in situ, with core of foamed plastic; *c* - ditto, with face plate reinforced; *d* - stiffener moulded in situ over a former of sheet aluminium

N o t e s: 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.

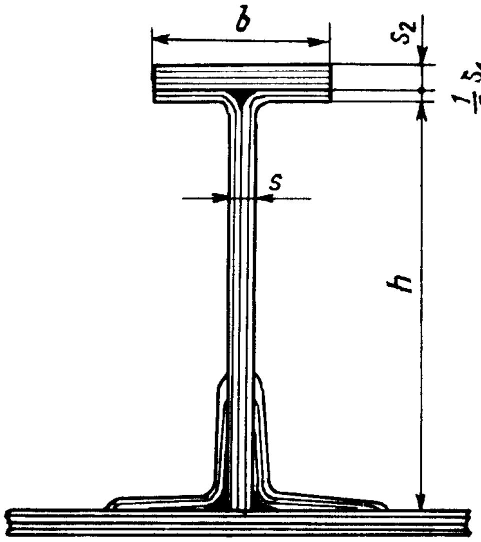


Fig. 2.1.3-5

b	s_1	s_2
$(\frac{1}{1,5} \cdots \frac{1}{3,0})h$	$(\frac{1}{10} \cdots \frac{1}{20})h$	$(2...3)s_1$

N o t e: The warp of glass fabric in face plate shall be directed along the stiffener.

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.

The scantlings of bottom stiffeners (centre girder and side girders) are to be determined in accordance with 2.3.5 of this Part of the Rules.

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 of this Part of the Rules.

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 is not to 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 is to 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.

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} is to be modified in the ratio of $\left(\frac{\text{actual spacing}}{\text{Table spasing}}\right)^2$.

2. For intermediate ship lengths m_{perm} is to 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 is to 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 $^1/_3D$.

2.2.2 The minimum side and bottom shell thickness is not to be less than:

.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 is to 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 are to 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 are not to have butts.

2.2.7 The thickness and width of the plate keel and sheerstrake are to be determined in accordance with Table 2.2.1 (see Note 3).

2.2.8 The thickness of the stern laminates (transom included) is not to 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 is to be taken equal to that of the midship portion.

2.2.10 The plate keel and sheerstrake are to be moulded by addition of reinforcing material layers which should be uniformly distributed between the shell basic layers and alternate with the latter.

The change in thickness is to be made in accordance with Table 2.2.1 (see Note 5).

2.3 BOTTOM FRAMING

2.3.1 Floors are to be fitted at each frame.

2.3.2 Floors of increased section modulus are to be fitted at all web frames. The depth of floors of increased section modulus is to 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 is to 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.

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 is to 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 are to be increased by the factor of three.

3. The scantlings of longitudinal framing members are given for compartments whose 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 are to be considered specially.

4. Where the actual spacing differs from that shown in the table, the scantlings of the centre girder and side girders are not to be modified.

5. For intermediate ship lengths the section modulus is determined by interpolation.

2.3.6 The intersection of the side girders with floor is to 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 is to be made by means of an edge cross-lap joint (see Fig.2.4.6).

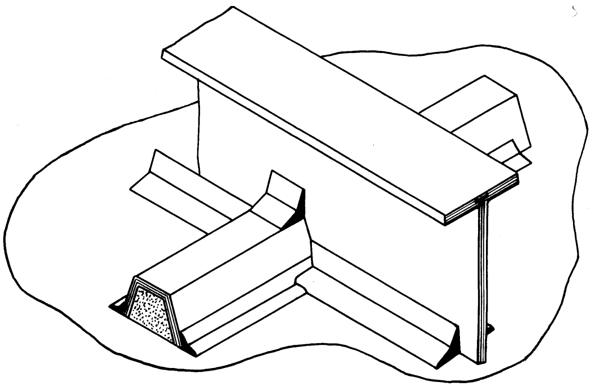


Fig. 2.3.6-1

Note: The framing member which is formed the first will not be cut at a deep member.

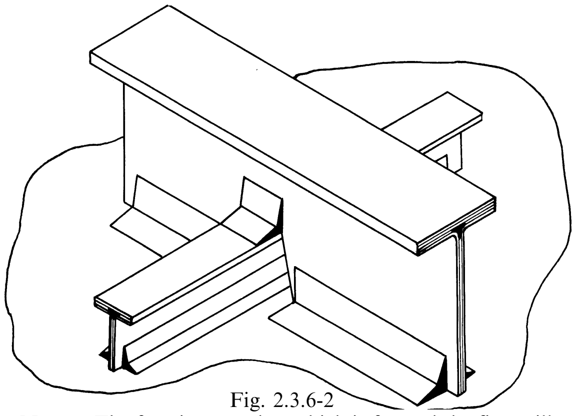


Fig. 2.3.6-2

Note: The framing member which is formed the first will not be cut at a deep member.

2.3.7 The depths of non-continuous longitudinals are to 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 should be provided. The recommended structural design of a water course is shown in Fig. 2.3.8.

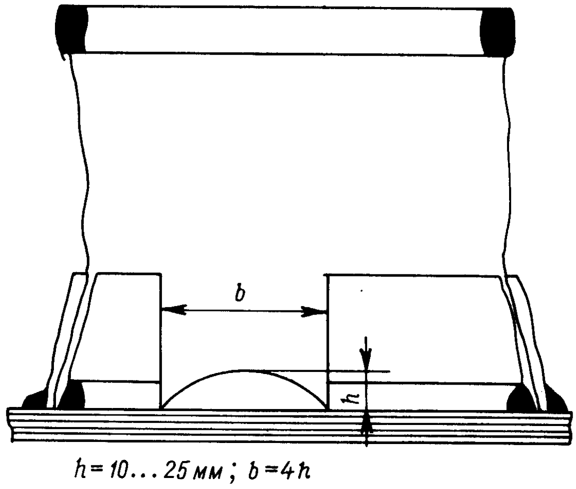


Fig. 2.3.8

Notes: 1. The hole is cut at $^1/_4$ of the spacing distance from the intersection with a floor.

2. The edge of the hole is to be covered with resin.

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.

2.4 SIDE FRAMING

2.4.1 The scantlings of frames are to 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 is not to exceed 6 spacings.

2.4.3 The section modulus of a web frame is not to 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 is to be fitted.

Table 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

Note: Where a side stringer is fitted, the section modulus of the frame is to 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.

2.4.5 The section modulus of a side stringer is to be equal to that of a web frame.

2.4.6 The intersection of a web frame and a side stringer is to 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 is to be made as shown in Figs 2.3.6-1 and 2.3.6-2 without cutting the frame.

2.5 DECKS AND DECK FRAMING

2.5.1 The upper deck laminate thickness is to 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 is to be 4 mm.

2.5.3 The thickness and width of a deck stringer should 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 is to be laid up in accordance with the requirements of 2.2.4, 2.2.5 and 2.2.6 of this Part of the Rules.

Table 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

Notes: 1. Where the spacing differs from the table value, m_{perm} is to 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 (see Table 2.2.1).

3. For intermediate ship lengths m_{perm} is to be determined by linear interpolation.

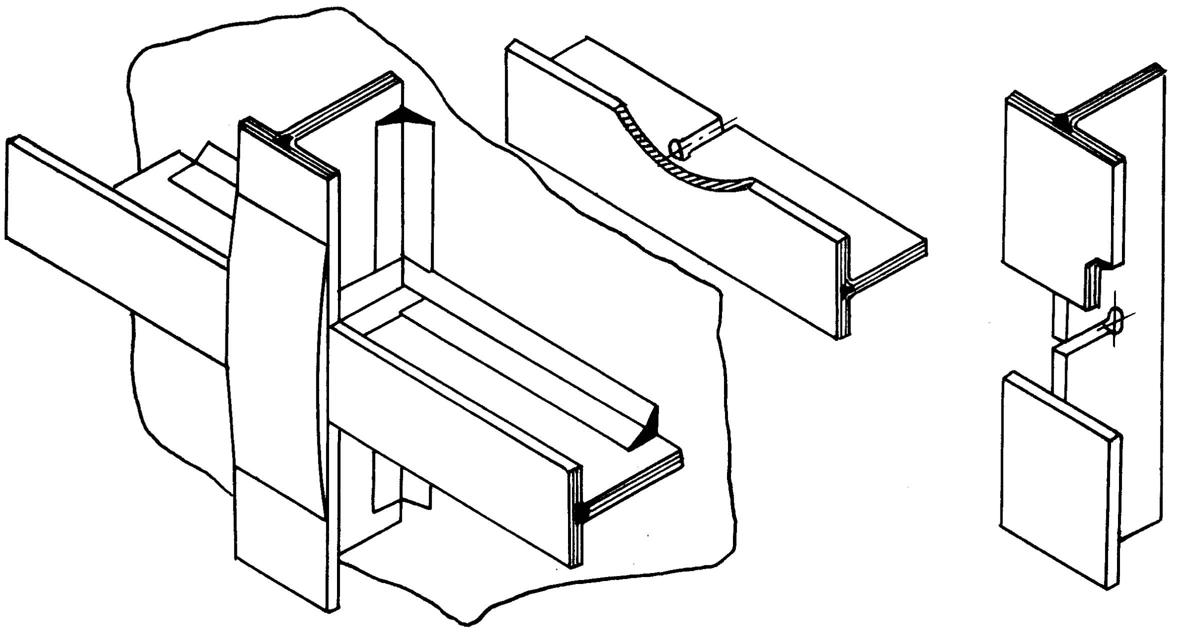


Fig. 2.4.6

Notes: 1. Deep members are jointed by means of an edge cross lap.

2. The length of the outer strap is to be not more than three widths of the flange of longitudinal framing member. A 20 mm overlap in adjacent layers is to be provided. The strap thickness is to be equal to that of the flange of transverse framing member.

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.

2.5.6 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.

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.

2.5.10 Intersection of deck framing members is to be made in accordance with Figs 2.3.6-1, 2.3.6-2 and 2.4.6.

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 is to 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).

2.6 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 will be in compliance with the requirements of Part XIII "Materials".

2.6.2 The scantlings of pillars of aluminium alloys are to be taken according to Table 2.6.2.

2.6.3 The pillars are to 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 is to 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 is to 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 is not to 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 is to be fitted.

2.7.6 Where a horizontal girder is provided, a stiffener of the same section modulus as the horizontal girder is to be fitted at the centre line.

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, in m.

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 is to be not less than half the bottom strake thickness.
3. The width of each strake is to be 0,7... 1,0 m.
4. For bulkheads of intermediate height m_{perm} is determined by linear interpolation.

2.7.7 The design of openings in the bulkheads is to comply with the requirements of 2.10 of the present Part of the Rules.

2.7.8 The longitudinals are not to be cut at bulkheads. The slots in the bulkheads for the longitudinals are to be 3—4 mm higher and wider than the longitudinals proper and after the installation of bulkheads are to be filled with glass rovings and covered with not less than 3 layers of glass fabric.

2.7.9 The horizontal girders of bulkheads are to be fitted in one plane with side stringers and interconnected by means of brackets whose arm length is to be equal to the web depth of the side stringer.

2.7.10 The bulkhead stiffeners supported by longitudinal framing members are to be connected thereto by means of straps and mattings-in.

2.7.11 The bulkhead stiffeners receiving support from the bottom or deck are to be interconnected with the nearest transverse member by means of short longitudinals whose depth is to be equal to the stiffener depth. The connection of these short longitudinals to stiffeners is to be effected in accordance with 2.7.9.

2.8 TANKS

2.8.1 The thickness of the laminates for the tank boundary structures is to 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 is to be used in lieu of the full height of the bulkhead shown in Table 2.7.1 (see also 2.7.2).

2.8.2 The scantlings of tank framing members are to 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 is to be equal to the thickness of shell laminates in this area.

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 is to 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 is to 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.

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 are to be provided with earthing arrangements for discharging static electricity approved by the Register.

2.8.6 The construction of tank manholes and covers is to 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 are to be provided with water courses and air holes.

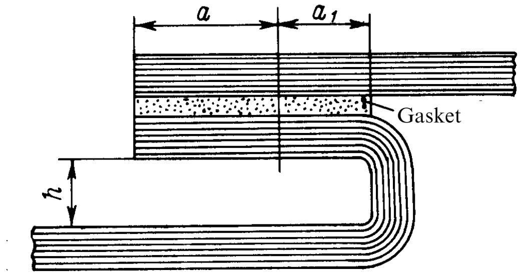


Fig. 2.8.6:
a — minimum distance from the edge to bolts;
$a \geqslant 3d$ (*d* is a diameter of bolt);
h — depth of suit bolt or nut fitting;
$a_1 \geqslant 1{,}5d$. Bolts are to be spaced not more than 4*d* apart

2.9 SUPERSTRUCTURES AND DECKHOUSES

2.9.1 The superstructure outer shell which is the continuation of the ship's side plating is to be integral with this plating. The laminate thickness of the superstructure is to be equal to that of the hull sides. The thickness reduction from the sheerstrake to the superstructure sides is to 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 are to 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 is to be 30 to 50 mm. The average density of the foam plastic core for superstructure sides is not to 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 is to 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 is to be modified in proportion to the ratio of (spacing, mm)/400, but it is not to 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 is to 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 is to be modified in proportion to the ratio of (spacing, mm)/800 but it is not to 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 is to be modified in proportion to the ratio of $\frac{\text{spacing, mm}}{400}$.

2. For intermediate values of stiffener spans the section modulus is to 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 is to be modified in proportion to the ratio of $\frac{\text{spacing, mm}}{800}$.

2. The spacing for superstructure sides is to be brought in conformity 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 are to 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 are to 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 are to be strengthened with straps.

2.10.6 Dimensions of openings and the structure of closures in the outer shell and watertight bulk-

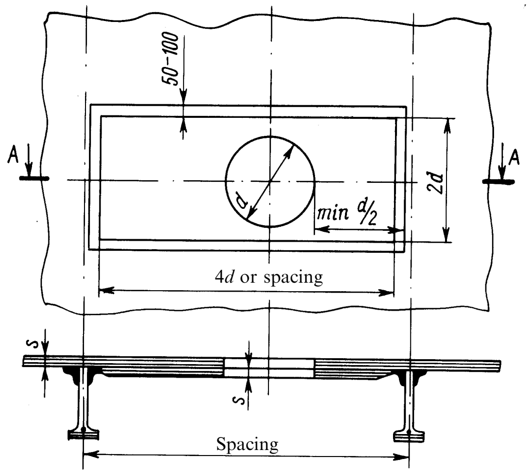


Fig.2.10.2

N o t e s : 1. Reinforcing is to be made only with glass fabric whose warp is oriented along the hull.

2. The thickness of the strap is to 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 should 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.

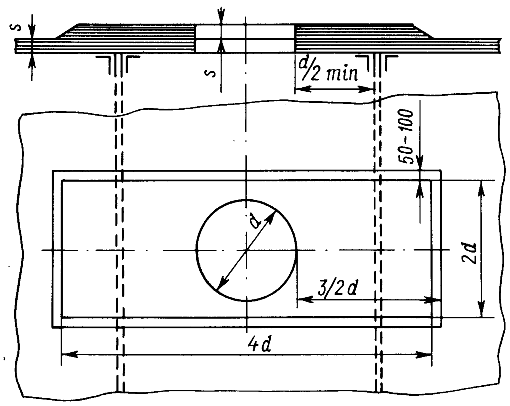


Fig.2.10.3-1

N o t e s : 1. Reinforcing is to be made only with glass fabric whose warp is oriented along the hull.

2. The thickness of the strap is to 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.

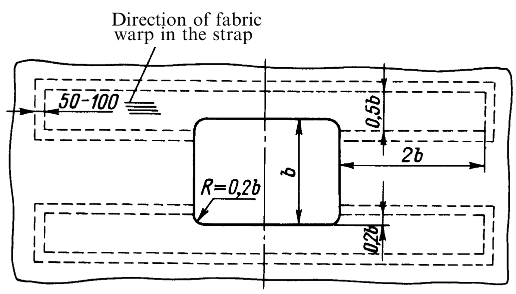


Fig.2.10.3-2

N o t e s : 1. Reinforcing is to 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 is to be equal to the deck laminate thickness.

heads of ships whose subdivision is regulated by Part V "Subdivision" are to be specially agreed with the Register.

2.11 BULWARK

2.11.1 The bulwark thickness is to be equal to half the thickness of the side laminate but not less than 4 mm.

2.11.2 The bulwark stays are to be fitted at alternate beams.

2.11.3 In ships over 15 m in length the bulwark laminate is not to form an integral part of the side laminate, and its sectional area should 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 is to be specially considered by the Register.

2.12 ENGINE SEATINGS

2.12.1 Side girders should be used as far as possible as bearers of the main engine seatings. Where this is not feasible, additional bottom longitudinals are to be fitted with the web thickness equal to that of the side girder.

2.12.2 The engine seating girders are to 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 are to 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 are to be moulded into the stem.

2.13.4 The stem moulded of glass-reinforced plastic is to be shaped as a rectangle with the width b and length l calculated by the formulae, in mm:

$$b = 1{,}5L + 30,$$

$$l = 2{,}5b$$

where L = ship's length, m.

The thickness of the stem laminate reinforced with glass fabrics (types II, III or IV) is to be 1,5 times the sheerstrake thickness. The space inside the stem is to be filled with plastic reinforced with glass-fibre bundles which are to 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:

$$b_1 = 0{,}4L + 10,$$

$$b_2 = b_1 + 2s,$$

$$l_1 = 2{,}5b_2$$

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 (see 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 are to be as required in 2.10.4.5, Part II "Hull". The flanges of the brackets are to 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 is to be agreed with the Register should be provided in this area.

2.13.9 Bilge keels, if fitted, are to be of glass-reinforced plastic of type II. The attachment of bilge keels to the hull is to be effected by means of matting-in double angles (without using bolts) which are to be fitted on both sides of the keel laminate. The thickness of the matting-in double angles is to be equal to that of the keel laminate. The structural design of bilge keels is to 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 PROVISIONS

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 **ЛУ2** in their class notation.

The definitions of ice category marks are given in Part I "Classification".

3.2 ICE STRENGTHENING IN SHIPS OF CATEGORY ЛУ2

3.2.1 An ice belt is to be provided on the shells the upper edge of which is to be extended 0,5 m above the winter load waterline, while the lower edge is to be 0,5 m below the waterline in the ballast condition.

The ice belt is to 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 is to be thoroughly cleaned.

3.2.4 The thickness of the ice belt strap is not to be less than 1/3 of the shell thickness in the area. The thickness of the strap is to 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 is to 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 is to be fitted along the stem in way of the ice belt. The strap is to overlap the ice belt for one spacing. The strap thickness is to 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 is to 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 for the spacing reduction.

4 LIFEBOAT HULL

4.1 GENERAL PROVISIONS

4.1.1 The determination of scantlings and selection of the required type of glass-reinforced plastic are to 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 of this Part of the Rules.

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 is not to 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 is to be laid on the laminate faces.

4.2.2 Seams and butts of strips of reinforcing material in members with parallel and diagonal reinforcement are to be formed as butts without overlap for any thickness exceeding 6 mm; for thicknesses between 2 and 6 mm, the overlap is to be at least 50 mm.

The butts and seams in each adjacent layer are to 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 is to be 4 mm, the outer and inner skins in the case of sandwich construction are to be 3 mm and 2 mm, respectively.

4.2.4 The thickness of shell laminate in the case of single-skin construction is to 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, see Table 2.2.1.
3. The thickness adopted for the bottom shell is to be maintained from the keel to a level not less than 1/3 of the side depth.

4.2.5 The laminate thickness of air cases of glass-reinforced plastic of type I or II is to 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 is to be increased by 3 mm.

4.2.6 For double-skin and sandwich constructions, the laminate thickness of the outer skin is to be 75 per cent and the thickness of the inner skin — 50 per cent of the thickness of the single-skin construction, respectively (see Table 4.2.4).

4.2.7 Special care should 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 is to be formed by additional reinforcing material layers which should 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 is to 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 are not to 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 is to 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 is not to 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 are to be chosen in accordance with Table 4.3.4 and 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 are to be fitted (one on each side). The section moduli of the keelsons are to be found in Table 4.3.6.

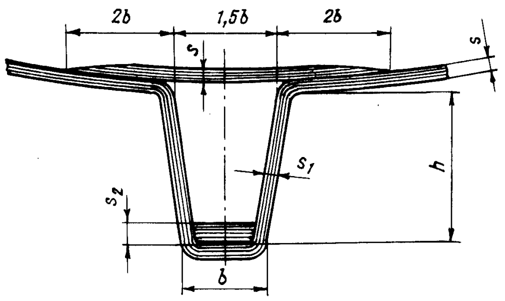


Fig. 4.3.4

Table 4.3.4

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 – 6, Appendix 2 to the present Part of the Rules.
3. Thickness s_2 is obtained by addition of rovings to be laid inside the keel.

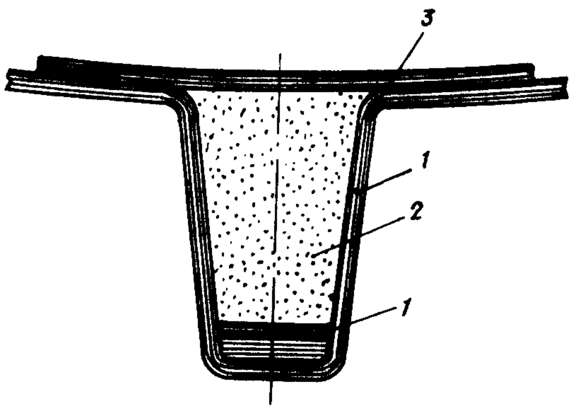


Fig. 4.3.5:

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 is to be increased by the factor of three.
3. Keelson is to 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 is to be not less than 0,75 of the value given in this Table.

4.4 ATTACHMENT OF LIFTING GEAR AND EQUIPMENT

4.4.1 The attachment of lifting gear to the lifeboat hull is to 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 should be checked by a static load equal for each lifting hook to 0,75 times the mass of the lifeboat when loaded with full complement of persons and equipment which is to be applied for at least 5 min.

4.4.3 The structure of the mounts for lifting gear parts is to 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.

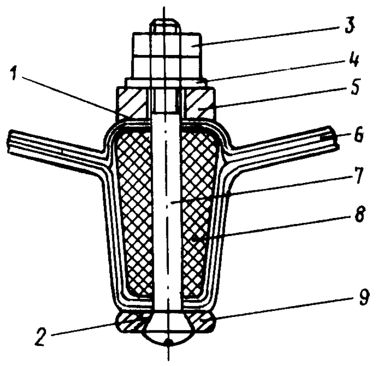


Fig.4.4.3
1, 2 — tarpaulin gaskets; 3 — nut; 4 washer; 5 — lifting lug; 6 — deck laminate; 7 — bolt; 8 — insert; 9 — base plate

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.

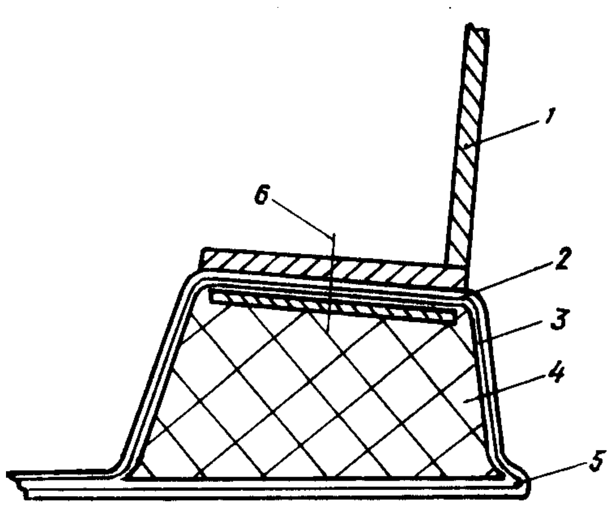


Fig.4.4.4-1
1 — engine bearer; 2 — steel plate; 3 — girder moulded integral with the inner shell skin; 4 — core (ПХВ-1); 5 — inner shell skin; 6 — screw

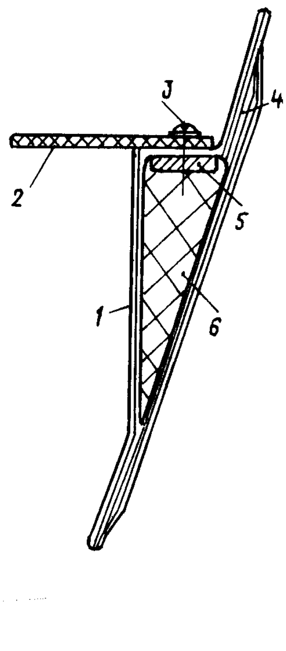


Fig.4.4.4-2
1 — step moulded integral with the inner shell skin; 2 — platform (thwart); 3 — screw; 4 — inner shell skin; 5 — steel plate; 6 — core (ПХВ-1)

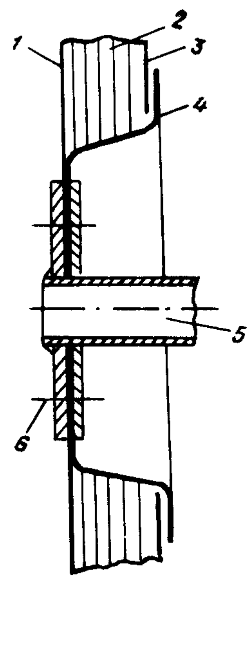


Fig.4.4.4-3
1 — outer shell skin; 2 — core; 3 — inner shell skin; 4 — glass-reinforced plastic lined hole in the inner shell skin and core; 5 — pipeline; 6 — bolt

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;

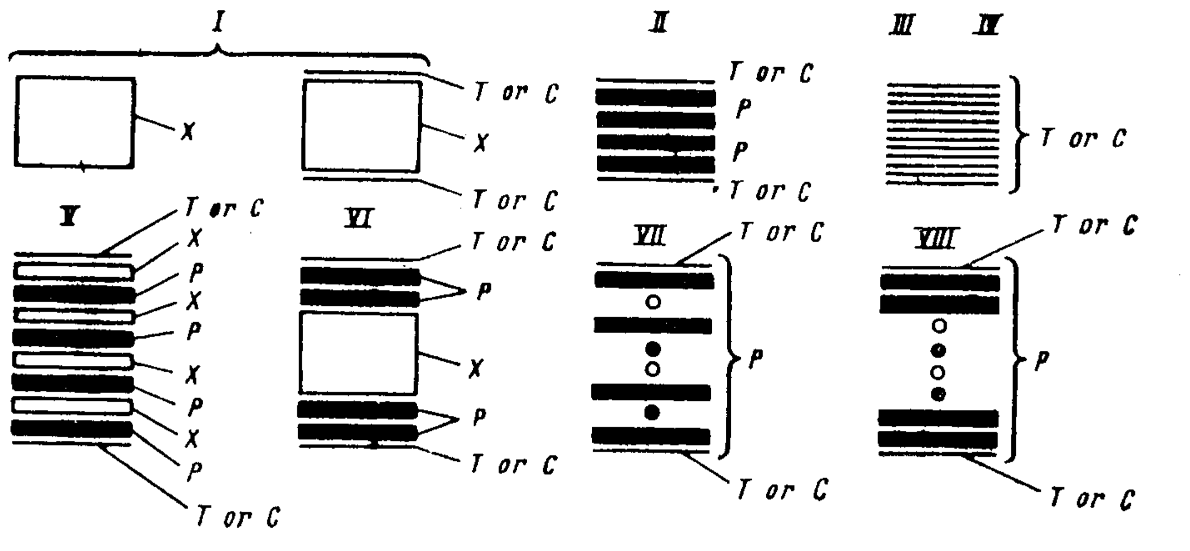
.6 *type VI:* plastic with the same reinforcement thickness ratio as for type V, but with mats concentrated in the middle and woven rovings laid on the outer and inner faces and amounting to 1/4 of the thickness on each side;

.7 *type VII:* plastic with parallel and diagonal reinforcement of woven rovings at angles +45° and −45° whose layers, laid parallel to the warp, should amount to half the laminate thickness, while the diagonal parts plied at +45° and −45° to the layers of parallel orientation should 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 are to occupy the middle portion of the laminate thickness while those of parallel reinforcement are to form the outer and inner faces of the laminate (packet arrangement).

Glass-reinforced plastics, types II, V, VI, VII and VIII are to 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 the drawing.



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 are to be in accordance with the values stated in Tables 1 – 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	$0{,}60\cdot10^4$	$0{,}22\cdot10^4$	0,35	80,0	110,0	40,0
2	I_2	30	18	1,50	$0{,}70\cdot10^4$	$0{,}26\cdot10^4$	0,35	90,0	120,0	50,0

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. 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	$\frac{1{,}30\cdot10^4}{1{,}30\cdot10^4}$	$0{,}21\cdot10^4$	$\frac{0{,}12}{0{,}12}$	$\frac{170{,}0}{170{,}0}$	$\frac{105{,}0}{105{,}0}$	60,0
2	II_2	50	32	1640	$\frac{1{,}50\cdot10^4}{1{,}50\cdot10^4}$	$0{,}25\cdot10^4$	$\frac{012}{0{,}12}$	$\frac{200{,}0}{200{,}0}$	$\frac{110{,}0}{110{,}0}$	70,0
3	II_3	55	37	1700	$\frac{1{,}70\cdot10^4}{1{,}70\cdot10^4}$	$0{,}29\cdot10^4$	$\frac{0{,}12}{0{,}12}$	$\frac{230{,}0}{230{,}0}$	$\frac{115{,}0}{115{,}0}$	80,0

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 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	$\frac{1{,}05\cdot10^4}{1{,}05\cdot10^4}$	$0{,}24\cdot10^4$	$\frac{0{,}21}{0{,}21}$	$\frac{135{,}0}{135{,}0}$	$\frac{77{,}0}{77{,}0}$	55,0
2	V_2 / VI_2	30	55	42,5	1600	$\frac{1{,}2\cdot10^4}{1{,}2\cdot10^4}$	$0{,}28\cdot10^4$	$\frac{0{,}21}{0{,}21}$	$\frac{160{,}0}{160{,}0}$	$\frac{80{,}0}{80{,}0}$	65,0

N o t e s : 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	$\frac{1{,}1\cdot10^4}{1{,}1\cdot10^4}$	$0{,}37\cdot10^4$	$\frac{0{,}30}{0{,}30}$	$\frac{140{,}0}{140{,}0}$	$\frac{80{,}0}{80{,}0}$	56,0
2	VII_2 / $VIII_2$	50	1650	$\frac{1{,}3\cdot10^4}{1{,}3\cdot10^4}$	$0{,}45\cdot10^4$	$\frac{0{,}30}{0{,}30}$	$\frac{170{,}0}{170{,}0}$	$\frac{95{,}0}{95{,}0}$	68,0
3	VII_3 / $VIII_3$	55	1700	$\frac{1{,}5\cdot10^4}{1{,}5\cdot10^4}$	$0{,}52\cdot10^4$	$\frac{0{,}30}{0{,}30}$	$\frac{200{,}0}{200{,}0}$	$\frac{110{,}0}{110{,}0}$	79,0

N o t e s : 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 LIFE-BOATS 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.

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 (see Appendix 2).

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 are to be taken, whichever are less.

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 (see Appendix 2 to this Part of the Rules).

1.5 For hull structural components the factor of safety against buckling should 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 is then to be not less than 95 per cent of the moment of inertia calculated in the first approximation without regard for 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:

.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 are to 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.

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 is to be determined by linear interpolation.

The design pressure on the side is taken to be 80 per cent of the relevant pressure on the bottom;

.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);

.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 is to be 1/333L.

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 is to be taken;

.4 the factors of safety against buckling are not to be less than:

3 for side girders and keel;

1,5 for gunwale;

1 for shell.

In this case, the local buckling strength only is to be checked.

2.2 Testing of finished hulls of lifeboat for strength and rigidity is to be effected in accordance with the requirements of 5.2, Part II "Life-Saving Appliances" of Rules for the Convention Equipment of Sea-Going Ships.

Notes