ClassIBS

ISTHMUS BUREAU OF SHIPPING

PART 7
MACHINERY INSTALLATIONS

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PRINCIPLES FOR THE CLASSIFICATION AND CONSTRUCTION OF STEEL SHIPS

PART 7 MACHINERY INSTALLATIONS

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PRINCIPLES FOR THE CLASSIFICATION AND CONSTRUCTION OF STEEL SHIPS

PART 7 MACHINERY INSTALLATIONS

Chapter 1 GENERAL

1.1 General

1.1.1 Scope

1. The requirements of this part apply to the main propulsion machinery, power transmission systems, shafting systems, propellers, prime movers other than main propulsion machinery, boilers etc., incinerators, pressure vessels, auxiliaries, piping systems, and their control systems (hereinafter referred to as “machinery installations” in this Part).

2. For machinery installations, fitted in ships with restricted area of service or fitted in small ships, some of the requirements in this part may be modified according to the requirements given in **Chapter 20**, and additionally may be modified appropriately provided that the Society considers it acceptable.

1.1.2 Equivalency

Machinery installations which do not comply with the requirements of this Part may be accepted provided that they are deemed by the Society to be equivalent to those specified in this Part.

1.1.3 Machinery Installations with Novel Design Features

Machinery installations with novel design features may be accepted, provided that it complies with additional requirements on design and test procedures other than those in this Part as deemed necessary, with the results satisfactory to the Society.

1.1.4 Modification of Requirements

For the following machinery installations, piping systems and their control systems, some requirements of this Part may be modified appropriately provided that the Society considers it acceptable:

1) Small prime movers for driving generators or auxiliary machinery (including power transmission systems and shafting systems)
2) Auxiliary machineries for cargo handling and their driving prime movers
3) Machinery installations as deemed appropriate by the Society in consideration of the capacity, purpose and conditions of service.

1.1.5 Terminology

1. In this part auxiliaries are classified into the following groups:

When auxiliaries listed from **(1)** to **(5)** are used for multiple services they are deemed to belong to the higher class.

(1) Auxiliary machinery essential for main propulsion.
Auxiliary machinery used for the operation of main propulsion machinery.

(2) Auxiliary machinery for manoeuvring and the safety.
Auxiliary machinery used for ship manoeuvring for safety, and auxiliary machinery used for securing the safety of the ship and life of persons on board.

(3) Auxiliary machinery for cargo handling.
Auxiliary machinery used for cargo loading and unloading, as well as for cargo maintenance.

(4) Auxiliary machinery for specific use.
Auxiliary machinery used for specific operation while at sea or in port.

(5) Other auxiliary machinery. Other auxiliary machinery not included in **(1)** to **(4)** above.

2. Propulsion Shafting Systems

The propulsion shafting system means a thrust shaft, intermediate shaft, stern tube shaft, propeller shaft and their bearings and propeller.

1.1.6 Drawings and Data to be Submitted

The drawings and data to be submitted in connection with machinery installations are to conform to the requirements specified in each Chapter of this Part.

1.2 Materials

1.2.1 Selection of Materials

1. Materials under the requirements of **Part 10.**

Materials used for machinery installations are to be selected, according to the provisions of each Chapter of this Part, from those complying with the requirements specified in **Part 10** considering the purpose and conditions of their service.

2. Other Materials

Materials used for machinery installations which are not specified in each Chapter of this Part, are to conform to the following **(1)** and **(2)**.

(1) Of materials for machinery installations, those used for main propulsion machinery, power transmission systems, shafting systems, propellers, boilers, pressure vessels and control systems, and those used for auxiliary machinery essential for main propulsion, auxiliary machinery for manoeuvring and the safety, and auxiliary for cargo handling are to complying with the requirements of standards deemed appropriate by the Society.

(2) Of materials for machinery installations, those used for auxiliaries, excluding auxiliary machinery essential for main propulsion, auxiliary machinery for manoeuvring and the safety, and auxiliary machinery for cargo handling (hereinafter referred to as auxiliary machinery for specific use etc.) and

those used for their associated power transmission systems, shafting systems, piping systems and their control systems are to be selected considering the purpose and conditions of their service.

1.3 General Requirements for Machinery Installations

1.3.1 General

1. The machinery installations are to be of a design and construction adequate for the service for which they are intended and are to be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards.

The design is to have regard to the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

2. When the following machinery is fitted singly on board, special consideration is to be given to the reliability of the machinery and its components.

For ships in which unconventional machinery is used as the main propulsion machinery and propulsion shafting system, the additional machinery which enables the ship to proceed at a navigable speed in the event of possible failure of the machinery may be required by the Society.

(1) For diesel ships :

Diesel engines used as the main propulsion machinery, high elastic couplings, reduction gears and propulsion shafting systems

(2) For steam turbine ships:

Steam turbine engines used as the main propulsion machinery, main boilers, main condensers, reduction gears and propulsion shafting systems

(3) For gas turbine ship:

Gas turbine engines used as the main propulsion machinery, compressors, combusters, reduction gears and propulsion shafting systems

(4) For electric propulsion ships: Propulsion motors, reduction gears and propulsion shafting systems

3. For electric propulsion ships two or more propulsion generators are to be provided.

4. Means are to be provided whereby normal operations of main propulsion machinery can be sustained or restored even though one of the essential auxiliaries becomes inoperative. Special consideration is to be given to the malfunctioning of:

(1) a generating set which serves as a main source of electrical power;

(2) the sources of steam supply;

(3) the boiler feed water systems;

(4) the fuel oil supply systems for boilers or engines;

(5) the sources of lubricating oil pressure;

(6) the sources of water pressure;

(7) a condensate pump and the arrangements to maintain vacuum in condensers;

(8) the mechanical air supply for boilers;

(9) an air compressor and a receiver for starting or control purposes;

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

However, having regard to overall safety consideration, a partial reduction in propulsion capability from normal operation may be accepted.

5. Means are to be provided to ensure that machinery installations can be brought into operation from the dead ship condition without external aids. In addition, the starting systems in conjunction with other machinery are to be so arranged as to restore the propulsion from dead ship condition within 30 *minutes* after blackout.

6. Main propulsion machinery and prime movers for driving generators, and auxiliary machinery (excluding auxiliary machinery for specific use etc.) and the prime movers driving them are to be designed to operate under the conditions given in **Table 1.1**, as fitted in the ship. Deviation from the angles given in **Table 1.1** may be permitted, taking into consideration the type, size and service conditions of the ship.

7. Machinery installations are to be designed to operate smoothly under the temperature conditions given in **Table 1.2**.

8. Provision is to be made to facilitate cleaning, inspection and maintenance of machinery installations.

9. Special consideration is to be given to the design, construction and installation of the machinery installations so that any mode of vibrations shall not cause undue stresses in normal operating ranges.

Table 1.1 Angle of Inclination

Type of machinery installations	Athwartships(2)		Bow-and-stern(2)	
	Static inclination (List)	Dynamic inclination (Rolling)	Static inclination (Trim)	Dynamic inclination (Pitching)
Main propulsion machinery. Main boilers and essential auxiliary boilers Prime movers driving generator (excluding those for emergency) auxiliary machinery (excluding auxiliary machinery for specific use, etc.) and their driving units	15°	22.5°	5°(4)	7.5°
Emergency installation (emergency installation (emergency generators, emergency fire pumps and prime movers to drive them) Switchgears(1) (Circuit breakers, etc.) Equipment for automatic.	22.5° (3)	22.5° (3)	10°	10°

10.The exhaust gas treatment systems specified in the following (1) and (2) fitted onto machinery installations are to be to the satisfaction of the Society.

(1) Selective catalytic reduction (SCR) systems

(2) Exhaust gas cleaning systems (EGCS) (excluding those specified in 2.1.1-5)

Notes:

1 Up to an angle of inclination of 45°, undesired switching operations or operational changes are not to be caused.

2 Athwartships and bow-and-stern inclinations may occur simultaneously.

3 In ships carrying liquefied gases in bulk and ships carrying dangerous chemicals in bulk, the arrangement is to besuch that the emergency power supply must also remain operable with the ship flooded to a final athwartship inclination up to a maximum of 30°

4 Where the length of the ship exceeds 100 *m*, the fore-and-aft static angle of inclination may be taken as follows:

$\theta = 500/L$

θ: The static angle of inclination (°)

L: Length of the ship specified in **1.2.2 Part 1 A** (*m*)

Table 1.2 Temperature

	Installed located	Temperature (˚C)
Air	In encolsed spaces	0 to 45(Note)
	Machinery components or boilers in spaces subject to temperatures exceeding 45˚C, and below 0˚C	According to specific conditions
	On the open deck	-25 to 45(Note)
Seawater	-	32(Note)

Note:

Other temperatures deemed appropriate by the Society may be accepted in ships not intended for unrestricted service.

1.3.2 Astern Power

1. Sufficient power for going astern is to be provided to secure proper control of the ship in all normal circumstances.

2. The main propulsion machinery is to be capable of maintaining in free route astern at least at 70% of the ahead revolutions, for a period of at least 30 *minutes*. The output astern which may be developed in transient conditions is to be such as to enable the braking of the ship within reasonable time.

3. For the main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern is not to lead to the overload of propulsion machinery.

1.3.3 Limitation in the Use of Fuel Oil

Limitation in the use of fuel oil is to comply with the requirements in 4.2.1, Part 6.

1.3.4 Fire Protections

1. Machinery installations are to be free from leakages of fuel oil, lubricating oil and other flammable oils, as far as practicable. For those from which these oils may leak, proper means of leading the leaked oil to a safe location are to be provided.

2. Machinery installations are to be free from leakage of harmful gases or flammable gases which may cause fire, as far as possible. Those from which these gases may leak are to be installed in well ventilated spaces to be capable of purging such gases quickly.

3. In addition to 1.3.4, fire protections are to comply with the requirements in 4.2 and 5.2, Part 6.

1.3.5 Ventilating Systems for Machinery Spaces

Machinery spaces of category *A* are to be adequately ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions including heavy weather, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery. Any other machinery space are to be adequately ventilated appropriate for the purpose of that machinery space.

1.3.6 Protection against Noise

Measures are to be taken to reduce machinery noise in machinery spaces to acceptable levels as determined by the National Regulations of the country in which the ship is registered. If this noise cannot be sufficiently reduced the source of excessive noise is to be suitably insulated or isolated or a refuge from noise is to be provided if the space is required to be manned. Ear protectors are to be provided for personnel required to enter such spaces, if necessary.

1.3.7 Communication between Navigating Bridge and Control Stations for Speed and Direction of Thrust of Propellers

Communication between navigating bridge and control stations for the control of speed and direction of thrust of propellers are to comply with following requirements.

(1) At least two independent means are to 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 means is to be an engine-room telegraph which provides visual indication of the orders and responses both on the navigating bridge and in such control stations mentioned above.

(2) Means of communication as deemed appropriate by the Society, are to be provided from the navigating bridge and the engine-room to any position, other than those specified in **(1)** above, from which the speed or direction of thrust of the propellers may be controlled.

1.3.8 Engineers Alarm

An engineers alarm is to be provided to be operated from the engine control room or at the manoeuvring platform as appropriate, and is to be clearly audible in the Engineers accommodation.

1.3.9 Operating and Maintenance Instructions for Ship Machinery and Equipment

Operating and maintenance instructions and engineering drawings for ship machinery and equipment essential to the safe operation of the ship are to be provided and written in a language understandable by her officers and crew members who are required to understand such information in the performance of their duties.

1.4 Test

1.4.1 Shop Tests

1. Before installation on board, equipment and components constituting the machinery (excluding auxiliary machinery for specific use etc.) are to be tested at the plants provided with installations and equipment necessary for the tests (hereinafter referred to as the Shop Tests) in accordance with the relevant requirements of this Part.

2. For equipment and component parts of the machinery, in case where the shop tests are not specified in the requirements in each Chapter of this Part, and those of auxiliary machinery for specific use etc., the records of the tests carried out by the manufacturer are to be submitted to the Society when requested.

1.4.2 Mass-production Equipment

For equipment manufactured by mass-production system deemed appropriate by the Society, the test procedure suited to the production method may be accepted in place of the tests specified in the Rules upon the request of the manufacturer, notwithstanding the requirements of **1.4.1-1** above.

1.4.3 Omission of Tests

Where machinery installations have test certificates which are deemed appropriate by the Society, a part or all of tests for the machinery specified in **1.4.1** may be omitted.

1.4.4 Tests after Installation on Board

1. Machinery is to be tested after installed on board in accordance with the requirements specified in each Chapter of this Part.

2. Those of auxiliary machinery for specific use etc. deemed necessary by the Society are to be tested to the satisfaction of the Society to verify that they do not endanger the ship and crew in their operating condition at the appropriate occasions before they are used.

3. The Society may require, where deemed necessary, other tests than those specified in this Part.

Chapter 2 DIESEL ENGINES

2.1 General

2.1.1 Scope

1. The requirements of this Chapter apply to diesel engines which are used as the main propulsion machinery or used to drive generators and auxiliaries (excluding auxiliary machinery for specific use etc., hereinafter the same in this Chapter).

2. For diesel engines driving emergency generators, the requirements of **3.3** and **3.4, Part 8** and, if controlled automatically or remotely for non-emergency purposes, **18.5.2** apply, in addition to the requirements in this Chapter (excluding **2.2.4**, section **2.3**, **2.4.1-4** and the requirement for devices to stop the operation of the engine specified in **2.5.5-1**).

3. Electronically-controlled diesel engines used for the main propulsion machinery are to be in accordance with the requirements specified otherwise by the Society in addition to those provided in this Chapter.

4. Diesel engines fitted with exhaust gas recirculation (EGR) systems are to be in accordance with requirements specified otherwise by the Society in addition to those in this Chapter

2.1.2 Drawings and Data

Drawings and data to be submitted are generally as follows:

(1) Drawings and data for approval

- (a) Engine particulars (to be in the form designated by the Society)
- (b) Details of welding procedure for principal components
- (c) Crankshaft (including component details, shaft coupling bolts, balance weights and their fastening bolts)
- (d) Connecting rod and its bearings (including bolts details) of 4 stroke cycle engine
- (e) Thrust shaft (if integral with engine)
- (f) Arrangement of foundation bolts (including foundation bolts, chocks and stoppers)
- (g) Structural detail and arrangement of crankcase explosion relief valves
- (h) Material specifications of principal components
- (i) High pressure oil pipe for driving exhaust valve with its shielding
- (j) High pressure fuel oil pipe with its shielding and clamping
- (k) Piping arrangements fitted to engine (including fuel oil, lubricating oil, cooling oil, cooling water,

(l) pneumatic and hydraulic systems, and indicating size, materials and working pressure of pipes)

(m) Sectional assembly of exhaust driven turboblower

(2) Drawings and data for reference

(a) A list containing all drawings and data submitted (with relevant drawing numbers and revision status)

(b) Longitudinal section of engine

(c) Transverse cross-section of engine

(d) Bedplate and thrust block (if integral with engine)

(e) Frames

(f) Cylinder cover, cylinder jacket and cylinder liner

(g) Piston and gudgeon pin

(h) Tie rods (including coupling and set-screw)

(i) Assembly of piston and piston rod

(j) Piston rod

(k) Connecting rod and its bearings (including bolts details) of 2 stroke cycle engine

(l) Assembly of thrust bearing

(m) Assembly of crosshead

(n) Camshaft driving gear and assembly of cam and camshaft

(o) Rocker valve gear

(p) Fuel oil injection pump

(q) Main bearing bolts

(r) Cylinder cover fixing bolts and valve box fixing bolts

(s) Flywheel (in the case of a power transmission component)

(t) Engine control system diagram (including monitorings, safety and alarm systems)

(u) Construction and arrangement of thermal insulation for exhaust pipes fitted to the engine

(v) Construction and arrangement of dampers, detuners, balancers or compensators, bracings, and calculation sheets on balancing and prevention of vibration of the engine

(w) Operation and service manuals of engine

(x) Other drawings and data deemed necessary by the Society

2.2 Materials, Construction and Strengh

2.2.1 Materials

1. Materials intended for the principal components of diesel engines and their non-destructive test are to conform to the requirements given in **Table 2.1**. In the case of ultrasonic test, submission or presentation of test results to the Surveyor may be considered sufficient.

2. Cylinders, pistons and other parts subjected to high temperature or pressure, and parts for transmitting propulsion torque are to be of materials suitable for the temperature and load to which they are exposed.

Table 2.1 Application of Materials and Non-destructive Tests to Principal Components of Diesel Engines

Principals components			Cylinder bore D (mm)								
			$D \leq 300$			$300 < D \leq 400$			$400 < D$		
			I	II	III	I	II	III	I	II	III
1	Chankshaft	Solid forged type	○	○	○	○	○	○	○	○	○
		Web, pin and journal of built-up or semi-built-up type	○	○	○	○	○	○	○	○	○
		Others (for example welded type)	○	○	○	○	○	○	○	○	○
2	Coupling flanges on crank shaft (if not integral)								○		
3	Coupling bolts for crankshaft								○		
4	Steel piston crowns				○			○	○	○	○
5	Piston road		○	○		○	○		○	○	○
6	Connecting rods together with connecting rod bearing caps		○	○		○	○		○	○	○
7	Steel parts of cylinder liners					○			○		
8	Steel cylinder covers				○	○		○	○	○	○
9	Bed-plates of welded construction	Plates and transverse bearing girders made of forged or cast steel	○			○			○		
		Cast steel parts including welded joints		○	○		○	○		○	○
10	Thrust blocks of welded construction, plates and transverse bearing girders made of forged or cast steel		○			○			○		
11	Frames and crankcases of welded construction		○			○			○		
12	Entablatures of welded construction		○			○			○		
13	Tie rods		○	○		○	○		○	○	
14	Steel gear wheels for camshaft drive								○	○	
15	Bolts and studs (for cylinder crossheads, connecting road bearings, main bearings)					○			○	○	
15	Turbine discs, blades, blower impellers and rotor shafts of exhaust driven turboblowers, and shafts, rotors and blades of		○	○	○	○	○	○	○	○	○

	superchargers, excluding auxiliary blowers									
17	Crossheads							○		
18	Pipes, valves and fittings attached to engine classified in Group I or Group II in Chapter 12	○			○			○		

Notes:

1 Materials intended for the components marked with circlets in Column I. are to comply with the requirements in **Part 10**.

2 Materials intended for the components marked with circlets in Column II. are to be tested by magnetic particle test or liquid penetrant test.

3 Materials intended for the components marked with circlets in Column III. are to be tested by ultrasonic test.

2.2.2 Construction, Installation and General

1. Cylinders, pistons and other parts subjected to high temperature or pressure are to be of the construction suitable for the mechanical and thermal stresses to which they are exposed.

2. Where the principal components of diesel engine are of welded construction, they are to comply with the requirements of **Chapter 11**.

3. The frames and bedplates are to be of rigid and oil tight construction and the bedplate is to be provided with a sufficient number of foundation bolts to secure it on the engine seating for the entire length.

4. Crankcase and crankcase doors are to be of sufficient strength, and crankcase doors are to be so fastened securely that they may not be readily moved by an explosion within the crankcase.

5. A warning notice is to be posted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time sufficient to permit adequate cooling has elapsed after stopping the engine.

6. Ventilation of crankcase and any arrangement which can produce an inflow of external air into the crankcase, are forbidden except in cases **(1)** and **(3)** below.

(1) Vent pipes, where provided, are to be made as small as practicable to minimize the inrush of air after explosion.

However, no interconnection is to be made between the ventilating pipes of two or more engines. Vent pipes from crankcase of main propulsion engine are to be led to a safe position on deck or other approved position.

(2) If provision is made for the extraction of gases from the crankcase (e.g. for oil mist detection purpose), the vacuum in the crankcase is not to exceed 2.5×10^{-4} *MPa*

(3) In case where the trunk piston type dual fuel diesel engines are provided with crankcase ventilation for preventing the accumulation of leaked gas.

7. The ambient reference conditions for the purpose of determining the power of diesel engines are to be as follows:

Total barometric pressure: 0.1 *MPa*

Air temperature: 45°C

Relative humidity: 60%

Seawater temperature (at charge air intercooler inlet): 32°C

2.2.3 Crankpin Bearings of 4 Stroke-cycle Engines

Crankpin bearings of 4 –stroke cycle engines are to be designed and constructed to keep a fair contact pressure upon the contact face of the bearing caps and not to cause an excessive stress on the crankpin bolts, against the alternating load to be acting on the connecting rod.

2.2.4 Flywheel Shafts and Other Shafts

Where flywheels or eccentric sheaves for pumps are fitted on crankshafts or additional shafts between the aftermost journal bearing and the thrust shaft, the shaft diameter in way of the part is not to be less than the required diameter of the crankshaft determined by the formula in 2.3.

2.3 Crankshafts

2.3.1 Solid Crankshafts

1. The diameters of the crankpins and journals are to be not less than the value given by the following formula:

$$d_c = \left\{\left(M + \sqrt{m^2 + T^2}\right) D^2\right\}^{\frac{1}{3}} K_m K_s K_h$$

where;

d_c: Required diameter of crankshaft (*mm*)

M: $10^{-2}\, ALP_{max}$

T=$10^{-2} BSP_{mi}$

S: Length of stroke (*mm*)

L: Span of bearings adjacent to crank measured from centre to centre (*mm*)

P_{max}: Maximum combustion pressure in cylinder (*MPa*)

P_{mi}: Indicated mean effective pressure (*MPa*)

A and B: Coefficients given in Table 2.2 and Table 2.3 for engines having equal firing intervals (in case of Vee engines, equal firing intervals on each bank.) Special consideration will be given to values A and B for diesel engines having unequal firing intervals or those not covered by the Tables.

D: Cylinder bore (mm)

K_m: Value given by the following (1) or (2) in accordance with the specified tensile strength of crankshaft material. However, the value of K_m for materials other than steel forgings and steel castings is to be determined by the Society in each case.

(1) In case where the specified tensile strength of material exceeds 440 N/mm^2;

$$K_m = \sqrt[3]{\frac{440}{440 + \frac{2}{3}(T_s - 440)}}$$

where;

T_s: Specified tensile strength of material (N/mm^2)

The value of T_s is not to exceed 760 N/mm^2 for carbon steel forgings and 1080 N/mm^2 for low alloy steel forgings.

(2) In case where the specified tensile strength of material is not more than $440\ N/mm^2$ but not less than $400\ N/mm^2$

$K_m = 1.0$

K_s Value given by the following **(1), (2)** or **(3)** in accordance with the manufacturing methods of crankshafts

(1) In case where the crankshafts are manufactured adopting the special forging process approved by the Society, the product quality is stable, and the fatigue strength is considered to be improved by 20% or more compared with that in free forging process ;

$$K_s = \sqrt[3]{\frac{1}{1.15}}$$

(2) In case where the crankshafts are manufactured adopting the manufacturing process using the surface treatment approved by the Society, the product quality is stable, and a superiority is considered in the fatigue strength;

$$K_s = \sqrt[3]{\frac{1}{1 + \rho/100}}$$

where;

ρ: Degree of improvement in strength approved by the Society relative to the surface hardening (%)

(3) In other cases than **(1)** and **(2)** above ;

$K_s = 1.0$

K_h: Value given by the following **(1)** or **(2)** in accordance with the inside diameter of crankpins or journals.

(1) In case where the inside diameter is one-third of the outside diameter or more;

$$K_h = \sqrt[3]{\frac{1}{1 - R^4}}$$

where;

R: Quotient obtained by dividing the inside diameter of hollow shaft by its outside diameter

(2) In case where the inside diameter is less than one-third of the outside diameter;

$K_h = 1.0$

Table 2.2 Value of Coefficients A and B for Single Acting In-line Engine

Number of Cylinders	2-stoke cycle		4-storke cycle	
	A	*B*	*A*	*B*
1	1.00	8.8	1.25	4.7
2		8.8		4.7
3		10.0		4.7
4		11.1		4.7
5		11.4		5.4
6		11.7		5.4
7		12.0		6.1
8		12.3		6.1
9		12.6		6.8
10		13.4		6.8
11		14.2		7.4
12		15.0		7.4

Table 2.3 (a) Value of Coefficients A and B for Single Acting 2-stroke cycle Vee Engine with Parallel Connecting Rods

Number of cylinders	Minimum firing interval between two cylinders on one crankpin					
	45º		60º		90º	
	A	*B*	*A*	*B*	*A*	*B*

6	1.05	17.0	1.00	12.6	1.00	17.0
8		17.0		15.7		20.5
10		19.0		18.7		20.5
12		20.5		21.6		20.5
14		22.0		21.6		20.5
16		23.5		21.6		23.0
18		24.0		21.6		23.0
20		24.5		24.2		23.0

Table 2.3(b) Value of Coefficients A and B for Single Acting 4-stroke cycle Vee Engine with Parallel Connecting Rods

Number of cylinders	Minimum firing interval between two cylinders on one crankpin											
	45º		60º		90º		270º		300º		315º	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
6	1.60	4.1	1.47	4.0	1.40	4.0	1.40	4.0	1.30	4.4	1.20	4.3
8		5.5		5.5		5.5		5.5		5.3		5.2
10		6.7		7.0		6.5		6.5		6.1		5.9
12		7.5		8.2		7.5		7.5		6.9		6.6
14		8.4		9.2		8.5		8.5		7.5		7.3
16		9.3		10.1		9.5		9.5		8.2		7.9
18		10.1		11.1		10.5		10.5		8.8		8.5
20		11.5		14.0		11.5		11.5		9.5		9.2

2. The dimensions of crank webs are to comply with the following requirements in **(1)** and **(2)**:

(1) The thickness and breadth of crank webs are to comply with the following formula in connection with the diameters of crankpins and journals. In this case, the thickness of crank webs is to be not less than 0.36 times the diameter of crankpins and journals. When the actual diameters of the crankpin and journal are larger than the required diameter of the crankshaft determined by the formula in **-1**, the left side of the following formula may be multiplied by $(d_c/d_a)^3$

$$\{0.122(2.20 - b/d_a)^2 + 0.337\}(d_a/t)^{1.4} \leq 1$$

where;

b: Breadth of crank web (*mm*)

d_a: Actual diameter of crankpin or journal (*mm*)

t: Thickness of crank web (*mm*)

(2) The radius in fillets at the junctions of crank webs with crankpins or journals is to be not less than 0.05 times the actual diameter of crankpins or journals, respectively.

2.3.2 Built-up Crankshafts

1. The dimensions of crankpins and journals of built-up crankshafts are to comply with the followings.

(1) The diameters of crankpins and journals of built-up crankshafts are to comply with the requirements in **2.3.1-1**.

(2) The diameters of axial bores in journals of built-up crankshafts are to comply with the following formulae:

$$D_{BG} \leq D_S \cdot \sqrt{1 - \frac{4000 \cdot S_R \cdot M_{max}}{\mu \cdot \pi \cdot D_S^2 \cdot L_S \cdot \sigma_{SP}}}$$

D_{BG}: Diameter of axial bore in journal (*mm*)

D_S: Journal diameter at the shrinkage fit (*mm*)

S_R: Safety factor against slipping (a value not less than 2 is to be taken)

M_{max}: Absolute maximum torque at the shrinkage fit (*N·m*)

m: Coefficient for static friction (a value not greater than 0.2 is to be taken)

L_S: Length of shrinkage fit (*mm*)

σ_{SP}: Minimum yield strength of material for journal (*N/mm*^{2})

2. The dimensions of crank webs are to comply with the following requirements in **(1)** and **(2)**:

(1) The thickness of crank webs in way of the shrinkage fit is to comply with the following formulae:

$$t \geq \frac{C_1 T D^2}{C_2 d_h^2} \frac{1}{\left(1 - \frac{1}{r_s^2}\right)}$$

$$\mathrm{t} \geq 0.525 d_c$$

Where;

t: Thickness of crank web measured parallel to the axis (*mm*)

C_1: 10 for 2-stroke cycle in-line engines / 16 for 4-stroke cycle in-line engines

T: Same as given in 2.3.1-1

D: Cylinder bore (*mm*)

C_2: 12.8α - 2.4α^2, but in case of the hollow shaft, C^2 is to be multiplied by (1 - R^2)

$$\alpha = \frac{Shrinkage\ allowance\ (mm)}{d_h} \times 10^3$$

R: Quotient obtained by dividing the inside diameter of the hollow shaft by its outside diameter

d_h: Diameter of the hole at shrinkage fit (*mm*)

$$r_s = \frac{External\ diameter\ of\ web\ (mm)}{d_h}$$

d_c Required diameter of crankshaft determined by the formula in **2.3.1-1** (*mm*)

(2) The dimensions in fillets at the junctions of crank webs with crankpins of semi-built-up crankshafts are to comply with the requirements in **2.3.1-2**.

3. In case of built-up crankshafts, the value of a used in **-2(1)** is to be within the following range:

$$\frac{1.1Y}{225} \le \alpha \le \left(\frac{1.1Y}{225} + 0.8\right)\frac{1}{1-R^2}$$

where;

Y: Specified yield point of crank web material (N/mm^2)

R: Quotient obtained by dividing the inside diameter of the hollow shaft by its outside diameter

When the specified yield point of the crank web exceeds 390 N/mm^2 or when the value obtained by the following formula is less than 0.1, the value of α is to be specially approved by the Society.

where;

$$\frac{S - d_p - d_j}{2d_p}$$

S: Length of stroke (mm)

d_p: Diameter of crankpin (mm)

d_j: Diameter of journal (mm)

2.3.3 Shaft Couplings and Coupling Bolts

1. The diameter of coupling bolts at the joining face of the coupling between crankshafts or between a crankshaft and a thrust shaft or between a crankshaft and a shaft mentioned in 2.2.4 is to be not less than the value obtained by the following formula.

$$d_b = 0.75\sqrt{\frac{(0.95d_c)^3}{nD}\left(\frac{440}{T_b}\right)}$$

where;

d_b: Diameter of coupling bolts (mm)

n: Number of bolts

D: Diameter of pitch circle (mm)

d_c: Required diameter of crankshaft calculated by the formula in 2.3.1-1 when values of K_m, K_s and K_h are replaced with 1.0 (mm) .

T_b: Specified tensile strength of bolt material (N/mm^2)

In case where the value exceeds 1000 N/mm^2, the value used for the formula is to be as considered appropriate by the Society.

2. Shaft couplings are to have sufficient strength against working stresses. The fillets of shaft couplings are to have an enough radius to avoid an excessive stress concentration. Where shaft couplings are separate from the shafts, the fitting method and construction of the couplings are to be capable to resist the astern pull. In case where keys are used for fitting shaft couplings to shafts, the grooves for the keys are to have construction to avoid an excessive stress concentration.

2.3.4 Detailed Evaluation for Strength

Special considerations will be given to the crankshafts, notwithstanding the requirements in 2.3.1 and 2.3.2, provided that the detailed data and calculations on the strength of crankshafts are submitted to the Society and considered appropriate.

2.4 Safety Devices

2.4.1 Speed Governors and Overspeed Protective Devices

1. Diesel engine used as main propulsion machinery in diesel ships is to be provided with a speed governor so adjusted to prevent the engine speed from being exceeded by more than 15% of the maximum continuous revolutions.

2. In addition to the normal governor, each diesel engine used as main propulsion machinery of diesel ships with a continuous maximum output of 220 *kW* or over which can be declutched or drives controllable pitch propeller, is to be provided with a separate overspeed protective device. In this case, the overspeed protective device and its driving gear are to be independent from the governor required in **-1**, and so adjusted that the speed may not be exceeded by more than 20% of the maximum continuous revolutions.

3. Diesel engines to drive generators are to be provided with governors specified in the requirements in **2.4.2, Part 8**. However, if a diesel engine which is used as main propulsion machinery for an electric propulsion ship drives a generator used to supply electrical power exclusively to propulsion motors, the requirements specified in **5.1.2-2, Part 8** are to be applied.

4. In addition to the normal governor, each diesel engine used as main propulsion machinery of electric propulsion ships and diesel engine used to drive generators with a maximum continuous output of 220 *kW* or over is to be provided with a separate overspeed protective device. In this case, the overspeed protective device and its driving gear are to be independent from that of the governor required in **-3**, and so adjusted that the speed may not be exceeded by more than 15% of the maximum continuous revolutions.

2.4.2 Alarm for Overpressure in the Cylinders

Each cylinder of diesel engines having a bore exceeding 230 *mm* is to be provided with an effective sentinel valve or other means for overpressure.

2.4.3 Protection against Crankcase Explosion

1. For diesel engines having cylinders not less than 200 *mm* bore or having the crankcase gross volume not less than 0.6 m^3, the crankcase are to be provided with explosion relief valves of approved type for preventing an overpressure in the event of explosion within the crankcases. The crankcase explosion relief valves are to be in accordance with the following requirements.

(1) The valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent the inrush of air thereafter.

(2) The valve discs are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

(3) The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0.02 *MPa*.

(4) The valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

(5) The valves are to be provided with a copy of manufacturer's installation and maintenance manual. The copy of the manual is to be provided on board ship.

2. The number and locations of the explosion relief valves specified in **-1** are to be in accordance with **Table 2.4.**

3. Additional explosion relief valves corresponding to **-1** above are to be fitted in separate spaces on the crankcase such as gear or chain case for camshaft or similar drives, when the gross volume of such spaces is not less than 0.6 m^3.

4. The each explosion relief valve given in **-1** and **-3** above is to conform to the requirements in **(1)** and **(2)** below.

(1) The free area of each explosion relief valve is not to be less than 45 cm^2.

(2) The combined free area of the valves fitted on an engine is not to be less than 115 cm^2 per cubic metre of the crankcase gross volume. The volume of the stationary parts in the crankcase or separate space may be deducted in estimating the gross volume.

Table 2.4 Number and Location of Explosion Relief Valves

Cylinder bore (mm)	Number and location of explosion relief valves
200 to below 250	At least one valve is to be fitted near each end, but, where crankthrows exceed 8, an additional valve is to be fitted near the middle of the engine.
250 to below 300	At least one valve is to be fitted in way of each alternate crankthrow, with a minimum of two valves.
300 and over	At least one valve is to be fitted in way of each crankthrow

2.4.4 Protection against Scavenging Spaces

1. Scavenging spaces in open connection to the cylinders are to be provided with explosion relief valves. These devices are to be so arranged to discharge that no damage for operators can occur.

2. Scavenging spaces in open connection to the cylinders are to be connected to an approved fire extinguishing system, which is to be entirely separate from the fire extinguishing system of the engine room.

2.4.5 Crankcase Oil Mist Detection Arrangements

Crankcase oil mist detection arrangements required to be fitted to engines are to be approved type and in accordance with the following requirements.

(1) The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

(2) The oil mist detection arrangements are to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

(3) The oil mist detection arrangements are to be capable of being tested on the test bed and board under engine at standstill and engine running at normal operating conditions.

(4) Oil mist monitoring and alarm information is to be capable of being read from a safe location away from engine.

(5) Where there are multi engine installations, each engine is to be provided with oil mist detection and monitoring and a dedicated alarm.

(6) The layout of the arrangements, pipe dimensions, the location of engine crankcase sample points, sample extraction rate and the way of maintenance and test are to be in accordance with the engine designer's and oil mist manufacturer's instructions.

(7) Where sequential oil mist detection arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

(8) A copy of the maintenance and test manual is to be provided on board ship.

2.5 Associated Installations

2.5.1 Exhaust Driven Turboblowers

1. For main propulsion engine equipped with exhaust driven turboblowers, means are to be provided to ensure that the engine can be operated with sufficient power to give the ship a navigable speed in case of failure of one of the turboblowers.

2. Where the main propulsion engine cannot be operable only with the exhaust driven turboblowers in case of starting or low speed range, an auxiliary of scavenging air system is to be provided. For the event of failure of such an auxiliary system, proper means are to be provided so that the main propulsion engine can be brought into the condition that its output increases enough as the exhaust driven turboblowers show their function.

2.5.2 Exhaust Gas Arrangements

1. The exhaust gas pipes of surface temperature may exceed 220°C are to be water-cooled or efficiently lagged with thermal insulation. However, in case where no fire is likely to occur, the requirements may be dispensed with.

2. The exhaust gas arrangements are additionally to comply with the requirements specified in **1**in this Part.

2.5.3 Starting Arrangements

1. The starting air mains are to be protected by the following arrangements **(1)** through **(5)** against the explosion due to back fire from the cylinders or excessive temperature rise in the starting air manifold at the time of starting:

(1) An isolating non-return valve or equivalent thereto is to be provided at the starting air supply connection to each engine.

(2) An adequate rupture disc device or a flame arrester is to be fitted at the starting valve on each cylinder for direct reversing engines having a starting air manifold. At least one such device is to be fitted at the supply inlet to the starting air manifold for each non-reversing engine. However, the above mentioned device may be omitted for engines having cylinder bore not exceeding 230 *mm*.

(3) An adequate rupture disc device is to be fitted at an appropriate position on the starting air manifold as an emergency means of relieving a pressure caused by explosion for direct reversing engines fitted with flame arresters in accordance with **(2)** above.

(4) For rupture disc devices of which ruptured discs cannot be replaced easily, a mechanism of blocking up the exhaust way is to be provided for the purpose of quick restart of the engine. This blocking mechanism is to be fitted with a means of indicating whether it is blocking or not.

(5) An effective arrangement to prevent the accumulation of combustibles (fuel oil, lubrication oil, system oil, etc.) in the starting air manifold or to prevent the excessive temperature rise in the starting air manifold is to be provided for direct reversing engines.

2. Where main propulsion engines are arranged for starting by compressed air, at least two starting air reservoirs are to be provided. These reservoirs are to be connected ready for use. In this case, the total capacity of the starting air reservoirs is to be sufficient to provide, without replenishment, the number of consecutive starts not less than that specified in **(1)** and **(3)** below. Where the arrangements of the main propulsion engines and shafting systems are other than shown below, the required number of starts is to be as deemed appropriate by the Society.

(1) For direct reversible engines

$Z = 12C$

where;

Z: Total number of starts of engine

C: Constant determined by the arrangement of main propulsion engines and shafting systems, where the following values are to be referred to as the standard;

C = 1.0 For single screw ships, where one engine is coupled with the shaft either directly or through reduction gears

C = 1.5 For twin screw ships, where two engines are coupled with the shafts either directly or through reduction gear, or for single screw ships, where two engines are coupled with the shaft through declutchable coupling provided between engine and reduction gear

C = 2.0 For single screw ships, where two engines are coupled with one shaft without any declutchable coupling between engine and reduction gear

(2) For non-reversible type engines using a separate reversing gear or controllable pitch propeller, 1/2 of the total number of starts specified in **(1)** above may be accepted.

(3) For electric propulsion ships:

$Z = 6 + 3(k - 1)$

where;

Z: Total number of starts of engine

k: Number of engines and it is not necessary for the value of k to exceed 3.

3. Where main propulsion engines are arranged for starting by battery, 2 sets of batteries are to be provided. The total capacity of the batteries is to be sufficient, without recharging, to provide the number of starts of the main propulsion engine required in **-2** within 30 *minutes*.

4. The starting arrangement of diesel engines which drive generators or auxiliaries are to be as deemed appropriate by the Society.

5. The starting air systems are additionally to comply with the requirements in **13.13**.

2.5.4 Fuel Oil Arrangements

1. Where a diesel engine is mounted on an elastic support, fiexible joints approved by the Society are to be provided at the connections between the engine and the fuel oil supply pipe.

2. The fuel oil arrangements for diesel engines are additionally to comply with the requirements in **13.9, Part 7** and **4.2.2, Part 6**.

2.5.5 Lubricating Oil Arrangements

1. The lubricating oil arrangements of diesel engines with maximum continuous output exceeding 37 kW are to be provided with alarm devices which give visible and audible alarming in the event of failure of supply of lubricating oil or appreciable reduction in lubricatings oil pressure, and also with devices to stop the operation of the engine automatically by lower pressure after the function of alarms.

2. The lubricating oil arrangements are to be provided with lubricating oil sampling connections at proper locations.

3. Lubricating oil arrangements for rotor shafts of exhaust gas turboblower are to be designed so that the lubricating oil may not be drawn into charging air.

4. Lubricating oil drain pipes from the engine crankcase sump to the sump tank are to be submerged at their outlet ends.

5. The lubricating oil drain pipes shown in **-4**, above of two or more engine units are not to be inter-connected.

6. Arrangements for lubricating oil system are additionally to comply with the requirements in **13.10, Part 7** and **4.2.3, Part 6**.

2.5.6 Cooling Arrangements

Cooling arrangements are to comply with the requirements in 13.12 in addition to the requirements in the following **(1)** and **(2)**:

(1) In the engines having more than one cylinder, an adequate means is to be provided to make cooling uniform for each cylinder and piston.

(2) Drain cocks are to be fitted to water jackets and water pipe lines at their lowermost position.

2.6 Tests

2.6.1 Shop Tests

1. For components or accessories specified in **Table 2.5** hydrostatic tests are to be carried out at pressures shown in the Table.

2. For rotating assemblies of exhaust gas turboblower, dynamic balancing tests are to be carried out after their assembly.

3. For diesel engines, shop trials are to be carried out by the test procedure as deemed appropriate by the Society.

4. For diesel engines with novel design features or those with no service records, in case of deemed necessary by the Society, tests are to be carried out to verify their endurance by the procedure as deemed appropriate by the Society.

Table 2.5 Hydrostatic Test Pressure

Part	Test Pressure(6)(*MPa*)
Cylinder cover, cooling space(1)	0.7
Cylinder liner, over the whole length of cooling space(2)	0.7
Cylinder jacket, cooling space	0.4(3) or 1.5P, whichever is the greater
Exhaust valve, cooling space	0.4 or 1.5P, whichever is the greater
Piston crown(1),(4)	0.7
Fuel injection system: Pump body (pressure side(5)), Valve(5), Pipe	1.5P or P+30, whichever is the smaller
Scavenging pump cylinder	0.4
Turboblower, cooling space	0.4 or 1.5P, whichever is the greater
Exhaust pipe, cooling space	0.4 or 1.5P, whichever is the greater
Heat excharger	0.4 or 1.5P, whichever is the greater
Engine driven pumps	0.4 or 1.5P, whichever is the greater
Piping system	Apply the requirements in **12.6**

Notes:

1 For forged steel cylinder covers of which cooling spaces are machined up without welding procedure or for pistoncrowns, the accurate gauging for thickness after machining up on both inside and outside, and confirmation of beingfree from surface defects by the Surveyor, may be accepted as substitution for the above hydrostatic test.

2 Where cylinder liners are machine finished on both inside and outside, accurately gauged for thickness, and confirmed being free from surface defects by the Surveyor, the above test pressure of cylinder liners may be reduced to 0.4 *MPa*.

3 For diesel engines having no cylinder liner, the hydrostatic test pressure is to be 0.7 *MPa*.

4 Notwithstanding the preceding Note(1), the cooling space of piston crowns of crosshead type diesel engines are to be hydrostatically tested after assembled with piston rods.

5 Where fuel oil injection pumps and fuel injection valves are made of forged steel, the hydrostatic test may be omitted.

6 P is the maximum working pressure (*MPa*) in the parts concerned.

Chapter 3 STEAM TURBINES

3.1 General

3.1.1 Scope

The requirements in this Chapter apply to steam turbines used as main propulsion machinery, or used to drive generators and auxiliaries (excluding auxiliary machinery for specific use etc., hereinafter the same in this Chapter).

3.1.2 Drawings and Data

Drawings and data to be submitted are as follows:

(1) Drawings and data for approval

- (a) Turbine casings
- (b) Turbine rotors
- (c) Turbine blades
- (d) Details of turbine installation
- (e) Shaft coupling and bolts
- (f) Piping arrangements fitted to turbine (including steam, lubricating oil and drain system, and indicating pipe materials, pipe sizes and service pressures specified)
- (g) Particulars of turbine (power and number of revolutions at maximum continuous rating of turbines, steam pressure and temperature of turbine inlet, degree of vacuum at condenser top or steam condition in exhaust chamber)
- (h) Critical speed of each turbine rotor
- (i) Number of blades in each stage
- (j) Number of nozzles and their arrangements in each stage
- (k) Technical data for strength calculations specified in 3.2.3
- (l) Material specifications of principal components
- (m) Welding details of principal components

(2) Drawings and data for reference

- (a) Sectional assembly

(b) Control system diagram

(c) Drawings and data which are deemed necessary by the Society

3.2 Materials, Construction and Strength

3.2.1 Materials

1. Materials of the components of steam turbine specified below (hereinafter referred to as the principal components of steam turbine) are to comply with the requirements in **Part 10**.

(1) Turbine rotors

(2) Turbine blades

(3) Turbine casings

(4) Shaft couplings and coupling bolts

(5) Pipes, valves and fittings attached to steam turbine classified in Group I or II specified in **Chapter 12**

2. The principal components of steam turbine (excluding coupling bolts, pipes, valves and fittings) are to have been subjected to the nondestructive tests specified in **5.1.10** and **6.1.10, Part 10**.

3. The materials used in high temperature parts are to have properties suitable for the design performance and service life against corrosions, thermal stresses, creeps and relaxations.

4. Cast iron is not to be used for the turbine casing and others subjected to pressure where steam temperature exceeds 230°C.

3.2.2 General Construction

1. For ships provided with one cross-compound type main steam turbine, the turbine is to be so constructed as to be capable of ensuring operation at navigable speed even when the steam led to any one of the cylinders is cut off in an emergency. For this operation, the following **(1)** and **(2)** are to be complied with.

(1) The permissible steam pressures and temperatures, speeds, etc. are to be specified and the information is to be provided on board considering the safety of the turbine and condenser and the potential influence on shaft alignment and gear teeth loading conditions.

(2) The necessary pipes and valves are to be readily available and properly marked, and the procedure is to be documented locally.

2. Each part of a turbine is to have such constructions as no detrimental deformations are caused by their thermal expansions. Turbines are to be installed on the seatings so that no excessive structural constraints are caused by thermal expansions.

3. Where the principal components of steam turbine are of welded construction, they are to comply with the requirements in **Chapter 11**.

4. Turbine casings are to be provided with drain connections at suitable locations.

5. Non-return valves or other approved means which prevent steam and drain returning to the turbines, are to be fitted in bled steam connections.

6. In steam turbines used for the main propulsion, steam strainers are to be provided at the turbine inlet or the inlet to the manoeuvring valves.

7. The construction of main condensers is to conform to the requirements in **Chapter 10**.

3.2.3 Strength of Turbine Rotors and Blades

1. The strength of turbine rotors is to comply with the requirements of the following **(1)** and **(2)**.

(1) Turbine rotors (or discs) are to be so designed that no excessive vibration is induced within the operating speed range.

(2) Mean tangential stress of turbine rotors are to satisfy the following conditions. Since no factors of creep and other design considerations for the materials are taken into account in the given conditions, special considerations are to be taken on these stress conditions, as considered necessary.

$$T_m = \frac{n^2(1.10\rho I + 0.1766mr)}{A}$$

$$T_m \leq Y/3$$

$$T_m \leq T_s/4$$

where;

T_m: Mean tangential stress (*N/mm*^{2})

n: Number of the maximum continuous revolutions per minutes divided by 1,000

A: Sectional area of wheel profile on one side of axis of rotation (*cm*^{2})

I: Moment of inertia of area A about the axis of rotation (*cm*^{4})

r: Density of turbine disc or rotor (*kg/cm*^{3})

m: Total mass of blades including roots (*kg*)

r: Distance between the centre of gravity of blade (including root) and the centre line of shaft (*cm*)

Y: Specified yeild strength or proof stress of the material (*N/mm*^{2})

T_s: Specified tensile strength of the material (*N/mm*^{2})

2. Strength of turbine blades is to comply with the requirements of the following **(1)** and **(2)**.

(1) Turbine blades are to be so designed as to avoid abrupt changes in section and to provide a sufficient rigidity to minimize deflection and vibration.

(2) The sectional area at the root of the blade is not to be less than the value obtained from the following formula.

Where, however, deemed appropriate by the Society, the formula may be modified.

$$A = \frac{4.395mrn^2}{T_s}$$

where;

A: Required minimum sectional area at root of blade (*cm*^{2})

m: Mass of a blade upward of the section with area A and shroud (*kg*)

r: Distance between the centre of gravity of blade (including root) and the centre line of shaft (*cm*)

T_S: Specified tensile strength of blade material (N/mm^2)

n: Number of maximum continuous revolutions per minute divided by 1,000.

3.3 Safety Devices

3.3.1 Governors and Overspeed Protective Devices

1. All main and auxiliary turbines are to be provided with overspeed protective devices to prevent the speed from being exceeded by more than 15% of the maximum continuous speed. Where two or more turbines are coupled to the same main gear wheel, it may be accepted that only one overspeed protective device is provided for all the turbines.

2. Where steam turbine used as main propulsion machinery in steam turbine ships incorporates a coupling which can be declutched or drives a controllable pitch propeller, a separate and independent speed governor in addition to the overspeed protective device specified in **-1** above is to be fitted and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.

3. Turbines to drive generators are to be provided with governors complying with the requirements in **2.4.2, Part 8** in addition to the overspeed protective device specified in **-1** above. However, if steam turbines used as main propulsion machinery in electric propulsion ships are used to drive generators for supplying electrical power exclusively to propulsion motors, the requirements in **5.1.2-2, Part 8** are to be applied.

3.3.2 Steam Shut-off Devices

1. Main propulsion turbines are to be provided with devices which automatically shut off the steam supply to the ahead turbine (in turbines used as main propulsion machinery in electric propulsion ships, the turbine used for that purpose) in the following cases :

(1) In case of low lubricating oil pressure

(2) In case of low main condenser vacuum

2. Turbines to drive generators or auxiliaries are to be provided with devices which automatically shut off the steam supply in case of low lubricating oil pressure.

3. Arrangements are to be provided for shutting off the steam supply to the main propulsion turbines by suitable hand trip gears installed at the manoeuvring stand and at the turbine respectively. Hand trip gears for turbines to drive generators or auxiliaries are to be arranged in the vicinity of the turbines.

3.3.3 Lubricating Oil Supply System

1. Main propulsion turbines are to be provided with a satisfactory emergency supply of lubricating oil which comes into service automatically when the pressure drops below predetermined pressure level. The emergency supply may be obtained from a gravity tank or equivalent means (e.g. attached pump) with sufficient amount of oil to ensure adequate lubrication until the turbine is brought to rest.

2. The lubricating oil arrangements of steam turbine are to be provided with alarm devices which give visual and audible alarming in the event of failure of supply of lubrication oil or appreciable reduction of lubricating oil pressure before the function of steam shut off devices specified in **3.3.2-1(1)** and **-2**.

3.3.4 Sentinel Valve for Exhaust Steam Outlet

A sentinel valve is to be provided at the exhaust end of all turbines against abnormal rise of the exhaust steam pressure.

3.4 Tests

3.4.1 Shop Tests

1. The following components are to be subjected to hydrostatic tests at pressures specified below :

(1) Turbine casings: 1.5 times the design steam pressure for the turbine casing or 0.2 *MPa* whichever is the greater.

(2) High pressure turbine steam chests: 1.5 times the nominal pressure of the boiler.

(3) Steam receivers, pipes and valve chests etc.: The same pressure as the hydrostatic test pressure applicable to the turbine casing to which they belong.

(4) Steam strainers, and manoeuvring valve chests: 2 times the nominal pressure of the boiler

(5) Steam space of main condenser :

1.1 *MPa*

Cooling water space: 0.2 *MPa* or 0.1 *MPa* plus the maximum discharge pressure which the circulating pumps can develop with the discharge valve closed and the maximum suction pressure which develops under the full draught condition, whichever is the greater. Where the service condition is unknown and the pressure under the condition is unable to be calculated, the test pressure is not to be less than 0.34 *MPa*.

2. For turbine rotors, dynamic balancing tests are to be carried out by the test procedure deemed appropriate by the Society.

3. For steam turbines, shop trials are to be carried out including the test of the safety devices specified in **3.3** before by the procedure deemed appropriate by the Society.

3.4.2 Tests after Installation on Board

A fit up test, to ensure the availability of the operation in compliance with **3.2.2-1**, is to be carried out prior to the sea trials. This test may be carried out at the shop tests.

Chapter 4 GAS TURBINES

4.1 General

4.1.1 Scope

1. The requirements in this Chapter apply to gas turbines of the open cycle type used as main propulsion machinery, or used to drive generators and auxiliaries (excluding auxiliary machinery for specific use etc., hereinafter the same in this Chapter).

2. Gas turbines for driving emergency generators are to conform to the requirements in **3.3** and **3.4, Part 8**, in addition to the requirements in this Chapter (excluding **4.2.1-1**, **4.2.1-2**, **4.3.1-1**, **4.3.2** and **4.3.3**.).

4.1.2 Drawings and Data

Drawings and data to be submitted are as follows:

(1) Drawings and data for approval

- (a) Discs (and/or rotors) of turbine and compressor
- (b) Combustion chambers
- (c) Details of fixing of moving and stationary blades
- (d) Shaft couplings and bolts
- (e) Piping arrangements fitted to turbine (including fuel oil, lubricating oil, cooling water, pneumatic and hydraulic system, and indicating pipe materials, pipe sizes and service pressures specified)
- (f) Pressure vessels and heat exchangers (classified in Group I and Group II defined in **10.1.3**) attached to turbine.
- (g) Details of turbine installation
- (h) Particulars (type and product number of turbine, power and number of revolutions per minute of turbine and compressors at maximum continuous rating, gas pressure and temperatures at turbine inlet and outlet, pressure losses in inlet and exhaust ducts, ambient condition intended for operation, service fuel oil and lubricating oil)
- (i) Material specifications of principal components
- (j) Welding details of principal components
- (k) Maintenance instructions
- (l) Critical speeds of turbine rotors and compressors

(m) Number of moving blades in each stage

(n) Number and arrangements of stationary blades

(o) Lists of safety devices based on the failure mode and effect analysis.

(2) Drawings and data for reference

(a) Sectional assembly

(b) Moving blade and stationary blade

(c) General arrangement

(d) Starting arrangement (attached to turbine)

(e) Inlet air and exhaust gas arrangements

(f) Diagram of engine control systems

(g) Calculation sheets for strength of principal components

(h) Calculation sheets for vibration of turbine blades

(i) Operation instructions for fuel oil control systems

(j) Illustrative drawing of cooling method for each PART of turbine

(k) Other drawings and data deemed necessary by the Society

4.2 Materials, Construction and Stregth

4.2.1 Materials

1. Materials of the components of gas turbine specified below (hereinafter referred to as the principal components of gas turbine) are to comply with the requirements in **Part 10**.

(1) Discs (or rotor), stationary blades and moving blades of turbine

(2) Discs, stationary blades and moving blades of compressor

(3) Turbine and compressor casings

(4) Combustion chambers

(5) Turbine output shaft

(6) Connecting bolts for main components of turbine

(7) Shaft coupling and bolts

(8) Pipes, valves and fittings attached to gas turbine classified in Group I or II in **Chapter 12**

2. The principal components of gas turbine (excluding bolts, pipes, valves and fittings) are to have been subjected to the non-destructive tests specified in **5.1.10** and **6.1.10, Part 10**.

3. The materials used in high temperature parts are to have properties suitable for the design performance and service life against corrosions, thermal stresses, creeps and relaxations. In case where the base material coated with corrosion-resistant surfacing, the coating material is to have such properties that it is hardly detached from the base material as well as not to impair the strength of the base material.

4.2.2 Construction and Installations

1. Gas turbines are to be so designed that no excessive vibration and surging are induced within the speed range of normal operation.

2. Each Part of a gas turbine is to have such constructions as no detrimental deformations are caused by their thermal expansions.

3. Where the principal components of gas turbines are of welded construction, they are to comply with the requirements in **Chapter 11**.

4. In the event of failure of the main source of electrical power, the gas turbines for main propulsion are to be so designed as not to cause gas generator to stop, or to enable to restart immediately after the gas generator stopping.

5. Gas turbines are to be installed on the seating so that no excessive structural constraints are caused by thermal expansions.

6. Gas turbines are to be designed and installed such that any reasonably probable shedding of compressor or turbine blades will not endanger the ship, other machinery and any persons on board.

4.3 Safety Devices

4.3.1 Governors and Over speed Protective Devices

1. Gas turbines are to be provided with an over speed protective device. The over speed protective device is to be so adjusted that the output shaft speed may not exceed by more than 15 % of the maximum continuous speed as well as to have functions as specified in **4.3.2-2**.

2. Gas turbines are to be provided with a speed governor independent of the over speed protective device specified in **-1** above. The speed governor is to be capable of controlling the speed of the unloaded gas turbine without bringing the over speed protective device into action.

3. The governors of gas turbines to drive generators are to conform to the requirements in **2.4.2-1** and **-2, Part 8**.

However, when gas turbines used for main propulsion machinery in electric propulsion ships are used to drive generators to supply electric power exclusively to propulsion motors, the requirements in **5.1.2-2, Part 8** are to be applied.

4.3.2 Emergency Stopping Devices

1. Gas turbines are to be provided with emergency stopping devices operated by suitable hand trip gears installed at the control station.

2. Gas turbines are to be provided with automatic fuel oil shut-off devices that operate in the following cases. In addition, means are to be provided so that alarms will be issued at the control station when the automatic fuel oil shut-off devices come into action.

(1) Over speed

(2) Low lubricating oil pressure

(3) Failure in automatic starting

(4) Flame-out

(5) Excessive vibrations

3. In addition to the requirements specified in **-2** above, gas turbines for main propulsion are to be provided with shut-down devices which automatically shut off the fuel supply to the turbines in the following conditions as well as to be provided with such alarm devices that give alarms at the control station when the shut-down devices come into action.

(1) Excessive axial displacement of each rotor (except for gas turbines with roller bearings)

(2) Abnormal rise of turbine inlet or outlet gas temperature

(3) Unacceptable lubricating oil pressure drop of reduction gear

(4) Excessive high vacuum pressure at the compressor inlet (except for gas turbines with automatic by-pass doors etc.)

4.3.3 Alarms

1. Gas turbines are to be provided with alarm devices which come into action in the following conditions. In case where the shut-down devices specified in **4.3.2** are also required, the alarm is to work before the shut-down devices come into action.

(1) Abnormal rise of turbine inlet or outlet gas temperature

(2) Drop of lubricating oil pressure

(3) Drop of fuel oil supply pressure

(4) Excessive vibration

2. In addition to the requirements specified in -1 above, gas turbines for main propulsion are to be provided with alarm devices which come into action in the following conditions. In case where the shut-down devices specified in **4.3.2** are also required, the alarm is to work before the shut-down devices come into action.

(1) Abnormal rise of differential pressure across lubricating oil filter

(2) Abnormal rise of lubricating oil inlet temperature

(3) Abnormal rise of cooling medium temperature in case where an intercooling cycle is adopted

(4) Abnormal rise of bearing temperature or lubricating oil outlet temperature

(5) Excessive high vacuum pressure at the compressor inlet

4.3.4 Fire Detection and Extinction in Enclosures

Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure oil pipes, a fire detection and extinguishing system is to be provided for the enclosure.

4.4 Associated Installations

4.4.1 Air Inlet Systems

The air inlet system is to have such construction and arrangement that intrusion of harmful particles and water into the compressor can be minimized. Additionally, means are to be provided to minimize the detrimental effects caused by salt deposits in suction air, and if necessary, by icing at the air intake.

4.4.2 Exhaust Gas Arrangement

1. The open ends of exhaust gas pipes are to be located so as to prevent exhaust gas from entering into the air inlet system.

2. Boilers and heat exchangers utilizing the exhaust heat of gas turbines are additionally to comply with the requirements specified in **Chapter 9** and **Chapter 10**.

3. Exhaust gas arrangement is correspondingly to comply with the requirements specified in **2.5.2**.

4.4.3 Starting Arrangements

1. Gas turbines are to be provided with suitable means effective for the prevention of abnormal combustion or ignition trouble at the time of starting or restarting after starting failure.

2. Where compressed air or batteries are used for starting, the starting arrangement is correspondingly to comply with the requirements in **2.5.3**.

4.4.4 Ignition Arrangements

1. Each device in ignition arrangements is to be composed of two or more systems independent with each other.

2. The cable of electric ignition device is to have good electrical insulation and to be laid in such a way that it is hardly damaged.

3. Ignition distributors are to be of explosion-proof construction or to be provided with proper shielding. No coils for ignition device are to be situated in areas where explosive gases may accumulate.

4.4.5 Fuel Oil Arrangements

1. Sufficient consideration is to be given to the prevention of clogging of the fuel manifolds and fuel nozzles due to solid particles contained in the fuel, and also for the prevention of corrosions of turbine blades and other parts due to salts and similar corrosive substances.

2. The fuel control system is to comply with the following requirements.

(1) The fuel control system is to be capable of adjusting the fuel supply to the burners so as to maintain the exhaust gas temperature within the pre-determined range throughout the normal operation.

(2) The fuel control system is to be capable of ensuring stable combustion throughout the operation range where the fuel supply is adjustable.

(3) The fuel control system is to be capable of maintaining the minimum speed of the turbines without stopping the gas generator at a sudden load fluctuation.

3. The fuel oil arrangements are additionally to comply with the requirements in **13.9, Part 7** and **4.2.2, Part 6**.

4.4.6 Lubricating Oil Arrangements

1. Gas turbines for main propulsion are to be provided with an effective emergency supply of lubricating oil which comes into service automatically and has sufficient amount of oil to ensure adequate lubrication until the turbine is brought to rest, in case of failure of the lubricating oil supplying system. The emergency supply may be obtained from a gravity tank or from an auxiliary lubricating oil pump driven by the turbine.

2. The lubricating oil arrangements for main gas turbines are to be provided with the automatic temperature controlling devices.

3. An oil sampling connection is to be provided at a proper location.

4. Lubricating oil arrangements are additionally to comply with the requirements in **13.10, Part 7** and **4.2.3, Part 6**.

4.5 Tests

4.5.1 Shop Test

1. For gas turbines and their accessories hydrostatic tests are to be carried out at pressures specified below.

(1) Casing: 1.5 times the maximum design pressure.

(2) Piping system: Pressures specified in section **12.6**.

2. For rotating assemblies of turbines and compressors, dynamic balancing tests are to be carried out after their assembly.

3. For turbine rotors, excess speed tests are to be carried out at 115% of the maximum continuous rotational speed or over at least for 2 *minutes* after completion of manufacture. When the Society recognizes that the rotational speed does not exceed 115% the maximum continuous rotational speed, tests may carried out at 115% of the maximum rotational speed.

4. For gas turbines, Shop Tests are to be carried out including the test of safety devices specified in **4.3** above by the test procedure deemed appropriate by the Society. In this case the Society may request tests regarding starting characteristics and critical speeds of rotor shafts.

Chapter 5 POWER TRANSMISSION SYSTEMS

5.1 General

5.1.1 Scope

The requirements of this Chapter apply to power transmission systems which transmit power from main propulsion machinery and prime movers driving generators and auxiliaries (excluding auxiliary machinery for specific use etc., hereinafter the same in this Chapter).

5.1.2 Drawings and Data

Drawings and data to be submitted are generally as follows:

(1) Drawings:

- (a) Sectional assembly
- (b) Gears
- (c) Gear shafts
- (d) Couplings
- (e) Construction of main parts such as clutches and flexible shafts

(2) Data:

- (a) Specifications for materials used in the power transmission parts (chemical compositions, heat treatment methods, mechanical properties and their test methods)
- (b) Transmitted power and number of revolutions per minute of each pinion at the maximum continuous output
- (c) Particulars of each gears (number of teeth, module, pitch circle diameters, pressure angles of teeth, helix angles, face widths, centre distances, tool tip radius, backlash, amount of profile shift, amount of profile and tooth trace modification, finishing method of tooth flank, expected finishing accuracy of gears)
- (d) Welding methods of principal components (including tests and inspection)
- (e) Necessary data for strength calculation of principal components of the power transmission systems.

5.2 Materials and Construction

5.2.1 Materials

1. Materials used for the following components (hereinafter referred to as the principal components of the power transmission system) are to comply with the requirements in **Part 10**.

(1) Power transmission shafts and gears

(2) Power transmission parts of couplings

(3) Power transmission parts of clutches

(4) Coupling bolts

2. The principal components of power transmission systems (excluding coupling bolts, clutch discs and the like) are to have been subjected to the non-destructive tests specified in **5.1.10** and **6.1.10, Part 10**.

5.2.2 Welding

Where the principal components of power transmission systems are of welded construction, the requirements in **Chapter 11** are to be complied with.

5.2.3 General Construction of Gearings

1. Gears are to comply with the requirements in the following **(1)**, **(2)** and **(3)**.

(1) Where a gear rim is shrunk on the boss, the rim is to be so thick as to ensure sufficient strength and is to have enough shrinkage allowance against transmitted power. Where shrinkage fit is made after tooth cutting, the construction is to be such as to fully guarantee the accuracy of gearing, or final tooth finishing is to be carried out after the shrinkage fit.

(2) Where gears are of welded construction, they are to have sufficient rigidity and are to be stress-relieved before tooth cutting.

(3) Gears are not to have harmful unbalanced weight.

2. Gear casings are to have sufficient rigidity, and their construction is to be such that all possible facilities are provided for inspection and maintenance.

3. In case where heavy articles are intended to be fitted on extended part of the pinion shaft, the construction of pinions is to be such that the whirling moves of pinions and deviation of shaft centre may be minimized.

5.2.4 General Construction of Power Transmission Systems other than Gearings

1. The power transmission systems other than the gearings are to be of those approved by the Society in their constructions and materials, functioning safely and reliably and having sufficient strength against transmitted power. Rubber couplings are to be designed and constructed so that they are suitable for heating due to hysteresis.

2. The construction of electro-magnetic slip couplings is to conform to the requirements in **2.4, PART 8**, as well as to the requirements as deemed appropriate by the Society.

3. Where the clutch of power transmission systems for main propulsion is operated with hydraulic or pneumatic system, a stand-by pump or compressor connected ready for use or any other appropriate unit is to be provided, thereby to ensure that a ship can keep the normal service condition.

4. Rubber couplings are to be designed so that the heat may be effectively emitted from rubber elements and to be constructed for easy inspection as far as practicable.

5.2.5 Lubricating Oil Arrangements

1. Lubricating oil arrangement is to comply with the requirements in 13.10. Additionally, it is recommended to use, for gearings, strainers with magnets.

2. The lubricating oil arrangements of power transmission systems with the driving units above 37 kW are to be provided with alarm devices which give visible and audible alarming in the event of failure of supply of lubricating oil appreciable reduction of lubricating oil pressure.

5.3 Strength of Gears

5.3.1 Application

The requirements in 5.3 apply to the external tooth cylindrical gears having an involute tooth profile. The other gears are to be as deemed appropriate by the Society.

5.3.2 General Requirements

1. The roots of the tooth are to be connected with smooth fillets of radius as large as possible. It is recommended that the tooth tip and the both ends of the tooth trace are chamfered suitably.

2. The gears, which are to be subjected to surface hardening process, are to have necessary flank hardness and depth of hardened zone.

5.3.3 Allowable Tangential Loads for Bending Stress

The tangential loads on gear-teeth are to satisfy the following condition for bending stress at the root section of gear-teeth:

$$P_{MCR} \leq 9.81(K_1 S_b - K_2)K_3\left(4.85 - \frac{30.6}{Z}\right)M_n$$

Where;

P_{MCR}: Tangential load on gear-teeth at the maximum continuous output, to be given in the following formula:

$$P_{MCR} = \frac{1.91H}{N_0 D_1 b} \times 10^6 (N/cm)$$

H: Output which the pinion shares at the maximum continuous output (kW)

N_0: Number of revolutions of the pinion at the maximum continuous output (rpm)

D_1: Pitch circle diameter of the pinion (cm)

b: Effective face width of the gears on the pitch circle of the shaft parallel section (cm)

Z: Number of teeth

mn : Rectangular module of tooth

K_1: External load magnification factor, determined by the amount of fluctuating loads working on the gears and given by the following formula:

$$K_1 = \frac{1.10 P_{MCR}}{P_{MAX}}$$

P_{MAX}: Instantaneous maximum tangential load occuring within the service revolution range (*N/cm*).

Where, however, value K_1 is unknown, the values in **Table 5.1** may be used.

K_2: Internal load magnification value, derived from the following formula or **Fig. 5.1**, depending on the accuracy of gears and their overlap ratio.

$$K_2 = k_2 (Dn)^{0.8}$$

D: Pitch circle diameter of gears (*cm*)

n: Number of revolutions per minute of gears divided by 1,000.

K_2: Value given in **Table 5.2**; in this case, ε_{sp} is the value derived from the following formula:

$$\varepsilon_{sp} = \frac{b_e \sin \beta_0}{0.1 \pi m_n}$$

b_e: Face width (in case of double-helical gears, the face width is that on one side) (*cm*)

β_0: Herical angle

K_3: Load magnification coefficient due to flexibility, given by the following formula or **Fig. 5.2**, which is dependent on the face width and pitch circle diameter

$$K_3 = 1 - k_3 \left(\frac{b_t}{D_1}\right)^3$$

b_t : Total face width of pinions (in case of double-helical gears, central gap is included) (*cm*)

D_1 : Pitch circle diameter of the pinion (*cm*)

K_3 : Value given in **Table 5.3**

S_b : The value related mainly to the material of gears, given by the following formula. In case of ahead idle gears and astern gears, however, 0.7 times and 1.2 times respectively such value are regarded as S_b values. In this case, S_b is not to exceed 25.

(1) In case of gears to which surface hardening process was applied, including bottom land :

$$S_b = 0.83\sqrt{T}$$

(2) In case of other gears :

$$S_b = \frac{\frac{T+Y}{49}}{1 + (0.0096T - 2.4)\left(\frac{0.04}{r_0} + 0.02\right)(0.023 m_n + 0.75)}$$

T: Specified tensile strength of gear material (N/mm^2)

Y: Specified yield strength of gear material (N/mm^2)

r_0: Ratio of tool tip radius to module

Table 5.1 Values of k_1 (3)(4)

Driving unit	Construction	Use	
	Kind of coupling	Gear for main propulsion	Gear for auxiliaries
Steam turbine Gas turbine Electric motor	Single-stage reduction gear Multiple-stage reduction gear	1.00 1.00(1), 1.10(2)	1.15 1.15
Diesel engine	Hydraulic or electromagnetic coupling High elastic coupling Elastic coupling	1.00 0.90 0.80	1.15 1.05 0.95

Notes

1 Applicable only to the gearing connected directly with the main propulsion shafting system.

2 Applicable to the gearing connected with the propulsion shafting system through effective flexible couplings.

3 Where one pinion meshes with more than two wheels, 0.9 times these values may be applied as value K_1.

4 For value K_1 of rigid coupling, the value of K_1 is to be approved by the Society.

Table 5.2 Values of k_2

Expected accuracy	$\varepsilon_{sp} \geq 1.25$	$\varepsilon_{sp} < 1.25$
Those correspond to finishing shaved or groud	0.044	0.088
Those correspond to finishing hobbed	0.11	0.22

Table 5.3 Values of k_3

	When one pinion meses with one wheel	When two wheels mesh with one pinion in the positions forming a row
k_3	0.01	0.003

Fig. 5.1 Values of K_2

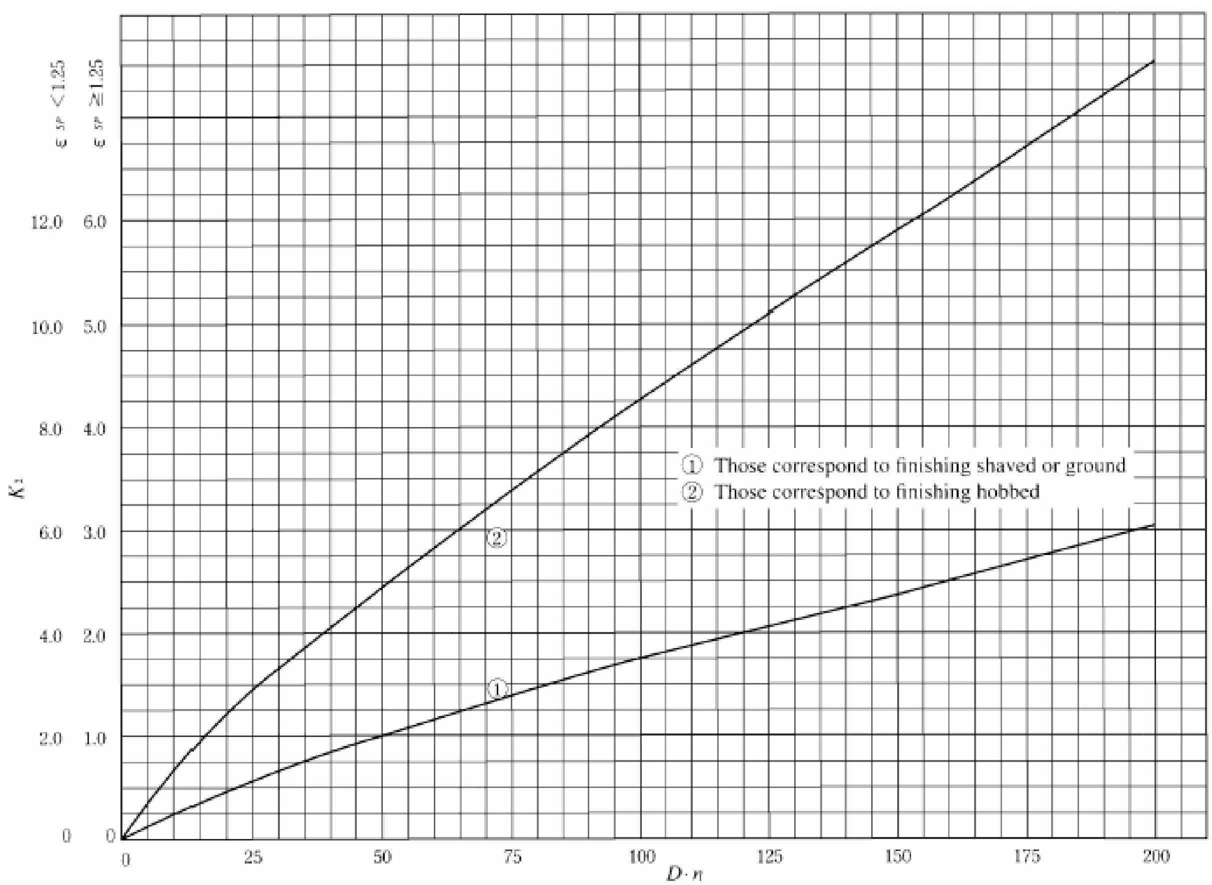
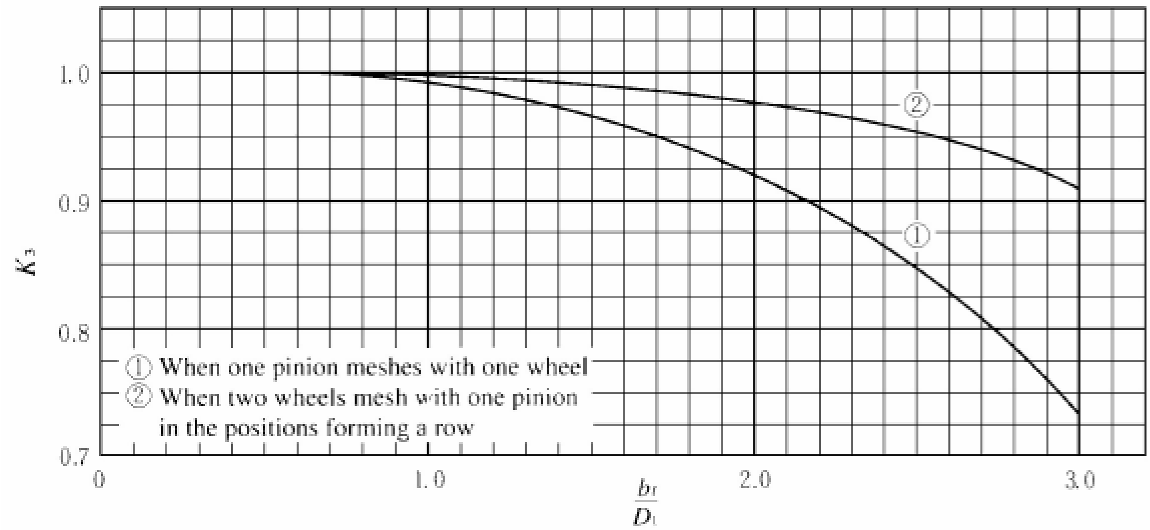


Fig. 5.2 Values of K_3



5.3.4 Tangential Loads for Surface Stress

The tangential loads on gear-teeth are to satisfy the following condition for limiting tooth surface stress, but these do not apply to astern gears.

$$P_{MCR} \leq 9.81(K_1 S_S - K_2) K_3 K_4 \frac{i}{1+i} D_1$$

where;

S_S : The value related mainly to the material of gears, given by the following formula:

(1) Combination of hardened gear

$$S_S = 2.23\sqrt{T_w}$$

(2) Combination of other gears

$$S_S = \left(0.005\frac{H_{BP}}{H_{BW}} + 0.007\right) T_w + 7.5$$

H_{BP} : Hardness of tooth face of pinion (Brinell hardness)

H_{BW} : Hardness of tooth face of wheel (Brinell hardness)

T_w : Specified tensile strength of wheel material (N/mm^2)

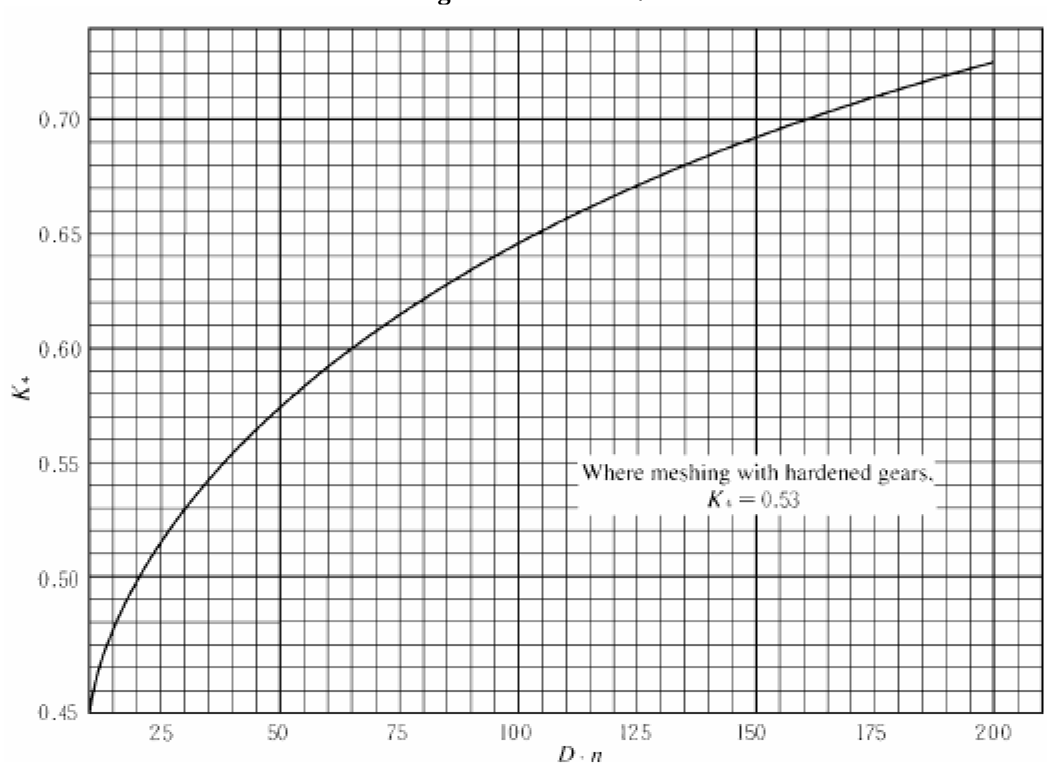
K_4 : Lubricating coefficient given by the following formula or Fig. 5.3, depending on pitch circle diameter and number of revolutions per minute. However, in case of combination of hardened gears, $K_4 = 0.53$

$$K_4 = 0.3(Dn)^{1/6}$$

i : Gear ratio (the number of teeth of wheel divided by the number of teeth of pinion)

Other symbols are same as in 5.3.3.

Fig. 5.3 Values of K_4



5.3.5 Detailed Evaluation for Strength

Special consideration will be given to the gearing devices, notwithstanding the requirements in **5.3.3** and **5.3.4,** provided that detailed data and calculations on the strength are submitted to the Society and considered appropriate.

5.4 Gear Shafts and Flexible Shafts

5.4.1 Gear Shafts

1. The diameter of gear shafts is to comply with the following requirements specified in **(1)** to **(3)** :

(1) The diameter of a gear shaft by which power is transmitted is not to be less than the value given by the formula in 6.2.2. In this case, H and R in the formula represent respectively the output and the number of revolutions per minute of the shaft at the maximum continuous rating.

(2) The diameter of the pinion shaft between the pinion shaft bearings is to have sufficient rigidity against the bending force generated by meshing of gears.

(3) The diameter of the wheel shaft between the wheel shaft bearings is not to be less than 1.16 times the value specified in **(1)**, when one pinion is gearing, or two pinions which are arranged at an angle less than 120° are gearing, and not to be less than 1.10 times the value specified in **(1)** when two pinions which are arranged at an angle more than 120° are gearing.

2. Special consideration will be given to the gear shaft, notwithstanding the requirements in **-1**, provided that detailed data and calculations on the strength are submitted to the Society and considered appropriate.

5.4.2 Flexible Shafts

The diameter of a flexible shaft is not to be less than the value given by the following formula:

$$d = 93\sqrt[3]{\frac{560H}{N_0(T + 160)}}$$

where;

d: Diameter of flexible shaft (mm)

H: Output which the flexible shaft shares at the maximum continuous output (kW)

N_0 : Number of revolutions of flexible shaft at the maximum continuous output (rpm)

T: Specified tensile strength of shaft material (N/mm^2)

5.4.3 Couplings and Coupling Bolts

The dimensions of couplings and coupling bolts are to be of values not less than those obtained from the formula given in 6.2.12-1 in this Part. Further, in case where they support heavy materials in cantilever style, they are to be designed so as to have sufficient strength to resist the weight. Additionally, *d*o in the formula is to be used the value of the shaft diameter specified respectively according to the kinds of shaft.

5.5 Tests

5.5.1 Shop Tests

1. For the parts subjected to surface hardening process, the measurement of the hardened depth are to be carried out on sample materials.

2. For parts subjected to surface hardening process, hardness tests and non-destructive tests by suitable procedure are to be carried out.

3. For gears, accuracy tests to examine the machining accuracy of finish are to be carried out.

4. In case of the gears where the value given by the following formula exceeds 50, dynamic balancing tests are to be carried out.

$$\frac{DN_0}{1000}$$

where;

D: Pitch circle diameter of gear (*cm*)

N_0: Number of rotations of gear (*rpm*)

5. The contact marking of the teeth of all gearing is to be verified under appropriate loads by coating with suitable paint thinly and uniformly.

Chapter 6 SHAFTINGS

6.1 General

6.1.1 Scope

The requirements of this Chapter apply to propulsion shafting systems (excluding propellers) and shafting systems which transmit power from prime movers to drive generators and auxiliaries (excluding auxiliary machinery for specific use etc., hereinafter the same in this Chapter). For torsional vibrations, the requirements in **Chapter 8** are to be complied with.

6.1.2 Drawings and Data

Drawings and data to be submitted are generally as follows:

(1) Drawings for approval (including specifications of material)

- (a) Shafting arrangement
- (b) Thrust shaft
- (c) Intermediate shaft
- (d) Stern tube shaft
- (e) Propeller shaft
- (f) Stern tube
- (g) Stern tube bearing
- (h) Stern tube sealing device
- (i) Shaft bracket bearing

(j) Shaft couplings and coupling bolts

(k) Shafts which transmit power to generators or auxiliaries

(2) Data for reference

(a) Data for the calculations of shafting strength specified in this Chapter

(b) Data which deemed necessary by the Society

6.2 Materials, Construction and Strength

6.2.1 Materials

1. Materials used for the following components (hereinafter referred to as the principal components of shafting) are to be of the steel forgings conforming to the requirements specified in **6.1 of Part 10**, of the stainless steel forgings conforming to the requirements specified in **6.2 of Part 10**, of the rolled stainless steel bars approved for shaft use conforming to the requirements specified in **3.5.1-2 of Part 10**, (hereinafter, stainless steel forgings and rolled stainless steel bars are to be referred to as stainless steel forgings, etc.) or of the material specially approved for shaft use by the Society under **1.1.1-2 of Part 10**. Built-up type shaft couplings may be of steel castings conforming to the requirements in **Part 10**.

(1) Thrust shafts

(2) Intermediate shafts

(3) Stern tube shafts

(4) Propeller shafts

(5) Shafts which transmit power to generators or auxiliaries

(6) Shaft couplings

(7) Coupling bolts

2. The principal components of shafting excluding coupling bolts are to have been subjected to non-destructive tests specified in **5.1.10**, **6.1.10** or **6.2.10 of Part 10** according to the kind of materials.

3. The specified tensile strength of the shaft materials is to be between 400 and 800 N/mm^2 in general and to be between 500 and 800N/mm^2 for shafts experience torsional vibration stress exceeding 85 % of T_2 given in **8.2.2.**

Steel forgings with specified tensile strength exceeding 800 N/mm^2 are not to be used for a shaft unless specially approved by the Society.

6.2.2 Intermediate Shafts

1. The diameter of the intermediate shafts of steel forgings (excluding stainless steel forgings, etc.) is not to be less than the value given by the following formula:

$$d_0 = F_1 k_1 \sqrt[3]{\frac{H}{N_0}\left(\frac{560}{T_s + 160}\right)K}$$

where:

d_0: Required diameter of intermediate shaft (*mm*)

H: Maximum continuous output of engine (*kW*)

N_0: Number of revolutions of intermediate shaft at the maximum continuous output (*rpm*)

F_1 : Factor given in **Table 6.1**

k_1 : Factor given in **Table 6.2**

T_s : Specified tensile strength of intermediate shaft material (N/mm^2)

The upper limit of the value of *TS* used for the calculation is to be 760 N/mm^2 for carbon steel forgings and 800 N/mm^2 for low alloy steel forgings.

K: Factor for hollow shaft and given by the following formula. In case of $d_i \leq 0.4d_a$,it may be considered that $K = 1$

$$K = \frac{1}{1 - \left(\frac{d_i}{d_a}\right)^4}$$

d_i: Inside diameter of hollow shaft (*mm*)

d_a : Outside diameter of hollow shaft (*mm*)

2. The diameter of the intermediate shaft of material other than specified in -1 above is to be deemed appropriate by the Society

Table 6.1 Values of F_1

For steam turbine installation, gas turbine installation, diesel installation with slip type coupling (Note), electric propulsion installation	For all other diesel installation than those noted in the left hand column
95	100

Note:

Slip type coupling signifies hydraulic coupling, electromagnetic coupling or the equivalent.

Table 6.2 Values of k_1

Shaft with integral flange coupling	Shaft with flange coupling either shrink fit, push fit or cold fit(1)	Shaft with keyway(2)	Shaft with transverse hole (3)	Shaft with longitudinal slot(4)	Shaft with splines (5)
1.0	1.0	1.1	1.1	1.2	1.15

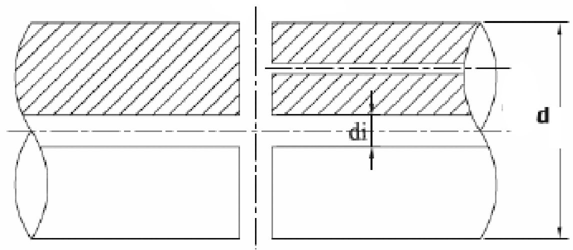
Notes:

1 Where shafts experience torsional vibration stress exceeding 85 % of τ_1 given in 8.2.2-1**(1)** during continuous operation, an increase of 1 to 2 % in diameter to the fit diameter and a blending radius nearly equal to the change in diameter are to be provided.

2 After a length of not less than 0.2 d_0 from the end of the keyway, the diameter of a shaft may be reduced progressively to the diameter calculated with k_1=1.0.

The fillet radius in the transverse section of keyway bottom is to be 0.0125 d_0 or more.

3 The hole diameter is not to be more than 0.3 d_0. When a transverse hole intersects an eccentric axial hole (see below), the value is to be determined by the Society based on the submitted data in each case.



4 The shape of the slot is to be in accordance with the followings. An edge rounding other than chamfering is to be avoided in general. The number of slots is to be 1, 2 or 3 and they are to be arranged 360, 180 or 120 degrees apart from each other respectively.

(a) $l < 0.8d_a$

(b) $d_i < 0.8d_a$

(c) $0.1d_a < e \leq 0.2d_a$

(d) $r = e/2$

where;

l: slot length

d_a : outside diameter of the hollow shaft

d_i: inside diameter of the hollow shaft

e: slot width

r: end rounding of the slot

5 The shape of the spline is to conform to recognized national or international *standards*.

6.2.3 Thrust Shafts

1. The diameter of the thrust shaft transmitting the torque of main propulsion machinery, and which is made of steel forgings (excluding stainless steel forgings, etc.), on the both sides of thrust coller, or in way of axial bearing where a roller bearings are used as thrust bearings, is not to be less than the value given by the following formula:

$$d_t = 1.1F_1\sqrt[3]{\frac{H}{N_0}\left(\frac{560}{T_s+160}\right)K}$$

where;

d_t : Required diameter of thrust shaft (*mm*)

Other symbols used here are the same as those used in **6.2.2-1**.

2. Where the required diameter of the thrust shaft given by **-1**. is larger than the diameter of the intermediate shaft, the diameter of the thrust shaft may be reduced gradually at either fwd or aft of the thrust block by multiplying 0.91 on the required diameter of the intermediate shaft given by **-1**.

3. The diameter of the thrust shaft of material other than specified in **-1** above is to be deemed appropriate by the Society.

6.2.4 Propeller Shafts and Stern Tube Shafts

1. The diameter of propeller shaft and stern tube shafts made of carbon steel forgings or low alloy steel forgings are not to be less than the value given by the following formula. In case of propeller shaft Kind 2 or stern tube shafts Kind 2, however, the diameters are to be deemed appropriate by the Society.

$$d_s = 1000k_2 \sqrt[3]{\frac{H}{N_0}\left(\frac{560}{T_s + 160}\right)K}$$

where;

d_s: Required diameter of propeller shaft or stern tube shaft (*mm*)

k_2 : Factor concerning shaft design, values given in **Table 6.3**

T_s: Specified tensile strength of shaft material (N/mm^2)

The upper limit of the value of T_S used for the calculation is to be 600 N/mm^2

Other symbols used here are the same as those used in **6.2.2-1**

2. The diameter of propeller shaft and stern tube shafts made of stainless steel forgings, etc. are not to be less than the value given by the following formula.

$$d_s = 1000k_3 \sqrt[3]{\frac{H}{N_0}}$$

k_3 : The factor determined by the material of shaft and portion concerned, which is given in **Table 6.4**. The material other than specified in the table is to be determined by the Society on each case.

Other symbols used here are the same as those used in **6.2.2-1**.

3. The diameter of the propeller shafts and stern tube shafts other than those prescribed in **-1** and **-2** are to be deemed appropriate by the Society.

Table 6.3 Values of k_2

	Application		k_2
1	The portion between the big end of the tapered part of propeller shaft (in case where propeller is fitted with flange, the fore face of the	For a shaft carrying a keyless propeller, or where the propeller is attached to an integral flange	1.22

	flange) and the fore end of the aftermost stern tube bearing, or 2.5 d_s, whichever is the greater	For a shaft carrying a keyed propeller	1.26
2	Excluding the potion given in 1 above, the portion in the direction toward the bow up to the fore en the fwd stern tube seal		$1.15^{(1)}$
3	Stern tube shaft		$1.15^{(1)}$
4	The portion located forward of the fore end of the fwd stern tube seal		$1.15^{(2)}$

Notes:

1 At boundary, the shaft diameter is to be reduced with either a smooth taper or a blending radius nearly equal to the change in diameter.

2 The shaft diameter may be reduced with either a smooth taper or a blending radius nearly equal to the change in diameter to the diameter calculated by the formula given in 6.2.2.

Table 6.4 Values of k_3

	Application	*KSUSF* 316 *KSUS*316-*SU*	*KSUSF* 316*L* *KSUS*316L-*SU*
1	The portion between the big end of the tapered part of propeller shaft (in case where the propeller is fitted with flange) and the fore end of the aftermost stern tube bearing, or 2.5$\boldsymbol{d_S}$, whichever is the greater	1.28	1.34
2	Excluding the portion given in 1above, the portion in the direction toward the bow up to the fore end of the fwd stern tube seal	$1.16^{(1)}$	$1.22^{(1)}$
3	The portion located forward of the fore end of the fwd stern tube seal	$1.16^{(2)}$	$1.22^{(2)}$

Notes:

1 At boundary, the shaft diameter is to be reduced with either a smooth taper or a blending radius nearly equal to the change in diameter.

2 The shaft diameter may be reduced with either a smooth taper or a blending radius nearly equal to the change in diameter to the diameter calculated by the formula given in 6.2.2-1 considering T_S =400.

6.2.5 Other Shafts

The diameter of shafts transmitting power to generators or essential auxiliary machinery is to, in principle, conform to the requirements in 6.2.2.

6.2.6 Detailed Evaluation for Strength

Special consideration will be given to the shaft diameters, notwithstanding the requirements in 6.2.2, 6.2.3, 6.2.4 and 6.2.5, provided that the detailed data and calculations are submitted to the Society and considered appropriate.

6.2.7 Corrosion Protection of Propeller Shafts and Stern Tube Shafts

1. Propeller shaft Kind 1 and stern tube shaft Kind 1 are to be effectively protected against corrosion by sea water with one of means specified below.

(1) To effectively protect for propeller shaft and stern tube shaft against contact with sea water by the mean approved by the Society.

(2) To use *KSUSF*316, *KSUSF*316*L*, *KSUS*316-*SU* or *KSUS*316*L*-*SU* specified in **Part 10** for the shaft with diameter not exceeding 200 *mm*.

(3) To use corrosion resistant materials approved by the Society other than specified in **(2)** above.

2. Effective means are to be provided to prevent sea water from having access to the part between the aft end of propeller shaft sleeve or the aft end of the aftermost stern tube bearing and the propeller boss.

3. Spaces between the propeller cap or propeller boss and the propeller shaft are to be filled up with tallow, or provided with other effective means to protect the shaft against corrosion by sea water.

6.2.8 Propeller Shaft Sleeves and Stern Tube Shaft Sleeves

The sleeves to be fitted to a propeller shaft and a stern tube shaft are to comply with the requirements in the following **(1)** to **(3)**.

(1) The thickness of the sleeve is not to be less than the value given by the following formulae:

$$T_1 = 0.03d_d + 7.5$$

$$t_2 = \frac{3}{4}t_1$$

where;

t_1: Thickness of sleeve in way of stern tube bearing or shaft bracket bearing in contact with the bearing face (*mm*)

t_2: Thickness of sleeve of other parts than the above (*mm*)

d_S : Required diameter of propeller shaft given by the formula in 6.2.4 (*mm*)

(2) Sleeves are to be of bronze or equivalent thereto and to be free from porosity and other defects.

(3) Sleeves are to be fitted to the shafts by a method free from stress concentration such as shrinkage fit, etc.

6.2.9 Fixing of Propellers to Shafts

1. Where propellers are force fitted on the propeller shaft, the fixing part is to be of sufficient strength against torque to be transmitted.

2. Where a key is provided to fixing part, ample fillets are to be provided at the corners of the keyway and key is to have a true fit in the keyway. The fore end of keyway on the propeller shaft is to be rounded smoothly for avoiding an excessive stress concentration.

3. Where the propeller and propeller shaft flange are connected with bolts, the bolts and pins are to be of sufficient strength.

4. The thickness of the aft propeller shaft flange at the pitch circle is not to be less than 0.27 times the diameter of the intermediate shaft (calculated with $k1 = 1.0$, $K = 1.0$ and $TS = 400$) in **6.2.2**.

6.2.10 Stern Tube Bearings and Shaft Bracket Bearings

1. The aftermost stern tube bearing or shaft bracket bearing which supports the weight of propeller is to comply with the following requirements **(1)**, **(2)** and **(3)**:

(1) In the case of water-lubricated bearings of lignumvitae

(a) The bearing length is not to be less than four times the required diameter of the propeller shaft given by the formula in **6.2.4-1** or **-2**, or three times the actual shaft diameter, whichever is the greater

(b) Adequate means are to be provided to supply ample amount of clean water for lubrication and cooling.

(2) In the case of oil-lubricated bearings of white metal

(a) The length of the bearing is not to be less than 2 times the required diameter of the propeller shaft given by the formula in **6.2.4-1** or **-2**, or 1.5 times the actual diameter, whichever is the greater. However, where special consideration is given on the construction and arrangement in accordance with the provisions specified elsewhere and specially approved by the Society, the length of the bearing may be fairly shorter than that specified above.

(b) The stern tube is to be always filled with oil. Adequate means are to be provided to measure the temperature of oil in the stern tube.

(c) Where a gravity tank supplying lubricating oil to the stern tube bearing is fitted, it is to be located above the load water line and provided with a low level alarm device. However, in case where the lubricating system is designed to use under the condition that the static oil pressure of the gravity tank is lower than the water pressure, the tank is not required to be above the load water line.

(d) The lubricating oil is to be cooled by submerging the stern tube in the water of the after peak tank or by other suitable means.

(3) Where bearing materials other than **(1)** and **(2)** above are intended to be used, the materials, construction and arrangement are to be approved by the Society. The length of these bearings is to comply with the following requirements in **(a)** and **(b)**:

(a) In the case of oil-lubricated bearing of synthetic materials; For bearings of synthetic rubber, reinforced resin or plastics materials which are approved for use as oil-lubricated stern tube bearings, the length of the bearing is to be not less than 2 times the required diameter of the propeller shaft given by the formula in 6.2.4-1 or -2, or 1.5 times the actual diameter, whichever is the greater. However, for bearings having construction and arrangement specially approved by the Society, the length of the bearing may be fairly shorter than that specified above.

(b) In the case of water-lubricated bearings of synthetic materials; For bearings of synthetic materials which are approved for use as water-lubricated stern tube bearings such as rubber or plastics, the length of the bearing is to be not less than 4 times the required diameter of the propeller shaft given by the formula in 6.2.4-1 or -2, or 3 times the actual diameter, whichever is the greater. However, for bearings having construction and arrangement specially approved by the Society, the length of the bearing may be fairly shorter than that specified above.

2. The sealing devices other than grand packing type sea water sealing device are to be approved by the Society in their materials, construction and arrangement.

6.2.11 Additional Requirement for the Propeller Shaft Kind 1*C*

Means are to be provided to sufficiently ensure the integrity of the stern tube bearings in accordance with the requirements specified otherwise by the Society where the propeller shaft is intended to be the propeller shaft Kind 1*C*.

6.2.12 Shaft Couplings and Coupling Bolts

1. The diameter of coupling bolts at the joining face of the couplings is not to be less than the value given by the following formula:

$$d_b = 0.65\alpha\sqrt{\frac{d_0^3(T_s + 160)}{nDT_b}}$$

Where;

d_b: Bolt diameter (*mm*)

d_0: Diameter (*mm*) of intermediate shaft calculated with k_1 = 1.0 and K = 1.0 in 6.2.2

n: Number of bolts

D: Pitch circle diameter (*mm*)

T_s: Specified tensile strength of intermediate shaft material taken for the calculation in 6.2.2

T_b: Specified tensile strength of bolt material (N/mm^2), while in general $T_S \le T_b \le 1.7\ T_s$, and the upper limit of the value of T_b used for the calculation is to be 1,000 N/mm^2

α: Coefficient concerning vibratory torque, given by the following formula or to be taken as 1.0, whichever is greater.

However, α =1.0 may be accepted for coupling bolts used for shafting systems which transmit power from prime movers to drive generators and auxiliaries.

$$\alpha = 0.95\sqrt[3]{\frac{Q_a}{Q_m}}$$

Q_a: Torsional vibratory torque acting on the joining face of the couplings rotating at resonant critical speed in all conditions (*Nm*)

Q_m : Nominal rated torque given by the following formula (*Nm*)

$$Q_m = 9549\frac{H}{N_0}$$

H : Maximum continuous output of engine (*kW*)

N_0 : Rate of revolutions of intermediate shaft at the maximum continuous output (*rpm*)

2. The thickness of the coupling flange at the pitch circle is not to be less than the required diameter of bolts determined by the formula in **-1** assuming that the bolts have the tensile strength compatible with that of the corresponding shaft material. However it is not to be less than 0.2 times the required diameter of the corresponding shaft.

3. The fillet radius at the base of the flange is not to be less than 0.08 times the diameter of the shaft, where the fillet is not to be recessed in way of nuts and bolt heads.

4. Where the shaft couplings are not integral with the shaft, the couplings are to have sufficient strength against the torque to be transmitted to the shaft and also the astern pull. In this case, consideration is to be taken so as not to cause an excessive, stress concentration.

6.2.13 Shaft Alignment

For the main propulsion shafting having a oil-lubricated propeller shaft of which diameter is not less than 400 *mm*, the shaft alignment calculation including bending moments, bearing loads, deflection curve of the shafting is to be carried out for approval.

6.3 Tests

6.3.1 Shop Tests

The following components are to be subjected to hydrostatic tests at pressures specified below:

(1) Stern tube:

0.2 *MPa*

(2) Propeller shaft sleeves and stern tube shaft sleeves:

0.1 MPa (tests are to be carried out before shrinkagefit)

6.3.2 Tests after Installation on Board

1. The sealing devices specified in **6.2.10-1(2)** are to be tested for leakage under working oil pressure after installation on board.

2. For the main propulsion shafting (excluding those of water jet propulsion systems or azimuth thrusters), confirmation tests relating to shaft alignment are to be carried out in accordance with the requirements specified otherwise by the Society.

Chapter 7 PROPELLERS

7.1 General

7.1.1 Scope

The requirements in this Chapter apply to screw propellers.

7.1.2 Drawings and Data

Drawings and data to be submitted are generally as follows:

(1) Drawings

- (a) Propeller
- (b) Operating oil piping diagram of controllable pitch propeller indicating pipe materials, pipe sizes and service pressure
- (c) Blade fixing bolts of controllable pitch propeller

(2) Data

- (a) Particulars of propeller (maximum continuous output and number of maximum continuous revolutions per minute of main propulsion machinery, details of blade profile, diameter, pitch, developed area, propeller boss ratio, rake or rake angle, number of blades, mass, moment of inertia, material specifications, etc.)
- (b) Calculation sheet of propeller pull-up length (where it is proposed to fit keyless propellers)

7.1.3 Material

1. The materials of propellers and blade fixing bolts of controllable pitch propellers are to comply with the requirements in **Part 10**.

2. Propellers are to have been subjected to non-destructive tests on their principal parts.

7.2 Construction and Strength

7.2.1 Thickness of Blade

1. The thickness of the propeller blades at radius of 0.25 R and 0.6 R for solid propellers, and at radius of 0.35 R and 0.6 R for controllable pitch propellers are not to be less than the values given by the following formula. The thickness of the highly skewed propeller blades are to conform with the provisions specified elsewhere.

$$t = \sqrt{\frac{K_1}{K_2}\frac{H}{ZN_0\ell}SW}$$

Where;

t: Thickness of blades (excluding the fillet of blade root) (*cm*

H: Maximum continuous output of main propulsion machinery (*kW*)

Z: Number of blades

N_0: Number of maximum continuous revolutions per minute divided by 100 (*rpm* /100)

ℓ: Width of blade at radius in question (*cm*)

K_1: Coefficient given by the following formula at radius in question

$$K_1 = \frac{30.3}{\sqrt{1 + k_1\left(\frac{P'}{D}\right)^2}}\left(k_2\frac{D}{P} + k_3\frac{P'}{D}\right)$$

D: Diameter of propeller (*m*)

K_1, K_2, K_3: Values given in **Table 7.1**

P': Pitch at radius in question (*m*)

P: Pitch at radius of 0.7 R (*m*), (R = Radius of propeller (*m*))

K_2: Coefficient given by the following formula

$$K_2 = K - \left(k_4\frac{E}{t_0} + k_5\right)\frac{D^2N_0^2}{1000}$$

K_4, K_5: Values given in **Table 7.1**

E: Rake at the tip of the blade (Measuring from face side base line, and taking positive value for backward rake) (*cm*)

t_0: Imaginary thickness of blade at propeller shaft centreline (t_0 may be obtained by producing the each side line which connects the blade tip thickness with the thickness at 0.25 R (or 0.35 R for controllable pitch propeller), in the projection of blade section along maximum blade thickness line.) (*cm*)

K: Value given in **Table 7.2**

S: Coefficient concerning to the increase of stress by weather. Where S>1.0 or S<0.8, the value of S is to be taken as 1.0 or 0.8 respectively.

$$S = 0.095\left(\frac{D_S}{d_S}\right) + 0.677$$

D_s: Depth of ship for strength computation (*See* **1.2.7, Part 1A**)

d_s: Load draught (*See* **1.2.12, Part 1A**)

W: Coefficient concerning the alternate stress, given by the following formula or to be taken as 2.80, whichever is greater.

$$W = 1 + 1.724\left(\frac{A_2A_3 + A_4A_1P'/D}{A_3 + A_4P'/D}\right)$$

$$A_1 = \frac{\Delta\omega}{\omega + C_1}$$

$$A_2 = \frac{\Delta\omega}{\omega + C_2}$$

$$A_3 = \frac{(C_1 + 1)(C_2 + \omega)}{C_3(C_2 + 1)(C_1 + \omega)}$$

$$A_4 = \begin{cases} 3.52(0.25R) \\ 2.41(0.35R) \\ 1.26(0.6R) \end{cases}$$

$$C_1 = \frac{D}{0.95P}\left\{\frac{P}{D}\left(1.3 - \frac{2a_e}{Z}\right) + 0.22\right\} - 1$$

$$C_2 = \frac{D}{0.95P}\left(1.1\frac{P}{D} - \frac{1.19a_e}{Z} + 0.2\right) - 1$$

$$C_3 = 0.122\frac{P}{D} + 0.0236$$

a_e : Expanded area ratio of propeller

ω: Nominal mean wake in the propeller disc

$\Delta\omega$: Peak to peak value of wake fluctuation in the propeller disk at radius of 0.7 R. The values of ω and $\Delta\omega$ are to be calculated by using the following formulae, except the case of multi-screw ship or being expressly approved by the Society.

$$\Delta_\omega = 7.32\left\{1.56 - 0.04\left(\frac{B}{D} + 4\right)\sqrt{\frac{B}{d_S}} - C_b\right\}\omega$$

$$\omega = 0.625\left\{0.04\left(\frac{B}{D} + 4\right)\sqrt{\frac{B}{d_S}} + C_b\right\} - 0.527$$

B: Breadth of ship (m)

C_b: Block coefficient of ship

2. The fillet radius between the root of a blade and the boss of the propeller is to be not less than the value of R_0 given by the following formula, on the pressure side at the maximum blade thickness part.

$$R_0 = t_r + \frac{(e - r_B)(t_0 - t_r)}{e}$$

R_0: Required radius of the fillet (cm)

t_r: Required thickness of blades at radius of 0.25 R (or 0.35 R for controllable pitch propeller) specified in **-1** (cm)

t_0: Same as that used in **-1**

r_B: Boss ratio of propeller

e: 0.25 (or 0.35 for controllable pitch propeller)

3. Special consideration will be given to the thickness of blades or the radius of the fillet, notwithstanding the requirements in **-1** or **-2** above, provided that detailed data and calculations are submitted to the Society and considered appropriate.

Table 7.1 Values of k_1, k_2, k_3, k_4, and k_5

Radial position	k_1	k_2	k_3	k_4	k_5
0.25R	1.62	0.386	0.239	1.92	1.71
0.35R	0.827	0.308	0.131	1.79	1.56
0.6R	0.281	0.113	0.022	1.24	1.09

Table 7.2 Values of *K*

Material		K
Copper alloy casting	KHB_sC1	1.15
	KHB_sC2	
	$KAlBC3$	1.3
	$KAlBC4$	1.15

Notes:

1 For the blades of materials different from those specified in the above Table, the value of K is to be determined in each case.

2 For propellers having a diameter of 2.5 *metres* or less, the value of K may be taken as the value in the above Table multiplied by the following factor:

$2 - 0.4D \quad for\ 2.5 \geq D > 2.0$

$1.2 \quad for \quad 2.0 \geq D$

7.2.2 Controllable Pitch Propellers

1. The thickness of the controllable pitch propeller blade is to be in accordance with the requirements specified in 7.2.1.

2. The diameter of blade fixing bolts of controllable pitch propellers is not to be less than the value calculated by the following formula:

$$d = 0.55\sqrt{\frac{1}{\sigma_a n}\left(\frac{AK_3}{L} + F_c\right)}$$

where;

d: Required diameter of blade fixing bolt (*mm*) (*See* Fig. 7.1)

A: Value given by the following formula, where *H*, N_0 and *Z* are the same as those specified in 7.2.1.

$$A = 3.0 \times 10^4 \frac{H}{N_0 Z}$$

K_3: Value given by the following formula

$$K_3 = \left\{\left(\frac{D}{P}\right)^2 \times (0.622 - 0.9x_0)^2 + (0.318 - 0.499x_0)^2\right\}^{\frac{1}{2}}$$

x_0: Ratio of the radius at boundary between blade flange and pitch control gear to the propeller radius (*See* Fig. 7.1). Where $x_0 > 0.3$, the ratio is to be taken as 0.3

L: Mean value of L_1 and L_2 (*cm*)

L_1 and L_2 show the length of the perpendicular lines constructed to the line which passes through the rotating centre of blade flange and has an inclination compatible with the pitch angle b at 0.7 *R* in maximum continuous output, from the centres of bolts located on each edge side in face side when the pitch angle is b. (*See* Fig. 7.2)

F_c: Centrifugal force (*N*) of propeller blade given by the following formula:

$$F_c = 1.10 \times mR'N_0^2$$

m: Mass of one blade (*kg*)

R': Distance between centre of gravity of blade and propeller shaft centre line (*cm*)

n: Number of bolts on the face side of blade

σ_a: Allowable stress of bolt material given by the following formula (N/mm^2)

$$\sigma_a = 34.7 \times \left(\frac{\sigma_B + 160}{600}\right)$$

σ_B: Specified Tensile strength of bolt material (N/mm^2)

Where $\sigma_B > 800\ N/mm^2$, it is to be taken as 800 N/mm^2.

Other symbols are the same as those given in the formula of 7.2.1-1.

3. For blade fixing bolts, corrosion-resistant materials are to be used, or special means precluding their direct contact with sea water are to be provided.

4. The thickness of the flange for fitting the blade to the pitch control gear (the thickness as measured from the seat of fixing bolt or nut to the boundary face between the flange and the pitch control gear) is to be not less than the value calculated by the following formula :

$$t_f = 0.9d$$

where;

t_f: Thickness of flange (*mm*) (*See* **Fig. 7.1.**)

d: Required diameter of bolt calculated by the formula specified in **-2**. (*mm*)

5. Blade fixing bolts are to be fitted tightly into the pitch control gear and provided with effective means for locking.

6. In case where recesses for bolts are provided on the fillet at the root of blades, the design blade section determined by the requirements for blade thickness in **7.2.1** is not to be reduced for the recess.

7. The face of the flange of the blade is to be fitted up tightly to the face of pitch control gear, and the circumferential clearance of the edge of flange is to be minimized.

8. Where pitch control gears are operated by hydraulic oil pump, a stand-by oil pump so connected as to be ready for use or other suitable device is to be provided, thereby to ensure that the ship can keep the normal service condition, in the event of failure of the oil pump.

9. The operating oil piping arrangement is to comply with the requirements in **13.10**.

Fig. 7.1 Measuring Method of Blade Fixing Bolt Dimensions

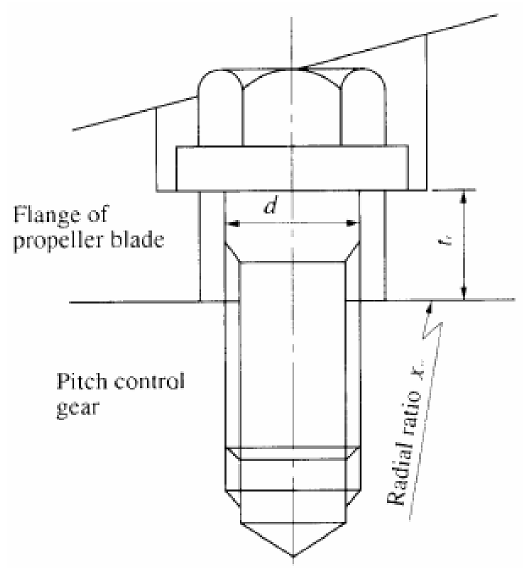
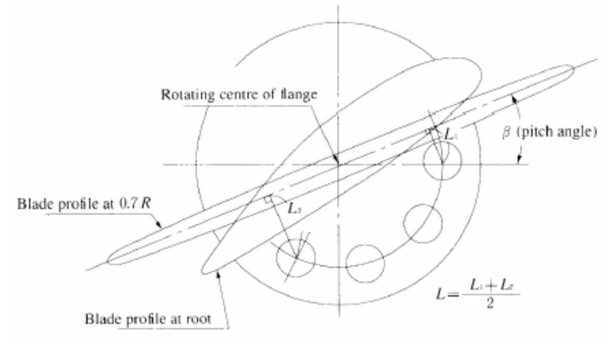


Fig. 7.2 Determination of *L*



7.2.3 Blade fitting of Built-up Propeller

The blade fixing bolts and the flanges for fitting the blade of built-up propellers are to so designed as to comply with the requirements concerning to those for controllable pitch propellers specified in 7.2.2.

7.3 Force Fitting of Propellers

7.3.1 Pull-up Length

1. Where propeller is force fitted on the propeller shaft without the use of a key, the lower and upper limits of pull-up length are to be as given by the following formulae. For the taper of more than 1/15, these limits of pull-up length are to be subject to the satisfaction of the Society :

$$L_1=PK_E+K_C(C_b\text{-}C_0)$$

$$L_2=K_E+K_w\frac{\left(K_{R1}{}^{2}\text{-}1\right)}{\sqrt{\left(3K_{R1}{}^{4}+1\right)}}+K_c\left(C_b\text{-}C_0\right)$$

$$L_3=19.6\mathrm{K_E}\left(K_{R1}{}^{2}\text{-}1\right)+K_c\left(C_b\text{-}C_0\right)$$

L_1: Lower limit of pull-up length (mm)

L_2 : Upper limit of pull-up length (mm) (in case other than the case of L_3 shown below)

L_3 : Upper limit of pull-up length (mm) (in case where the material of boss is manganese bronze casting and $K_{R1} < 1.89$)

K_w: The value given by Table 7.3. In case where the material of propeller boss is other than those specified in Table 7.3, the value is to be determined by the Society in each case.

K_{R1}: Rate of R_1 to $R_0 (R_1/R_0)$

K_{R2}: Rate of R_2 to $R_0 (R_2/R_0)$

R_0: Radius of the propeller shaft at the midpoint of taper in the axial direction (mm)

R_1: Radius of propeller boss at the determinant point of the propeller boss ratio (mm)

R_2: Inner radius at the section corresponding to R_0 for the hollow propeller shaft (mm)

C_b: Temperature of propeller boss at time of fitting propeller (°C)

C_0 : Reference temperature: 35°C for L_1, 0°C for L_2 and L_3

P: Value given by the following formula (*N/mm*^{2});

$$P = \frac{2.8T}{SB}\left\{-2.8\tan\alpha + \sqrt{0.0169 + B\left(\frac{F_v}{T}\right)^2}\right\}$$

S: Contact area between propeller shaft and propeller boss on the drawing (*mm*^{2})

α: half angle of the taper at the propeller shaft cone part (*rad*)

B: 0.0169 - 7.84tan^2 α

T: Thrust force given by the following formula (*N*)

$$T = 1.76 \times 10^3\left(\frac{H}{V_S}\right)$$

V_S: Ship speed at máximum continuous output (*kt*)

F_v: Tangential force acting on contact surface given by the following formula (*N*);

$$F_v = \frac{9.55cH}{N_0R_0} \times 10^4$$

c: 1.0 for turbine ship,

For dieses ships, 1.2 or the value given by the following formula whichever is greater for diesel ship. Where the maximum torque acting on the propeller fitted portion is evaluated precisely according to the satisfaction of the Society, however, it may comply with the provisions specified otherwise.

$$(0.194\ 1\text{n}\ D + 0.255)\left\{\left(\frac{N_c}{N_0}\right)^2 + 1.047\frac{Q_vN_0}{H} \times 10^{-2}\right\}$$

Q_v: Torsional vibratory torque acting on the propeller fitted portion at rotational speed of resonant critical above 25% MCR, (*N-m*)

H, N_0 ,*D* : Same as those specified in **7.2.1-1**, However, *D* is to be taken as 2.6 *m* for $D <$ 2.6m, and as 10.2 *m* for $D >$ 10.2m.

N_c: Number of revolutions (*rpm*) at resonant critical divided by 100

K_E : Value given by the following formula (*mm*^{3}/*N*);

$$K_E = \frac{R_0}{\tan\alpha}\left\{\left(\frac{{K_{R1}}^2 + 1}{{K_{R1}}^2 - 1}\right)K_4 + 4.85\left(\frac{1 + {K_{R2}}^2}{1 - {K_{R2}}^2}\right) + K_5\right\} \times 10^{-6}$$

Where the material of the propeller shaft is other than forged steel or the material of propeller boss is other than specified in **Table 7.3**, the value is to be determined by the Society as considered appropriate.

K_4 and K_5 : Values given in **Table 7.3**

K_c: Value given by the following formula (*mm* /°C)

$$K_c = \left(K_6 + K_7\frac{C_b - C_s}{C_b - C_0}\right)\left(\ell_0 - \frac{R_0}{\tan\alpha}\right) \times 10^{-5}$$

Where the material of the propeller shaft is other than forged steel or the material of propeller boss is other than specified in **Table 7.3**, the value is to be determined by the Society as considered appropriate.

C_s : Temperature of propeller shaft at time of fitting propeller (°C).

ℓ_0: Half length of the tapered part in the propeller boss hole in the axial direction (mm)

K_6 and K_7 : Values given in **Table 7.3**

2. Where propeller is force fitted on the propeller shaft with the use of a key, the strength of the fitted part is to be such that they are sufficient for the torque to be transmitted.

7.2.3 Propeller Boss

1. Where a propeller is force fitted on propeller shaft, the edge at the fore end of the tapered hole of the propeller boss is to be appropriately rounded off.

2. Propeller boss is not to be heated locally to a high temperature at time of forcing on or drawing out.

7.4 Tests

7.4.1 Shop Tests

Propellers are to be subjected to static balancing tests.

7.4.2 Tests after Installation on Board

When a propeller is force-fitted on the propeller shaft, irrespective whether it is done with or without a key, a force-fitting test is to be carried out to measure and record the pull-up length. This test may be carried out as a Shop Tests.

Table 7.3 Values of K_4, K_5, K_6, K_7 and K_w

Material of propeller boss	K_4	K_5	K_6	K_7	K_w
*KHBsC*1	9.27	1.65	0.55	1.20	123
*KHBsC*2	9.27	1.65	0.55	1.20	123
*KAlBC*3	8.49	1.40	0.55	1.20	172
*KAlBC*4	8.49	1.40	0.55	1.20	193

Chapter 8 TORSIONAL VIBRATION OF SHAFTINGS

8.1 General

8.1.1 Scope

1. The requirements of this Chapter apply to power transmission systems for propulsion and propulsion shafting systems (except propellers), shafting systems to transmit power from main propulsion machinery to generators, crankshafts of diesel engines used as main propulsion machinery and shafting systems of generating plants using diesel engines.

2. The requirements of this Chapter apply mutatis mutandis to the shafting systems of auxiliaries (excluding auxiliary machinery for specific use etc., hereinafter the same in this Chapter) driven by diesel engines.

8.1.2 Data to be Submitted

1. Torsional vibration calculation sheets covering the following items are to be submitted for approval.

(1) Natural frequency calculation tables for one node and two nodes vibration, also more nodes vibrations if necessary

(2) Calculation results of the torsional vibration stress at each resonant critical within a speed range up to 120% of the maximum continuous revolutions, and for the diesel installations, those of the torsional vibration stress for the flank appearing in the speed range from 90 to 120% caused by a resonance of the first major order, i.e. the *n* th or *1/2 n* th order (*n* denotes the number of cylinders), having its critical speed above 120% of the maximum continuous revolutions.

(3) Arrangement of crank throws and firing order (in case for the diesel installations)

(4) For propulsion shafting systems intended to be continuously operated under one cylinder misfiring (i.e. no injection but with compression) condition, calculation results of the torsional vibration stress with any one cylinder misfiring giving rise to the highest torsional vibration stress.

2. Notwithstanding the requirements specified in **-1**, submission of the torsional vibration calculation sheets may be omitted in the following cases provided that approval of the Society is obtained.

(1) In case where the shafting system is of the same type as previously approved one

(2) In case where there is a slight alternation in specifications of the vibration system, and the frequency and torsional vibration stress can be deduced with satisfactory accuracy on the basis of the previous results of calculations or measurements.

8.1.3 Measurements

For the shafting systems where the submission of the torsional vibration calculation sheets is required, measurements to confirm correctness of the estimated value are to be carried out. However, where the submission of the calculation sheets is omitted according to the requirement in 8.1.2-2 and the Society considers that there is no critical vibration within the service speed range, the measurement of torsional vibration may by omitted.

8.2 Allowable Limit

8.2.1 Crankshafts

The torsional vibration stresses on the crankshafts of diesel engines used as main propulsion machinery of diesel ships are to be in accordance with the following requirements **(1)** through **(4)**:

(1) For continuous operation, the torsional vibration stresses are not to exceed τ_1 given in followings, within the range from 80% to and at 100% of the maximum continuous revolutions.

(a) For 4-stroke cycle in-line diesel engines or 4-stroke cycle vee type diesel engines with firing intervals of 45°or 60° , the value of τ_1 is given by the following formula:

$$\tau_1 = 45 - 24\lambda^2$$

(b) For 2-stroke cycle diesel engines or 4-stroke cycle vee type diesel engines other than shown in **(a)** above, the value of τ_1 is given by the following formula:

$$\tau_1 = 45 - 29\lambda^2$$

τ_1 : Allowable limit of torsional vibration stresses for the range of $0.8 < \lambda \leq 1.0$ (N/mm^2)

λ: Ratio of the number of revolutions to the number of maximum continuous revolutions

(2) Within the range below and at 80% of the maximum continuous revolutions, the torsional vibration stresses are not to exceed τ_2 given in followings. In case where the stresses exceed the value calculated by the formula of τ_1 in **(1)**, the barred speed ranges specified in **8.3** are to be imposed.

$\tau_2 = 2\tau_1$

τ_2: Allowable limit of torsional vibration stresses for the range of $\lambda \leq 0.8$ (N/mm^2)

λ : Ratio of the number of revolutions to the number of maximum continuous revolutions

(3) The torsional vibration stresses are not to exceed 3 t given in the followings, within the range from the maximum continuous revolutions to 115%.

(a) For 4-stroke cycle in-line diesel engines or 4-stroke cycle vee type diesel engines with firing intervals of 45°or 60° , the value of τ_3 is given by the following formula:

$$\tau_3 = 21 + 237(\lambda - 0.8)\sqrt{\lambda - 1}(1 < \lambda \leq 1.15)$$

(b) For 2-stroke cycle diesel engines or 4-stroke cycle vee type diesel engines other than shown in **(a)** above, the value of τ_3 is given by the following formula:

$$\tau_3 = 16 + 237(\lambda - 0.8)\sqrt{\lambda - 1}(1 < \lambda \leq 1.15)$$

τ_3: Allowable limit of torsional vibration stresses for the range of $1.0 < \lambda \leq 1.15$ (N/mm^2)

λ: Ratio of the number of revolutions to the number of maximum continuous revolutions

(4) In case where the tensile strength of the shaft material exceeds 440 N/mm^2, or its yield strength exceeds 225 N/mm^2, the values of τ_1, τ_2 and τ_3 given in **(1)**, **(2)** and **(3)** may be increased by multiplying the factor f_m given in the following formula:

(a) For τ_1 and τ_3

$$f_m = 1 + \frac{2}{3}\left(\frac{T_s}{440} - 1\right)$$

(b) For τ_2

$$f_m = \frac{Y}{225}$$

Where

f_m : Correction factor for allowable limit of torsional vibration stress concerning the shaft material

T_s: Specified tensile strength of the shaft material (N/mm^2). However, the value of T_s for calculating f_m is not to exceed 760 N/mm^2 for carbon steel forgings, or 1080 N/mm^2 for low alloy steel forgings.

Y: Specified yield strength of the shaft material (N/mm^2)

8.2.2 Intermediate Shafts, Thrust Shafts, Propeller Shafts and Stern Tube Shafts

1. For diesel ships, the torsional vibration stresses on the intermediate shafts, thrust shaft, propeller shafts and stern tube shafts made of steel forgings (excluding stainless steel, etc.) are to be in accordance with the following requirements **(1)** and **(2)**. Those belong to the propeller shafts Kind 2 or the stern tube shafts Kind 2, however, are to be deemed appropriate by the Society.

(1) For continuous operation, the torsional vibration stresses are not to exceed τ_1 given in the following formulae, within the range from 80% to and at 105% of the maximum continuous revolutions.

$$\tau_1 = \frac{T_s + 160}{18} C_K C_D (3 - 2\lambda^2)(\lambda \leq 0.9)$$

$$\tau_1 = 1.38 \frac{T_s + 160}{18} C_K C_D (0.9 < \lambda)$$

τ_1: Allowable limit of torsional vibration stresses for the range of $0.8 < \lambda \leq 1.05$ (N/mm^2)

λ : Ratio of the number of revolutions to the number of the maximum continuous revolutions

T_s : Specified tensile strength of shaft material (N/mm^2)

However, the value of T_s for using in the formulae is not to exceed 800N/mm^2 (600N/mm^2 for carbon steels in general) in intermediate shafts and thrust shafts, and 600 N/mm^2 in propeller shafts and stern tube shafts. Where propeller shafts and stern tube shafts are made of the approved corrosion resistant materials or other materials having no effective means against corrosion by sea water, the value of T_s for using in the formulae is to be as deemed appropriate by the Society.

C_K : Coefficient concerning to the type and shape of the shaft, given in **Table 8.1**.

C_D: Coefficient concerning to the shaft size and determined by the following formula:

$$C_D = 0.35 + 0.93d^{-0.2}$$

d = Diameter of the shaft *(mm)*

(2) Within the range below and at 80% of maximum continuous revolutions, the torsional vibration stress (including those in one cylinder misfiring conditions if intended to be continuously operated under such conditions) are not to exceed τ_2 given in followings. In case where the stresses exceed the value calculated by the formula of τ_1 for the range of $\lambda \leq 0.9$in **(1)**, the barred speed ranges specified in **8.3** are to be imposed.

$$\tau_2 = 1.7\tau_1/\sqrt{C_K}$$

where;

τ_2 : Allowable limit of torsional vibration stesses for the range of $\lambda \leq 0.8$ (N/mm^2)

Other symbols used here are the same as in **(1)**

2. For diesel ships, the torsional vibration stresses on the propeller shafts and stern tube shafts made of stainless steel forgings, etc. are to be in accordance with the following requirements **(1)** and **(2)**.

(1) For continuous operation, the torsional vibration stresses are not to exceed τ_1 given in the following formulae, within the range from 80% to and at 105% of the maximum continuous revolutions.

$$\tau_1 = A - B\lambda^2 (\lambda \leq 0.9)$$

$$\tau_1 = C(0.9 < \lambda)$$

τ_1 : Allowable limit of torsional vibration stresses for the range of $0.8 < \lambda \leq 1.05$ (N/mm^2)

λ: Ratio of the number of revolutions to the number of the maximum continuous revolutions

A, B, C: Values determined by the materials used, given in **Table 8.2**. For the materials other than specified in the Table, however, the values are to be deemed appropriate by the Society.

(2) Within the range below and at 80% of maximum continuous revolutions, the torsional vibration stress (including those in one cylinder misfiring conditions if intended to be continuously operated under such conditions) are not to exceed τ_2 given in followings. In case where the stresses exceed the value calculated by the formula of τ_2 for the range of $\lambda \leq 0.9$ in **(1)**, the barred speed ranges specified in **8.3** are to be imposed.

$$\tau_2 = 2.3\tau_1$$

τ_2: Allowable limit of torsional vibration stresses for the range of $\lambda \leq 0.8$ (N/mm^2)

Other symbols used here are the same as in **(1)**.

3. Allowable limits of torsional vibration stresses on the shafts made of materials other than specified in **-1** and **-2**, and allowable limits of torsional vibration stresses on the intermediate shafts, thrust shafts, propeller shafts and stern tube shafts for steam turbine ships, gas turbine ships, and electric propulsion ships, or for diesel ships which have electromagnetic slip couplings between main propulsion machinery and main propulsion systems are to be deemed appropriate by the Society.

Table 8.1 Values of C_K (5)

Intermediate shaft with						Thrust shaft		Propeller shaft and stern tube shaft	
integral flange coupling	flange coupling either shrink fit, push fit or cold fit	keyway, tapered connection	keyway, cylindrical connection	transverse hole(1)	Longitudinal slot (2)	on both sides of thrust collar	In way of part subjected to axial load of roller baring	near the big end of the tapered part of propeller shaft(3)	excluding the portion given in the left column(4)
1.0	1.0	0.6	0.45	0.50	0.30	0.85	0.85	0.55	0.80

Notes:

1 To be in accordance with **note (3) of Table 6.2**.

2 To be in accordance with **note (4) of Table 6.2**.

3 The portion between the big end of the tapered part of propeller shaft (in case where propeller is fitted with flange, the fore face of the flange) and the fore end of the aftermost stern tube bearing, or 2.5 d_s, whichever is the greater. Where; d_s: required diameter of the propeller shaft or stern tube shaft.

4 The portion in the direction toward the bow up to the fore end of the fwd stern tube seal.

5 The value of C_K other than above is to be determined by the Society based on the submitted data in each case.

Table 8.2 Values of A, B and C

	A	B	C
KSUSF316 *KSUS316-SU*	40.7	30.6	15.9
KSUSF316L KSUS316L-SU	37.6	28.3	14.7

8.2.3 Shafting System of Generating Plants

1. The torsional vibration stresses on the crankshafts of diesel engines used for generating plants (including propulsion generating plants used for electric propulsion ships, hereinafter the same in this Chapter) are to be in accordance with the following requirements **(1)** and **(2)** :

(1) The torsional vibration stresses are not to exceed τ_1 given in the followings, within the range from 90% to 110% of the maximum continuous revolutions.

(a) For 4-stroke cycle in-line diesel engines or 4-stroke cycle vee type diesel engines with firing intervals of 45°or 60°, the value of τ_1 is given by the following formula :

$$\tau_1 = 21\ N/mm^2$$

(b) For 2-stroke cycle diesel engines and 4-stroke cycle vee type diesel engines other than shown in **(a)** above, the value of τ_1 is given by the following formula :

$$\tau_1 = 16N/mm^2$$

(2) Within the range below and at 90% of the maximum continuous revolutions, the torsional vibration stresses are not to exceed τ_2 given in the followings. In case where the stresses exceed the value of τ_1 given in **(1)**, the barred speed ranges specified in **8.3** are to be imposed.

$$\tau_2 = 90N/mm^2$$

2. The torsional vibration stresses on the generator shafts of generating plants using diesel engine are to be in accordance with the following requirements **(1)** and **(2)** :

(1) The torsional vibration stresses are not to exceed τ_1 given in the followings, within the range from 90% to110% of the maximum continuous revolutions.

$$\tau_1 = 31N/mm^2$$

(2) Within the range below and 90% of the maximum continuous revolutions, the torsional vibration stresses are not to exceed τ_2 given in the followings. In case where the stresses exceed the value of τ_1 given in **(1)**, the barred speed ranges specified in **8.3** are to be imposed.

$$\tau_2 = 118 N/mm^2$$

3. In case where the tensile strength of the shaft material exceeds 440 N/mm^2, or its yield strength exceed 225 N/mm^2, the values of τ_1 and τ_2 given in **-1** and **-2** may be increased by multiplying the factor f_m given in **8.2.1(4).**

8.2.4 Power Transmission Systems

1. The torsional vibration torques on the power transmission systems are to be in accordance with the following requirements **(1)** and **(2)** :

(1) Within the range applied the allowable limit of 1 t specified in **8.2.1**, **8.2.2** and **8.2.3**, the amplitudes of the torsional vibration torques are not to exceed the mean transmitting torque of the systems.

(2) Within the range other than that specified in **(1)**, the barred speed ranges are to be imposed in case where the amplitudes of the torsional vibration torques exceed the mean transmitting torque.

2. The torsional vibration stresses on the gear shafts are to comply with the requirements for the intermediate shafts specified in **8.2.2**.

3. The allowable limits of the torsional vibration torques, stresses or amplitudes for the power transmission systems (including shaft couplings) other than gearings are to comply with the provisions specified elsewhere.

8.2.5 Avoidance of Major Criticals

The major criticals of one node vibration in in-line diesel engine, (e.g. the *n* th and *n*/2 th order for 4-stroke cycle and the *n* th order for 2-stroke cycle *n* denotes the number of cylinders), are not to exist within the following speed range except when an approval is specifically obtained by the Society:

For main propulsion shafting system $0.8 \leq \lambda \leq 1.1$

For shafting system of generating plants $0.9 \leq \lambda \leq 1.1$

Where

λ : Ratio of the number of revolutions at the major critical to the maximum continuous revolutions

8.2.6 Detailed Evaluation for Strength

Special consideration will be given to the allowable limit of torsional vibration stresses not complying with the requirements in **8.2.1**, **8.2.2** and **8.2.3**, provided that detailed data and calculations are submitted to the Society and considered appropriate.

8.3 Barred Speed Range

8.3.1 Barred Speed Range for Avoiding Continuous Operation

1. In case where the torsional vibration stresses exceed the allowable limit $\tau_1$specified in **8.2**, the barred speed ranges are to be imposed in accordance with the followings. The barred speed ranges are to be marked with red zones on the engine tachometers for passing through the ranges as rapidly as possible.

(1) The barred speed ranges are to be imposed between the following speed limits.

$$\frac{16N_c}{18-\lambda} \leq N_0 \leq \frac{(18-\lambda)N_c}{16}$$

Where

N_0: The number of revolutions to be barred (*rpm*)

N_c : The number of revolutions at the resonant critical (*rpm*)

λ: Ratio of the number of revolutions at the resonant critical to the maximum continuous revolutions

(2) For controllable pitch propellers, both full and zero pitch conditions are to be considered.

(3) Restricted speed ranges in one cylinder misfiring conditions are to enable safe navigation even where the ship is provided with one propulsion engine.

2. In case where the range in which the stresses exceed the allowable limit τ_1 specified in **8.2** is verified by measurements, such range may taken as the barred speed range for avoiding continuous operation, notwithstanding the required range specified in **-1**, having regard to the tachometer accuracy.

3. For engines where clearing the barred speed range for avoiding continuous operation specified in **8.3.1-1** and **-2** above is not readily available, transferring of the resonant points of torsional vibrations and other necessary measures are to be taken.

Chapter 9 BOILERS AND INCINERATORS

9.1 General

9.1.1 Scope

The requirements in this Chapter apply to boilers excluding those given in the following **(1)** and **(2)**, thermal oil heaters and incinerators:

(1) Steam boilers with design pressure not exceeding 0.1 *MPa* and heating surface not exceeding 1 m^2

(2) Hot water boilers with design pressure not exceeding 0.1 *MPa* and heating surface not exceeding 8 m^2

9.1.2 Terminology

Terms used in this Part are defined as follows:

(1) "Boiler" is plant which generates steam or hot water by means of flame, combustion gas or other hot gases including the superheater, reheater, economizer and exhaust gas economizer and other equivalents.

(2) "Essential auxiliary boiler" is a boiler which supplies steam necessary for the operation of auxiliary machinery essential for main propulsion, auxiliary machinery for manoeuvring and the safety, and of generators.

(3) "Exhaust gas boiler" is a boiler which generates steam or hot water using only the exhaust gas from diesel engines and has a steam space or a hot well and has an outlet of steam or hot water.

(4) "Exhaust gas economizers" is equipment which generates steam or hot water using only the exhaust gas from diesel engine and has not a steam space or a hot well.

(5) "Heating surface of a boiler" is an area calculated on the combustion gas side surface where one side is exposed to combustion gas and the other side to water, but the heating surface of superheater, reheater, economizer or exhaust gas economizer is excludes, unless specially specified.

(6) "Approved working pressure of boilers" and "nominal pressure of boilers with built in superheater" are as defined in **1.2.21** and **1.2.22, Part 1A**.

(7) Design pressure is a pressure used in the calculations made to determine the scantlings of each component and is the maximum permissible working pressure to the component. The design pressure of boiler drum is not to be less than the approved working pressure of the boiler.

9.1.3 Drawings and Data to be Submitted

Drawings and data to be submitted are generally as follows:

(1) Drawings (with materials and scantlings)

a. General arrangement of boiler
b. Details of shells and headers (including the internal fittings)
c. Details of seats for boiler fittings and nozzles
d. Arrangement and details of boiler tubes
e. Arrangement and details of tubes of superheater and reheater
f. Details of internal desuperheater
g. Arrangement and details of tubes of economizer or exhaust gas economizer
h. Details of air preheater
i. Arrangement and details of boiler fittings
j. Arrangement of safety valves (with principal particulars)
k. Details of bursting disk (where fitted in accordance with the requirement in **9.9.3-12(4)**)
l. Other drawings considered necessary by the Society

(2) Data

a. Particulars of boiler
b. Welding specifications (with welding procedures, welding consumables and welding conditions)
c. Operating instructions (shell type exhaust gas economizer only)
d. Other data considered necessary by the Society

9.2 Materials and Welding

9.2.1 Materials

1. The materials used for the construction of the pressure parts of boilers are to comply with the requirements in **3.2**, **3.7**, **4.1**, **4.2**, **4.4**, **5.1**, **5.4**, or **6.1**, **Part 10** according to respective services, and to be tested in accordance with the requirements in **Chapter 1** and **Chapter 2** of the said Part. However, other materials than stated in the above may be used, provided that the material specifications are submitted and approved by the Society.

2. Notwithstanding the requirements given in **-1**, materials specified in the recognized standards may be used for the fittings such as valves and nozzles fitted on the boiler, where approved by the Society in consideration of the dimensions and service conditions.

9.2.2 Service Limitation of Materials used for Fittings

For service limitation of materials to be used for the fittings, the requirements in **9.9.1** are to be complied with.

9.2.3 Heat Treatment of Steel Plates

In case where heat treatment, such as hot forming or stress relieving, is carried out on steel plates during the manufacturing process of boilers, the manufacturer of the boiler is to inform such intention with an order for the materials. What are expected of the manufacturer of steel plates in this case, are specified in **3.2.4, Part 10.**

9.2.4 Non-destructive Test for Cast Steels

The cast steel materials used for boiler drum exposed to internal pressure are to be subjected to radiographic test and magnetic particle test and it is to be confirmed that they are free from detrimental defects.

9.2.5 Welding

Welding workmanship of the boiler is to comply with the requirements in **Chapter 11**.

9.3 Design Requirements

9.3.1 Symbols

Unless expressly specified otherwise, the symbols used in this Chapter are as follows:

f: Allowable stress (N/mm^2) conforming to the requirements in **9.4.1** or **12.2.1**.

T_r: Required thickness (mm) calculated by design pressure. Allowable pressure is a pressure obtained by replacing the required thickness with actual thickness in the formulae.

P: Design pressure (MPa)

J: Minimum value of the efficiency specified in 9.4.2

R: Internal radius of drum (mm)

9.3.2 Design Pressure of Economizers and Exhaust Gas Economizers

1. The design pressure of economizer is not to be less than the maximum working pressure of the economizer determined basing upon the maximum working pressure of the feed pump.

2. The design pressure of exhaust gas economizer is not to be less than the maximum working pressure of the exhaust gas economizer determined basing upon the maximum working pressure of the boiler water circulating pump.

9.3.3 Considerations for Structural Strength

1. Where effects of additional stresses such as local stress concentration, repeated loads and thermal stress are significant, suitable measurements such as to increase thickness are to be taken if necessary.

2. The fixed parts of the flue tube of the vertical boilers are to be so designed that deformation of the flue tube induced by the thermal expansion of the hemispherical furnace may not be extremely restricted.

3. Sufficient consideration is to be given to the following **(1)** and **(2)** to prevent overheat of the water tubes for the boilers having a high carolific capacity of combustion chamber :

(1) Boiler water is to sufficiently circulate to the water tubes, and

(2) Proper means such as water softner, etc. are to be provided to.

9.3.4 Boilers of Unusual Shape

1. Where it is not practicable or reasonable to calculate the strength according to the requirements in 9.5 to 9.7 as the shape of the Part subject to a pressure is unusual, other suitable detailed calculation is to be carried out with the approval by the Society and the Society will consider it as complying with the requirements in 9.5 to 9.7 taking into account of the calculation results.

2. Where it is not appropriate to design according to the requirements in 9.5 to 9.7 as the shape of the Part subject to a pressure is unusual, strains or deformations under a suitable load are to be measured with the approval by the Society and the Society will consider them as complying with the requirements in 9.5 to 9.7 taking account of the results of the measurement.

9.3.5 Considerations for Installing

1. Boilers are to be so installed as to minimize the effects of the following loads or external forces:

(1) Ship motions or vibrations caused by machinery installations

(2) External forces caused by the piping and supporting members fitted on the boiler

(3) Thermal expansions due to temperature fluctuation

2. Boilers are to be installed at a position clear of the bulkheads as far as practicable, (*See*, **20.3.3, Part 2**.)

3. Shell type exhaust gas economizer are to be installed as the tube plate to shell connection can be inspected easily.

9.3.6 Protections against Flame

In case where part of the boiler drum and tube header is of the construction exposed to flames or high temperature gas, proper thermal insulation or other suitable means is to be provided thereto. For the shell type exhaust gas economizer, the insulation at the circumference of the tube end plate are to enable ultrasonic examination of the tube plate to shell connection.

9.3.7 Consideration for Soot Fire

Consideration is to be given to prevent exhaust gas boilers and exhaust gas economizers, from being damaged by a soot fire.

9.4 Allowable Stress and Efficiency

9.4.1 Allowable Stress

The allowable stress for each material is to be determined in accordance with the following. In this case, metal temperatures used to evaluate the allowable stress of boilers are to be the designed maximum temperature of the internal fluid and the temperature of the heating surface is to be increased by that given in **Table 9.1**. The metal temperature is not to be less than 250°C.

Table 9.1 Temperature Increment to Internal Fluid Temperature for Metal Temperature at Heating Surface

Heating surface, in general	Heated by contact	25˚C
	Heated by radiation	50˚C
Heating surface of superheater	Heated by contact	35˚C
	Heated by radiation	50˚C
Heating surface of economizer and exhaust gas economizer		25˚C

(1) Excluding all cast steels, the allowable stress (f) of carbon steel (including carbon manganese steel, hereinafter referred to as the same in this Chapter) and low alloy steels is not to be greater than value obtained from the following formulae, whichever is the smallest. However, the values given in **Table 9.2** for the allowable stress for each material temperature may also be used instead from the formulae.

$$f_1 = \frac{R_{20}}{2.7}, f_2 = \frac{E_t}{1.6}, f_3 = \frac{S_R}{1.6}, f_4 = \frac{S_C}{1.0}$$

where:

R_{20}: Specified tensile strength for steel concerned, at room temperature (*N/mm*^{2})

E_t: Yield point of steel concerned, at metal temperature (or 0.2% proof stress) (*N/mm*^{2})

S_R : Average stress for steel concerned to produce rupture in 100,000 *hours* at metal temperature or, if the width of the end of the scatter band of results exceeds ±20% of the average value, 1.25 times the minimum stress at metal temperature to produce rupture in 100,000 *hours* (*N/mm*^{2})

S_C: Average stress to produce an elongation (creep), for steel concerned, of 1% in 100,000 *hours* at metal temperature (*N/mm*^{2})

(2) The allowable stress of electric resistance welded steel pipes is to be 85% of the values given in **Table 9.2**.

(3) The allowable stress of cast steels is to be 80% of the value obtained by the formula in **(1)** or the value given in **Table 9.2**. Cast steel exceeding 50 *mm* in thickness is not to be used unless specially approved by the Society.

(4) The stress values of materials other than those specified in **(1)** and **(3)** will be considered in each case by the Society taking account of the mechanical properties of the materials.

Table 9.2 Value of Allowable Stress

Kind of material (grade)	Allowable stress (*f*) *N/mm*^{2}											
	250 ˚*C* or below	300 ˚*C*	350 ˚*C*	375 ˚*C*	400 ˚*C*	425 ˚*C*	450 ˚*C*	475 ˚*C*	500 ˚*C*	525 ˚*C*	550 ˚*C*	575 ˚*C*
Rolled steel plate for boiler												
*KP*42	110	104	103	96	88	76	57	39	-	-	-	-
*KP*46	122	117	113	106	95	80	58	39	-	-	-	-
*KP*49	124	122	121	114	102	84	58	39	-	-	-	-
*KPA*46	122	117	113	113	113	108	101	90	69	48	-	-
*KPA*49	124	122	121	121	121	117	106	91	69	48	-	-
Steel header												
*KBH*1	105	104	103	97	88	76	57	39	-	-	-	-

*KBH*2	117	115	113	106	95	80	58	39	-	-	-	-
*KBH*3	102	99	96	96	96	93	91	87	67	-	-	-
*KBH*4	106	104	103	103	103	102	98	92	74	-	-	-
*KBH*5	106	104	103	103	103	102	98	92	81	64	-	-
*KBH*6	106	104	103	103	103	102	98	92	81	64	-	-
Steel tuve for boiler												
*KSTB*33	86	84	81	78	74	66	-	-	-	-	-	-
*KSTB*35	88	87	86	82	76	76	53	-				
*KSTB*42	113	104	103	97	88	94	57	-	-	-	-	-
*KSTB*12	102	99	96	96	96	102	91	87	69	-	-	-
*KSTB*22	106	104	103	103	103	102	98	92	81	64	44	-
*KSTB*23	106	104	103	103	103	102	98	92	81	64	47	34
*KSTB*24	106	104	103	103	103	102	98	92	81	64	48	36
Forged steel (see **Part 10**)	¼ of specified tensile strength of material (where used at 350˚C or below)											
Cast steel (see **Part 10**)	1/5 of specified tensile strength of material (where used at 350˚C or below)											

Note:
In case where the metal temperature is between those given in the Table, the value of allowable stress is to be determined by interpolation.

9.4.2 Efficiencies of Joints and Ligament

1. The efficiency of joints is to be as follows:

(1) Seamless shells: 1.00

(2) Welded shells

(a) Double-welded butt joints: 1.00

(b) Other cases: 0.90

2. The efficiency of ligament is to be as follows:

(1) The efficiency of longitudinal ligament (hereinafter referred to as "longitudinal efficiency") along the row of tube holes of shell plate having a row parallel or nearly parallel to the shell axis, or of shell or tube plate having several parallel rows with sufficient distance to each other, is to be determined by the following formulae:

(a) In case where the pitch of tube holes is uniform:

$$J_1 = \frac{p-d}{p}$$

where:

J_1: Efficiency of ligament

p: Pitch of tube holes (*mm*)

d : Diameter of tube holes (mm)

(b) In case where the pitch of tube holes is irregular :

$$J_2 = \frac{L - nd}{L}$$

where:

J_2 : Efficiency of ligament

d: As specified in **(a)**

L: Total length between centers corresponding to n consecutive ligaments (mm)

n: Number of tube holes in length L

(2) The efficiency of circumferential ligament (hereinafter referred to as circumferential efficiency) at the part of tube holes drilled in the circumferential direction of the shell is to be calculated in a similar manner to that specified in **(1)**, and is not to be less than 50% of the longitudinal efficiency. In this case, the pitch of tube holes in the circumferential direction is to be measured either on the flat plate before rolling or along the median line of plate thickness after rolling.

(3) The efficiency of ligament at the part of tube holes drilled in the diagonal direction of the shell is to be determined by the following formula :

(a) Where tube holes are drilled in the diagonal direction of the shell as shown in **Fig. 9.1** and **Fig. 9.2**: The efficiency obtained from the following formula or the longitudinal efficiency, whichever is the smaller, is to be taken as the efficiency of ligament at the part of tube holes.

$$J_3 = \frac{2}{A + B + \sqrt{(A - B)^2 + 4C^2}}$$

Where:

J_3 : Efficiency of ligament

$$A = \frac{cos^2\alpha + 1}{2\left(1 - \frac{dcos\,\alpha}{a}\right)}$$

$$B = \frac{1}{2}\left(1 - \frac{dcos\,\alpha}{a}\right)(sin^2\alpha + 1)$$

$$C = \frac{sin\alpha cos\alpha}{2(1 - \frac{dcos\,\alpha}{a})}$$

$$cos\alpha = \frac{1}{\sqrt{1 + \frac{b^2}{a^2}}}$$

$$sin\alpha = \frac{1}{\sqrt{1 + \frac{a^2}{b^2}}}$$

α: As shown in **Fig. 9.1**, **Fig. 9.2** and **Fig. 9.3**

a, b : As shown in **Fig. 9.1**, **Fig. 9.2** and **Fig. 9.3** (mm)

d: Diameter of tube holes (mm)

(b) In **(a)**, where the tube holes are arranged in a regular staggered spacing as shown in **Fig. 9.3**:

The efficiency obtained from the formula in **(a)**, twice the circumferential efficiency or the longitudinal efficiency, whichever is the smallest, is to be taken as the efficiency of ligament at the part of tube holes.

Note: The efficiencies of ligament obtained from **(a)** and **(b)** are shown in **Fig. 9.4** and **Fig. 9.5** taking the ratio $\frac{b}{a}$ on the abscissa, and ratio $\frac{2a-d}{2a}$ as parameter.

(4) The efficiency of ligament per unit length, where the tube holes are irregularly arranged along the longitudinal direction of the shell, is to be the smallest value calculated by the following **(a)** or **(b)**, whichever is the smaller.

However, the efficiency need not be smaller than the minimum efficiency calculated by taking L_1 as the distance between the centres of tubes on both ends of the tube rows within the length equal to the inside diameter of the shell (the distance to the center of the adjacent tube hole, in case where there is only one tube hole within the length equal to the inside diameter of the shell).

(a) For the length L_1 equal to the inside diameter of the shell (1,520 *mm* maximum)

$$J_4 = \frac{a+b+c\ldots\ldots\ldots}{L_1}$$

(b) For the length L_2 equal to the inside radius of the shell (760 *mm* maximum)

$$J_5 = \frac{a+b+c\ldots\ldots\ldots}{L_2} \text{x}1.25$$

where:

J_4 and J_5 : Efficiency of ligament

a, b, c : Distances between tube holes arranged along the longitudinal direction of shell. If they are arranged in a diagonal direction, the distances are to be the length projected on the longitudinal direction multiplied by the efficiency obtained from **(3)**.

9.5 Calculations of Required Dimensions of Each Member

9.5.1 Restrictions to Thickness of Each Member

1. The thickness of shell plate and end plate are not to be less than 6 *mm*. The thickness of the formed end plate except for the full hemispherical end plate is not to be less than the thickness (calculated by using the efficiency equal to 1.00) of the shell to which the end plate is attached.

2. The thickness of tube plates and flat plates is not to be less than 10 *mm* for tube plates, nor 6 *mm* for flat plates.

3. The thickness of nozzles welded to drum shells and connected with mountings, etc. is not to be less than either the value 2.5 *mm* added to 1/25 of the outside diameter of the nozzle or the value calculated by the formula given in **9.7.4**. However, this value need not be more than the thickness of the drum at which the nozzle is welded.

4. The thickness of furnace plate is not to be less than 5 *mm* nor more than 22 *mm*.

9.5.2 Required Thickness of Cylindrical Shell Plates subjected to Internal Pressure

The required thickness of the cylindrical shell plates subjected to internal pressure is to be calculated by the following formula. However, in the case of the cylindrical shell plate having openings for which reinforcement is required, openings are to be reinforced in accordance with the requirements in 9.6.3.

$$T_r = \frac{PR}{fJ - 0.5P} + 1$$

Fig. 9.1-9.3

Fig. 9.1 Spacing of Holes on Diagonal Line Longitudinal direction of the shell

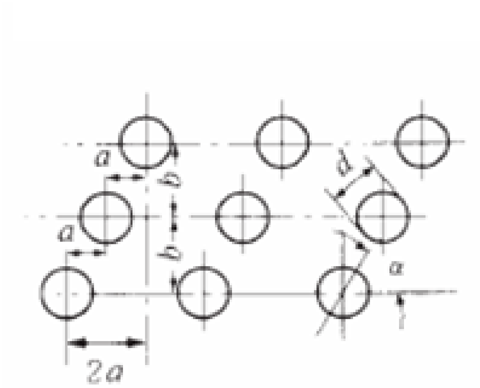


Fig. 9.2 Saw Tooth Pattern of Holes Longitudinal direction of the shell

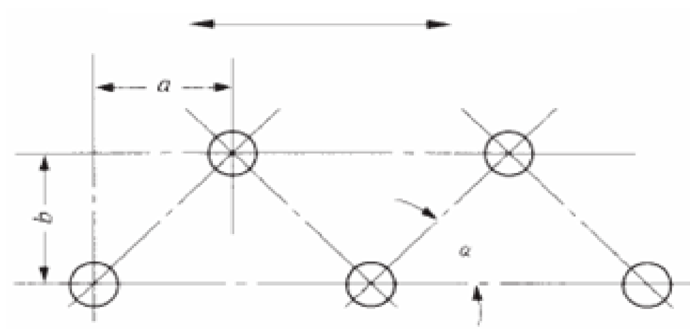


Fig. 9.3 Regular Staggered Pattern of Holes Longitudinal direction of the shell

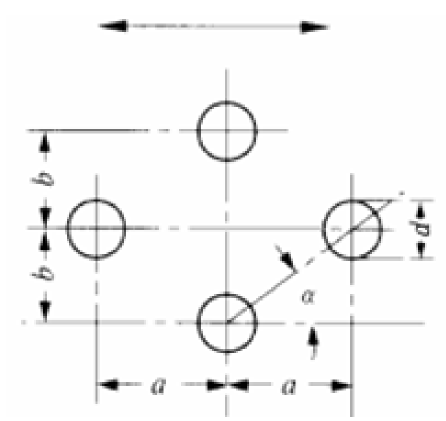


Fig. 9.4 The Efficiency of Ligament at the Part of Tube Holes drilled in the Circumferential Direction

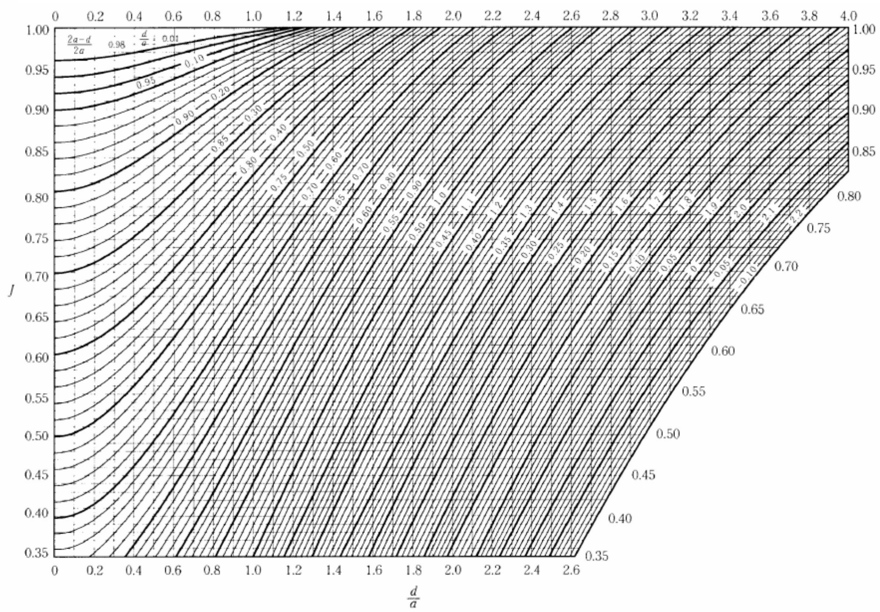
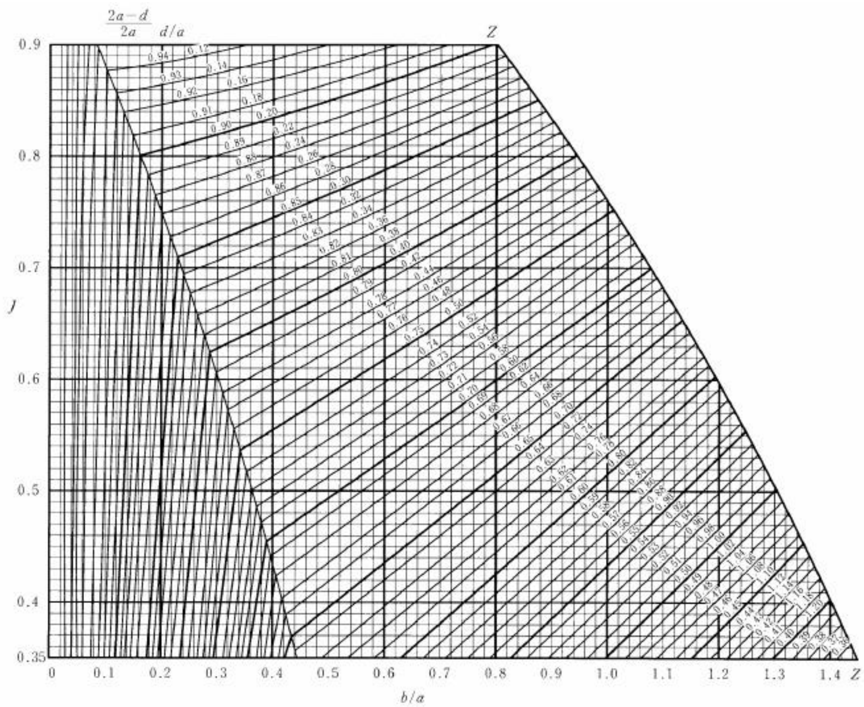


Fig. 9.5 The Efficiency of Ligament at the Part of Tube Holes drilled in the Diagonal Direction



Note:

Where the point falls in the field on the right side of the intersection *Z-Z*, the longitudinal efficiency is to be deemed as the efficiency at the part of tube holes.

9.5.3 Required Thickness of Formed End Plates subjected to Pressure on Concave Side without Stays or Other Supports

1. The required thickness of end plate having no opening is to be calculated by the following formula:

(1) Dished and hemispherical end plates

$$T_r = \frac{PR_1W}{2fJ - 0.5P}$$

where:

$W = \frac{1}{4}\left(3 + \sqrt{\frac{R_1}{r}}\right)$ for dished end plate

W = 1 for hemispherical end plate

R_1: Inside crown radius

It is to be less than the outside diameter of the end plate.

r: Inside knuckle radius

It is not to be less than 6% of the outside diameter of the skirt of the end plate or 3 times the actual thickness of the end plate, whichever is the greater.

(2) Semi-ellipsoidal end plates (in case where half of the inside minor axis of the end plate is not less than 1/4 of the inside major axis of the end plate)

$$T_r = \frac{PR}{fj - 0.25P} + 1$$

2. The required thickness of the end plate having openings is to comply with the following requirements in **(1)**, **(2)** or **(3)**:

(1) In case where no reinforcement for openings is necessary according to the requirements in **9.6.2**, or the openings are reinforced in accordance with the requirements in **9.6.3-3** and **-4,** the required thickness is to be calculated by the formula specified in **-1**

(2) Where an end plate has a flanged-in manhole or access opening with a maximum diameter exceeding 150 *mm*, and the flanged-in reinforcement complies with the requirement in **9.6.3-7,** the thickness is to be calculated as follows:

(a) Dished or hemispherical end plates

The thickness is to be increased by not less than 15% (if the calculated value is less than 3 *mm*, the value is to be taken to 3 *mm*) of the required thickness calculated by the formula specified in **-1(1)**. In this case, where the inside crown radius of the end plate is smaller than 0.80 times the inside diameter of the shell, the value of the inside crown redius in the formula is to be 0.80 times the inside diameter of the shell. In calculating the thickness of the end plate having two manholes in accordance with this **(a)**, the distance between the two manholes is not to be less than 1/4 of the outside diameter of the end plate.

(b) Semi-ellipsoidal end plates

The requirements in **-1(1)** are to be applied. However, in this case R_1 is to be 0.80 times the inside diameter of shell and W to be 1.77.

(3) The required thickness, where the openings are not reinforced in accordance with the requirements in **(1)** or **(2)**, is to be calculated by the following formula. However, the thickness is not to be less than the value obtained by the formula given in **-1**.

$$T_r = \frac{PD_0}{2f}K + 1$$

where:

D_0: Outside diameter of end plate (*mm*)

K: As shown in **Fig. 9.6**, however, this is applicable to the end plates complying with the following conditions:

Hemispherical end plates:

$$0.003D_0 \leq T_e \leq 0.16D_0$$

Semi-ellipsoidal end plates:

$$0.003D_0 \leq T_e \leq 0.08D_0$$

$$H \geq 0.18D_0$$

Dished end plates:

$$0.003D_0 \leq T_e \leq 0.08D_0$$

$$r \geq 0.1D_0$$

$r \geq 3T_e$

$R_1 \leq D_0$

$H \geq 0.18D_0$

$or \quad 0.01D_0 \leq T_e \leq 0.03D_0$

$r \geq 0.06D_0$

$H = 0.18D_0$

$or\ 0.02D_0 \leq T_e \leq 0.03D_0$

$r \geq 0.06D_0$

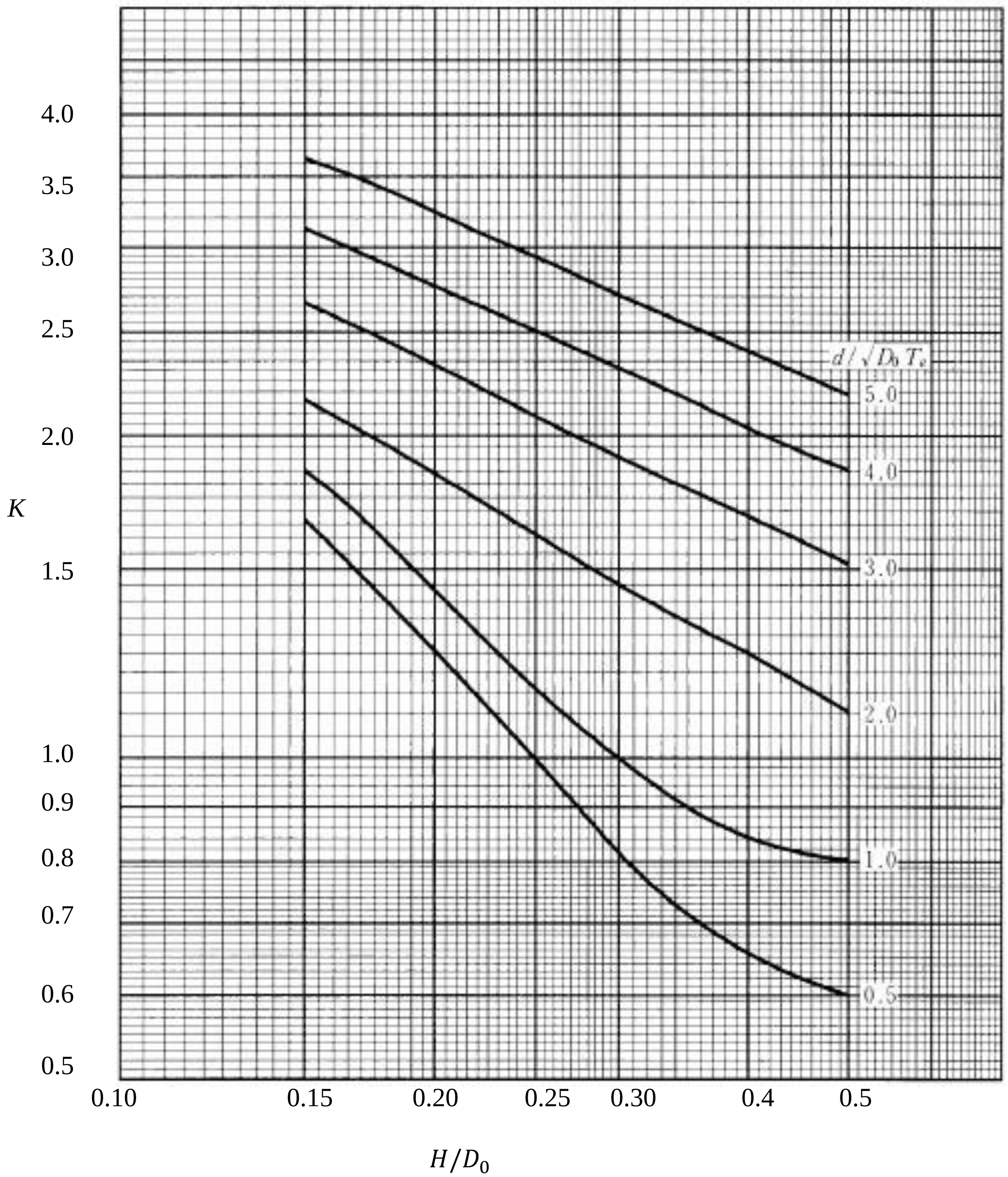
$0.18D_0 \leq H \leq 0.22D_0$

T_e : Actual thickness of end plate (*mm*)

H: Depth of end plate measured on its external surface from the plane of junction of the dished Part with the cylindrical part (*mm*)

R_1 and *r:* As specified in **-1(1)**

Fig. 9.6 Value of *K*



Note:

d: Diameter of openings(mm)

H: Depth of end plate measured on its external surface from the plane of junction of the dished part with the cylindrical part (mm)

D_0: Outside diameter of end plate (mm)

9.5.4 Required Thickness of Formed End Plates subjected to Pressure on Convex Side

The required thickness of formed end plates subjected to pressure on their convex sides is not to be less than the thickness calculated on the assumption that their concave sides are subjected to the pressure at least 1.67 times the design pressure.

9.5.5 Required Thickness of Flat End Plates and Cover Plates, etc., without Stays or Other Supports

1. Where the flat end plates and cover plates without stays or other supports are welded to the shell plates, the required thickness is to be calculated by the following formulae :

(1) Circular plate

$$T_r = C_1 d\sqrt{\frac{P}{f}} + 1$$

(2) Non-circular plate

$$T_r = C_1 C_2 d\sqrt{\frac{P}{f}} + 1$$

where:

C_1: Constant shown in **Fig. 9.9**

$C_2 = \sqrt{3.4 - 2.4\frac{d}{D'}}$ but need not be over 1.6.

d: Diameter shown in **Fig. 9.9** (for circular plates), or minimum length (for non-circular plates) (*mm*

D': Long span of non-circular end plates or covers measured perpendicular to short span (*mm*)

2. Where the flat cover plates without stays are bolted to the shell plate, the required thickness is to be calculated by the following formulae:

(1) Where full face gaskets are used;

For circular plate

$$T_r = d\sqrt{\frac{C_3 P}{f}} + 1$$

For non-circular plate

$$T_r = d\sqrt{\frac{C_3 C_4 P}{f}} + 1$$

(2) Where moment due to gasket reaction is to be taken into account ;

For circular plate

$$T_r = d\sqrt{\frac{C_3 P}{f} + \frac{1.78 W h_g}{f d^3}} + 1$$

For non-circulat plate

$$T_r = d\sqrt{\frac{C_3 C_4 P}{f} + \frac{6 W h_g}{f L d^2}} + 1$$

where:

C_3: Constant determined by bolting methods as shown in **Fig. 9.10**

C_4: $3.4 - 2.4\frac{d}{D'}$, but need not be over 2.5.

d: Diameter shown in **Fig. 9.10** (for circular plates), or minimum length (for non-circular plates) (mm)

D': Long span of non-circular end plates or covers measured perpendicular to short span (mm)

W: Mean load (N) of bolt loads necessary for the watertightness and allowable load for the bolt used actually

L: Total length of the circle passing through bolt centres (mm)

h_g: Arm length of moment due to gasket reaction shown in **Fig. 9.10** (mm)

9.5.6 Required Thickness of Flat Plates with Stays or Other Supports

1. The required thickness of flat plates except tube nests supported by stays or stay tubes is to be calculated by the following formula:

$$T_r = C_5 S\sqrt{\frac{P}{f}} + 1$$

where:

C_5 : Constant determined by the fixing methods of stays or stay tubes and given in **Table 9.3**. In case where various fixing methods are used, the value C_5 is to be the mean of the constants for the respective methods.

S: In case where stays or stay tubes are arranged regularly, "S" is to be calculated by the following formula:

$S = \sqrt{a^2 + b^2}\ (mm)$

a: Horizontal pitch of stays or stay tubes (mm)

b: Vertical pitch of stays or stay tubes (mm).

In case where stays or stay tubes are arranged irregularly, S is the diameter of the maximum circle (mm), which is passing through three supported points at least, but not including any supported point in the circle.

2. The position and constant C_5 of the supported point at the welding part between the plain end and the curved flange or shell, furnace, etc. are as follows:

(1) The commencement of curvature of the flange is to be regarded as point of support. Where, however, the inner radius of the curvature is greater than 2.5 times the thickness of the plate, the points located at a distance of 3.5 times the thickness of the plate from the outer surface of the flange may be considered as a commencement of the curvature. In this case, the value of constant C_5 is to be 0.39 where the plates are exposed to flame, or 0.36 where the plates are not exposed to flame.

(2) The inside of the welding part between the plain ends and the shell, furnaces, etc. are to be regarded as points of support. In this case, the value of constant C_5 is to be 0.47 where the plates are exposed to flame, or 0.43 where the plates are not exposed to flame.

3. The required thickness of tube nests of boiler tube plate supported by stay tubes is to be calculated by the following formula:

$$T_r = C_6 p \sqrt{\frac{P}{f}} + 1$$

where:

C_6: Constant determined by fixing methods of stay tubes as given in **Table 9.4**

p: In case where tube stays are arranged regularly, mean pitch of stay tubes obtained by dividing the sum of four sides of the quadrilateral formed by four supports (*mm*). In case where stay tubes are arranged irregularly, "S" (*mm*) is the diameter of the maximum circle, which is passing through three points at least, but not including any supported point in the circle, and $S/\sqrt{2}$ is to be used in lieu of "p"

4. The required thickness of the tube plates of vertical boilers having horizontal smoke tubes which form smoke tube nests is to be calculated by the formula in **-3** or by the following formula, whichever is the greater:

$$T_r = \frac{PDp}{1.97f(P - d_s)} + 1$$

where:

D: Twice the radial distance of the center of the outer row of tube holes from the axis of the shell (*mm*)

p: Vertical pitch of tubes (*mm*)

d_s: Diameter of tube holes in tube plate (*mm*)

5. The required thickness of back tube plates in cylindrical boiler with wet combustion chamber is to be calculated by the formula in **-3** or by the following formula, whichever is the greater :

$$T_r = \frac{PWH}{183(H - d_i)}$$

where:

H: Horizontal pitch of smoke tubes (*mm*)

d_i: Inside diameter of ordinary smoke tube (*mm*)

W: Depth of the upper part of combustion chamber (*mm*)

6. As for the scantlings of stayed top plate and stayed side plate of combustion chamber of the cylindrical boiler, the distance between the row of stays nearest to the tube plate or back plate and the commencement line of curvature of the tube plate or back plate is not to be greater than "a "determined by the formula in **-1**, substituting the actual thickness for the required thickness.

Table 9.3 Value of Constant C_5

Fixing method of stay or stay tube		In case the plates are not exposed to flame	In case the plates are exposed to flame
(1)	In case the stay are inserted into the plate as (5) *A* in **Fig.-9.9**	0.35	0.38
(2)	In case the stay are inserted into the plates as (5) *B* in **Fig.-9.9**	0.37	0.40
(3)	In case the stay are inserted into the plates as (5) *C* in **Fig.-9.9**	0.41	0.44
(4)	In case the stay are inserted into the plates as (5) *D* in **Fig.-9.9**	0.50	0.53
(5)	In case the stay tubes are inserted into the plates as (6) *A* in **Fig.-9.9**	0.42	0.45
(6)	In case the stay tubes are inserted into the plates as (6) *B* in **Fig.-9.9**	0.49	0.52
(7)	In case the stay tubes are inserted into the plates as (6) *C* in **Fig.-9.9**	0.49	0.52

Table 9.4 Values of Constant C_6

Fixing method of stay or stay tubes	In case the plates are not exposed to flame	In case the plates are exposed to flame
In case the stay tubes are inserted into the plates as (6) *A* in **Fig.-9.9**	0.51	0.54
In case the stay tubes are inserted into the plates as (6) *B* in **Fig.-9.9**	0.57	0.61
In case the stay tubes are inserted into the plates as (6) *C* in **Fig.-9.9**	0.57	0.61

9.5.7 Required Thickness of Corrugated Furnaces

The required thickness of the corrugated furnace is to be calculated by the following formula:

$$T_r = \frac{PD}{C} + 1$$

where:

D: Minimum outside diameter at corrugated part of furnace (*mm*)

C: Constant given in **Table 9.5**

Table 9.5 Value of Constant *C*

Type of furnace	*C*
Morrison, Deighton and similar furnace	107
Leeds forge bulb furnace	104

9.5.8 Required Thickness of Plain Cylindrical Furnaces

The required thickness of plain cylindrical furnace or cylindrical bottom and smoke uptake of combustion chambers which are not reinforced by stay or other means is to be calculated by the following formulae, whichever is the greater:

$$T_r = \sqrt{\frac{PD(L+610)}{10500}} + 1$$

$$T_r = \frac{1}{325}\left(\frac{PD}{0.35} + L\right) + 1$$

where:

D: External diameter of furnace of combustion chamber bottom (*mm*)

L: Length of furnace or depth of combustion chamber bottom (*mm*)

The length of furnace is measured from the commencement of curvature where the furnace plates are flanged and jointed to other plates, reinforcing rings, etc.

9.5.9 Required Thickness of Hemispherical Furnaces without Stays or Other Supports

The required thickness of the hemispherical furnace without stay or other supports is to be calculated by the following formula:

$$T_r = \frac{PR_f}{62} + 1$$

where:

R_f: Outer radius of curvature of furnace (*mm*)

9.5.10 Required Thickness of Ogee Rings of Vertical Boilers

The required thickness of ogee rings connecting the furnace bottom of vertical boilers to the shell which sustain the whole vertical load of the furnace is to be calculated by the following formula:

$$T_r = \sqrt{\frac{PD(D-d)}{1010}} + 1$$

where:

D: Inside diameter of shell (*mm*)

d: External diameter of lower part of furnace where it joins the ogee ring (*mm*)

9.5.11 Required Thickness of Furnace Foundation Ring Plates of Vertical Boilers

The required thickness of furnace foundation ring plate (refer to **Fig. 9.9 (d)** (4)E) connecting the furnace bottom of vertical boiler to the shell is to be calculated by the following formula :

$$T_r = 1.28\sqrt{DP}$$

where:

D: Inside diameter of shell (*mm*)

9.5.12 Required Diameter of Stays

1. The required diameter of stay is to be calculated by the following formula:

$$d = C\sqrt{PA} + 3$$

where:

d: Required diameter of stay (*mm*)

A: Net area supported by one stay (mm^2)

C: 0.13

2. In applying the formula in **-1** to diagonal stays, *C* in the formula is to be replaced by C_1 given by the following formula:

$$C_1 = 0.13\sqrt{\frac{L}{H}}$$

where:

L: Length of diagonal stay (*mm*)

H: Equivalent length of stays perpendicular to the support surface (*mm*)

9.5.13 Required Dimensions of Stay Tubes

The required dimensions of stay tube supporting tube plates are to be calculated by the following formula. However, the thickness of stay tubes is not to be less than 6 *mm* for those in bounding rows of tube nests nor 4.5 *mm* for others.

$$a = \frac{PA}{51.7}$$

where:

a: Minimum net sectional area of one stay tube (mm^2)

A: Net area supported by one stay tube (mm^2)

9.5.14 Required Thickness of Girders Supporting Top Plates of Combustion Chambers and Their Distance to Side Plates

1. The required thickness of steel girders supporting top plates of combustion chambers is to be calculated by the following formula:

$$T_r = \frac{DLP(L-p)}{Cd^2S}$$

where:

T_r: Required thickness of girders of sum of the thickness in case of double plate construction (*mm*)

d: Depth of girders at centre (*mm*)

L: Width of combustion chamber measured along inner upper part (*mm*)

p: Pitch of stays supporting girder (*mm*)

D: Pitch of girders (*mm*)

S: Specified tensile strength of the material of girders (N/mm^2)

C: Constant given in **Table 9.6**

2. Where the outer radius of the knuckle connecting the top plate to the side plate of the combustion chamber of a boiler is less than 1/2 of the pitch D of the supporting beam obtained from the formula in **-1**, by substituting the actual thickness of girders of a boiler into it, the distance between the inner surface of the side plate and the centre of the supporting beam nearest to it is not to be more than pitch D. And, where the outer radius of the knuckle is larger than $D/2$, the width of the flat surface measured from the centre of the supporting beam to the starting point of the knuckle is not to be more than D/2.

Table 9.6 Value of Constant *C*

When number of stays (n) in each girder is odd	$\frac{0.253n}{n+1}$
When number of stays (n) in each girder is even	$\frac{0.253(n+1)}{n+2}$

9.5.15 Required Thickness of Cylindrical Headers

The required thickness of cylindrical headers is to be calculated by the formula in **9.5.2.** However, in case where the thickness of the header exceeds 1/2 of the inside radius of the header and the material temperature is 375°C or below, the required thickness is to be calculated by the following formula:

$$T_r = R\left(\sqrt{\frac{fJ+P}{fJ-P}}-1\right)+1$$

9.5.16 Required Thickness of Square Headers

The required thickness of square headers made of forged steel or welded steel plate is to be calculated by the following formula:

(1) In case where the holes are not arranged in succession:

$$T_r = \frac{Pl_2}{4f}\left(1+\sqrt{1+4f\frac{l_1^2}{Pl_2^2}}\right)+1.5$$

(2) In case where the holes are arranged in succession:

$$T_r = \frac{Pl_2}{4f}\left(1+\sqrt{1+\frac{8fl_1^2}{(1+J)Pl_2^2}}\right)+1.5$$

where:

l_1: Inside breadth measured between supports of flat surfaces for the strength calculation (*mm*)

l_2: Inside breadth of another side adjacent to l_1 (*mm*)

9.6 Manholes, Other Opening for Nozzle, etc. and their Reinforcements

9.6.1 Manholes, Cleaning Holes and Inspection Holes

1. Boilers are to be provided with manholes or cleaning holes with sufficient size at suitable positions, so that they permit easy access for inspection and maintenance. Where, however, it is impractical to provide manholes or cleaning holes due to constructions or dimensions, two or more inspection holes provided at suitable positions for internal inspection will be accepted as a substitute for them.

2. The construction of manholes or cleaning holes is to comply with the following requirements in **(1)** to **(3)**:

(1) The minor axis of the oval manhole provided on the shell plate is to be parallel to the longitudinal direction of the drum.

(2) The manhole cover of internal type is to be provided with a spigot which has a clearance of not more than 1.5 *mm* all round.

(3) Covers are to have sufficient strength, and so constructed that the repetition of covering and uncovering is not to impair safety. In case where covers are bolted, they are to be of such construction that the breakage of a bolt does not cause danger.

3. The inspection holes of headers are to be machine-finished so that inspection hole covers can be effectively fitted.

9.6.2 Reinforcement of Openings

In case where manholes, other openings for nozzles, etc. are provided in the shell, the openings are to be reinforced. However, the reinforcement may be omitted for the single opening shown in the following:

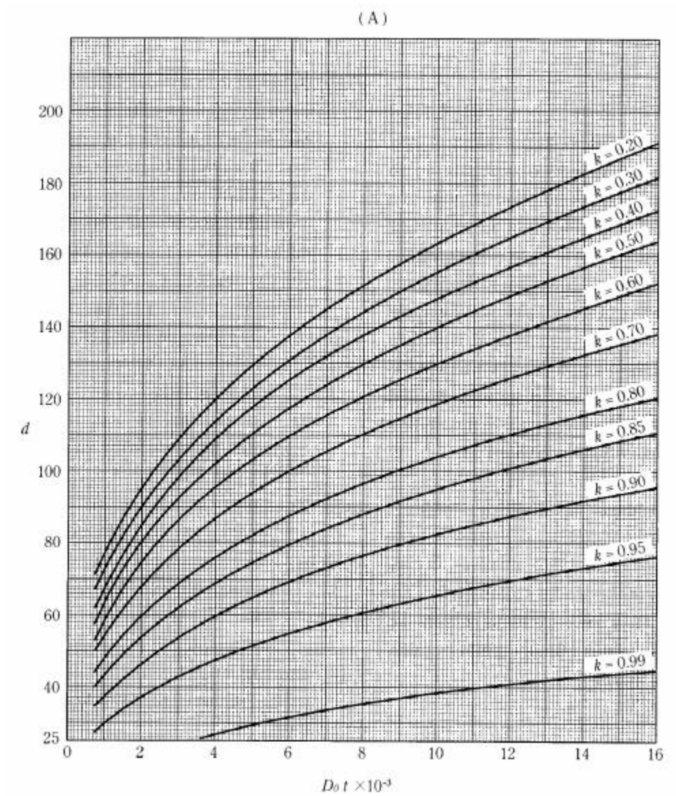
(1) Openings having a maximum diameter (in threaded opening, the diameter of the root) of not more than 60 *mm* nor more than 1/4 of the inside diameter of the shell.

(2) Openings provided on the shell plate having a maximum diameter not exceeding the value given in **Fig. 9.7**. In this case, no unreinforced opening is to exceed 200 *mm* in diameter.

(3) Openings provided on the end plate complying with the requirement in **9.5.3-2(3)** where no reinforcement is required due to the increased thickness of the end plates.

(4) Openings provided on the end plate or cover plate where the thickness of the end plate or cover plate is increased in accordance with the requirements in **9.6.3-3(2).**

Fig. 9.7(a) Maximum Diameter of Openings provided on the Shell for which Reinforcement may be Omitted (to be continued)



Notes:

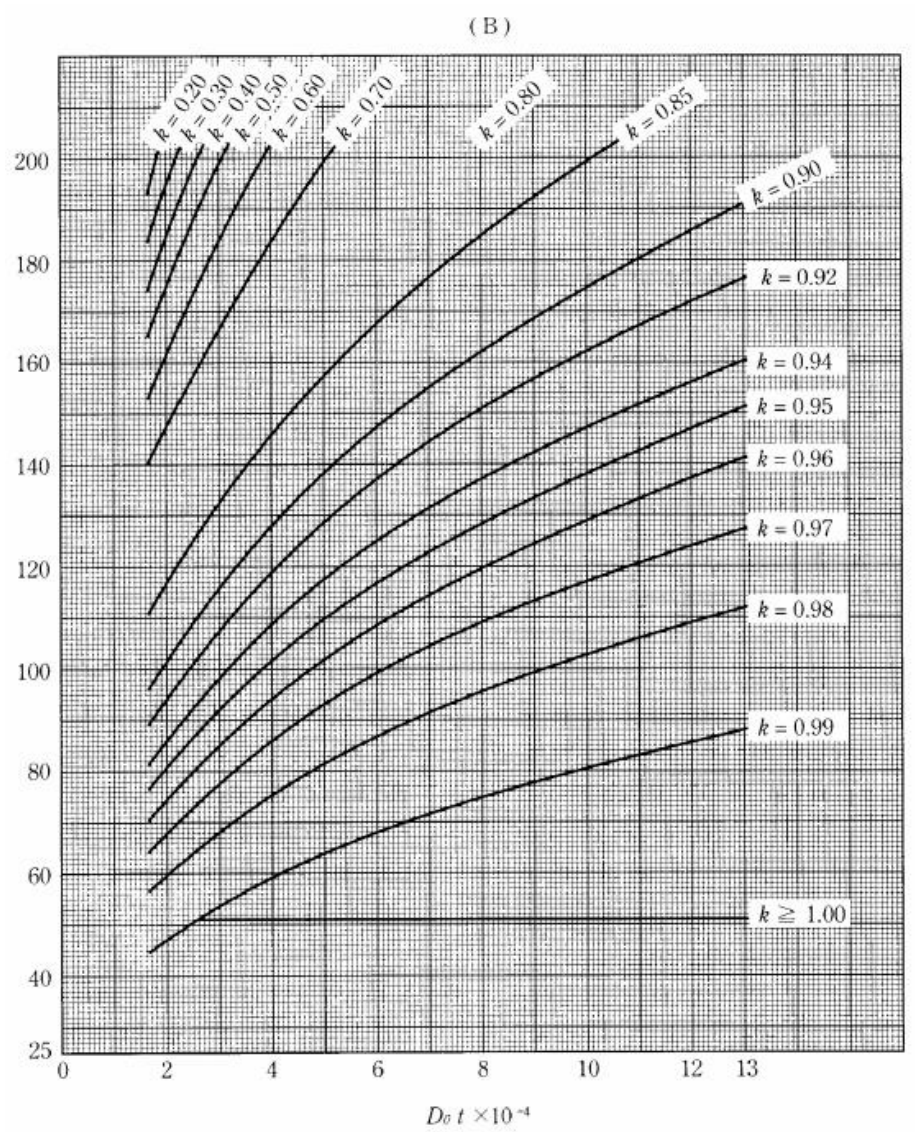
d: Maximum diameter of openings(*mm*) which are not requires to be reinforced, in this case the maximum diameter of the oval opening means the mean of major and minor axes.

D_0: Outside diameter of the shell (*mm*)

t: Actual thickness of the shell plate(*mm*)

$$k = \frac{PD_0}{1.82ft}$$

Fig. 9.7(b) Maximum Diameter of Openings Provided on the Shell for which Reinforcement may be Omitted (concluded)



Notes:

d: Maximum diameter of openings(mm) which are not required to be reinforced, in this case the maximum diameter of the oval opening means the mean of major and minor axes.

D_0: Outside diameter of the shell (mm)

t: Actual thickness of the shell plate(mm)

$$k = \frac{PD_0}{1.82ft}$$

9.6.3 Reinforcing Procedures of Openings

1. The meaning of the symbols used in **9.6.3** is as follows:

a: Area of the shell or end plate available for reinforcement (mm^2)

A_0: Required cross sectional area of the reinforcement (mm^2)

d_1: Diameter of opening in the cross section where reinforcement is intended (mm)

d_0: Maximum diameter of the finished opening in the longitudinal cross section for the shell plate or in the cross section for the end plate (mm)

h: Depth of the flange measured along the major axis of opening from the outer surface of end plate (mm)

t_n: Actual thickness of the nozzle (mm)

t_{nr}: Required thickness of the nozzle (mm)

T: Actual thickness of the shell plate or end plate (mm)

T_0: Required thickness of the shell plate or of the blank end plate (mm) calculated by assuming the efficiency as 1.00, except that, where the opening and its reinforcement are entirely within the spherical portion of a dished end plate, T_0 is the thickness required for a hemispherical end plate having the equal radius to the spherical portion of the end plate, and where the opening and its reinforcement are in semi-ellipsoidal end plate and are located entirely within a circle on the end plate with the diameter of the circle taking 80% of the inside diameter of the shell, T_0 is the thickness required for a hemispherical end plate of a radius equal to 90% of the inside diameter of the shell.

2. For openings in shell plates and formed end plates, reinforcement is to be provided in such a manner that the area of its cross section through the center of the opening and normal to the surface of the opening is not less than that calculated by the following formula:

$$A_0 = d_0 T_0$$

3. Where the flat end plates or cover plates specified in 9.5.5 have openings, they are to comply with the following:

Where the flat end plates or cover plates have openings with a diameter not exceeding one-half of the diameter for the circular plates or the minimum length (*d* shown in Fig. 9.9 and Fig. 9.10) for non-circular plates, the end plates or cover plates are to have a total cross sectional area of reinforcement not less than that calculated by the following formula:

$$A_0 = 0.5 d_0 T_0$$

(1) Where the flat end plates or cover plates have openings with a diameter exceeding one-half of the diameter for the circular plates or the minimum length (*d* shown in Fig. 9.9 and Fig. 9.10) for non-circular plates, the thickness of end plates or cover plates are to be 1.5 times the required thickness specified in 9.5.5 except for the corrosion allowance.

4. Reinforcement is to be provided within its effective limit. The effective limit of reinforcement is bounded by two lines along the wall and also by two lines parallel to the axis of the opening on the vertical plane to the wall containing the center of the opening. The lengths of the four lines are as follows: (*See* **Fig. 9.8**)

(1) The length of lines measured along the wall is to be a distance, in either direction from the center of the opening, equal to the greater of the following:

(a) The diameter of the finished opening in the cross section (*mm*)

(b) The radius of the finished opening in the cross section plus the thickness of the wall plus the thickness of the nozzle wall (*mm*)

(2) The length of the lines measured parallel to the axis of the opening from each surface of the wall is to be equal to the smaller of the following (*mm*)

(a) 2.5 times the thickness of the wall (*mm*)

(b) 2.5 times the thickness of the nozzle wall plus the thickness of any added reinforcement exclusive of weld metal

5. Any portion which exceeds the required thickness of the shell, end plate or nozzle, calculated according to the requirements in **9.5** and the deposit metal for welding may be considered as the reinforcement, provided that it lies within the effective limit of reinforcement. In this case, the area of the shell or end plate available for reinforcement is to be the area calculated by the following formulae, whichever is the greater.

$$a = d_1(T - T_0)$$

$$a = 2(T - T_0)(T + t_n)$$

6. In case where the allowable stress of the reinforcing material differs from that of the material used for the shell, correction is to be made by the following formula:

$$K_R = \frac{f_R}{f_S}$$

where:

K_R: Coefficient to be multiplied to the area of reinforcement. This is not to exceed 1.0.

f_S: Allowable stress of material used for the shell (N/mm^2)

f_R: Allowable stress of reinforcement (N/mm^2)

7. The opening in the end plate may be reinforced by flanged-in. In this case, the depth of the flange is not to be less than the value calculated by the following formula:

Where the thickness of the plate is not greater than 38 *mm*;

$$h = 3T_0$$

Where the thickness of the plate is greater than 38 *mm*;

$$h = T_0 + 76$$

Fig. 9.8 Effective Limit of Reinforcement

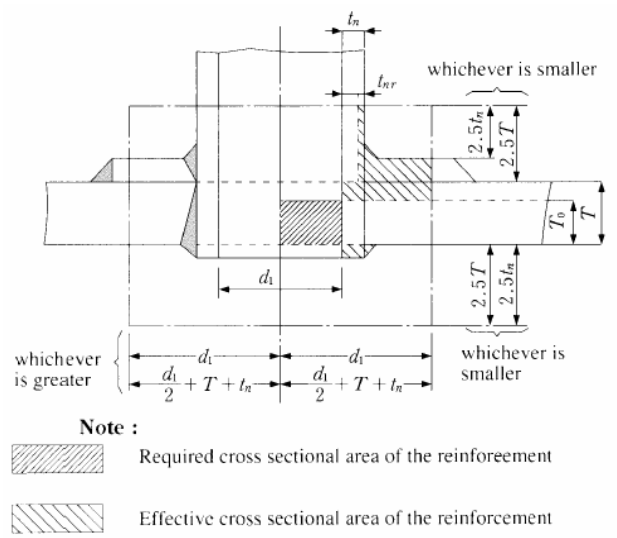


Fig. 9.9 (a) Examples of Welded Joints Approved for Each Case (to be continued)

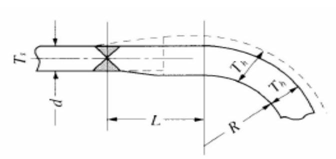
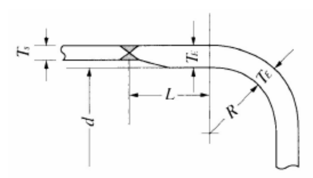
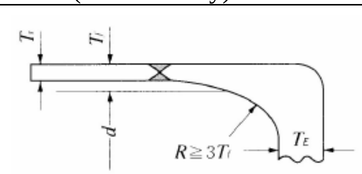
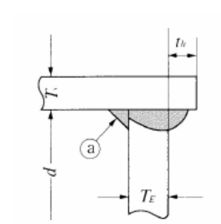
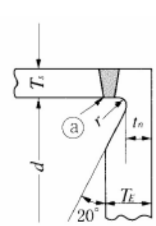
Welding part	Symbol	Welding mode and value of constant C:	Remarks
(1) Welding joint between formed end plate and shell	*A*		$L \geq 3T_h$, but need not be more than 38 mm. Where $T_h = 1.25T_s$, the above – mentioned value may be reduced
(2) Welding joint between flat end plate or cover plate and shell	*A*	 In case L is not restricted, $C_1 = 0.50$ (Circular or non-circular) $R \geq 3T_E$ In case $L \geq (1.1 - 0.8 \times \frac{Ts^2}{TE^2})\sqrt{dT_E}$ $C_1 = 0.39$ (Circular only)	
	B	 $C_1 = 0.50$ (Circular or noncircular)	$T_f \geq 2T_S$
	C	 $C_1 = 0.70$ (Circular or noncircular)	(1) $T_S \geq 1.25T_s$ (2)$t_h \geq T_S$ (3) Where the welding of part ⓐ, is considered difficult, the backing strip is to be used or the welding process, which ensures a good penetration to the root, is to be employed
	D	 $C_1 = 0.55$ (Circular) $C_1 = 0.70$ (or noncircular)	(1) $r \geq 0.2T_E$, but not less than 5mm (2) $T_n \geq 1.25t_{ro}$ (3) In welding the part ⓐ, such a welding process as to have a good penetration to the root, is to be employed. (4) End plates or cover plates are to be made of forged steel

Fig. 9.9 (b) Examples of Welded Joints Approved for Each Case (to be continued)

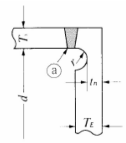
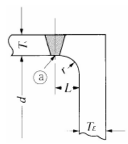
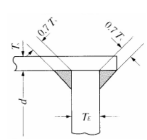
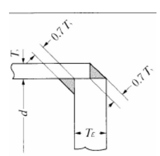
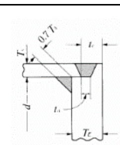
Welding Part	Symbol	Welding mode and value of Constant C_1	Remarks
(2) Welding joint between flat end plate or cover plate and shell	*E*	 $C_1 = 0.55$ (circular) $C_1 = 0.70$ (noncircular)	(1) $r \geq 0.2T_E$, but not less than 5mm (2) $t_n \geq 1.25T_m$ (3) In welding the part ⓐ, such as welding process as to have a good penetration to the root, is to be employed. (4) End plates or cover plates are to be made of forget steel
	F	 $C_1 = 0.55$ (circular) $C_1 = 0.70$ (noncircular)	(1) $r \geq 0.3T_E$ (2) $L \geq T_E$ (3) For the part ⓐ, the same is required as above (4) End plates or cover plates are to be made of forged steel
	G	 $C_1 = 0.55$ (circular) $C_1 = 0.70$ (noncircular)	$T_S \geq 1.25T_m$
	H	 $C_1 = 0.55$ (circular) $C_1 = 0.70$ (noncircular)	$T \geq 1.25T_m$
	I	 $C_1 = 0.55$ (circular)	(1) $T_S \geq 1.25T_m$ (2) $T_a \geq T_S$, but need not be over 6.5 mm (3)T_E, is not be less than $2T_m$ or $1.25T_S$, whichever is the greater.

Fig. 9.9(c) Examples of Welded Joints Approved for Each Case (to be continued)

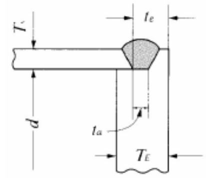
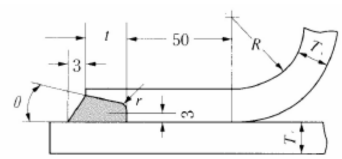
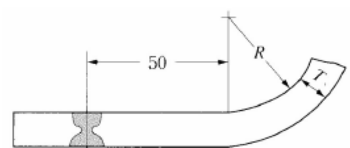
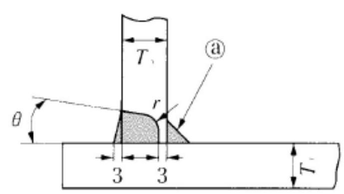
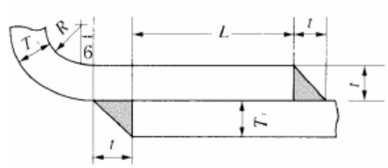
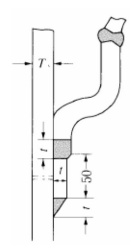
Welding part	Symbol	Welding mode and value of constant C_1	Remarks
(2) Welding joint between flat end plate or cover place and shell	J	 $C_1 = 0.70$ (circular or noncircular)	(1) Tube headers only. (2) $T_s \geq 1.25T_{ro}$ (circular only). (3) $T_a \geq T_s$, but need not be over 6.5 mm (4) T_s is not be less than $2T_{ro}$ or $1.25T_s$, whichever is the greater.
(3) Welding joint between furnace and shell plate or end plate	A		(1) To be applied to welding joint on the front side of boiler. (2) $t \geq T_s - 3$ (3) θ ranges between 10° and 20° inclusive (4) $10 \geq r \geq 5$
	B		
	C		(1) To be applied to welding joint on the front side of boiler (2) The part ⓐ is to be of light fillet weld (throat thickness 4~6mm) (3) θrange between 10° and 20° inclusive (4) $10 \geq r \geq 5$
	D		(1) To be applied to welding joint on the front side of boiler (2) $t \geq T_f$ (3) $L \geq 2T_s$
(4) Welding joint between ogee ring and shell plate	A		$t \geq T_S$

Fig. 9.9 (d) Examples of Welded Joints Approved for Each Case (to be continued)

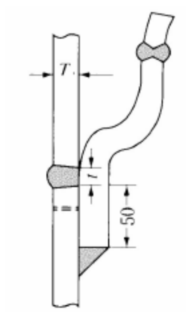
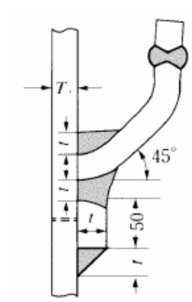
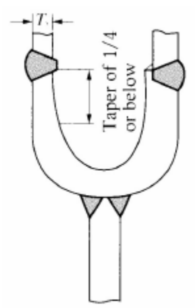
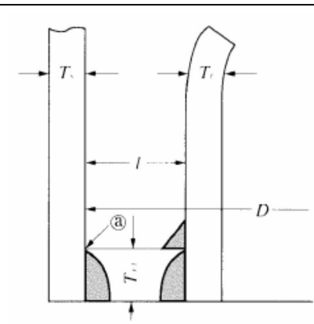
Welding part	Symbol	Welding mode	Remarks
(4) Welding joint between ogee ring and shell plate	*B*		$t \geq T_s$
	C		$t \geq T_s$
	D		$t \geq T_s$
	E		(1) If $D \leq 750, l \geq 50$ If $D > 750, l \geq 60$ (2) In welding the part ⓐ, such a welding process as to have a good penetration to the root, is to be employed.

Fig. 9.9 (e) Examples of Welded Joints Approved for Each Case (to be continued)

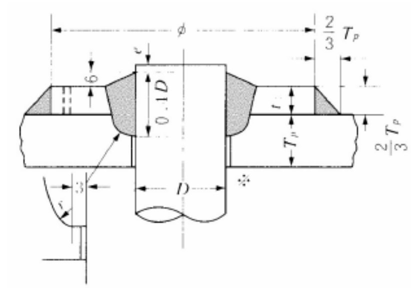
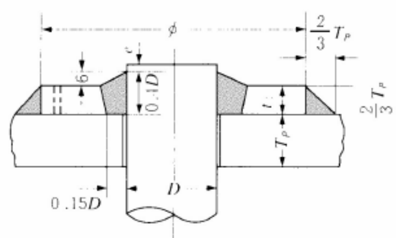
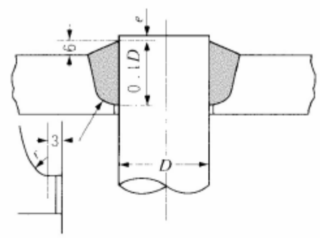
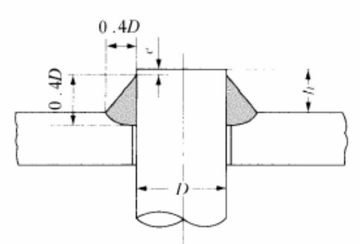
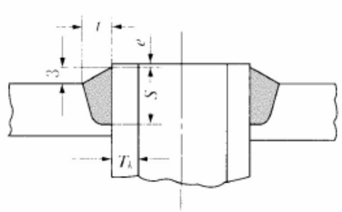
Welding part	Symbol	Welding mode	Remarks
(5) Welding joint between stay and tube plate or end plate	*A*		(1) $\emptyset \ge \frac{2}{3}p$ (p means the pitch of stays, hereinafter the same being referred) (2) $t_1 \ge \frac{2}{3}T_p$ (3) The part marked by ⁎ is to be applied with light fillet welding (root thickness, 4~6mm) or caulking from the side of plate for filling the gap. (4) on the fire side, to be $e \le 1.5$
	B		(1) $\frac{2}{3}\rho > \emptyset \ge 3.5D$ (2) $t_1 \ge \frac{2}{3}T_p$` (3) The part marked by ⁎ is to be same as above (4) On the fire side, to be $e \le 1.5$
	C		On the side exposed to flame $e \le 1.5$
	D		On the side exposed to flame, $h \le 10$ and $e \le 1.5$
(6) Welding joint between stay tube or tube and tube plate or end plate	*A*		(1) $t \ge t_k$ (2) $S \ge 2t$ (3) On the side exposed to flame, $e \le 1.5$

Fig. 9.9 (f) Examples of Welded Joints Approved for Each Case (to be continued)

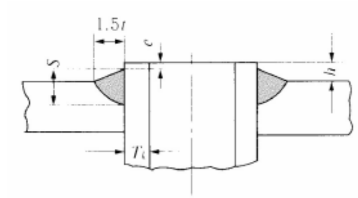
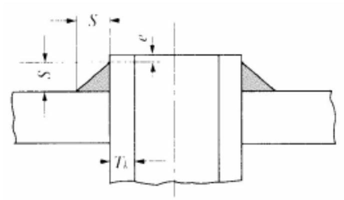
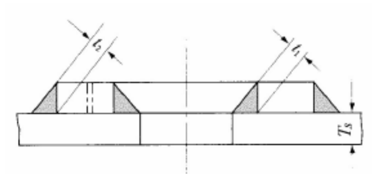
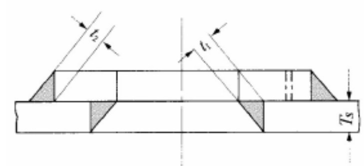
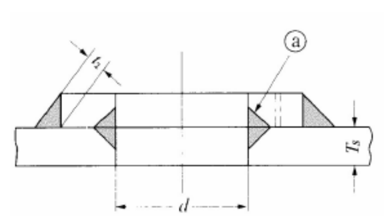
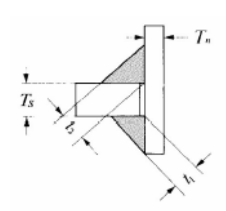
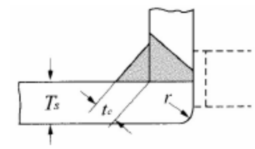
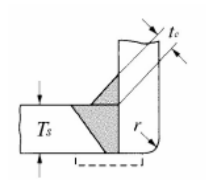
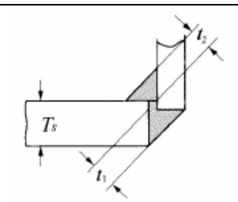
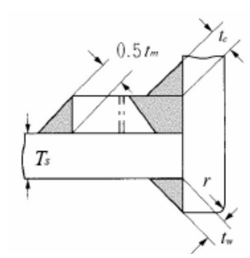
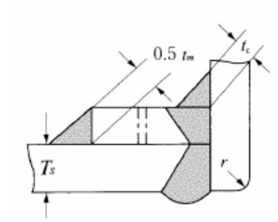
Welding part	Symbol	Welding mode	Remarks
(6) Welding joint between stay tube or tube plateo or end plate.	*B*		(1) $t \geq T_e$ (2) $S \geq 1.5t$ or $t + 3$ (3) On the side exposed to flame, $h \leq 10$ and $e \leq 1.5$
(7) Welding joint between seat or reinforcement ring and shell plate or end plate	*C*		(1) $S \geq T_k + 3$ (2) To be welded after having tube expansion. (3) On the side exposed to flame, $e \leq 1.5$
	A		(1) $t_1 + t_2 \geq 1.25t_m$ (2) $t_1, t_2 \geq t_m$, but the minimum is 6.5mm
	B		
	C		(1) To be applicable only for the case of $d < 60$ (2) $t_2 \geq 0.7t_m$ (39 The part ⓐ is to be welded for stopping leakage.
(8) Welding joint between nozzle and shell plate or end plate	*A*		(1) $t_1 \geq 6.5$ *or* $0.7t_m$, whichever is the smaller (2)) $t_1 + t_2 \geq 1.25t_m$ (3)) $t_1, t_2 \geq \frac{1}{3}t_m$, but the minimum is 6.5 mm

Fig. 9.9 (g) Examples of Welded Joints Approved for Each Case (concluded)

Welding part	Symbol	Welding mode	Remarks
(8) Welding joint between nozzle and shell plate or end plate	*B*		(1) $t_c \geq 6.5$ or $0.7t_m$, whichever is the smaller (2) $t_1 + t_2 \geq 1.25t_m$ (3) $t_1 + t_2 \geq \frac{1}{3}t_m$, but the minimum is 6.5mm
	C		
	D		
	E		(1) $t_c \geq 6.5$ or $0.7t_m$, whichever is the smaller 2) $t_1 + t_2 \geq 1.25t_m$ (3) $t_1 + t_2 \geq \frac{1}{3}t_m$, but the minimum is 6.5mm (4) $t_{u'} \geq 0.7t_m$
	F		

Note:

1 Constant C_1 is the value used for the formula in 9.5.5.

2 The dimensions of welding parts are the minimum values.

3 The unit of values in the figures is all in *mm*.

4 The definitions of representative symbols used in the figures are as Follows (unit:*mm*):

T_s: Actual thickness of the shell plate

T_h Actual thickness of the formed end plate

T_E: Actual thickness of the flat end plate or cover plate

T_{ro}: Required thickness of the seamless shell

T_p: Actual thickness of the tube plate or flat end plate (formed end plate)

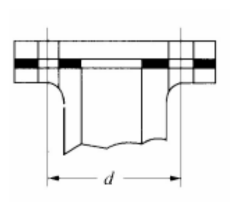
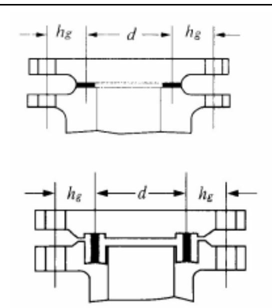
T_{rf}: Required thickness of furnace foundation ring plate

T_k: Actual thickness of the stay tube or tube

T_n: Actual thickness of the nozzle

T_m: Smaller value of thickness of plates to be welded, but the maximum value is 20 *mm*.

Fig. 9.10 Examples of Bolting Covers and End Plates

Joint method	Shape and dimensions	C_3
Bolted with full face gastek		0.25
Bolted		0.3

9.7 Tubes

9.7.1 Fitting of Tubes

1. Tubes are to be attached to the tube plate by expanding or other suitable methods and the tubes are to project through the neck or belt of parallel seating by not less than 6 *mm*, except for those attached by welding. In case where the tube end is fitted by welding, consideration is to be given for preventing the deformation (thermal ratchet effect) of tubes due to tube-to-tube differentials of thermal expansions.

2. In case where the water tubes are secured from drawing out by means of bellmouthing only, the included angle of belling is to be not less than 30 *degrees*.

3. Tube holes are to be formed in such a way that the tubes can be effectively tightened in them. Where the tubes are practically normal to the tube plates, the parallel seating of the holes is not to be less than 10 *mm* in depth. Where the tube ends are not normal to the tube plate, the depth of the holes perpendicular to the tube plate is not to be less than 10 *mm* for tubes not exceeding 60 *mm* in outside diameter, and not to be less than 13 *mm* for tubes exceeding 60 *mm* in outside diameter.

4. In horizontal smoke tube type vertical boiler, each alternate smoke tube in outer vertical rows of tubes is to be of stay tube.

9.7.2 Minimum Thickness of Tubes

The thickness of tube used for boiler is not to be less than 2 *mm* for tubes less than 30 *mm* in outside diameter, or 2.5 *mm* for tubes 30 *mm* or more in outside diameter.

9.7.3 Required Thickness of Smoke Tubes

The required thickness of smoke tubes is to be calculated by the following formula:

$$T_r = \frac{P_d}{70} + 2$$

where:

d: Outside diameter of the smoke tube (*mm*)

9.7.4 Required Thickness of Tubes Subjected to Internal Pressure

The required thickness of tubes (evaporating tubes, water wall tubes, downcomers, superheater tubes, economizer tubes and exhaust gas economizer tubes, etc.) subjected to internal pressure is to be calculated by the following formula:

$$T_r = \frac{P_d}{2f + P} + 1.5$$

where:

d: Outside diameter of the tube (*mm*)

9.8 Joints and Connection of Each Member

9.8.1 Welded Joints

1. The dimensions and shapes of edge preparation are to be such that satisfactory penetration is obtainable without failure. The welded joint is to be so designed as not to be subjected to excessive bending stress. Where the construction is such that bending stress is concentrated at the root of the welded joints due to deformation caused by bending, single welded butt joints of fillet welded joints are to be avoided.

2. Where plates of unequal thickness are jointed by butt welding, the thicker plate is to be reduced in thickness to a taper for a distance not less 4 times the offset so that the two plates are of equal thickness at the portion of the weld. In this case, the taper may be made only on one side for circumferential joints of shells, however, for the longitudinal joints, as a rule, the taper is to be made on both sides so that the center lines of both plates may coincide. In case where the reduction in thickness is made on one side of the longitudinal joints, the distance between the center line of the weld and the origin of the taper is not to be less than the thickness of the thinner plate.

3. The circumferential joints and the longitudinal joints of shells are to be double welded butt joints, or to be single-welded butt joints approved by the Society.

9.8.2 Shapes of Joints and Connections

The shapes of welded joints and connections are to be as shown in **Fig. 9.9** or to be as considered equivalent by the Society.

9.8.3 Construction of Bolted Cover Plates

The construction of unstayed flat cover plates bolted to shells is to be as shown in **Fig. 9.10** or to be as considered equivalent by the Society.

9.9 Fittings, etc.

9.9.1 Materials of Fittings

1. The material of the nozzles, flanges or distance pieces attached directly to a boiler drum (including tube headers) is to be of steel which is suitable for the working temperatures.

2. Except for those specified in **-1** the material of the valve boxes or other fittings, which are connected to a boiler and are subjected to its pressure, are to be suitable for the working temperature and be of steel excluding the following:

(1) The copper alloy castings may be used in cases where the maximum working temperature does not exceed 210°C.

(2) The grey cast iron may be used in cases where the maximum working temperature does not exceed 220°C nor the approved design pressure exceed 1 *MPa*, except for blow-off valves.

(3) Special cast iron made by the approved manufacturers may be used in cases where the maximum working temperature does not exceed 350°C nor the approved design pressure exceed 2.5 *MPa*.

9.9.2 Construction of the Fittings

1. Fittings such as valves, flanges, and bolts, nuts, gaskets, etc. are to have the construction and dimensions conforming to the recognized standards and they are to conform to the service conditions specified in such standards.

2. The manual stop valve is to be provided with an indicator to show whether it is open or closed, except for that of rising stem type.

3. Fittings are to be attached to a boiler drum with flanged joints or by welding. However, in case where the thickness of the drum is over 12 *mm* or in case where a seat for screwing is fitted to the drum, the fittings of 32 *mm* or under in nominal diameter may be attached to the boiler by screwing.

4. In case where boiler fittings are secured by studs, the stud holes are not to penetrate the whole thickness of the shell, and the depth of threaded part is not to be less than the diameter of the studs.

9.9.3 Safety Valves and Relief Valves

1. Each boiler is to be provided with not less than two spring loaded safety valves. However, only one safety valve will be accepted for the following boilers:

(1) Boilers with heating surface of less than $10m^2$

(2) Boilers with the approved design pressure of not more than 1 *MPa*, provided that they are equipped with a pressure controlling device and a device which cuts off fuel supply automatically at a pressure not exceeding the approved design pressure

(3) Exhaust gas boilers fitted with the relief valves specified in **-11**

2. Safety valves with spring pilot valve may be used in lieu of spring loaded safety valves.

3. The seat diameter of safety valves is not to be less than 25 *mm*, unless specifically approved.

4. Safety valves are to start releasing steam automatically at the set pressure in accordance with the requirements in **-14** and are to be capable of discharging the total evaporative capacity of the boiler under the maximum designed operating condition without raising steam pressure to 10% or more above the approved working pressure of the boiler.

5. The total area of safety valves in consideration of the maximum designed evaporation of the boiler is not to be less than the required area which is calculated under each steam condition and for each type of safety valves specified below. However, safety valves of the boiler having a superheater are to comply with the requirements in **-7**, **-8** and **-9**.

Further, for any boiler with an exhaust gas economizer which is so designed that it may be additionally heated while in use, the required area of the safety valves is to be calculated after the maximum evaporation of the boiler is added with the evaporation of the exhaust gas economizer.

(1) For saturated steam

(a) For low lift valve $\left(\frac{D}{24} \le L < \frac{D}{15}\right)$

$$A = \frac{W}{K_1(1.03P + 0.1)} \times 10^2$$

(b) For high lift valve $\left(\frac{D}{15} \le L < \frac{D}{17}\right)$

$$A = \frac{W}{K_2(1.03P + 0.1)} \times^{10-2}$$

(c) For full lift valves $\frac{D}{7} \le L$

$$A = \frac{W}{K_3(1.03P + 0.1)} \times 10^{-2}$$

(d) For full bore valve (Diameter of seat is 1.15 times the diameter of throat or more):

$$A' = \frac{W}{K_4(1.03P + 0.1)} \times 10^{-2}$$

where:

D: Seat diameter of safety valve (*mm*)

L : Lift of safety valve (*mm*)

A: Required seat area of safety valve (mm^2)

A' : Required nozzle throat area of safety valve (mm^2)

W: Maximum designed evaporation capacity of boiler (g/h)

P: Set pressure of safety valve (MPa) K_1

K_1 : 4.8

K_2: 10.0

K_3: 20.0

K_4: 30.0

However, if the tests and examinations designated by the Society, such as discharge capacity test and the measurement of lift have been carried out on each prototype under the condition equivalent to the actual one, the values of K_2, K_3 or K_4 may be increased to the values approved by the Society on the basis of these results.

(2) For superheated steam

$$A_S \frac{A}{\sqrt{V_H/V_S}}$$

where:

A_S: Required seat area of safety valve (mm^2)

A: As specified in **(1)**

V_H: Specific volume of saturated steam (mm^3/g)

V_S: Specific volume of superheated steam (mm^3/g)

6. The area of steam passages of safety valve is to be of the following value for each type of safety valves.

(1) The minimum areas of steam passages of the low lift safety valve at the chest inlet and outlet are not to be less than 0.5 time and 1.1 times the required valve seat area respectively.

(2) The minimum areas of steam passages of the high lift safety valve at the chest inlet and outlet are not to be less than 1.0 time and 2 times the required valve seat area respectively.

(3) The minimum areas of steam passage of the full lift safety valve at the chest inlet and outlet are not to be less than 1.1 times and 2 times the steam passage area respectively when the valve is lifted to 1/7 of the valve seat diameter.

(4) The minimum area of steam passage at the valve seat for the full bore safety valve is not to be less than 1.05 times the area at the throat, when the valve is open. Further, the minimum areas of steam passages at the valve inlet and the nozzle are not to be less than 1.7 times the area at the throat, and the minimum steam passage area at the outlet is not to be less than 2 times the area at the valve seat when the valve is open.

7. In case where a boiler is provided with a superheater, at least one safety valve is to be fitted at the outlet of the superheater.

8. The discharge capacity of the safety valve attached to the superheater is to be such that the superheater is not damaged when main steam supply is shut down in an emergency while the boiler is operated under load at the maximum continuous output. In cases where this purpose is not fulfilled, means are to be provided to automatically shut off or control the fuel supply to the boiler in an emergency for preventing the superheater from damage.

9. In case where there is no intervening device between the superheater and the boiler, the area of the superheater safety valve may be included in the total area of safety valves of the boiler. However, the total area of the safety valves fitted to the evaporating parts of the boiler is not to be less than 0.75 time the required area calculated by the formulae in **-5**.

10. The safety valves are to be fitted at the inlet and the outlet of the independent reheater or the independent superheater respectively, and the total discharge capacity is not to be less than the maximum passing steam quantity.

The total discharge capacity of the safety valve provided at its outlet is to be less than the quantity necessary to keep the steam temperature of the independent reheater or independent superheater not higher than the designed value.

However, for the independent superheater, connected directly to the boiler, which is designed with the same approved design pressure as that of the boiler drum, one safety valve capable of discharging the quantity of steam necessary to keep the steam temperature of the independent superheater not higher than the designed value may be fitted at its outlet.

11. Where the economizer and exhaust gas economizer (including the heating element of the exhaust gas boiler) are equipped with an intervening valve between the boiler and the economizer or exhaust gas economizer, they are to be provided with at least one relief valve capable of discharging the quantity not less than that calculated from the maximum absorbable energy. However, the shell type exhaust gas economizer which has a total heating surface of 50 m^2 or more is to be provided with at least two relief valves.

12. The construction of safety valve and relief valve is to comply with the following requirements:

(1) The safety valve and the relief valve are to be so constructed that spring and valve are housed in a cage and they cannot be overloaded intentionally from outside and that in case of spring failure they cannot come out of their cage.

(2) The safety valve and the relief valve are to be fitted to the boiler shell, header, or outlet connection of the superheater by a flanged joint or welded joint. The valve chests are not to be made common to other valve chests.

However, the safety valve of the superheater may be fitted with flanges to the distance pieces welded to the outlet connection.

(3) The safety valve and the relief valve are to be provided with an easing gears, and their handles are to be so arranged that they can be operated from an accessible place free from danger.

(4) The relief valves for shell type exhaust gas economizers are to incorporate features that ensure pressure relief even with solid matter deposits on the valve and guide, or features that prevent the accumulation of solid matter in way of the valve and the in the clearance between the valve spindle and guide. However, where no relief valves incorporating the features are fitted, a bursting disc discharging to suitable waste steam pipe is to be provided in addition to the valves. The alternative arrangements for ensuring pressure

relief in the event of solid matter on the valve and guide are to function at a pressure not exceeding 1.25 times the economizer design pressure and are to have sufficient capacity to prevent damage to the economizer when operating at its design heat input level.

(5) The housings of the safety valve, relief valve and bursting disk are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the boiler or exhaust gas economizer where it will not pose threats to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements.

13. The waste steam pipes for safety valve and relief valve are to comply with the following requirements :

(1) The waste steam pipes for the safety valve and relief valve are to be of such construction that back pressure does not interfere with operation of the valves. The inside diameter of the waste steam pipes are not to be less than the diameter of the valve outlet, and are to be designed at the pressure 1/4 or more of the set pressure of the valves.

(2) Where a common waste steam pipe is provided for two or more safety valves or relief valves, its cross sectional area is not to be less than the aggregate area of steam passage of each safety valve or relief valve. The waste steam pipes of boiler safety valves are to be separated from pipe lines likely to contain a large amount of drains such as steam blow-off pipes to the atmosphere or waste steam pipes of relief valves for exhaust gas economizer.

14. The safety valve or relief valve is to be set in accordance with the following requirements **(1)** to **(5)** after the installation on board the ship.

(1) The safety valve is to be set to blow-off steam automatically at a pressure not greater than 1.03 times the approved working pressure of the boiler.

(2) The superheater safety valve is to be set to blow-off steam automatically at a pressure not greater than the value which is obtained by subtracting the set pressure of the safety valve(s) on the boiler drum by the value of 0.035 *MPa* plus the steam pressure drop in the superheater at the normal load. However, in case where this pressure exceeds 1.03 times the nominal pressure of the boiler, at least one safety valve is to be set to blow-off steam at a pressure not greater than 1.03 times the nominal pressure, and other valve(s) not greater than 1.05 times.

(3) The blow-off pressure of a safety valve at the outlet of the superheater is to be set lower than that at the inlet.

(4) The blow-off pressure of the relief valve provided on the economizer or exhaust gas economizer is to be set at a pressure not greater than the respective approved design pressure.

(5) The safety valve or relief valve is to function satisfactorily while blowing-off at its set pressure specified by the respective requirements **(1)** to **(4)**.

15. In case where the calculated discharge capacity of the safety valve does not comply with the requirements in **-5** on account of the reduction of the approved working pressure for the boiler, it may be accepted, provided that the accumulation test satisfied by the Society has been carried out and it is confirmed that the pressure in boiler drum has not exceeded 110% of the approved working pressure.

9.9.4 Steam Connections

1. A stop valve is to be fitted directly to the boiler drum at each steam outlet.

2. In case where the steam from more than two boilers is led to one common steam pipe, the stop valve to be provided on each steam outlet as required in **-1** is to be of the screw-down non-return valve, and one additional stop valve is to be provided on each steam pipe between the non-return valve and the point of steam pipe connection.

3. In ships provided with two or more main boilers of essential auxiliary boilers, the steam line is to be led in such a way that uninterrupted steam supply to the auxiliary machinery for maneuvering and the safety can be ensured even in case of possible failure on one of these.

9.9.5 Feed Water System

1. A stop valve is to be fitted to the feed water connection and a screwdown non-return valve is to be provided at a point as close to the stop valve as practicable. An approved feed regulator may, however, be installed between the screw-down non-return valve and the stop valve.

2. Notwithstanding the requirement in **-1**, where the boiler, has an economizer which is recognized to be an integral part of the boiler, a feed water stop valve may be provided at the economizer inlet. In this case, a screw-down non-return valve is to be provided at a point as close to the stop valve as practicable.

3. The part of the boiler drum where feed water is introduced is to be provided with sleeves or other suitable devices so that an extreme thermal stress may not occur due to direct contact of cold feed water with the drum. This requirement also applies to the desuperheater in the boiler drum, if installed, where the superheated steam pipes penetrate through the drum. Further, feed water discharge within the drum is to be so distributed that it may not impinge directly on the heating surfaces of the boiler at high temperature.

9.9.6 Blow-off System

1. Each boiler is to be provided with a blow-off valve fitted directly to its drum so that the boiler water may be discharged from the bottom of its water space; its nominal diameter is not to be less than 25 *mm* but not more than 65 *mm*, except that for a boiler with heating surface of 10 m^2 or less, the blow-off valve may be 20 *mm* in nominal diameter.

2. In case where blow-off pipes are exposed to the flue, they are to be protected by thermal insulation materials and to be so arranged that they may be readily inspected.

3. The design pressure of blow-off piping is not to be less than 1.25 times the design pressure of the boiler drum.

4. Blow-off valves are to be of such construction that they are free from deposition of scales and other sediments.

5. In case where the blow-off pipes of two or more boilers are joined onto one common discharge, a screw-down non-return valve is to be provided in each pipe line from each boiler.

9.9.7 Burning Systems

1. Fuel Oil Burners

(1) Fuel oil burners are to be so arranged that they cannot be withdrawn unless the fuel oil supply to those burners is shut off.

(2) For top firing boilers, in order to absorb the vibration, flexible joints approved by the Society are to be provided at the connections between the fuel oil burner and the fuel oil supply pipe.

2. Draught Fans

The boilers are to be provided with draught fans with a capacity sufficient for the designed maximum steam evaporation of the boiler and for the stable combustion in the boiler within its service range. An alternative means which is available to ensure the normal navigation and cargo heating that is required continuously is to be provided, in the case of failure of the draught fan.

9.9.8 Water Level Indicators

1. Each boiler is to be provided with at least two independent water level indicators, one of which is to be a glass water gauge and the other is to comply with either one of the following requirements:

(1) Glass water gauge located at a position where the water level is readily sighted.

(2) Remote water level indicator, but, for the boiler whose design pressure is 1 *MPa* or under, this may be replaced by a high and low level alarm device.

2. For forced circulation or once-through boilers, where the requirements in **-1** are not applicable for the indication of water level, a suitable level detector and a low water level safety device which is comprised of two detectors so designed as to prevent the overheating of any part of the boiler by lack of water supply are to be provided.

3. In case where the water space in the boiler is long in the transverse direction of the ship or an excessive difference in water level may occur, the water level indicators specified in **-1** are to be so arranged as to indicate the water levels at both ends of the water space.

4. The lowest visible part of the glass water gauge is to be not less than 50 *mm* above the lowest critical water level.

The visible range of the remote level indicator is to be such provided with such means as to ascertain their proper that it covers all ranges related to the water level control in the boiler.

5. Construction of water level indicator is to comply with the following requirements.

(1) Construction of glass water gauge is to be of the built-up rectangular-section box type (double-plate-type) specified in the recognized standard or the equivalent approved by the Society.

(2) In case where the water gauge is placed outside the boiler, a stop valve (or cock) is to be fitted on the top and bottom of the gauge respectively and in addition, an effective draining device is to be provided.

(3) In case where the water gauge or the water column is connected by a pipe to the boiler drum, a stop valve is to be fitted to the boiler drum.

(4) The stop valves (or cocks) for the water gauge and the connection pipes to the boiler drum are to be of the shape free from deposition of scale and other sediments from the boiler water.

(5) The water column to which the water gauge(s) are attached is to be strongly supported so that it may maintain its correct position. The inside diameter of the water column is not to be less than 45 *mm* and the draining hole having sufficient size is to be provided at the bottom of the column.

(6) The connection pipes to the boiler drum are to be 15*A* or over in nominal diameter for the water gauge, and 25*A* or over in nominal diameter for the water column.

(7) In case that the connection pipes from the water column to the boiler penetrate the uptake, they are to be enclosed all the way through the uptake and further the air passage of not less than 50 *mm* is to be provided around the pipes.

9.9.9 Pressure and Temperature Measuring Devices

1. Each boiler is to be provided with one set of pressure measuring device at the boiler drum and at the superheater outlet respectively, and pressure indicators are to be arranged in the monitoring station.

2. The pressure indicator is to be such that it has a scale of 1.5 times or over the set pressure of the safety valve.

The approved working pressure for the drum or the nominal pressure for the superheater is to be specially marked on the scale of the pressure gauges, respectively.

3. Pressure measuring and indicating devices are to be operation while the boiler is in operation.

4. At the steam outlet of the superheater or reheater, temperature measuring devices are to be provided.

9.9.10 Safety Devices and Alarm Devices

1. Fuel oil shut-off device

Each boiler is to be fitted with a safety device which is capable of shutting off automatically the fuel supply to all burners in the cases of the following:

Alarms which indicate the action of the safety device are to be in accordance with **18.2.6-2**.

(1) When automatic ignition fails.

(2) When the flame vanishes (in this case, the fuel oil supply is to be shut-off within 4 *seconds* after the extinguishing of flame).

(3) When the water level falls.

(4) When the combustion air supply stops.

(5) When the fuel oil supply pressure to the oil burners falls in the case of pressure atomizing, or when the steam pressure to the burners falls in steam atomizing.

(6) When considered necessary by the Society.

2. Alarm device

(1) Each boiler is to be provided with an alarm device which operates when the water level in the drum falls.

(2) In addition to the above, the main boilers are to be provided with alarm devices which operate in the following cases:

(a) When combustion air supply reduces, of when the draught fan stops.

(b) When the fuel oil supply pressure to the burner falls, in the case of pressure atomizing, or when the steam pressure to burner falls, in steam atomizing.

(c) When the water level in boiler drum reaches to a high level.

(d) When the steam temperature at the superheater outlet rises, if the superheater is provided.

(e) When the exhaust gas temperature at the outlet of the gas type air preheater or economizer rises.

(3) For auxiliary boilers supplying steam to the turbines driving main generators, alarm devices which operate when the water level in the boiler drum reaches to a high level are to be provided in addition to those alarm devices given in **(1)**.

3. Water level detector

The water level detectors of the devices specified in **-1(3)** are to be separate from those of the feed regulating system and remote water level indicator specified in **9.9.8-1(2)**.

9.9.11 Monitoring of Boiler Water

1. Each boiler is to be provided with a boiler water sampling connection in a convenient location, but its sampling valve is not to be connected to the water column for water gauge.

2. Boilers are to be provided with means such as water analyzer or other suitable device to supervise and control the quality of the feed water and boiler water.

9.9.12 Drainage Arrangement of Superheaters and Reheaters

The superheaters and reheaters are to be provided with effective drainage systems and means for preventing damages arising from the thermal stresses or thermal shocks caused by drains.

9.10 Tests

9.10.1 Shop Tests

1. Tests for welds are to conform to the requirements specified in **Chapter 11**.

2. Boilers are to be subjected to hydrostatic tests at the pressure of 1.5 times for the design pressure for boilers and at the pressure of 2 times the design pressure for boiler fittings.

9.10.2 Tests after Installation on Board

For boilers, popping tests for safety valves and function tests for the safety devices and alarm devices are to be carried out, after having been installed on board.

9.11 Construction etc. of Small Size Boilers

9.11.1 General

Notwithstanding the requirements in **9.2** to **9.10**, the requirements in **9.11** may be applied to boilers with the design pressure not exceeding 0.35 *MPa* (hereinafter referred to as the small boilers).

9.11.2 Materials, Construction, Strength and Accessories of Small Boilers

1. The materials, construction and strength and accessories of small boilers are to comply with the requirements in recognized standard.

2. Small boilers are to be provided with safety valves or pressure relief piping of sufficient capacity.

3. Small boilers are to be provided with the following safety devices:

(1) Prepurging system for preventing explosion of furnace gas.

(2) Fuel oil shut-off system which operates in the case of flame vanishing, failure of automatic ignition or stoppage of draught fans.

(3) Fuel oil shut-off system which operates when the pressure is not exceeding the approved working pressure.

(4) Fuel oil shut-off system for preventing the overheating in case of short water.

9.11.3 Tests

1. Shop Tests

The pressure parts are to be subjected to hydrostatic tests at a pressure 2 times the design pressure or 0.2 *MPa*, whichever is the greater.

2. Tests after Installation on Board

For small boilers, the function tests for the safety devices specified, in **9.11.2-3** above are to be carried out after installation on board.

9.12 Construction of Thermal Oil Heaters

9.12.1 General

The thermal oil heaters heated by flame or combustion gas are to comply with the relevant requirements specified in **9.1** through **9.10** (in this case the term boiler is to be read as thermal oil heater) as well as the requirements in **9.12**.

9.12.2 Safety Devices, etc., for Thermal Oil Heaters heated by flame

1. Temperature regulators are to be provided to control the temperature of the thermal oil within the predetermined range.

2. The master valve of the expansion tank is to be kept always open, and the burning system is to be interlocked in such a way that it does not start when the master valve is closed.

3. Safety valve or pressure relief pipe of sufficient capacity is to be provided.

4. The discharge pipes from the safety valve of the pressure relief pipe specified in **-3** are to have their open ends in the thermal oil tank with sufficient capacity.

5. The following safety devices are to be provided:

(1) Prepurging system for preventing explosion of the furnace gas.

(2) Fuel oil shut-off systems which operate in the following cases:
   (a) When the temperature of the thermal oil rises abnormally.
   (b) When the flow rate of the thermal oil falls or when the pressure difference of the thermal oil between the inlet and outlet of the heater falls.
   (c) When the level of the thermal oil in the expansion tank falls abnormally.

9.12.3 Safety Devices etc., for Thermal Oil Heaters directly heated by the exhaust gas of engines

1. Safety devices etc., are to comply with the requirements in 9.12.2-1, -3 and **-**4.

2. The master valve of an expansion tank is to be kept normally open and, such an interlocking device that exhaust gas does not enter into the heater where the master valve is closed, is provided.

3. A shut-down device of exhaust gas is to be provided at the exhaust gas inlet of a thermal oil heater and, it is so arranged that the engine can be operable even when the supply of the exhaust gas to the heater is shutdown.

4. Means are to be provided to prevent the leakage oil from thermal oil heaters and water used for fire fighting or others from flowing into the exhaust gas duct of the engine.

5. Stop valves are to be provided at the inlet and outlet of the thermal oil.

6. An audible-visual alarm is to be provided to warn on the following occasions and relayed to the monitoring-station.

(1) When a fire breaks out in the thermal oil heater.
(2) When abnormal high temperature of the thermal oil arises.
(3) When the thermal oil leaks within the thermal oil heater.
(4) When the flow rate of the thermal oil falls, or when the pressure difference of the thermal oil between the inlet and outlet of the heater decreases.
(5) When the liquid level in the expansion tank drops

7. A fixed fire extinguishing and cooling system as deemed appropriate by the Society is to be provided.

9.12.4 Thermal Oil Systems

The thermal oil systems for the thermal oil heaters is to comply with the requirements in 13.11.

9.13 Incinerators

9.13.1 General

1. Notwithstanding the requirements in 9.2 to 9.12, incinerators are to comply with the requirements in this 9.13.

However, the requirements in this 9.13 do not apply to the incinerators with maximum capacity less than 34.5 *kW*.

2. Notwithstanding **-1**, incinerators for oil or rubbish other than those produced by normal operation of the ship or the like will be specially considered.

9.13.2 Drawings and Data to be Submitted

Notwithstanding the requirements in **9.1.3**, drawings and data to be submitted are as follows;

(1) Drawings

(a) General arrangement of incinerator

(b) Arrangement of incinerator fittings

(c) Other drawings considered necessary by the Society

(2) Data

(a) Particulars

(b) Instruction manual of safety devices

(c) Operation manual of incinerator

(d) Other data considered necessary by the Society

9.13.3 Construction and Fittings

The construction and fittings of the incinerators are to comply with the requirements in the following **(1)** to **(9)**.

(1) Major parts of the combustion chamber is to be framed by effective material.

(2) Combustion chambers are to be so constructed as to ensure that harmful combustion gas or drain will not leak.

(3) Uptakes from the combustion chambers are:

(a) not to be connected to the exhaust gas pipes from diesel engines and gas turbines;

(b) to be led to such positions that combustion gas will not enter inboard; and

(c) if they are connected to the uptakes from boilers, thermal oil heaters or other incinerators, to be subject to a special consideration by the Society.

(4) A temperature measuring device for combustion gas is to be provided.

(5) The fire door for rubbish is to be arranged so that back-firing from the combustion chamber is prevented.

(6) An over-pressure preventive device is to be provided to the water jacket, if any, of the incinerators.

(7) Waste oil piping systems are to comply with the relevant requirements in **13.9**.

(8) Burning systems are:

(a) to be so arranged that the combustion chamber is prepurged by air before ignition;

(b) if automatic ignition adopted, to be so arranged that the fuel valve does precede the ignition spark;

(c) if automatic fuel supply system is provided, to be capable of controlling the amount of fuel supplied; and

(d) if automatic combustion control device is provided, to comply with the requirements in **18.4.2-2(1)**, **(2)** and **(3)**.

(9) The location of the remote shut-off device for the incinerators is to comply with the requirements in **5.2.2-4, Part 6**.

9.13.4 Safety Devices and Alarm Devices

1. Incinerators fitted with automatic fuel or waste oil supply systems are to be provided with a safety device to stop the supply of fuel and waste oil to the burners automatically in the cases of the following **(1)** and **(2)**:

(1) When the maximum working temperature of the furnace is exceeded.

(2) When the flame vanishes.

2. Incinerators are to be provided with alarm devices which operate in the following cases:

(1) When the approved working temperature of the furnace is exceeded.

(2) When the flame vanishes.

(3) When the power supply to the alarm device stops.

(4) When cooling system, if any, stops.

(5) When the waste oil supply pressure to the furnace falls, in the case of pressure atomizing.

(6) When the fuel supply pressure to the furnace falls, in the case of pressure atomizing.

(7) When combustion air supply system, if any, stops.

9.13.5 Tests

Operation tests of the safety devices and alarm devices specified in **9.13.4** and burning test are to be carried out.

Chapter 10 PRESSURE VESSELS

10.1 General

10.1.1 Scope

1. The requirements in this Chapter apply to vessels, which contain gas or liquid, intended for pressure exceeding the atmospheric pressure at their top, including heat exchangers, but excluding those exposed to flame, combustion gas or hot gas.

2. For heat exchangers, etc. whose internal pressure does not reach atmospheric pressure, the relevant requirements in this Chapter apply (in this case negative gauge pressure of the vessel is to be substituted by positive gauge pressure of same value).

10.1.2 Design Pressure

The design pressure used for strength calculations of each structural number of the pressure vessels is not to be less than the following, whichever is the greatest:

(1) Approved working pressure specified in **1.2.21, Part 1A**.

(2) Maximum working pressure at maximum temperature (maximum working temperature) to be designed by the manufacturer

(3) The following pressure in the case of pressure vessels used for liquefied gases, stored under pressurized condition at or near the atmospheric temperature, whichever is the greatest:

  (a) Vapour pressure of the gas at 45 C°

  (b) Maximum working pressure

  (c) 0.7 *MPa*

10.1.3 Classification of Pressure Vessels

1. Pressure vessels are classified into the following three groups in accordance with the thickness of shell plates and, their service conditions.

(1) Pressure vessels, Group I (*PV*-1)

Pressure vessels which conform to either one of the following items:

  (a) Shell plate exceeding 38 *mm* in thickness (*See*, Note 1.)

  (b) Design pressure exceeding 4 *MPa* (*See*, Note 1.)

  (c) Maximum working temperature exceeding 350 *C*°

  (d) Steam generators with the design pressure exceeding 0.35 *MPa*

  (e) Vessels in which inflammable high pressure gas having the vapour pressure not less than 0.2 *MPa* at 38 °C is contained (*See*, Note 2.)

Notes:

1. The pressure vessels of which the shell plates exceed 38 *mm* in thickness and/or the design pressure exceed 4 *MPa* are classified into *PV*-2 , provided that they are only subjected to hydraulic oil or water pressure at the atmospheric temperature.
2. The requirements for *PV*-2 apply to materials, constructions and welding, when the pressure vessel has a capacity of 500 *liters* or under.

(2) Pressure vessels, Group II (*PV*-2)

Pressure vessels which conform to either one of the following items:

(a) Shell plate exceeding 16 *mm* in thickness

(b) Design pressure exceeding 1 *MPa*

(c) Maximum working temperature exceeding 150 C°

(d) Steam generators with design pressure not exceeding 0.35 *MPa*

(3) Pressure vessels, Group III (*PV*-3)

Pressure vessels not included in Group I and II

2. The class of pressure vessels used for dangerous substances not specified in **-1** will be determined in each case, in accordance with the property of the substance, the service, the service condition, etc.

10.1.4 Drawings and Data

Drawings and data to be submitted are generally as follows. However, for pressure vessels of Group III, no submission is required unless it is specifically requested by the Society.

(1) Drawings (with type and dimensions of materials specified)

(a) General arrangement

(b) Details of shells

(c) Arrangement of pressure relief devices

(d) Details of washers for fittings and nozzles

(e) Other drawings considered necessary by the Society

(2) Data

(a) Principal particulars

(b) Welding specifications (with welding procedures, welding consumables and welding conditions)

(c) Other data considered necessary by the Society

10.2 Materials and Welding

10.2.1 Materials

1. The materials used for the construction of the pressure parts of pressure vessels are to be adequate for their service conditions and to comply with the requirements in the following **(1)** to **(3)**. However, when special materials are intended to be used, sufficient information on the materials is to be submitted to the Society for approval in connection with the design and usage.

(1) Pressure vessels, Group I (*PV*-1)

All materials are to comply with the requirements in **Chapter 3** to **Chapter 7**, **Part 10** and they are to be tested in accordance with the requirements in **Chapter 1** and **Chapter 2** of the said Part.

(2) Pressure vessels, Group II (*PV*-2)

Same as Group I. However, for the pressure vessels which conform to either one of the following items, materials may be in accordance with the requirements in **(3)**.

(a) Design pressure below 0.7 *MPa*.

(b) Design pressure not exceeding 2 *MPa*, maximum working temperature not exceeding 150° and internal capacity not exceeding 500 *litres*

(3) Pressure vessels, Group III (*PV*-3)

The materials complying with the requirements in the recognized standards are to be used.

2. Notwithstanding the requirements in **-1(1)** and **(2)**, the materials of the fittings such as valves, nozzles, etc. to be fitted to the pressure vessels of Group I and Group II may be in accordance with the requirements in **-1(3)**, where approved by the Society in consideration of their dimensions and service conditions.

10.2.2 Service Limitation of Cast Iron

1. Grey cast iron is not to be used for shells of the following pressure vessels:

(1) The maximum working temperature exceeds 220 °*C* or the design pressure exceeds 1 *MPa*.

(2) Flammable or toxic substances are contained or handled.

2. Special cast iron such as nodular graphite cast iron etc. may be used for the pressure vessels with the maximum working temperature not exceeding 350 °*C* and the design pressure not exceeding 1.8 *MPa* where approved by the Society.

10.2.3 Service Limitation of Materials Used for Fittings

The service limitation of materials to be used for fittings is to comply with the requirements in **9.9.1**. For the fittings of the pressure vessels used for containing or handling flammable or toxic substances, no cast iron to be used unless approved by the Society.

10.2.4 Heat Treatment of Steel Plates

In case where the heat treatment, such as hot forming or stress relieving is carried out on steel plates during the manufacturing process of the pressure vessels, the manufacturer of the pressure vessels is to inform such intention with an order for the materials.

What are expected of the manufactures of steel plates in this case are specified in **3.3.4, Part 10**.

10.2.5 Heat Treatment of Materials subjected to Cold-forming

In case where the cold-forming is considered harmful to the materials of the pressure vessels which are used under the environment such that stress corrosion cracking is expected, suitable measures such as heat treatment are to be taken.

10.2.6 Non-destructive Testings for Cast Steels and Cast Irons

1. The cast steel and cast iron used for shells of pressure vessels of Group I subject to internal pressure are to be subjected to radiographic testing or ultrasonic testing as well as magnetic particle testing or dye penetrant testing for confirming that they are free from detrimental defects.

2. The cast steel and cast iron used for shells of pressure vessels of Group II subject to internal pressure are to be subjected to adequate non-destructive testing for confirming that they are free from detrimental defects.

10.2.7 Welding

The workmanship of welding for pressure vessels are to comply with the requirements in **Chapter 11**.

10.3 Design Requirements

10.3.1 Symbol

Unless expressly specified otherwise, the symbols used in this Chapter are as follows:

f: Allowable stress (*N/mm*^{2}) conforming to the requirements in **10.4.1-1, -2** or **12.2.1**

a: Corrosion allowance (*mm*) conforming to the requirements in **10.4.3**

T_r : Required thickness (*mm*) calculated by using design pressure. The allowable pressure means the pressure obtained by substituting the actual thickness for the required thickness

P: Design pressure (*MPa*)

J: Minimum value of the efficiency specified in **10.4.2**

R: Inside radius of the shell (*mm*)

R_{20} : Specified tensile strength for material concerned, at room temperature (*N/mm*^{2})

E_{20} : Specified minimum yield point (or 0.2% proof stress) of material concerned, at room temperature (*N/mm*^{2})

10.3.2 Design Load

1. In the design of a pressure vessel, the following loading is to be taken into account, where considered necessary, in addition to the internal pressure:

(1) Static head of contained fluid

(2) External pressure

(3) Dynamic loads caused by ship's motions

(4) Thermal stress

(5) Loading from fittings

(6) Loading due to reactions exerting on supporting structure

(7) Hydrostatic test pressure loads

(8) Other loading or external forces exerted on the actual pressure vessels

2. If deemed necessary, fatigue analysis and crack propagation analysis are to be carried out in consideration of the loading specified in **-1**.

10.3.3 Pressure Vessels of Unusual Shape

Where it is not appropriate to design according to the requirements in **10.5** and **10.6** as the shape of the Part subject to a pressure is unusual, strain or deformations under a suitable load are to be measured with the approval by the Society and the Society will consider them as complying with the requirements in **10.5** and **10.6** taking account of the results of the measurement.

10.3.4 Design Considerations

1. Pressure vessels for low temperature service are to have sufficient notch toughness for the lowest service temperature involved.

2. Pressure vessels used in an extremely corrosive environment are to be provided with effective corrosion control means.

3. Heat exchangers are to be provided with an effective sealing mechanism at the joints between tubes and tube plates, and tube plates and shell so as to prevent two types of heat exchanging fluid from mixing each other.

10.3.5 Considerations for Installation

1. Pressure vessels are to be so installed as to minimize the effects of ship's motions, vibrations from the machinery installations, external forces exerted by the piping and supports and thermal expansions due to temperature variation.

2. Pressure vessels and their fittings are to be installed at positions convenient for operation, repair and inspection.

10.4 Allowable Stress, Efficiency and Corrosion Allowance

10.4.1 Allowable Stress

1. The allowable stress of the materials used at room temperature is to be determined by the following items. The allowable stress (f) of carbon steel (including carbon manganese steel) and low alloy steels excluding cast steels is not to be taken to be greater than obtained from the following formulae, whichever is the smaller. For pressure vessels used for liquefied gas, the values of denominator for f_1 and f_2 are to be 3.0 and 2.0, respectively.

$$f_1 = \frac{R_{20}}{2.7}, f_2 = \frac{E_{20}}{1.6}$$

(1) The allowable stress of the electric resistance welded steel tubes except where they are used for the shell of pressure vessels is to be taken to the value specified in **(1)** when subjected to the ultrasonic testing or any other compatible flaw detection approved by the Society for the entire length of the weld, and other cases 85% of the value specified in **(1)**.

(2) The allowable stress of cast steel is to be taken to the value obtained by **(1)** multiplied by the coefficients given in **Table 10.1**.

(3) The allowable stress of cast iron is to be taken to 1/8 of the specified minimum tensile strength. However, the allowable stress of special cast iron approved by the Society may be taken to 1/6 of the specified minimum tensile strength.

(4) The allowable stress (f) of austenitic steel is to be taken to the following f_1 or f_2 whichever is the smaller.

$$f_1 = \frac{R_{20}}{3.5}, \qquad f_2 = \frac{E_{20}}{1.6}$$

(5) The allowable stress (f) of aluminium alloy is to be taken to the following f_1 or f_2, whichever is the smaller.

$$f_1 = \frac{R_{20}}{4.0}, \qquad f_2 = \frac{E_{20}}{1.5}$$

Table 10.1 Coefficients to be Multiplied to Allowable Stress of Cast Steels

Type of test	Coefficient
When no radiographic test or any other alternative testing is carried out	0.7
When random radiographic test or alternative testing is carried out	0.8
When the above test are carried out all parts	0.9

2. For the allowable stress of materials used for pressure vessels for high temperature service, the requirements in 9.4.1 or the value deemed appropriate by the Society apply.

3. The allowable tensile stress is to conform to the requirements in **-1** and **-2**. However, the allowable tensile stress of bolts is to comply with the following requirements:

(1) In case where bolts are used at room temperature, the value is to be taken to the following **(a)** or **(b)**, whichever is the smaller. However, for bolts complying with the requirements in the recognized standards the value may be1/3 of the proof load specified therein.

(a) $\frac{R_{20}}{5.0}$

(b) $\frac{E_{20}}{4.0}$

(2) In case where bolts are used at high temperature, the value will be considered by the Society in each case.

4. The allowable bending stress is to comply with the following requirements:

(1) In case where the materials are used at room temperature, the requirements in **-1** are to be complied with. However, for cast iron or cast steel, the value is to be taken to 1.2 times thereof.

(2) In case where the materials are used at high temperature, the value will be considered by Society in each case.

5. The allowable shearing stress for the mean primary shearing stress in the section subjected to shearing load is to be taken to 80% of the allowable tensile stress.

6. The allowable compression stress in the cylindrical shell of pressure vessels used at room temperature subject to a load causing compression stress in longitudinal direction is to be taken to the following **(1)** or **(2)**, whichever is the smaller:

(1) The value specified in **-1**

(2) The allowable buckling stress by the following formula:

$$\sigma_Z = \frac{0.3ET_0}{D_m(1 + 0.004\frac{E}{E_{20}})}$$

where;

σ_Z: Allowable buckling stress (*N/mm*^{2})

E: Modulus of longitudinal elasticity at room temperature (N/mm^2)

T_0: Net thickness of shell plate excluding corrosion allowance from the actual shell plate (*mm*)

D_m : Average shell diameter (*mm*)

7. The allowable stress for various stresses of carbon steel or carbon manganese steel used for the shell of pressure vessels formed by rotating unit when detailed calculations are carried out, may be as follows:

$$P_m \leq f$$

$$P_L \leq 1.5f$$

$$P_b \leq 1.5f$$

$$P_L + P_b \leq 1.5f$$

$P_m + P_b \leq 1.5f$

$P_L + P_b + Q \leq 3f$

where;

P_m: Equivalent primary general membrane stress (N/mm^2)

P_L : Equivalent primary local membrane stress (N/mm^2)

P_b: Equivalent primary bending stress (N/mm^2)

Q: Equivalent secondary stress (N/mm^2)

10.4.2 Efficiencies of Joint

The efficiency of joints is to be as follows:

(1) Seamless shells: 1.00

(2) Welded shells: As given in **Table 10.2**

(3) Where electric resistance welded steel tubes are used for shell: As given in **Table 10.2(1)**

Table 10.2 Joint Efficiency of Welded Joints

Type of joint	Type of radiographic testing		
	Full radiographic testing out	Partial radiographic testing carried out	No radiographic testing carried out
(1) Double-welded butt joint or the butt welded joint considered equivalent by the Society	1.00	0.85	0.75
(2) Single-welded butt joint where the backing strip is left unremoved or the single-welded butt joint considered equivalent by the Society	0.90	0.80	0.70
(3) Single-welded butt joint other than above (1) and (2)	-	-	0.60
(4) Double-welded full fillet lap joint	-	-	0.55

Note:

Radiographic testing may be substituted by ultrasonic testing if approved by the Society.

10.4.3 Corrosion Allowance

1. The corrosion allowance of the materials used for strength calculation, except where they are subjected to extreme corrosions or wear and tear, is to be taken to not less than 1.0 *mm* or 1/6 of the required thickness without the corrosion allowance for the inner surface whichever is the smaller. In case where corrosion resistance materials are used where effective corrosion control measures are taken or when there is no possibility of corrosion, the value may be reduced accordingly.

2. In case where the outer surface of the pressure vessel, which may suffer corrosion is provided with thermal insulation which prevents external inspection, appropriate amount of corrosion allowance is to be provided also on the outer surface of the pressure vessel.

10.5 Strength

10.5.1 Minimum Thickness of Each Component

1. The thickness of shell plate and end plate is not to be less than 5 *mm* except where specifically approved by the Society in consideration of the diameter, pressure, temperature, materials, etc. The thickness of the formed end plate except for the full hemispherical end plate is not to be less than the required thickness (calculated by assuming that the efficiency is 1.00) of the shell to which the end plate is welded.

2. The thickness of nozzles welded to pressure vessels is to comply with the following requirements. This requirement will be modified where approved by the Society in consideration of the dimensions or shape, materials, etc.

(1) The thickness is not to be less than either the value 2.5 *mm* added to 1/25 of the outside diameter of the nozzle or the value calculated by the formula in **10.5.2-2**. However, this value need not be more than the thickness of the shell at which the nozzle is welded.

(2) Notwithstanding the requirement in **(1)**, for pressure vessels of Groups II and III the value need not be more than 4 *mm*, if it is not less than the value calculated by the formula in **10.5.2-2**.

10.5.2 Strength of Shell Plates, End Plates and Flat Plates subjected to Internal Pressure

1. General Shell plates, end plates and flat plates without stays or other supports (excluding tube plates of heat exchanger) subjected to internal pressure are to comply with the requirements specified in **-2** to **-7**. However, the strength of the shell plate of pressure vessels under the following condition is to be calculated in accordance with suitable formulae considered appropriate by the Society.

(1) Cylindrical pressure vessel

$$\frac{T_r}{D} > 0.25 \text{ } or \text{ } P > \frac{fJ}{2.5}$$

(2) Spherical pressure vessel

$$\frac{T_r}{D} > 0.185 \text{ } or \text{ } P > \frac{fJ}{1.5}$$

2. Required thickness of cylindrical shell plates subjected to internal pressure

The required thickness of cylindrical shell plates subjected to internal pressure is to be calculated by the following formula. However, in the case of the cylindrical shell plate having openings for which reinforcement is required, openings are to be reinforced in accordance with the requirements in **10.6.3**

$$T_r = \frac{PR}{fJ - 0.25P} + a$$

3. Required thickness of spherical shell plates subjected to internal pressure

The required thickness of spherical shell plate subjected to internal pressure is to be calculated by the following formula. However, in the case of the spherical shell plate having openings for which reinforcement is required, the openings are to be reinforced in accordance with the requirements in **10.6.3**.

$$T_r = \frac{PR}{2fJ - 0.5P} + a$$

4. Required thickness of formed end plate subjected to pressure on the concave side without stays or other supports

(1) The required thickness of end plates having no openings is to be calculated by the following formula:

(a) Dished and hemispherical end plates

$$T_r = \frac{PR_1W}{2fJ - 0.5P} + a$$

where;

$$W = \frac{1}{4}\left(3 + \sqrt{\frac{R_1}{r}}\right) \text{ for dished end plate}$$

$W = 1$ for hemispherical end plate

R_1: Inside crown radius

It is to be less than the outside diameter of the skirt of the end plate.

r: Inside knuckle radius

It is not to be less than 6% of the outside diameter of the skirt of the end plate or 3 times the actual thickness of the end plate, whichever is the greater.

(b) Semi-ellipsoidal end plates (in case where half of the inside minor axis of the end plate is not less than ¼ of the inside major axis of the end plate)

$$T_r = \frac{PR}{fJ - 0.5P} + a$$

(2) The required thickness of end plates having openings is to comply with the following requirements in **(a)**, **(b)** or **(c)**:

(a) In case where no reinforcement for openings is necessary according to the requirements in **10.6.2**, or the openings are reinforced in accordance with the requirements in **9.6.3-3 and -4**, and the required thickness is to be calculated by the formula specified in **(1)**.

(b) Where an end plate has a flanged-in manhole or access opening with a maximum diameter exceeding 150 *mm*, and the flanged-in reinforcement complies with the requirement in **9.6.3-7**, the thickness is to be calculated as follows:

i. Dished or hemispherical end plates

The thickness is to be increased by not less than 15% (if the calculated value is less than 3 *mm*, the value is to be taken to 3 *mm*) of the required thickness calculated by the formula specified in **(1)(a)**. In this case, where the inside crown radius of the end plate is smaller than 0.80 times the inside diameter of the shell, the value of the inside crown radius in the formula is to be 0.80 times the inside diameter of the shell.

In calculating the thickness of the end plate having two manholes in accordance with this **i)**, the distance between the two manholes is not to be less than 1/4 of the outside diameter of the end plate.

ii. Semi-ellipsoidal end plates

The requirements in **(1)(a)** are to be applied, however, in this case $R1$ is to be 0.80 times the inside diameter of shell, and W to be 1.77.

(c) The required thickness, where the openings are not reinforced in accordance with the requirements in **(a)** o **(b)**, is to be calculated by the following formula. However, the thickness is not to be less than the value obtained by the formula given in **(1)**.

$$T_r = \frac{PD_0}{2f}K + a$$

where;

D_0: Outside diameter of end plate (mm)

K: As shown in **Fig. 9.6**. However, this is applicable to the end plates complying with the following conditions:

Hemispherical end plates:

$0.003D_0 \leq T_e \leq 0.16D_0$

Semi-ellipsoidal end plates:

$0.003D_0 \leq T_e \leq 0.08D_0$

$H \geq 0.18D_0$

Dished end plates:

$0.003D_0 \leq T_e \leq 0.08D_0$

$r \geq 0.1D_0$

$r \geq 3T_e$

$R_1 \leq D_0$

$H \geq 0.18D_0$

or $0.01D_0 \leq T_e \leq 0.03D_0$

$r \geq 0.06D_0$

$H = 0.18D_0$

Or $0.02D_0 \leq T_e \leq 00.03D_0$

$r \geq 0.06D_0$

$0.18D_0 \leq H \leq 0.22D_0$

T_e : Actual thickness of end plate (mm)

H: Depth of end plate measured on its external surface from the plane of junction of the dished part with the cylindrical part (mm)

R_1 and r: As specified in **(1)(a)**

5. Required thickness of formed end plates subjected to pressure on the convex side

The required thickness of formed end plates subjected to pressure on their convex sides is not to be less than the thickness calculated on the assumption that their concave sides are subjected to the pressure at least 1.67 times the design pressure.

6. Required thickness of flat end plates and cover plates, etc., without stays or other supports

(1) Where the flat end plates and cover plates without stays or other supports are welded to shell plates, the required thickness is to be calculated by the following formulae:

(a) Circular plate

$$T_r = C_1 d \sqrt{\frac{P}{f}} a$$

(b) Non-circular plate

$$T_r = C_1 C_2 d \sqrt{\frac{P}{f}} + a$$

where;

C_1: Constant shown in **Fig. 9.9**

$C_2 = \sqrt{3.4 - 2.4 \frac{d}{D'}}$ but need not be over 1.6

d: Diameter shown in **Fig. 9.9** (for circular plates), or minimum length (for non-circular end plates) (*mm*)

D' : Long span of non-circular end plates or covers measured perpendicular to short span (*mm*)

(2) Where the flat cover plates without stays are bolted to the shell plate, the required thickness is to be calculated by the following formula:

(a) Where full face gaskets are used

For circular plate

$$T_r = d \sqrt{\frac{C_3 P}{f}} + a$$

For non-circular plate

$$T_r = d \sqrt{\frac{C_3 C_4 P}{f}} + a$$

$$T_r = d \sqrt{\frac{C_3 C_4 P}{f} + \frac{6V h_g}{f L d^2}} + a$$

where;

C_3: Constant determined by bolting methods as shown in **Fig. 9.10**

$C_4 = 3.4 - 2.4 \frac{d}{D'}$ but need not be over 2.5

d: Diameter shown in **Fig. 9.10** (for circular plates, or minimum length (for non-circular plates) (*mm*)

D': Long span of non-circular end plates or covers measured perpendicular to short span (*mm*)

W: Mean load (*N*) of bolt loads necessary for the water tightness and allowable load for the bolt used actually

L: Total length of the circle passing through bolt centres (*mm*)

h_g: Arm length of moment due to gasket reaction shown in **Fig. 9.10** (*mm*)

7. Steam heated steam generators

For steam heated steam generators, flat end plates with stays or other supports, and dimensions of the stays are to comply with the requirements in 9.5.7, 9.5.13 and 9.5.14.

10.5.3 Required Thickness of Tube Plates for Heat Exchangers

The thickness of tube plates for heat exchangers without tube stays is to comply with the following requirements:

(1) Except for floating head, the required thickness of flat tube plates without tube stays for the heat exchangers and the like is to be either of the values calculated by the following formulae, whichever is the greater:

$$T_r = \frac{C_5 D}{2}\sqrt{\frac{P}{f_b}} + a$$

$$T_r = \frac{PA}{\tau L} + a$$

where;

f_b: Allowable bending stress of the material (*N/mm*^{2})

τ: Allowable shearing stress of the material (*N/mm*^{2})

C_5: Factor determined by the supporting method of tube and tube plate. Where the tube plates are not integral with the shell, when straight tubes are used. This value is to be taken to 1.0 and when *U*-tubes are used this value is to be taken to 1.25. Where the tube plates are integral with the shell, the value shown in Fig. 10.1 are to be used.

D: Diameter of outer circle of tube end plate (*mm*), i.e., in case where the tube end plate is bolted to flange, *D* is the diameter of a circle passing through the positions to which gasket reaction is acted ; where tube plate is fixed to the shell, the inside diameter of the shell (corrosion allowance is to be deducted)

A: Area of a polygon obtained by connecting the centers of the outermost tube holes (*see*, Fig. 10.2) (*mm*^{2})

L: Length obtained by deducting the sum of the tube hole diameters of the outermost tubes from the length of the outer periphery of the fore mentioned polygon (*mm*)

a: Corrosion allowance (*mm*). In case where a groove for the partition plate or a gasket groove with a depth greater than the corrosion allowance specified in 10.4.3 is provided, *a* is to be taken to the depth of such groove.

(2) In obtaining T_r in **(1)**, calculations are to be carried out on both sides by using respective *P*, *C*5 and *D*. However, in case where differential pressure calculation is carried out, consideration will be given by the Society in each case.

Fig. 10.1 Value of C_5

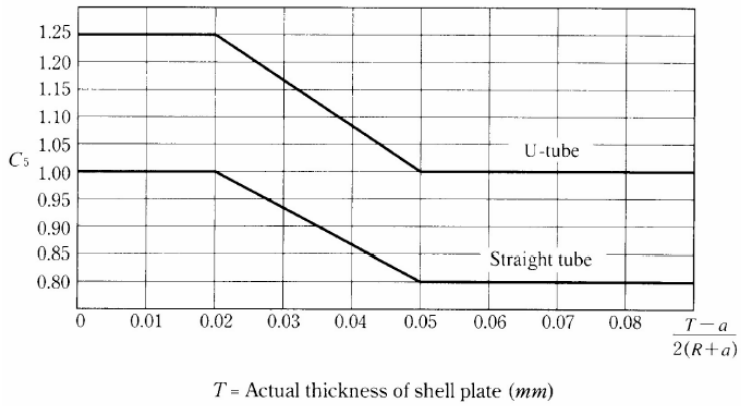
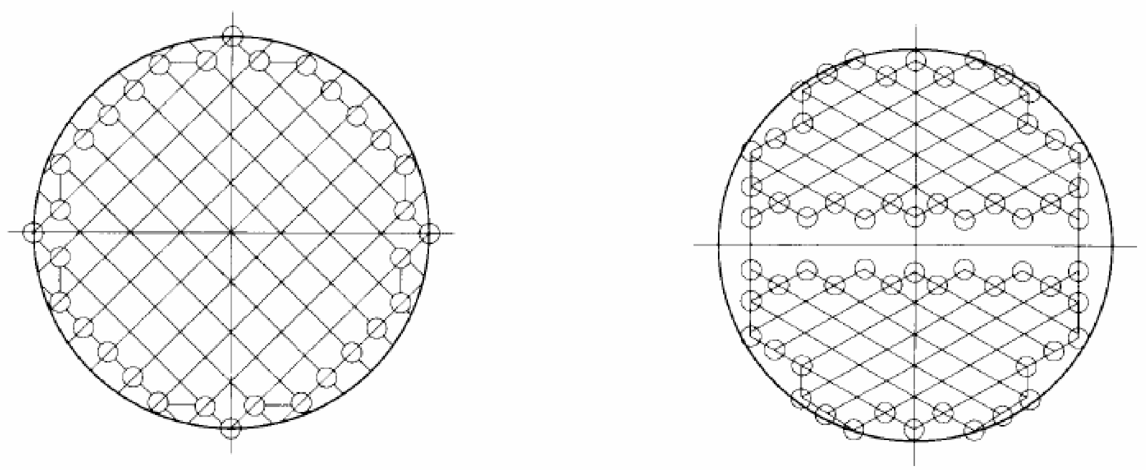


Fig. 10.2 Polygon used for Tube Plate Calculation



10.5.4 Required Thickness of Tubes for Heat Exchangers

1. The materials of the tubes for heat exchangers are to be suitable for their purposes, and the required thickness is to be calculated by the following formula:

$$T_r = \frac{PD_0}{2f} + a$$

where;

D_0: Outside diameter of tube (mm)

a: 1.5 mm for steel tube 0.1 T for copper or copper alloy tube

T: Actual thickness of tube (mm)

f: As given in 10.4.1 or Table 10.3

2. The thickness of the bent pipes for U-tube type heat exchangers is to be sufficient taking account of the thickness reduction caused by bending.

Table 10.3 Values of Allowable stress of Copper and Copper Alloy Pipes (f)

Kind of Materials (Grade)	Design Temperature (˚C)										
	50 or less	75	100	125	150	175	200	225	250	275	300
For phosphorous deoxidized copper seamless pipes and tubes (N/mm^2)											
C1201 C1220	41	41	40	40	34	27.5	18.5	-	-	-	-
For brass seamless pipes and tubes for condenser and heat exchanger (N/mm^2)											
C4430	68	68	68	68	68	67	24	-	-	-	-
C6870 C6871 C6872	78	78	78	78	78	51	24.5	-	-	-	-
For copper nickel seamless pipes and tubes for condenser and heat exchanger (N/mm^2)											
C7060	68	68	67	65.5	64	62	59	56	52	48	44
C7100	73	72	72	71	70	70	67	65	63	60	57
C7150	81	79	77	75	73	71	69	67	65.5	64	62

Notes: Intermediate values are to be determined by interpolation.

10.5.5 Strength of Pressure Vessels subjected to External Pressure

In case where the internal pressure of pressure vessels may become lower than the external pressure, strength calculations are to be carried out for buckling.

10.5.6 Fatigue Analysis

For pressure vessels subjected to dynamic loads or excessive cyclic external loads, fatigue analysis is to be carried out. The degree of cumulative fatigue in this case is to comply with the following formula. However, the value on the right side of the formula may be increased to a value considered appropriate by the Society according to the *S-N* curve used in the calculation but not exceeding 1.0.

$$\sum \frac{n_i}{N_i} \leq 0.5$$

where;

n_i: Number of cycles at each stress level

N_i: Number of cycles to fracture for the respective stress level given by the *S-N* curve of material used

10.5.7 Considerations for Secondary Stress

Where deemed necessary by the Society, consideration is to be given to the strength against secondary stress.

10.5.8 Considerations for Thermal Stress

For pressure vessels which may subject to excessive thermal stress or which contain fluid with a boiling point below -55 °C, consideration is to be given to the strength against thermal stress.

10.5.9 Strength Calculation by Special Method

Even in cases where the dimensions of each component of pressure vessels do not conform to the requirements in **10.5**, if detailed strength calculation sheets are submitted, the Society will examine the data and approve the pressure vessels provided that the results of such examination are acceptable to the Society.

10.6 Manholes, Other Openings for Nozzle, etc. and their Reinforcements

10.6.1 Manholes, Cleaning Holes and Inspection Holes

1. Pressure vessels are to be provided with manholes, cleaning holes and inspection holes on shell plates or end plates for inspection and maintenance in accordance with **Table 10.4**. However, where considered appropriate by the Society, the number and dimensions of these openings may be reduced.

2. The standard dimensions of manhole, cleaning holes and inspection holes are given in **Table 10.5**.

3. The construction of holes and covers is to comply with the requirements in **9.6.1-2**.

Table 10.4 Number of Manholes, Cleaning Holes and Inspection Holes

Inside diameter of shell	Number of manholes, cleaning holes and inspection holes	
	Vessel with internal volume for not more than 100*l* and with internal length of not more than 1.5*m*	All other vessels than those listed in the left hand column
300*mm* or below	One or more inspection holes	Two or more inspection holes
More than 300*mm* up to 500*mm* inclusive		Two or more cleaning holes; or One or more cleaning holes and inspection holes each
More than 500*mm* up to 750*mm* inclusive	-	One or more manholes; or Two or more cleaning holes; or One or more cleaning holes[1] and inspection holes each
More than 750*mm*		One or more manholes[2]

Notes:

1 The dimensions of the cleaning holes are generally to comply with the values for the cleaning holes required for the shell with an internal diameter more than 750*mm* by the **Table 10.5**

2 Pressure vessels such as heat exchangers, etc. which are not considered necessary to provide the manholes for the reasons of their shapes, purposes, etc. may be provided with two or more cleaning holes instead of the manholes.

Table 10.5 Dimensions of Holes

Type of hole	Inside diameter of shell	Dimensions of the holes
Manholes	For all dimensions	Oval: 400*mm*×300*mm* Circular: 400*mm*
Cleaning holes	More than 750*mm*	Oval: 150*mm*×100*mm* Circular: 150*mm*
	750*mm* and less	Oval: 100*mm*×75*mm* Circular: 100*mm*
Inspection holes	For all dimensions	50*mm*

10.6.2 Reinforcement of Opening

In case where manholes, other openings for nozzles, etc. are provided in the shell, openings are to be reinforced.

However, the reinforcement may be omitted for the single opening shown in the following:

(1) Openings having a maximum diameter (in threaded opening, the diameter of the root) of not more than 60 *mm* nor more than 1/4 of the inside diameter of the shell or of the flanged part of end plate.

(2) Openings provided on the shell plate having a maximum diameter not exceeding the value shown in **Fig. 9.7**. In this case, no unreinforced opening is to exceed 200 *mm* in diameter.

(3) Openings provided on the end plate complying with the requirement in **10.5.2-4(2)(c)** where no reinforcement is required due to the increased thickness of the end plates.

10.6.3 Reinforcing Procedures of Openings

The reinforcing procedures for openings provided in shell plates and end plates subjected to internal pressure are to comply with the requirements in **9.6.3**. However, the reinforcement of the following openings will be considered by the Society in each case.

(1) Openings provided in the shell plate and having a diameter not less than 1/2 of the inside diameter of the shell.

(2) Openings whose outer extremity is at a distance of one-tenth of the shell outside diameter from the outer surface of the shell.

(3) Multiple openings whose distance between the axes is close.

10.7 Joints and Connections of Each Member

10.7.1 Welded Joints

1. The dimension and shapes of edge preparation and the method of tapering of the unequal thickness plates are to comply with the requirements in **9.8.1-1** and **-2**.

2. The welded joints of shell of the pressure vessels of Group I are to comply with the following requirements:

(1) Longitudinal joints

To be of the double-welded butt joint or the butt welded joint considered equivalent by the Society.

(2) Circumferential joints

To be in accordance with **(1)**. However, when approved by the Society, the double-welded butt joint may be replaced by single-welded butt joint with backing strip or other butt welded joint considered equivalent by the Society.

3. The welded joints of shell of the pressure vessels of Group II are to comply with the following requirements:

(1) Longitudinal joints

To be in accordance with **-2(1)**.

(2) Circumferential joints

To be in accordance with **(1)** or single-welded butt joint with backing strip or other butt welded joint considered equivalent by the Society. However, for plates of not more than 16 *mm* in thickness, single-welded butt joint may be accepted.

4. The welded joints of shell of the pressure vessels of Group III are to comply with the following requirements:

(1) Longitudinal joints

(a) For plates over 9 *mm* in thickness

To be in accordance with **-3 (1)**, or single-welded butt joint with backing strip or other butt welded joint considered equivalent by the Society.

(b) For plates of not more than 9 *mm* in thickness

To be in accordance with **(a)**, or double-welded full fillet lap joint.

(c) For plates of not more than 6 *mm* in thickness

To be in accordance with the above **(b)**, or single-welded butt joint.

(2) Circumferential joints

To be in accordance with **(1) (c)**, or one side welded full fillet lap joint.

10.7.2 Shape of Welded Joint and Connection

The shape of welded joints and connections are to be as shown in **Fig. 9.9** or to be as considered equivalent by the Society.

10.7.3 Construction of Bolted Cover Plates

The construction of unstayed flat cover plates bolted to the shell is to comply with the requirements in **9.8.3**.

10.8 Fittings, etc.

10.8.1 Materials of Fittings

The material of the nozzles, flanges or distance pieces attached directly to the shell of pressure vessels of Group I and Group II is to be of the equivalent material of the shell. However, this requirement may be dispensed with for flanges to be bolted or where approved by the Society.

10.8.2 Construction of Fittings

1. Fittings such as valves, flanges, and bolts, nuts, gaskets, etc. are to have the construction and dimensions conforming to the recognized standards and they are to conform to the service conditions specified in such standards.

2. Fittings are to be attached to shells of pressure vessels of Group I and Group II with flanged joint or by welding.

However, in case where the thickness of the shell is over 12 *mm* or in case where a seat for screwing is fitted to the shell, the fittings of not more than 32 *mm* in nominal diameter may be attached to the shell by screwing.

10.8.3 Installation of Pressure Relief Devices

1. Pressure vessels in which pressure may exceed the design pressure under working condition are to be provided with relief valves which are set at a pressure not exceeding the design pressure and which are capable of preventing the pressure from exceeding by more than 10% above the design pressure.

2. Where it may create a dangerous condition only when the pressure vessel is exposed to a fire or other unexpected source of external heat, a pressure relieving device is to be provided to prevent the pressure from exceeding to more than 1.2 times the design pressure. However, if an air reservoir which is not used for a general emergency alarm system required by the *paragraph 4.2, Regulation 6, Chapter III, the Annex* to *SOLAS Convention* is provided with a fusible plug with melting point not exceeding 150 °C to release the pressure automatically in the case of a fire, the pressure relieving device may be omitted.

3. Heat exchangers or other similar pressure vessels, where internal pressure may exceed the design pressure due to failure of the heat exchanging tubes, tube plates, partition plates and other internals are to be provided with a suitable relief valve.

4. Steam generators belonging to Group I are to be provided with a safety valve specified in **9.9.3**.

5. No stop valve is to be provided between a pressure vessel and a relief valve or other pressure relieving devices, except where means are provided in such a way that the function of the pressure relieving device is not impaired during the use of the pressure vessels.

6. A rupture disc may be provided between a pressure vessel and a relief valve or at a discharge line of the relief valve. In this case, the bursting pressure of the rupture disc is not to exceed the set pressure of the relief valve. In addition, the discharge capacity of the rupture disc is not to be less than the discharge capacity of the relief valve.

10.8.4 Pressure and Temperature Measuring Devices

Pressure and temperature measuring devices are to be provided on pressure vessel where considered necessary.

10.8.5 Fittings of Air Reservoir

1. Pressure relieving devices for air reservoirs are to comply with the requirements in **10.8.3**.

2. Air reservoirs are to be provided with effective drainage system.

3. Air reservoirs are to be provided with pressure measuring devices.

10.9 Tests

10.9.1 Shop Tests

1. Tests for welds are to conform to the requirements in **Chapter 11** of this Part.

2. Pressure vessels and their fittings are to be subjected to hydrostatic tests according to the following requirements after completion of manufacture:

(1) Shells of pressure vessels

(a) Pressure vessels of Group I and Group II are to be subjected to hydrostatic tests at a pressure equal to 1.5 times the design pressure. However, when the primary general membrane stress of the shell is expected to exceed 90% of the specified yield point of the material by this test pressure, the test pressure is to be lowered to such a pressure that the stress becomes 90% of the specified yield point of the material.

(b) Pressure vessels of Group III considered necessary by the Society are to be subjected to hydrostatic tests in accordance with the requirements in **(a)** above.

(2) Fittings of pressure vessels

Fittings of pressure vessels of Group I and Group II are to be subjected to hydrostatic tests at a pressure equal to 2 times the design pressure.

(3) Hydrostatic tests of heat exchangers which are not specified in **(1)** and **(2)** and other special pressure vessels as well as their fittings will be considered by the Society in each case.

Chapter 11 WELDING FOR MACHINERY INSTALLATIONS

11.1 General

11.1.1 Scope

1. The requirements in this chapter apply to welding for machinery installations.

2. As for the matters other than those specified in this chapter, the requirements in **Part 11** are to apply.

11.1.2 Base Metals

1. Base metals used in the welding work are to be those suitable for welding. And the carbon content is not to exceed 0.23% for carbon steel and low alloy castings and forgings, or 0.35% for other carbon steel and low alloy steel. When approved by the Society in consideration of the welding conditions, the carbon content may be increased to the value approved.

2. The upper limit of the carbon equivalent for high tensile steels is to be as deemed appropriate by the Society.

11.2 Welding Procedure Qualification Tests

11.2.1 Requirements for Tests

1. The manufacturers are to conduct the welding procedure qualification tests, if they plan to carry out for the first time the welding work as follows:

(1) Welding work for boilers, pressure vessels of Group I and Group II

(2) Welding work for principal components of prime movers, etc. (the principal components specified in **Table 2.1**, **3.2.1-1**, **4.2.1-1** and **5.2.1-1**, hereinafter the same)

(3) Welding work using special materials

(4) Welding work using special welding procedure

2. In case where the welding procedures approved for the approval test as specified in **-1**, are intended to be modified partly, except minor changes in welding conditions, an welding procedure qualification tests is to be carried out.

3. The manufacturers are to submit the detailed data in connection with the welding work for the approval by the Society where they conduct the approval test for welding procedure.

11.2.2 Kinds of Test

1. The types of test are as follows:

(1) Mechanical tests

(a) Butt welding

i. Tensile test for joint

ii. Guided bend test or rolled bend test

iii. Impact test (the middle welded part, boundary between base metal and welded part, and heat affected zone)

(b) Fillet welding

Fracture test

(2) Visual inspection and hardness test

(3) Macroscopic and microscopic examinations (the middle part of weld metal, boundary between base metal and weld metal, and heat affected zone)

(4) Radiographic examination

2. In case where welding is made with a base metal having no impact value required, impact test may be omitted subject to the approval by the Society.

3. In fillet welding, microscopic examination and radiographic examination may be omitted.

4. For the welding procedure qualification tests on materials used at high temperature, the Society may require creep test or high temperature tensile test.

5. In case where special materials are used, or special welding procedure is employed, the Society may require other tests matching the specific requirements of such special materials or special welding procedure.

11.2.3 Welding of Test Assemblies

1. The shape and dimensions of test assemblies are to be as specified in **Fig. 11.1**.

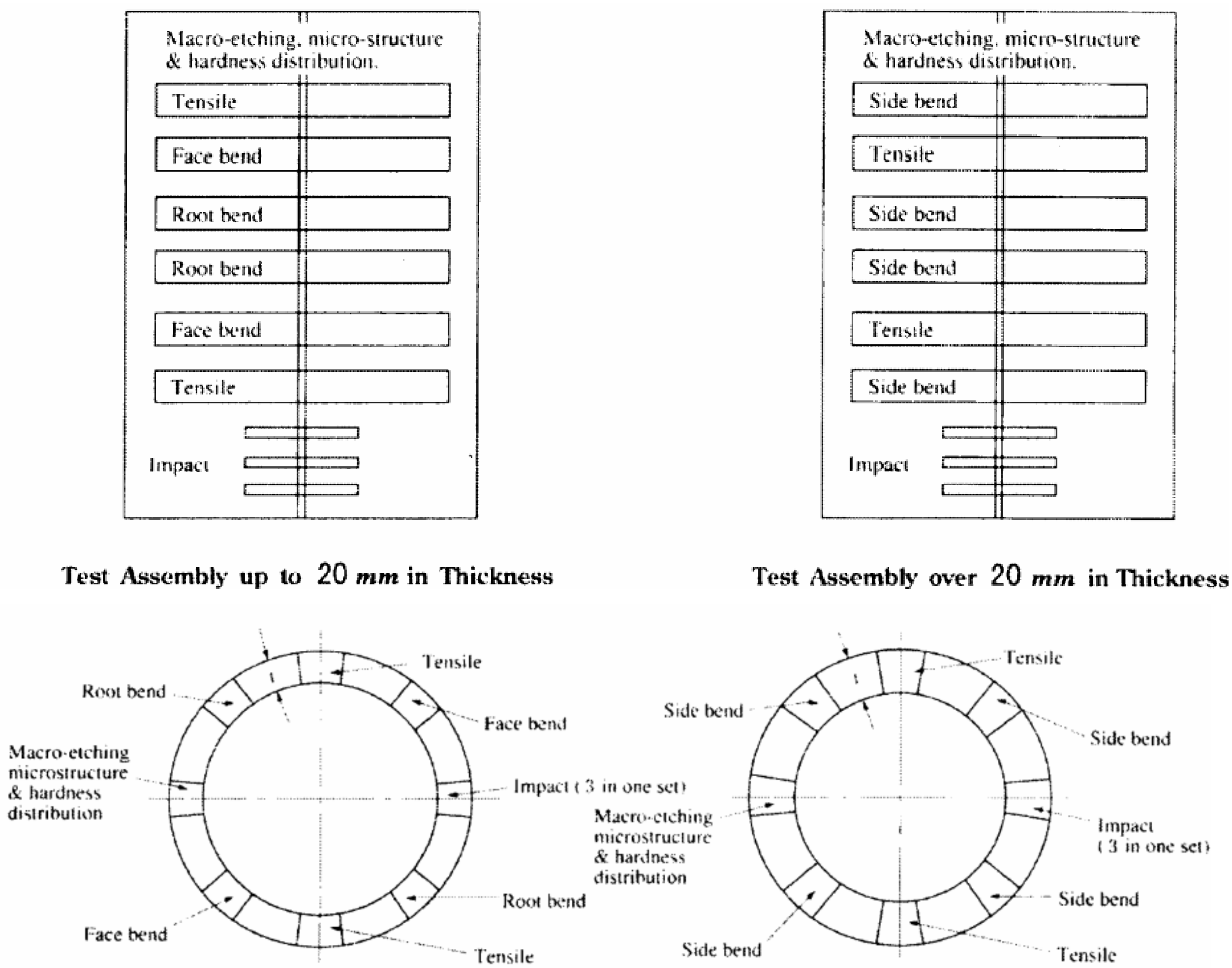
2. The test assemblies are to be of the same or equivalent material used in actual welding work.

3. In case where test assemblies of rolled steel plates for low temperature service are butt welded, the direction of welding is to be generally in parallel with the direction of rolling.

4. In general, the thickness of the test assemblies for welding procedure qualification test is to be equal to the maximum thickness of materials to be adopted in actual welding work.

5. The welding of the test assemblies is to be carried out under the same or similar conditions employed in the actual work.

Fig. 11.1 Welding Procedure Qualification Test Assemblies



11.2.4 Test Specimens and Test Procedures

The shape and dimensions of the test specimens and test procedure are to comply with the requirements in Chapter 3, Part 11. However, they may apply the requirements of other appropriate Codes or Standards subject to the approval by the Society.

11.2.5 Retests

1. Where a part of the tests fails to meet the requirements, the retests as to the failed test may be made on duplicate test specimens, and where all these additional tests are satisfactory, the tests are accepted as successful. However, for the impact test as applied to the cargo tanks in ships carrying liquefied gases in bulk, retests may be carried out in accordance with the requirements in 4.2.10-3, Part 11.

2. The test specimens for retest are to be taken from either the same test assembly of the first test or the test assembly newly welded under the same welding conditions as the first test assembly.

3. Where the retest also fails to meet the requirements, tests may be made over again after changing the welding conditions. In this case, where the whole tests specified for the test assembly are carried out and are in compliance with the requirements, the tests are accepted as successful.

11.2.6 Test Records

The test results are to be summarized and to be submitted to the Society as the test records.

11.2.7 Omission of Tests

In case where test records deemed appropriate by the Society are available, and the test results are considered to be satisfactory, a part or all of the tests may be omitted.

11.3 Post Weld Heat Treatment

11.3.1 Procedure of Post Weld Heat Treatment

1. The stress-relieving procedures by the post weld heat treatment for welds using carbon steel, carbon manganese steel and low alloy steel as the base metal are to be as follows:

(1) Furnace heating method

(a) The temperature of the furnace is to be less than 400°C at the time the object is placed in or out of it.

(b) The rate of heating and cooling above 400°C are to be as follows:

i. The heating rate $\leq 220 \times 25/t(^{\circ}C/hr)$,but in no case more than 220 (°C /*hr*)

ii. The cooling rate $\leq 275 \times 25/t(^{\circ}C/hr)$, but in no case more than 275 (°C /*hr*)

where;

t : Maximum weld thickness (*mm*)

(c) The temperature is to be held as given in **Table 11.1**, and after holding the temperature for a period of one hour per 25 *mm* thickness or more, then to be cooled slowly. When an approval from the Society is obtained, reduction to the temperature given in **Table 11.2** may be accepted.

(d) During the heating and cooling period there shall not be a greater variation in temperature throughout the portion being heated than 130°C within any 4500 *mm* interval of length. During the holding periods there shall not be a greater difference than 80°C between the highest and lowest temperature of each portion being heated.

(e) The maximum heating temperature at each portion of the object is not to reject the final temperature of heat treatment for the material of the portion.

(2) Local heating method

(a) In the post-heating processing, the temperature gradient between the heating and non-heating areas is to be made smooth so that no harmful effects will be given on the materials.

(b) The heating band is to be greater than such an area with a length of 6 times the plate thickness or more as measured from the center of the weld for each side respectively. In the circumferential joint, the heating band may be 3 times the plate thickness (2 times in case of pipe) on the outer side of the welding bead of maximum width.

(c) The rate of heating and cooling at temperatures of 400°C or above are to conform to the requirements in **(1)(b)**.

(d) The holding temperature and period in the post weld heat treatment are to conform to the requirements in **(1)(c)**. Throughout the holding period or, heating and cooling periods, the entire band is to be brought up uniformly to the required temperature as far as applicable.

2. For post weld heat treatment procedures on materials other than those specified in **-1**, the requirements shall be specially considered by the Society according to the type of base metal and welding materials, and welding procedures.

3. The post weld heat treatment of low alloy steels, alloy steels and other special steels is to be carried out with special consideration for avoiding undue degrading of the notch toughness of the material and cracks arising from the heat treatment.

Table 11.1 Post Weld Heat Treatment Temperature

Category	Kind of steels	Minimum holding temperature $^{\circ}C$
1	Carbon steel Carbon manganese steel $0.5M_0 steel$ $0.5C_r$ $0.5M_0 steel$ $1\ C_r$ $0.5M_0 steel$ $1\frac{1}{4}C_r$ $0.5M_0 steel$	600
2	$2\frac{1}{4}C_r$ $M_0 steel$ $5C_r$ $0.5M_0 steel$	680

Table 11.2 Temperature Reduction vs. Holding Time[2)3)]

Minimum holding temperature ˚C	Minimum holding time (hour)
T-30	2
T-60	3
T-90[(1)]	5

Notes:

1 Applicable to carbon steel and carbon manganese steel only.

2 Intermediate values are to be obtained by interpolation.

3 *T* is the minimum holding temperature in **Table 11.1**.

11.3.2 Temperature Measurements and Recordings during Post Weld Heat Treatment

The temperature measurement is to, in general, be carried out by automatic measurement by thermocouple. However, in case where the temperature of each part of the heated object can readily be assumed on the basis of the furnace temperature, such furnace temperature may be used in place of the temperature of the heated object. When post weld heat treatment is carried out, the following items are to be recorded:

(1) Type and kind of the furnace or heating equipment

(2) Holding temperature and period

(3) Rate of heating and cooling

(4) Other items deemed necessary

11.4 Welding of Boilers

11.4.1 General

Where pressure parts of boilers are fabricated by means of welding, the welding is to be carried out in accordance with the requirements in **11.4** of this Chapter.

11.4.2 Alignment of Joints and Out-of Roundness

1. For the alignment of butt welded joints, maximum offset is not to exceed the following limits:

(1) For longitudinal joint:

1 *mm* for plates of 20 *mm* or under in thickness.

5% of the plate thickness for plates more than 20 *mm* but less than 60 *mm* in thickness.

3*mm* for plates of 60 *mm* or over in thickness.

(2) For circumferential joint:

1.5 *mm* for plates of 15 *mm* or under in thickness.

10% of the plate thickness for plates more than 15 *mm* but less than 60 *mm* in thickness.

6 *mm* for plates of 60 *mm* or over in thickness.

2. The difference between the maximum and minimum inside diameters (out-of roundness) at any cross section is not to exceed 1% of the nominal inside diameter at the cross section under consideration.

11.4.3 Post Weld Heat Treatment

1. Each boiler including all mountings and fittings is to be subjected to post weld heat treatment for stress relieving after completion of all welding work. However, the post weld heat treatment for following parts may be omitted when the Society deems acceptable taking into account the welding procedure, preheating and post weld heating conditions in case where the thickness of welded part is less than 19 *mm* for carbon steel or less than 13 *mm* for alloy steel.

(1) Welded joints between tubes, tubes and tube flanges, and tubes and headers

(2) Circumferential joints of headers

(3) Welded parts specifically approved by the Society

2. In case where minor fillet welding is carried out for the following items **(1)** and **(2)** on the boilers subjected to post weld heat treatment, no post weld heat treatment is required after such welding work.

(1) Seal welding

(2) Intermittent welding for attaching fittings provided that the welds do not exceed 6 *mm* in throat thickness and 50 *mm* in length and have an interval of 50 *mm* or more.

11.4.4 Production Weld Tests

1. For welded joints of boiler shell, the production weld tests are to be carried out. The welded joints of furnace plate may only be subjected to guided bend test or roller bend test, or radiographic test as the production weld tests.

2. Test plates for the workmanship test are to be sampled in accordance with the following requirements:

(1) The test plates are to be attached to each shell in such a manner that they are to be welded

(2) The test plates for the circumferential joints of shells are to be made separately under the same welding conditions as the circumferential joint. However, test plates for the circumferential joints are not required except where the shell has no longitudinal joints or welding procedure for the circumferential joints is remarkably different from that for the longitudinal joints.

(3) The test plates are to be of the same specification, type and thickness as the base metal (where plates with different thickness are welded, test plates are to be taken from the thinner one), and no warping is to be caused by welding.

(4) The test plates are to be subjected to the same post weld heat treatment as in the actual welding, and are not to be heated beyond the heating temperature and holding period as applied in the actual welding.

3. In tests for the welded joints of the test plate, tensile test, bend test and macro-etching test are to be carried out.

Guided bend test or roller bend test may be accepted as the bend test. In this case, the number and dimensions of the test specimens are to be as given in **Table 11.3**.

4. Method of test and results required are to comply with the following requirements:

(1) Tensile test for joint

The tensile strength is not to be less than the minimum tensile strength specified for the base metal. However, if the test specimen breaks at the base metal but the specimen shows no sign of defect in the welded joint, and tensile strength is not less than 95% of the minimum tensile strength specified for the base metal, the test results may be judged acceptable.

(2) Guided bend test or roller bend test

The test specimen is to be put on the bend test jig, which deemed appropriate by the Society, and the center line of the welding part coincides with the center of the jig. For the side bend test, the test specimen is to be bent with one of both sides in tension, and for the root bend test to be bent with the narrow side of the weld in tension.

In all cases, the test specimens are to be bent in the jig through an angle of 180 *degrees*. Cracks or any other defect exceeding 3 *mm* in length are not to be observed on the outer surface of bent specimen on welding part. However, any crack on the corners of the test specimen may be considered irrelevant to the test results.

(3) Macro-etching test

Cracks, lack of fusion, incomplete penetration or any other defect are not to be observed.

5. In case where the tensile strength is not less than 90% of the values specified in the requirements, or in case where guided bend test or roller bend test fails to meet the requirements from defects other than those in the welded parts, retest is allowed. In this case, two additional test specimens are to be taken from the same test plate for each failure, and both of the two test specimens are required to satisfy the requirements.

Table 11.3 The Number and Dimensions of Test Specimens

Number of test specimens		Dimension of test specimens
Tensile test for joint: 1		As specified in **Table 3.1 Part 11**
Guided bend test or roller bend tests	Face bend test and root bend test: 1 set or Side bend test: 1	As specified in **Table 3.2 Part 11**
Macro-etching test: 1		

Note:

For test plates not more than 20*mm* in thickness, face bend test and root bend test are to be conducted. For those over 20*mm* in thickness, side bend test is to be conducted.

11.4.5 Radiographic Testing for Longitudinal and Circumferential Joints

1. For boiler shells (including headers), the entire length of both longitudinal and circumferential welded joints is to be subjected to radiographic testing.

2. The radiographic technique employed is to be such as to detect as small defect as 2% of the welding depth, and the wire of the penetrameter corresponding to 2% of the thickness of the base metal is to be clearly shown on the radiographic film.

3. Each radiograph film is to be marked clearly as to the relative position of the welds to the radiograph position.

4. The following items are to be included in the report of radiographic testing:

(1) Thickness of material (flush or reinforced)

(2) Distance from radiation source to weld surface

(3) Distance from film to weld surface

(4) Type of penetrameter used

5. The reinforcement of the welded joints, where radiographic testing is carried out, is to be evenly finished to ensure trouble free examination. In this case, the height of reinforcement is to be in accordance with the following standard:

(1) Double-welded butt joint: To be as given in **Table 11.4**

(2) Single-welded butt joint: To be 1.5 *mm* or under, regardless of the plate thickness.

6. The defects found in the radiographic tests are to be dealt with according to the following requirements:

(1) If there are defects, such as crack, lack of fusion, incomplete penetration, etc., the defective part is to be chipped off and to be rewelded.

(2) The defects such as blow-hole and slag-inclusion are to be reconditioned in accordance with the procedure deemed appropriate by the Society taking into consideration the shape, dimensions and distribution of the defects.

7. In case where repairs are carried out on the welded joints, the repaired part of the joints is to be subjected to the radiographic test once again.

Table 11.4 Allowable Height of Reinforcement

Thickness of base metal (*mm*)	12 or less	Exceeding 12 but not more than 25	Exceeding 25
Allowable height or reinforcement (*mm*)	1.5	2.5	3.0

11.4.6 Non-destructive Testing for Other Welds

1. For other important welds than those specified in **11.4.5**, non-destructive tests are to be carried out as considered appropriate.

2. The radiographic test procedures are to comply with the requirements specified in **11.4.5-2** through **-7**, and the other non-destructive testing procedures are to be appropriate for the type of tests employed.

11.5 Welding of Pressure Vessels

11.5.1 General

Where pressure parts of pressure vessels are fabricated by means of welding, the welding is to be carried out in accordance with the requirements in **11.5** of this Chapter.

11.5.2 Alignment of Joints, Out-of Roundness and Angular Deflection

1. For the alignment of the butt welded joints, maximum offset is not to exceed the following limits:

(1) For longitudinal joint, joints in end plate and joints between hemispherical end plate and shell:

(a) $1/4t$ for plates of 50 *mm* or under in actual thickness (t) (maximum: 3.2 *mm*)

(b) $1/16t$ for plates more than 50 *mm* in actual thickness (t) (maximum: 9 *mm*)

(2) For circumferential joint:

(a) $1/4t$ for plates of 40 *mm* or under in actual thickness (t) (maximum: 5 *mm*)

(b) $1/8t$ for plates more than 40 *mm* in actual thickness (t) (maximum: 19 *mm*)

(3) For welding joints of spherical shells and end plates, and welding joints between hemispherical end plates and shells, the values for longitudinal joints are applied.

2. The out-of roundness of shells subjected to internal pressure is to be in accordance with the requirements in **11.4.2**.

3. The welds are to be free from remarkable angular deflection.

4. The out-of roundness and angular deflection of the shell subjected to external pressure are to be examined in each case in consideration of the buckling strength.

11.5.3 Stress Relieving

1. Pressure vessels of Group I are to be subjected to the post weld heat treatment for stress relieving after all fittings, such as flanges, nozzles and reinforcement plates, have been welded in place.

2. Pressure vessels of Group II corresponding to the following **(1)** or **(2)** are to be subjected to stress relieving heat treatment in accordance with the requirements in **-1**.

(1) The thickness of shell plates exceeds 30 *mm*

The thickness of shell plate is not less than 16 *mm* and is greater than the value of T_n

(2) determined by the following formula:

$$T_n = \frac{D}{120} + 10$$

Where

D: Inside diameter of shell (*mm*)

3. Notwithstanding the requirements in **-1** and **-2**, the mechanical stress reliving by pressurizing for pressure vessels made of carbon steel or carbon manganese steel may be employed as an alternative to the post weld heat treatment with the approval of the Society and subject to the following conditions **(1)** through **(4)**:

(1) Complicated welded pressure vessel parts such as nozzles are to be heat treated before they are welded to larger parts of the pressure vessels.

(2) The plate thickness is not to exceed the value given by a standard acceptable to the Society.

(3) A detailed stress analysis is made to ascertain that the maximum primary membrane stress during the mechanical stress relieving closely approaches, but does not exceed, 90% of the yield stress of the material.

Strain measurements during the stress relief pressurization may be required by the Society for verifying the calculations.

(4) The procedure for mechanical stress relieving is to be submitted beforehand to the Society for approval.

4. In case where the material having a superior notch toughness is used, stress relieving may be omitted if approved by the Society.

5. In case where the following welding is carried out on the stress relieved pressure vessels, post weld stress relieving may be omitted:

(1) For carbon steels and carbon manganese steels

(a) When fittings with inside diameter not more than 50 *mm* are fitted by fillet welding with throat thickness not more than 12 *mm*

(b) When non-pressured fittings are fitted by fillet welding with throat thickness not more than 12 *mm*

(c) Stud welded parts

(2) Welds specifically approved by the Society for other materials except those specified in **(1)**. In this case, appropriate preheating is to be carried out during the welding.

11.5.4 Production Weld Tests

1. In case where pressure vessels of Group I are of welded construction, the production weld tests specified in this **11.5.4** is to be carried out.

(1) Test plates are to be sampled in accordance with the following requirements:

(a) The test plates are to be attached to each shell in such a manner that they are welded continuously corresponding to the edges of the longitudinal joint. Further, the deformation of the test plates during their manufacturing is to be restricted to a minimum as far as practicable.

(b) The test plates for the circumferential joints of shells are to be made separately under the same welding conditions as the circumferential joint. However, the test plate for the circumferential joints is not required except where the shell has no longitudinal joints or welding procedure for the circumferential joints is remarkably different from that for the longitudinal joints.

(c) The test plates are to be taken from the same materials used for manufacturing the pressure vessels as a general rule.

(2) In mechanical tests of the test plate, tensile test for joint, bend test and Charpy impact test are to be carried out. Guided bend test or roller bend test may be accepted as the bend test. In this case, the number and dimensions of the test specimens are to be as given in **Table 11.5**.

(3) Method of test and the results are to comply with the following requirements:

(a) The tensile test and guided bend test or roller bend test for joints are required to comply with the requirements in **11.4.4-4(1)** and **(2)**.

(b) Impact test

The impact test specimen is to be sampled from the welded joint portions such that its longitudinal axis is at right angle to the welding line and its surface is 5 *mm* inside from the surface of the plate. The notch on the test specimen is to coincide with the centre of the weld line and to be on the surface at right angle to the plate surface. The mean value of absorbed energies of three test specimens is not to be less than the value approved by the Society.

Table 11.5 Number and Dimensions of test Specimens

<table>
<tr><td colspan="2">Number of test specimens</td><td>Dimension of test specimens</td></tr>
<tr><td colspan="2">Tensile test for joint: 1</td><td>As specified in Table 3.1 Part 11</td></tr>
<tr><td rowspan="3">Guided bend test or roller bend test</td><td>Face bend test and root bend test: 1 set</td><td rowspan="3">As specified in Table 3.2 Part 11</td></tr>
<tr><td>or</td></tr>
<tr><td>Side bend test: 1</td></tr>
<tr><td colspan="2">Charpy impact test: 1 set</td><td>U4 type specimen as specified in 2.2.4, Part 10</td></tr>
</table>

Note:

For test plates not more than 20*mm* in thickness, face bend test and root bend test are to be conducted. For those over 20*mm* in thickness, side bend test is to be conducted.

2. The production weld tests of pressure vessels of Group II with welding construction are to be conducted in accordance with the requirements in **-1**, however, the guided bend test or roller bend test specified in **-1(2)** may be omitted.

3. Retest

(1) When tests fail, retest may be conducted. For the tensile and bend tests, two additional test specimens are to be taken from the same test plate or from other test plates manufactured in the same lot of the original test plate for each failure. In retests, both of the test specimens are to conform to the requirements. For the impact test, 1 set (three specimens) of additional test specimens are to be taken from the same test plate or other test plates manufactured in the same lot, and if the mean value of the test results on a total of 6 test specimens is higher than the required mean value, the test plates are judged acceptable.

(2) Retests are allowed in the following cases:

(a) In case where the results of tensile and impact tests are not less than 90% of the values specified in the requirements.

(b) In the case where the cause of failure in the guided or roller bend test is attributed to the defects other than those in the welded parts.

4. Reduction of test

The production weld tests for pressure vessels may be modified at the discretion of the Surveyor taking account of their past experiences.

11.5.5 Radiographic Testing for Welded Joints

1. For butt weld joints corresponding to the following **(1)** or **(2)**, the entire length of those are to be subjected full radiographic testing.

(1) Longitudinal and circumferential weld joints to pressure vessels of Group I

(2) The weld joints whose joint efficiency has been determined subjects to a full radiographic testing.

2. For the pressure vessels whose joint efficiency has been determined subject to spot testing, radiographic testing is to be carried out in accordance with the following requirements.

(1) The length which is not less than 20% of the longitudinal joints (minimum 300 *mm*) and the intersecting part of the circumferential joints with the longitudinal joints which were welded by the same method and by the same welder are to be spot radiographed.

(2) The locations to be spot radiographed are to be chosen by the Surveyor.

3. The radiographic testing procedures and disposal of test results are to conform to the requirements in 11.4.5.

4. Notwithstanding the requirements specified in **-1** and **-2**, ultrasonic tests may be conducted in lieu of the radiographic testing in case where the Society specifically approves.

11.5.6 Non-destructive Testing for Other Welded Parts

1. The welds of fittings such as the openings and their reinforcements for the pressure vessels requiring full radiographic testing are to be subjected to the radiographic testing or the magnetic particle testing considered appropriate by the Society. However, in case where application of these testing methods is considered impractical or when the Society approves in consideration of the welding position and welding shape, the radiographic testing may be replaced with liquid penetrant testing, ultrasonic testing or other testing as appropriate.

2. The welds at the fitted parts of fittings such as the openings and their reinforcements of the pressure vessels requiring radiographic spot testing are to be subjected to the non-destructive testing specified in **-1** by sampling method.

3. The requirements in 11.5.5 apply mutatis mutandis to the non-destructive testing procedure and disposal of test results.

11.6 Welding of Piping

11.6.1 Scope

The requirements in 11.6 apply to the welding of pipes, valves and pipe fittings belonging to Group I and II specified in Chapter 11.

11.6.2 Alignment of Joints

Maximum offset of joints between pipes is not to exceed 1/4 of the pipe thickness.

11.6.3 Preheating of Welds

When welding pipes, materials are to be preheated adequately depending on the kinds and thickness of materials.

11.6.4 Post Weld Heat Treatment

1. After the welding, pipes with the thickness specified in **Table 11.6** are to be subject to post weld heat treatment according to the grade of materials for relieving the residual stresses.

2. As for the post weld heat treatment for pipes and piping systems made of a material other than the materials in **-1** above, the treatment is to be made as deemed appropriate by the Society according to the grades of base metals, weld materials, procedure of weldings, etc.

Table 11.6 Pipes Requiring Post Weld Heat Treatment

Grade (Note 1)		Category in Table 11.1	Thickness of weld (t) (mm)
Grade 1, Grade 2 and Grade 3		1	$t \geq 15$
Grade 4	No. 12	1	$t \geq 15$
	No. 22 No. 23	1	$t > 8$
	No. 24	2	All (Note 2)

Notes:

1 Grades are as specified in **4.2, Part 10**.

2 The treatment may be omitted if the thickness is 8mm or less, outside diameter is 100mm or less, and design temperature is 450°C or less.

11.6.5 Non-destructive Testings

1. Butt weld joints of pipes belonging to Group I and having nominal diameters exceeding 65A are to be subjected to a full radiographic testing.

2. Butt weld joints of pipes belonging to Group I and having nominal diameters not more than 65A and pipes belonging to Group II and having nominal diameters exceeding 90A are to be subjected to a radiographic examination by sampling in accordance with the instructions of the Surveyor.

3. The Society may approve other appropriate non-destructive testings in lieu of a radiographic examination.

4. The requirements in **11.4.5** are to be applied mutatis mutandis to the radiographic examination.

5. With respect to the fillet welding of pipes belonging to Group I or Group II, the Society may require a magnetic particle examination or other suitable examinations in consideration of the material, dimensions and service conditions of pipes and the like.

6. The Society may require a special examination in consideration of welding materials or welding procedures.

11.7 Welding of Principal Components of Prime Movers, etc.

11.7.1 General

1. The welding for the principal components of prime movers, etc. is to comply with the requirements in **11.7**.

2. In case where the principal components of prime movers, etc. are intended to have welded construction, approval is to be obtained from the Society for the shape and dimensions of welded parts, welding materials, welding procedures, heat treatments and non-destructive testing requirements.

11.7.2 Alignments of Joints and Edge Preparations

1. The alignments in butt welded joints are to be in accordance with the following requirements:

(1) 1/4 of the thickness for welded part of 40 *mm* or under in thickness and, maximum 5 *mm*

(2) 1/8 of the thickness for welded part of more than 40 *mm* in thickness and, maximum 19 *mm*

2. In the butt welding between plates of different thickness, the end of the thicker plate is to be tapered down smoothly to that of the thinner plate.

3. The butt welding and T-joint welding of important strength members are to be subjected to back chipping or controlled effectively so as to avoid defects at the roots of welds.

4. In case where fillet welding is carried out in areas subjected to bending stress, toe parts are to be finished smooth.

5. Welding is to be carried out in such a way as not to cause excessive distortion at the welds.

11.7.3 Preheating of Welds

1. In the welding of thick plates, the welding of steels or low alloy steels with carbon content exceeding 0.23%, or the welding of alloy steels, where the Society considers necessary, preheating is to be carried out on the welds.

2. The method of preheating and minimum preheating temperature are to be determined as considered appropriate by the Society according to the types of the base metal and welding materials, thickness of weld and welding method.

11.7.4 Post Weld Heat Treatment

In case where thick materials are used or severe restraint conditions are brought about whereby considerable degree of detrimental effects of the residual stress after welding on the strength of structure are expected, post weld heat treatments are to be carried out.

11.7.5 Non-destructive Testing

For examining the welds, the Society may require ultrasonic tests, magnetic particle tests, liquid penetrant tests and other non-destructive tests as deemed appropriate taking into consideration the materials used, dimensions and service conditions.

Chapter 12 PIPES, VALVES, PIPE FITTINGS AND AUXILIARIES

12.1 General

12.1.1 Scope

The requirements in this Chapter apply to the design, fabrication and tests of pipes, valves, pipe fittings and auxiliaries.

12.1.2 Terminology

1. Design Pressure

Design pressure is the maximum working pressure of a medium inside pipes and is not to be less than the following pressures given in **(1)** to **(4)**:

(1) For piping systems fitted with a relief valve or other overpressure protective device, the pressure based on the set pressure of the relief valve or overpressure protective device. However, for steam piping systems connected to a boiler or piping systems fitted to a pressure vessel, the design pressure of the boiler shell (nominal pressure if the boiler has a superheater) or design pressure for the shell of a pressure vessel.

(2) For pipings on the discharge side of the pumps, the pressure based on the delivery pressure of the pump with the valve on the discharge side closed running the pump at rated speed. However, for pumps having a relief valve or overpressure protective device, the pressure based on its set pressure.

(3) For blow-off pipings of boilers, the design pressure specified in **9.9.6-3**.

(4) For pipes, valves and fittings containing fuel oil, the maximum working pressure or 0.3 *MPa*, whichever is the greater. However, for those containing fuel oil with the working temperature above 60 °C and the working pressure above 0.7 *MPa*, the maximum working pressure or 1.4 *MPa*, whichever is the greater.

2. Design Temperature

The design temperature is the highest working temperature of the medium inside pipes at the designed condition.

3. Pipe Fittings

The pipe fittings in this Part are pipe connecting fittings such as pipe flanges, mechanical joints, pipe pieces, expansion joints, flexible hose assemblies, etc. and items provided in piping systems such as strainers and separators.

4. Flexible hose assemblies

Flexible hose assemblies are flexible hoses with end fittings.

12.1.3 Classes of Pipe

1. Pipes are classified as shown in **Table 12.1** according to the type of medium, design pressure and design temperature. However, pipes having open ends such as drain pipes, overflow pipes, exhaust gas pipes, exhaust pipes of safety valves and steam relief pipes are classified into Group III regardless of the design temperature.

2. Piping systems for other media than specified in **-1** will be considered by the Society depending upon the nature of the medium and their service conditions

Table 12.1 Classes of Pipes

Kind of Medium	Design Pressure (*P*) and Design Temperature (*T*)		
	Group I	Group II (Note)	Group III
Steam	$P > 1.6MP_a$ or $T > 300^{\circ}C$	$P \leq 1.6MP_a$ and $T \leq 300^{\circ}C$	$P \leq 0.7MP_a$ and $T \leq 170^{\circ}C$
Thermal oil	$P > 1.6MP_a$ or $T > 300^{\circ}C$	$P \leq 1.6MP_a$ and $T \leq 300^{\circ}C$	$P \leq 0.7MP_a$ and $T \leq 150^{\circ}C$
Fuel oil, lubricating oil and flammable hydraulic oil	$P > 1.6MP_a$ or $T > 150^{\circ}C$	$P \leq 1.6MP_a$ and $T \leq 150^{\circ}C$	$P \leq 0.7MP_a$ and $T \leq 60^{\circ}C$
Air carbon dioxide gas, water and non-flammable hydraulic oil	$P > 4.0MP_a$ or $T > 300^{\circ}C$	$P \leq 4.0MP_a$ and $T \leq 300^{\circ}C$	$P \leq 1.6MP_a$ and $T \leq 200^{\circ}C$

Note: Excluding the pipes meeting the conditions for Group III

12.1.4 Materials

1. Materials used for auxiliary machinery are to be adequate for their service conditions. The materials used for essential parts of auxiliary machinery are to comply with the recognized standards.

2. Materials for pipes are to be adequate for their service conditions and are to comply with the following requirements:

(1) The materials for pipes belonging to Group I or II are to comply with the requirements in **Part 10**.

(2) The materials for pipes belonging to Group III are to comply with the recognized standards.

3. Materials for valves or cocks (hereinafter referred to as valves in this Chapter) and pipe fittings are to be adequate for their service conditions and are to comply with the following requirements:

(1) The materials for valves and pipe fittings used for the pipes belonging to Group I or II as well as valves and pipe fittings directly fitted to the shell plating and collision bulkhead are to comply with the requirements in **Part 10**.

However, the materials specified in the recognized standards may be used for them where approved by the Society in consideration of the dimensions and service conditions.

(2) The materials for valves and pipe fittings used for the pipes belonging to Group III are to comply with the recognized standards.

4. Pipes, valves and pipe fittings for fire-fighting systems are to be of corrosion resistance materials or to be protected effectively to prevent the fire-fighting capability of the system from deteriorating due to inside corrosion.

12.1.5 Service Limitations for Materials

1. Pipes are, as a rule, to be made of steel, copper, copper alloy or cast iron, and the material is to meet the requirements for the service limitations listed below according to design temperature, classification, service, etc., unless otherwise specified. However, for pipes which have an opening and are classed in Group III regardless of design temperature, the service limitations regarding temperature do not apply.

(1) Steel pipes are not to be used for the following pipes.

(a) Pipes with design temperature over 350°C for pipes of Grade 1 and Grade 2 specified in **4.2, Part 10**. These steel pipes may be used, however, up to 400°C if the allowable stress value is guaranteed.

(b) Pipes with a design temperature over 450°C for pipes of Grade 3, No.2 and No.3 specified in **4.2, Part 10**.

(c) Pipes with a design temperature over 425°C for pipes of Grade 3, No.4 specified in **4.2, Part 10**.

(d) Pipes with a design temperature over 500°C for pipes of Grade 4, No.12 specified in **4.2, Part 10**.

(e) Pipes with a design temperature over 550°C for pipes of Grade 4, No.22, No.23 and No.24 specified in **4.2, Part 10**.

(f) Pipes of Group I, pipes with a design pressure over 1.0 *MPa* or pipes with a design temperature over 230°C for carbon steel pipes for ordinary piping specified in **4.2, Part 10**.

(g) Other steel pipes as deemed appropriate by the Society.

(2) Copper pipes and copper alloy pipes are not to be used for the following pipes:

(a) Pipes with a design temperature over 200°C for pipes of phosphorous-deoxidized-copper seamless pipes and brass seamless pipes and tubes for condensers.

(b) Pipes with a design temperature exceeding 300°C for cupro-nickel seamless pipes and tubes for condensers.

(c) Section of pipes which penetrate partitions of Class *A* or Class *B* for copper alloy pipes except for the case which the Society approves as a special case.

(d) Service limitations regarding temperature for other copper pipes and copper alloy pipes to be as deemed appropriate by the Society.

(3) Cast iron pipes are not to be used for the following pipes:

(a) Pipes of Group I and Group II for cast iron pipes with elongation less than 12%.

(b) Pipes of Group I for cast iron pipes with elongation of 12% and over.

(c) Pipes which are liable to receive water hammering and pipes subject to a large deflection or vibration.

(4) In addition to **(2)** and **(3)**, copper pipes, copper alloy pipes and cast iron pipes are to conform to the requirements in **Table 12.2** according to the service. However, the requirements may be waived when deemed acceptable by the Society.

Table 12.2 Service Limitations for Pipes by Application

Service of pipe (Note 1)	Material		
	Cooper	Cooper alloy	Cast iron
Fuel oil pipes Lubricating oil pipes in machinery space Hydraulic oil pipes in machinery space Thermal oil pipes in machinery space Cargo oil pipes Air pipes Sounding pipes out of sounded area	X (Note 2)	X (Note 2)	X (Note 3)
Overflow pipes Bilge pipes Ballast pipes Drain pipes opening outboard and sanitary Pipes below the freeboard deck Pipes used for fire fighting aboard ships Pipes which develop danger or flood by damage to pipes in fire Boiler water blow off pipes	X	X	X
Control oil pipes in machinery space	○	X (Note 2)	X
Air pipes for remote closing of tank stop valve Air pipes for remote control of auxiliaries, valves, etc, used in fire	○	X	X

Notes:

1 Pipes for measurement, drain pipes and vent pipes are not included.

2 The portion which is placed in tank is usable.

3 Including out of machinery spaces.

Remarks:

1 ○ : Usable

2 × : Use prohibited

2. Valves and pipe fittings are, as a rule, to be made of steel, copper alloy or cast iron, and except the cases otherwise specified they are to conform to the requirements below for service limitations according to the design temperature, class, application, etc. For the valves and pipe fittings, however, which have an opening and are classified in Group III notwithstanding the design temperature, the service limitations regarding temperature do not apply.

(1) Cast steel products and forged steel products are not to be used for the following valves and pipe fittings:

(a) Valves and pipe fittings with a design temperature over 425°C for cast carbon steel products and forged carbon steel products specified in **5.1** and **6.1, Part 10**.

(b) Valves and pipe fittings with a design temperature over 550°C for cast low alloy steel products and forged low alloy products specified in **5.1** and **6.1, Part 10**.

(c) Other cast steel products and forged steel products when deemed appropriate by the Society.

(2) Valves and pipe fittings made of copper alloy are not to be used for valves and pipe fittings with a design temperature over 210°C. However, special bronze, when approved by the Society, can be used for valves and pipe fittings with a design temperature of 260°C or less.

(3) Cast iron products with elongation less than 12% are not to be used for the following valves and pipe fittings:

(a) Valves and pipe fittings with a design temperature over 220°C.

(b) Valves and pipe fittings used for pipes of Group I, except where deemed appropriate by the Society considering their construction and purpose.

(c) Valves and pipe fittings used for pipes of Group II (except steam pipes).

(d) Valves fitted on the external wall of fuel oil tanks or lubrication oil tanks, and subjected to the static head of internal fluid.

(e) Valves, seats and distance pieces mounted on the shell plating or sea chest.

(f) Valves directly mounted on the collision bulkhead.

(g) Valves and pipe fittings of boiler water blow-off piping systems.

(h) Piping systems which are liable to receive water hammering and valves and pipe fittings of piping systems which are liable to have large deflection or vibration.

(i) Valves and pipe fittings of clean ballast piping systems which penetrate cargo oil tanks and reach the forepeak tank.

(j) Valves and pipe fittings of cargo oil piping systems with a design pressure over 1.6 *MPa*.

(k) Valves provided at the ship/shore connection of the flammable liquid cargo line.

(4) Cast iron products with elongation of 12% or above are not to be used for valves and pipe fittings for pipes of Group I, except where deemed appropriate by the Society considering their construction and purpose.

12.1.6 Use of Special Materials

1. Notwithstanding the provisions in **12.1.5** above, such special materials as rubber hoses, plastic pipes, vinyl pipes, aluminum alloys, etc. may be used where approved by the Society taking into account safety against fire and flooding as well as their service conditions, where approved by the Society.

12.2 Thickness of Pipes

12.2.1 Required Thickness of Pipes subject to Internal Pressure

1. The required thickness of pipes subject to internal pressure is to be determined by the following formula:

$$T_r = t_0 + b + C$$

where:

T_r: Required thickness of pipe (*mm*)

$t_0 = \frac{PD}{2fJ+P}$

P: Design pressure (*MPa*)

D: External diameter of the pipe (*mm*)

f: Allowable stress specified in **-3** (*N/mm*^{2})

J: Joint efficiency and as given in the following:

Seamless pipes 1.00

Electric resistance welded pipes 0.85

(1.00 may be adopted in case that a ultrasonic flaw test or an alternative flaw test considered appropriate by the Society is conducted for the entire length of the welded joint)

b: Allowance for bending and as given in the following formula:

$$b = \frac{1}{2.5}\frac{D}{R}t_0$$

R: Mean radius of the bend (*mm*)

However, b need not be considered when it is ascertained that calculated membrane stress in the bend does not exceed the allowable stress.

C: Corrosion allowance specified in **-5** (*mm*)

2. The thickness of pipes having a negative tolerance in thickness is not to be less than value *t*1 determined by the following formula:

$$t_1 = \frac{t_r}{1 - \frac{a}{100}}$$

where:

t_r : Same as in **-1**.

a: Maximum negative tolerance (%)

3. The allowable stress of each material is to comply with the following requirements.

(1) The allowable stress (*f*) of carbon steel pipes and low alloy steel pipes is to be chosen as the lowest of the values given by the following formulae, or the value shown in **Table 12.3(1).** Where, however, the design temperature is not in the creep region of the material, the value of f_3 need not be considered.

$$f_1 = \frac{R_{20}}{2.7}, f_2 = \frac{E_t}{1.6}, f_3 = \frac{S_R}{1.6}$$

where:

R_{20}: Minimum tensile strength of the material at room temperature (*N/mm*^{2})

E_t: Yielding point or 0.2% proof stress of the material at design temperature (*N/mm*^{2})

S_R: Average stress for material concerned to produce rupture in 100,000 *hours* at the design temperature (*N/mm*^{2})

(2) The allowable stress of copper pipes, brass pipes and copper nickel pipes is to be taken to the value shown in **Table 12.3(2)**

(3) The allowable stress of material other than those specified in **(1)** and **(2)** will be considered by the Society in each case.

4. Where t_0 specified in **-1** is calculated by using the allowable stress to the value of 1/5 of the specified minimum tensile strength of the material at the room temperature, in lieu of the allowable stress specified in **-3(1)** for the steel pipes whose design temperature does not exceed 250°C, *b* required to be considered in the formula of t_r specified in **-1** and the increment for the negative tolerance required by **-2** need not be taken into consideration.

The corrosion allowance for steel pipes, and copper and copper alloy pipes is to comply with **Table 12.4** and **Table 12.5** respectively.

Table 12.3(1) Values of Allowable Stress of Steel Pipes (*f*)

Material \ Design Temperature (°C)		Allowable stress of steel pipes (*f*) *N/mm*^{2}													
		100 or less	150	200	250	300	350	375	400	425	450	475	500	525	550
Grade 1	No. 2	123	114	105	96	87	78	-	-	-	-	-	-	-	-
	No. 3	138	128	118	107	96	90	-	-	-	-	-	-	-	-
Grade 2	No. 2	123	114	105	96	87	78	-	-	-	-	-	-	-	-
	No. 3	138	128	118	107	96	90	-	-	-	-	-	-	-	-
	No. 4	156	145	133	122	117	113	-	-	-	-	-	-	-	-
Grade 3	No. 2	123	114	105	96	87	78	75	70	63	56	-	-	-	-
	No. 3	138	128	118	107	96	90	87	84	71	57	-	-	-	-
	No. 4	156	145	133	122	117	113	105	96	77	-	-	-	-	-
Grade 4	No. 12	119	112	105	97	89	85	83	80	77	73	70	65	-	-
	No. 22	121	116	111	105	99	93	91	89	85	80	76	71	55	38
	No. 23	121	116	111	105	99	93	91	89	85	80	76	71	56	40
	No. 24	121	116	111	105	99	93	91	89	85	80	76	71	56	41

Notes:

1 Intermediate values are to be determined by interpolation.

2 The materials of steel pipes shown in this Table are to comply with the requirements in **Part 10**.

Table 12.3(2) Values of Allowable stress of Copper and Copper Alloy Pipes

Kind of materials (Grade)	Design Temperature (˚C)										
	50 or less	75	100	125	150	175	200	225	250	275	300
For phosphorous deoxidized copper seamless pipes and tubes (*N/mm²*)											
C1201 C1220	41	41	40	40	34	27.5	18.5	-	-	-	-
For brass seamless pipes and tubes for condenser and heat exchanger (*N/mm²*)											
C4430	68	68	68	68	68	67	24				
C6870 C6871 C6872	78	78	78	78	78	51	24.5				
For cooper nickel seamless pipes and tubes for condenser and heat exchanger (*N/mm²*)											
C7060	68	68	67	65.5	64	62	59	56	52	48	44
C7100	73	72	72	71	70	70	67	65	63	60	57
C7150	81	79	77	75	73	71	69	67	65.5	64	62

Notes: Intermediate values are to be determined by interpolation.

Table 12.4 Corrosion Allowance for Steel Pipes(*C*)

Piping service		*C*(*mm*)
Superheated steam systems		0.3
Saturated steam system	General service	0.8
	Steam coil system in cargo oil tanks	2
	Steam coil system in fuel oil tanks	1
Feed water system for boilers	Open circuit systems	1.5
	Closed circuit systems	0.5
Blow-off systems for boiler		1.5
Compressed air systems		1
Lubricating and hydraulic oil systems		0.3
Fuel oil systems		1
Cargo oil Systems		2
Primary refrigerant systems for refrigerating plants		0.3
Fresh water systems		0.8
Sea water systems		3

Notes:

1 For pipes efficiently protected against the internal corrosion, the corrosion allowance in this Table may be reduced by 50% where approved by the Society.

2 Where special alloy steel with sufficient corrosion resistance is used, the corrosion allowance may be reduced to zero.

3 For sea water steel pipes whose nominal diameter is 25*A* or below, the corrosion allowance may be reduced to 1.5*mm*.

4 Where it is difficult to apply this Table or where a medium not specified in this Table is used, the corrosion allowance will be considered by the Society in case taking account of the corrosion conditions.

5 For pipes passing through tanks an additional corrosion allowance is to be considered according to the figures given in the Table, and depending on the external medium, in order to account for the external corrosion.

Table 12.5 Corrosion Allowance for Copper and Copper Alloy Pipes (*C*)

Kind of material	*C*(*mm*)
Phosphorous-deoxidized copper seamless pipes and brass seamless pipes specified in **Table 12.3(2)**	0.8
Cooper nickel seamless pipes specified in **Table 12.3(2)**	0.5

Note:

For media without corrosive action in respect of the material employed, the corrosion allowance may reduced to zero.

12.2.2 Minimum Thickness of Pipes

1. The thickness of steel pipes is to comply with the requirements in **12.2.1** and is not to be less than the value shown in **Table 12.6** depending on the service and location of the pipes. Where, however, corrosion resistant alloy steel pipes are used in lieu of steel pipes, the minimum thickness of these pipes will be considered by the Society in each case.

2. For pipes efficiently protected against corrosion, the minimum thickness specified in **Table 12.6(2)** may be reduced by an amount up to not more than 1 *mm* except for steel pipes for CO_2 fire extinguishing.

3. In determining the thickness of pipes from **Table 12.6(2)**, no allowance need be made for negative tolerance and a reduction in thickness due to bending. For threaded pipes, however, their minimum thickness is to be measured at the bottom of the thread, with the exception of the threaded portions for fitting the pipe head of air pipes, overflow pipes and sounding pipes as well as the threaded portions of pipes for CO_2 fire extinguishing from the distribution station to the nozzles.

4. The minimum thickness of copper and copper alloy pipes is to be as shown in **Table 12.7**.

Table 12.6(1) Minimum Thickness of Steel Pipes

Services of pipes	Location of pipes		Minimum thickness The encircled alphabets correspond to those in **Table-12.6(2)**
Bilge pipes	Passing through thanks except for cargo oil tanks		Ⓔ
	Passing through cargo oil tanks		16 *mm*
	Not passing through tanks		Ⓗ
	Passing through tank except for cargo oil (Note 2)		Ⓔ
Ballast pipes	Passing through cargo oil tanks	For outboard discharge	16*mm*
		For the ballast tanks forward of the collision bulkhead	16*mm*
		For other cases	Ⓔ, but Ⓓ when $D \geq 100A$
	Not passing through tanks		Ⓗ
Supper pipes Sanitary pipes (Note 1)	Penetrating shell plating except for cargo oil tanks and cargo holds and automatic non-return valves being required		Ⓖ
	Penetrating shell plating except for cargo oil tanks and cargo holds and automatic non-return valves being omitted		Ⓓ
	Led from exposed deck and passing through cargo oil tanks		Ⓐ, but 16*mm* when $D \geq 150A$
	Passing through cargo holds	Not protected	Ⓐ (Note 5)
		protected	Ⓒ (Note 5)
	Passing through ballast tanks		Ⓖ
	Not passing through tanks		Ⓖ
Air pipes, overflow pipes, sounding pipes	Passing through tanks except for cargo oil tanks		Ⓔ
	Passing through cargo oil tanks		Ⓑ
	For air pipes and sounding pipes for fuel oil tanks passing through the cargo holds of the bulk carrier		Ⓗ
	For tanks forming a part of ship`s structure		Ⓖ
	Exposed portions or air pipes which terminate above freeboard deck and superstructure deck (Note 1)	(Note 3)	Ⓔ
		(Note 4)	Ⓖ
Fuel oil pipes	Passing through tanks except for fuel oil tanks		Ⓔ
Sea water pipes	Passing through tanks		Ⓔ
	Not passing through tanks		Ⓗ
Fresh water pipes	Passing through tanks		Ⓔ
Cargo oil pipes	Passing through ballast tanks		Ⓔ, but Ⓓ when $D \geq 100A$
	Passing through cargo oil tanks		Ⓔ, but Ⓕ when $D \geq 250A$
	Not passing through tanks		Ⓕ
Pipes for CO_2, fire extinguishing	From bottles to distribution station		Ⓘ
	From distribution station to nozzles		Ⓙ
Pipes other than the above			Ⓚ

Notes:

1 This **Table** is not applied for scupper pipes and sanitary pipes for ships not engaged in international voyage and ships of less than 24m in length.

2 Ⓗ is applied when a safe (dangerous) ballast pipe passes through a safe (dangerous) ballast tank.

3 For air pipes in the position I or II defined in **19.1.2, Part 2** leading to spaces below the freeboard deck, enclosed super structure or enclosed deck house.

4 For air pipes other than described in **Note 3**.

5 The thickness of the pipe need not exceed the thickness of the shell plating in way of the pipe penetration

Table 12.6(2) Minimum Thickness of Steel Pipes (1), (3) (*mm*)

Corresponding Alphabet / Nominal dia. (*A*)	Ⓐ	Ⓑ	Ⓒ	Ⓓ	Ⓔ	Ⓕ	Ⓖ	Ⓗ	Ⓘ(2)	Ⓙ(2)	Ⓚ
6	-	-	-	-	-	-	-	-	-	-	1.6
8	-	-	-	-	-	-	-	-	-	-	1.8
10	-	-	-	-	-	-	-	-	-	-	1.8
15	-	-	-	-	-	2.8	-	3.2	3.2	2.6	2.0
20	-	-	-	-	-	2.9	-	3.2	3.2	2.6	2.0
25	-	-	-	-	-	3.4	-	3.2	4.0	3.2	2.0
32	6.4	-	4.9	-	6.3	3.6	4.5	3.6	4.0	3.2	2.0
40	7.1	-	5.1	-	6.3	3.7	4.5	3.6	4.0	3.2	2.3
50	8.7	8.7	5.5	-	6.3	3.9	4.5	4.0	4.5	3.6	2.3
65	9.5	8.7	7.0	7.0	6.3	5.2	4.5	4.5	5.0	3.6	2.6
80	11.1	8.7	7.6	7.6	7.1	5.5	4.5	4.5	5.6	4.0	2.9
90	12.7	8.7	8.1	8.0	7.1	5.7	4.5	4.5	6.3	4.0	2.9
100	13.5	11.1	8.6	8.6	8.0	6.0	4.5	4.5	7.1	4.5	3.2
125	15.9	11.1	9.5	9.5	8.0	6.6	4.5	4.5	8.0	5.0	3.6
150	18.2	11.1	11.0	11.0	8.8	7.1	4.5	4.5	8.8	5.6	4.0
175	20.6	11.1	11.9	11.8	8.8	7.7	5.3	5.3	-	-	4.5
200	23.0	12.7	12.7	12.5	8.8	8.2	5.8	5.8	-	-	4.5
225	25.8	12.7	13.9	12.5	8.8	8.8	6.2	6.2	-	-	5.0
250	28.6	15.1	15.1	12.5	8.8	9.3	6.3	6.3	-	-	5.0
300	33.3	15.1	17.4	12.5	8.8	10.3	6.3	6.3	-	-	5.6
350	35.7	-	19.0	12.5	8.8	11.1	6.3	6.3	-	-	5.6
400	40.5	-	21.4	12.5	8.8	12.7	6.3	6.3	-	-	6.3
450	45.2	-	23.8	12.5	8.8	12.7	6.3	6.3	-	-	6.3

Notes:

1 Where the thickness of pipes specified in standards does not comply with the minimum thickness in this Table, the standard pipe may be used if the difference is 0.4*mm* or less.

2 Pipes are to be galvanized at least inside, except those fitted in the engine room.

3 For pipes with a nominal diameter other than shown in this Table, their minimum diameter will be considered by the Society in each case.

Table 12.7 Minimum Thickness of Copper and Copper Alloy Pipes (*mm*)

Outside diameter	Cooper pipes	Copper alloy pipes
8-10	1	0.8
12-22	1.2	1
25-45	1.5	1.2
50-76.2	2	1.5
80-120	2.5	2
130-190	3	2.5
200-270	3.5	3
280	4	3.5

12.3 Construction of Valves and Pipe Fittings

12.3.1 General

Valves, pipe fittings, gaskets and packings are to be suitable for the conditions of use and to have a construction specified in a standard deemed appropriate by the Society or equivalent constructions thereto.

12.3.2 Special Valves and Pipe Fittings

Of valves, pipe fittings, gaskets and packing used for pipes of Group I and Group II those of special construction or those produced by the special manufacturing process are to be approved by the Society.

12.3.3 Mechanical Joint

1. Mechanical joints are to be of approved type and adequate for the service conditions and the intended application. The construction and type are to conform to the examples in **Fig. 12.1** according to their classified division of application shown in **Table 12.8** and **Table 12.9**.

Fig 12.1 Examples of mechanical joints

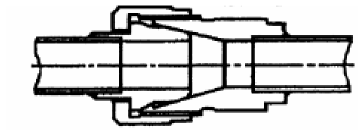
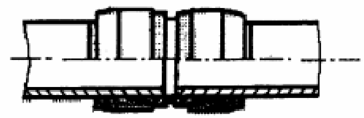
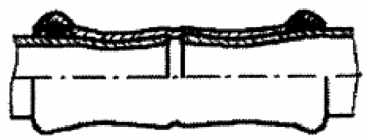
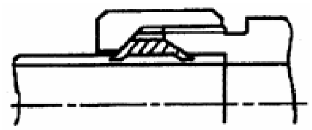
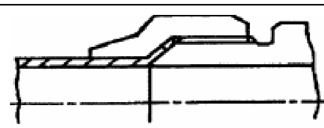
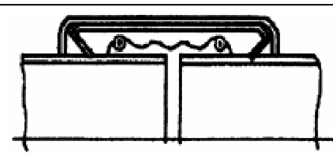
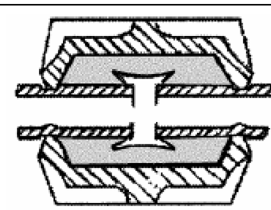
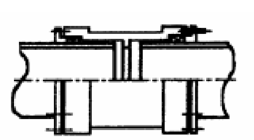
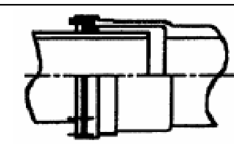
Pipe Unions		
Welded and Brazed Types		
Compression Couplings		
Swage Type		
Press Type		
Bite Type		
Flares Type		
Slip-on Joints		
Grip Type		
Machine Grooved Type		
Slip Type		

Table 12.8 Application of mechanical joints [1]

Service	Systems	Kind of Connections		
		Pipe Unions	Compression Couplings[7]	Slip-on Joints[10]
Flammable fluids[8] (Flash point $\leq 60^\circ C$)	Cargo oil lines	+	+	+[6]
	Crude oil washing lines	+	+	+[6]
	Vent lines	+	+	+[4]
Inert gas	Water seal effluent lines	+	+	+
	Scrubbre effluent lines	+	+	+[3][6]
	Main lines	+	+	+[6]
	Distributions lines	+	+	+[6]
Flammable fluids[8] (Flash point $> 60^\circ C$)	Cargo oil lines	+	+	+[3][4]
	Fuel oil lines	+	+	+[3][4]
	Lubricating oil lines	+	+	+[3][4]
	Hydraulic oil lines	+	+	+[3][4]
	Thermal oil	+	+	+[2]
Sea Water	Bilge lines	+	+	+[4]
	Fire main and water spray	+	+	+[4]
	Foam system	+	+	+[4]
	Sprinkler system	+	+	+[2]
	Ballast system	+	+	+[2]
	Cooling water system	+	+	+
	Tank cleaning services	+	+	+
	Non-essential systems	+	+	+[2]
Fresh Water	Cooling water system	+	+	+[2]
	Condensate return	+	+	+
	Non-essential system	+	+	+[5]
Sanitary/Drains/Scuppers	Deck drains (internal)	+	+	+
	Sanitary drains	+	+	-
	Scuppers and discharge (overboad)	+	+	+
Sounding/Vent	Water tanks/Dry spaces	+	+	+[3][4]
	Oil tanks (f.p.$> 60^\circ C$)	+	+	-
Miscellaneous	Staring/Control air[2]	+	+	+
	Brine	+	+	+
	CO_2 system [2]	+	+	-
	Steam	+	+	-[9]

Notes

1 + Application is allowed, - Application is not allowed

2 Inside machinery spaces of category A: only approved fire resistant types

3 Not inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.

4 Approved fire resistant types

5 Above free board deck only

6 In pump rooms and open decks: only approved fire resistant types

7 If Compression Couplings include any components which readily deteriorate in case of fire, they are to be of approved fire resistant type as required for Slip-on joints.

8 The number of mechanical joints in oil systems is to be kept to a minimum. In general, flanged joints conforming to recognized standards are to be used.

9 Slip type joints as shown in Fig. 12.1, provided that they are restrained on the pipes, may be used for pipes on deck with a design pressure of 1.0 *MPa* or less.

10 The use of slip joints is to comply with the requirements specified in 13.2.4.

Table 12.9 Application of mechanical joints depending upon the class of piping (1)

Type of joints		Classes of pining systems		
		Class I	Class II	Class III
Pipe Unions	Welded and brazed type	+(2)	+(2)	+
Compressions Couplings	Swage type	+	+	+
	Bite type	+(2)	+(2)	+
	Flared type	+(2)	+(2)	+
	Press type	-	-	+
Slip-on joints	Machine grooved type	+	+	+
	Grip type	-	+	+
	Slip type	-	+	+

Notes

1 + Application is allowed - Application is not allowed

2 May be used for pipes of a nominal diameter of 50*A* or below.

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

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

4. Slip-on joints are not to be used inside tanks except use for the same media in the tanks. Unrestrained Slip-on joints are to be used only in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

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

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

7. Material of mechanical joints is to be compatible with the piping material and internal and external media.

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

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

12.3.4 Flexible Hose Assembly

1. Flexible hose assemblies may be used for the following pipes.

(1) Fuel oil pipes (except fuel oil injection pipes)

(2) Lubricating oil pipes

(3) Hydraulic oil pipes

(4) Thermal oil pipes

(5) Compressed air pipes

(6) Bilge and ballast pipes

(7) Fresh water and sea water pipes

(8) Steam pipes of Group III (metallic pipes only)

(9) Exhaust gas pipes (metallic pipes only)

2. Flexible hose assemblies, used for the pipes of Group I or II as well as pipes likely to cause fire or flooding in case of their fracture, are to be approved by the Society.

3. Installation, design and construction of flexible hose assemblies are to comply with **12.1.6-2**.

4. The end fittings of flexible hose assemblies are to have flanges or to comply with **12.3.3** or **12.4.2**.

12.4 Connection and Forming of Piping Systems

12.4.1 Welding of Piping Systems

The welding for piping systems is to comply with the requirements in **Chapter 11**.

12.4.2 Direct Connection of Pipe Length

1. Direct connection of pipe lengths belonging to Group I or II is to be of butt welded type. However, for steel pipes having a nominal diameter of not more than 50*A*, slip-on sleeve welded joint may be used.

2. Threaded pipe joints (only tapered thread where used for pipes in Group I and Group II) are not to be used for the following pipes. However, the use for pipes specified in **(3)** and **(4)** may be accepted having regard to the service of the pipes.

(1) Pipes conveying flammable media, except for pipes with small diameter used for instrumentation.

(2) Pipes for CO_2 systems, except inside protected spaces and in CO_2 cylinder rooms.

(3) Pipes belonging to Group I with a nominal diameter exceeding 25*A*.

(4) Pipes belonging to Group II and Group III with a nominal diameter exceeding 50*A*.

12.4.3 Connection of Pipes with Pipe Fittings

1. Joints between pipes and pipe flanges are to be adequate for their service conditions, and their construction and strength are to conform to the requirements in **Fig. 12.2** according to their classified division of application shown in **Table 12.10**, or other type of joints as deemed appropriate by the Society.

2. Valves and pipe fittings made of non-ferrous metal may be mounted on a non-ferrous metal pipe by brazing or soldering. In this case the type of brazing and soldering and the method of application are to be suitable for the conditions of their use.

3. Joints between pipes and pipe fittings except flanges are to be in compliance with the requirements in **12.4.2** and **-1**.

Table 12.10 Types of Joints between Pipe and Pipe Flange and Their Application

Class of pipes	Design temperature ˚C	Type of joints	
		Steam, air and water	Fuel oil, lubricating oil, hydraulic oil and thermal oil
Group I	Over 400	*A*, *B* (Note 1.)	*A*,*B*
	400 or below	*A*, *B* (Note 2.)	
Group II	Over 250	*A*, *B*, *C*	*A*, *B*, *C*
	250 or below	*A*, *B*, *C*, *D*, *E*	*A*, *B*, *C*, *D*, *E* (Note 3.)
Group III	-	*A*, *B*, *C*, *D*, *E*, *F* (Note 4.)	*A*, *B*, *C*, *D*, *E* (Note 3.)

Notes:

1 Type (*B*) joints may be used for steam pipes of a nominal diameter of 50*A* or below.

2 Type (*B*) joints may be used for steam pipes of a nominal diameter of 150*A* or below.

3 Type (*E*) joints may be used for pipes with a design pressure of 1.0 *MPa* or less.

4 Type (*F*) joints may be used for water pipes or pipes with an open end.

12.4.4 Forming of Pipes and Heat Treatment after Forming

1. Hot Forming of pipes of Group I and Group II is to conform to the following requirements:

(1) Hot forming is to be generally carried out in the temperature range of 1000°C - 850°C, however the temperature may decrease to 750°C during the forming process.

(2) For steel pipes of Grade 4 in **Table 11.6**, the stress relieving heat treatment is to be carried out according to the requirements specified in **11.3.1** regarding the retaining temperature and period for the pipes.

2. When pipes of Group I and Group II are subjected to cold-forming suitable heat treatment is to be carried out according to the pipe material, service environment, etc. with consideration given to harmful plastic deformation due to cold-forming and development of residual stresses.

3. Regarding the forming and heat treatment after the forming for steel pipes other than those specified in **4.2, Part 10** and pipes of materials other than steel, they are to be approved by the Society as appropriate.

12.5 Construction of Auxiliary Machinery and Storage Tanks

12.5.1 General

1. Auxiliary machinery and storage tanks are to have sufficient strength and to be so constructed that maintenance and inspection are easily carried out.

2. The thickness of the steel plating used for fuel oil storage tank is not to be less than 6 *mm*, but in the case of small tanks, the thickness may be reduced to 3 *mm*.

3. Storage tanks for fuel oil and for heated lubricating oil, hydraulic oil, etc. which are installed in machinery spaces are not to have openings in the machinery space.

12.6 Tests

12.6.1 Shop Tests

1. Tests of welds in piping systems and auxiliaries are to comply with the requirements in **Chapter 11** of this Part.

2. Pipes in Group I and Group II and steam pipes, feed water pipes, compressed air pipes and fuel oil pipes with the design pressure exceeding 0.35 *MPa* are to be subjected to hydrostatic tests together with the welded fittings after completion of all the fabrication process at a pressure equal to 1.5 times the design pressure. This test may be carried out after installation on board.

3. Steel pipes with a design temperature exceeding 300°C are to be subjected to a hydrostatic test at the pressure determined by the formula below. However, it is not necessary that it exceeds 2 times the design pressure. However, the value of test pressure may be reduced to 1.5 times the design pressure, in order to avoid excessive stress in way of bends, T-pieces, etc. This test may be carried out after installation on board.

$$P_h = 1.5\frac{K_{100}}{K_T}P$$

where:

P_h : Test pressure (*MPa*)

K_{100}: Allowable stress of pipe material at 100°C (*N/mm*^{2})

K_T: Allowable stress of pipe material at the design temperature (*N/mm*^{2})

P: Design pressure (*MPa*)

4. Where the primary general membrane stress in the pipe wall is expected to exceed 90% of the specified yield stress at the test pressure specified in **-2** and **-3**, the test pressure is to be lowered to decrease the stress to 90% of the specified yield stress.

5. Valves and pipe fittings used for pipes in Group I and Group II are to be subjected to hydrostatic tests at a pressure equal to 1.5 times the design pressure.

6. Valves and distance pieces fitted to the ship's side below the load line are to be subjected to a hydrostatic test at a pressure of 1.5 times the design pressure or 0.5 *MPa*, whichever is the greater.

7. The pressure parts of auxiliaries (excluding auxiliary machinery for specific use etc.) are to be subjected to a hydrostatic test at a pressure equal to 1.5 times the design pressure or 0.2 *MPa*, whichever is the greater.

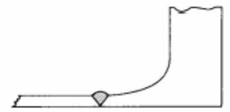
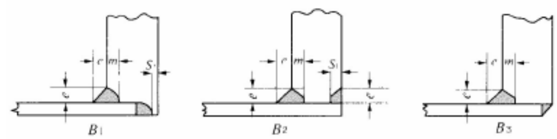
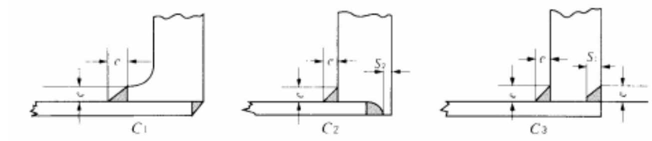
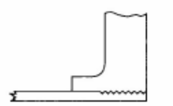
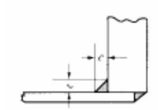
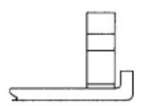
8. Free standing fuel oil storage tanks are to be subjected to a hydrostatic test at a pressure corresponding to a water head of 2.5 *m* above the top plate.

9. Auxiliaries (excluding auxiliary machinery for specific use etc.) is to be subjected to running tests as deemed appropriate by the Society.

12.6.2 Tests after Installation on Board.

Where joints between pipes or between pipes and valves are welded aboard ships, such a piping system is to be subjected to a hydrostatic test as deemed appropriate by the Society.

Fig. 12.2 Type of Flange Connection

	Types of Joints and Dimensions
A	
B	
C	
D	
E	
F	

Notes:

1 Standard dimensions of welds are as follows:

$e = 1.4t$

$m = t$

$S_1 = t$

$S_2 = 0.5t$

where t is the required thickness of the pipe.

2 For type *D*, the pipe and flange are to be screwed with a tapered thread and the pipe is to be secured to the flange by means of expansion. However, the outside diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe.

Chapter 13 PIPING SYSTEMS

13.1 General

13.1.1 Scope

The requirements in this Chapter apply to piping systems.

13.1.2 Drawings and Data

The drawings and data to be submitted are generally as follows:

(1) Drawings (with materials, sizes, kinds, design pressures, design temperatures, etc. of pipes, valves, etc.)

- (a) Piping diagrams in the ship
- (b) Piping diagrams in the engine room
- (c) Methods for preventing oil from spraying from flange joints and special joints (threaded pipe joints, mechanical joints, etc.) in fuel oil, lubricating oil and other flammable oil pipings (if any)
- (d) Other drawings considered necessary by the Society

(2) Data

- (a) Particulars of machinery
- (b) Other data considered necessary by the Society

13.2 Piping

13.2.1 General

1. Fixing of pipes

(1) Ample provision is to be made in consideration of the effects of expansion, contraction, deflection of the hull and vibration. Pipes are to be supported at suitable spans to avoid any excessive load.

(2) The number of detachable pipe connections is to be minimized as far as practicable.

2. Radius of curvatures of pipe

Where pipes are bent, the radius of curvatures of at the center line of the pipe is generally not to be less than twice the external diameter of the pipe.

3. Functions of pipes

Pipes are to be so arranged as not to give effects on the performance of machinery due to the stay of drain and air or the pressure loss in pipes.

4. Piping in the vicinity of electrical equipment

Pipes are not to be led to the vicinity of electrical equipment such as generators, switchboards, control gears, etc. as far as possible. Where such leading is unavoidable, care is to be taken to arrange no flange nor joint over or near the electrical equipment, unless provision is made to prevent any leakage from pouring on the equipment.

5. Protection of pipe lines and fittings

(1) All pipes, valves, cocks, pipe fittings, valve operating rods, handles, etc. located at positions in the cargo holds or on the weather decks where they are liable to be damaged are to be adequately protected. Where a casing is provided for protection, it is to be so constructed as to be easily removed for inspection.

(2) For pipes arranged in the positions inaccessible for maintenance and inspection, due consideration such as corrosion protection is to be given to prevent corrosion.

6. Relief valves

(1) All pipe lines which may be subjected to internal pressure exceeding the design pressure are to be safeguarded with relief valves or alternative overpressure protective devices.

(2) Discharge ends of the relief valves or overpressure protective devices are to be led to safe spaces.

7. Pressure and temperature measuring devices

(1) Pressure and temperature measuring devices are to be provided on piping systems where considered necessary.

(2) Cocks or valves are to be provided at the root of pressure measuring devices for isolating them from the pipes under a pressurized condition.

(3) Where thermometers are fitted in fuel oil, lubricating oil and other flammable oil pipings or apparatuses, the thermometer is to be put in a safe protective pocket to prevent oil from spraying in case of fracture or removal of the thermometer.

8. Distinction of pipe lines

(1) The pipes located in the space where deemed necessary for safety are to be marked with distinctive colours to avoid mishandling.

(2) Name plates, which show the purposes of the valves, are to be affixed to the valves where deemed necessary for safety, and the valves which are used for fire extinguishing are to be painted in red.

(3) Name plates are to be affixed to the open ends of air pipes, sounding pipes and overflow pipes.

9. Cleaning of piping systems

Piping systems are to be cleaned after fabrication or installation in ships where considered necessary.

13.2.2 Connection and Common Use of Pipes

1. Connection of oil pipes with other pipes

(1) Fuel oil pipes are to be entirely separate from other pipes, unless means are provided to prevent the accidental contamination with other liquid while in operation.

(2) Lubricating oil pipes are to be entirely separate from other pipe lines.

(3) Fresh water pipes for boiler feed water or drinking fresh water are to be entirely separate from other pipes to avoid contamination with oil or oily water.

(4) Oil pipes and heating pipes in deep tanks which may be used for the carriage of general cargo are to be capable of being disconnected or to be provided with a suitable arrangement such as blank flange or spool piece. Bilge pipes and ballast pipes in such deep tanks are to comply with the requirements in **13.5.1-10**.

2. Common use of sea water pipes and fresh water pipes

Sea water pipes and fresh water pipes are to be separated, unless adequate measures are taken to avoid accidental contamination of fresh water with sea water.

13.2.3 Penetration of Pipes

Where pipes are led through watertight bulkheads, decks, and top plates, bottom plates and bulkheads of deep tanks, and inner bottom plating, measures are to be taken to ensure the watertightness of the structures.

13.2.4 Slip-on Joints

Slip-on joints are not to be used in pipe lines in cargo holds deep tanks, and other spaces which are not easily accessible, unless approved by the Society.

13.2.5 Bulkhead Valves

1. Valves or cocks, such as drain valves, which do not constitute a part of any pipe line is not to be fitted on the collision bulkhead.

2. Pipes piercing the collision bulkhead are to be fitted with suitable valves operable from above the bulkhead deck and the valve chest is to be secured at the bulkhead inside the forepeak. The valve, however, may be fitted on the after side of the collision bulkhead provided that the valves are readily accessible under all service conditions and the space in which they are located is not a cargo space. The remote control device for this valve may be omitted.

3. Valves and cocks, such as drain valves, which do not constitute a part any pipe lines, may be fitted on watertight bulkheads other than the collision bulkhead, provided that they are readily accessible at any time for inspection. Such valves and cocks are to be operable from above the bulkhead deck and to be provided with an indicator to show whether they are open or closed, except where the valves or cocks are secured at the fore or after bulkhead inside the engine room.

4. Means for controlling the valves or cock from above the freeboard deck or bulkhead deck are to be so constructed that the weights thereof are not supported by the valves or the cocks.

13.2.6 Prevention of Freezing of Pipes

Suitable measures are to be taken to the prevention of freezing for bilge pipes, air pipes, sounding pipes, drain pipes, etc. passing through or arranged near the refrigerated chamber, where there is a risk of freezing on the inner surfaces of the pipes.

13.2.7 Prevention of Counterflow through Drain Pipes

When a drain pipe in the engine room is led to a double-bottom tank and when there is a danger of flood in the ship through the drain pipe in case that sea water flows into the tank by grounding, etc. a stop valve or suitable device to stop the counter flow of sea water, which can be readily operable from the engine room floor is to be provided.

However, the requirements do not apply to the ships of which length is less than 100 *m*.

13.2.8 Drain Installation around Boilers

A coaming of at least 100 *mm* in height is to be provided around boilers, and the drain inside the coaming is to be led to the bilge well or bilge tank etc.

13.3 Sea Suction Valves and Overboard Discharge Valves

13.3.1 Sea Suction Pipe and Overboard Discharge Pipes Connections

Sea inlet and overboard discharge pipes are to be connected to the valves or cocks which are fitted in accordance with the requirements in **13.3.2-2** and **-3**. However, for discharge pipes from positions above the freeboard deck, those having substantial wall thickness for the omission of a non-return valve in accordance with the provisions of **13.4.1-7**, up to appropriate level above the freeboard deck, need not to comply with the provisions of **13.3.2-3**.

13.3.2 Location and Construction of Sea Suction Valves, Overboard Discharge Valves, etc.

1. The locations of overboard discharges are not to be such that water can be discharged into lifeboats and liferafts at fixed launching positions including those under launching device when they are launched, unless special provision is made for preventing any discharge of water into them.

2. Sea suction valves and overboard discharge valves or cocks fitted to the ship's side, sea chests forming a part of the ship's structure or distance pieces attached to the shell plating are to be located at easily accessible positions.

3. Valves or cocks prescribed in **-2** are to be fitted in accordance with the following **(1)** or **(2)**:

(1) Valves or cocks are to be fitted to doublings which are welded to the shell plating or sea chest by using stud bolts not piercing the shell plating and sea chest.

(2) Valves or cocks are to be fitted by bolts to distance pieces attached to the shell plating. In this case, the distance piece is to be of rigid construction and as short as practicable.

4. The valve spindles of sea suction valves are to be extended above the lower platform where they are easily operable. Power-operated sea suction valves are to be arranged also for manual operation. Sea suction valves are to be provided with indicators to show whether they are open or closed.

5. Overboard discharge valves and cocks are to be fitted with spigots passing through the shell plating and a protection rings specified in **-6(1)**, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating and protecting rings. Overboard discharge valves and cocks are to be provided with indicators to show whether they are open or closed.

6. Blow-off valves or cocks of boilers and evaporators are to comply with the following requirements in **(1)** and **(2)**.

(1) Blow-off valves or cocks of boilers and evaporators are to be fitted in accessible positions and to be provided with protection rings on the outside of the shell plating to prevent corrosion.

(2) Cock handles are not to be capable of being removed unless the cocks are shut, and, if valves are fitted, the hand wheels are to be suitably retained on the spindle.

13.3.3 Construction of Sea Chests

Sea chests are to be of substantial construction not to blank off the suction due to air-locking.

13.3.4 Gratings of Sea Suctions

1. Gratings are to be fitted at the sea inlets. The net area through grating is not to be less than twice the total inlet area of sea suction valves.

2. Provision is to be made for cleaning the gratings specified in **-1** by use of low pressure steam, compressed air, etc.

13.4 Scuppers, Sanitary Discharges, etc.

13.4.1 General

1. Scupper pipes sufficient in number and size to provide effective drainage are to be provided in all decks. However the Society may permit the means of drainage to be dispensed with in any particular compartment of any ship or class of ship if it is satisfied that by reason of size or internal subdivision of those spaces the safety of the ship is not thereby impaired.

2. Scupper pipes draining weather decks and spaces within superstructures and deckhouses of which access openings are not provided with closing means complying with the requirements in **17.3.1, Part 2**, are to be led to overboard.

3. Scupper pipes from within enclosed superstructures or enclosed deckhouses on the freeboard deck are to be led directly to inboard bilge wells. Alternatively, they may be led to overboard where they are provided with valves in accordance with the following requirements.

(1) Each separate discharge is to have one automatic non-return valve with a positive means of closing it from a position above the freeboard deck or, alternatively, one automatic non-return valve having no positive closing means and one stop valve controlled from above the freeboard deck. However, where the scuppers lead overboard through the shell plating in way of manned engine room, the fitting to the shell plating of a locally operated positive closing valve, together with a non-return valve inboard, will also be accepted. The means for operating the positive action valve from above the freeboard deck are to be readily accessible and provided with an indicator showing whether the valve is open or closed.

(2) Where, however, the vertical distance from the load line to the inboard end of the scupper pipe exceeds $0.01Lf$, the scupper pipe may have two automatic non-return valves without positive means of closing in lieu of valves prescribed in **(1)** In this case, the inboard valve is to be located above the level of the deepest subdivision draught specified in **1.1.2(3), Part 3** of the Rules and always accessible for inspection under service condition.

If it is not practicable to fit inboard valve above the specified waterline then it can be accepted below provided locally controlled stop valve is fitted between two automatic non-return valves.

(3) Where the vertical distance prescribed in **(2)** exceeds $0.02L_f$, a single automatic non-return valve without positive means of closing may be accepted in lieu of valves prescribed in **(1)** and **(2)** subject to the approval of the Society.

4. Scupper pipes from spaces below the freeboard deck are to be led directly to inboard bilge wells. Alternatively, they may be led to overboard where they are provided with the valves in accordance with the following requirements.

(1) Each separate discharge is to have one automatic non-return valve with a positive means of closing it from a position above the freeboard deck or, alternatively, one automatic non-return valve having no positive closing means and one stop valve controlled from above the freeboard deck. The means for operating the positive action valve from above the freeboard deck are to be readily accessible and provided with an indicator showing whether the valve is open or closed.

(2) Where, however, the vertical distance from the load line to the inboard end of the scupper pipe exceeds $0.01L_f$, the scupper pipe may have two automatic non-return valves without positive means of closing in lieu of valves prescribed in **(1)**. In this case, the inboard valve is to be located above the level of the deepest subdivision draught specified in **1.1.2(3), Part 3** of the Rules and always accessible for inspection under service condition.

5. Notwithstanding the requirements in **-3**, scupper pipes from the enclosed cargo spaces on the freeboard deck are to be in accordance with the following requirements.

(1) Where the freeboard to the freeboard deck is such that the deck is immersed when the ship heels more than 5°, scupper pipes are to be led directly overboard, fitted in accordance with the requirement specified in **-3**.

(2) Where the freeboard to the freeboard deck is such that the deck is immersed when the ship heels 5° or less, scupper pipes are to be in accordance with the following requirements.

(a) Scupper pipes are to be led directly to inboard bilge wells.

(b) High water level alarm is to be provided in the bilge wells to where scupper pipes are led.

(c) Where the enclosed cargo space is protected by a carbon dioxide fire-extinguishing system the deck scuppers are to be fitted with means to prevent the escape of the smothering gas.

6. Notwithstanding the requirements in **-3** and **-4**, only one stop valve may be arranged to overboard discharge pipes which are always closed, except when discharging, during navigation. This stop valve, however, is to be capable of being closed from an easily accessible position during navigation by closing devices with indicators.

7. Scuppers originating at any level and penetrating the shell plating at either more than 450 *mm* below the freeboard deck or below 600 *mm* above the load line are to be provided with a non-return valve at the shell plating.

This valve, unless specifically required by **-3** and **-4** may be omitted provided that the thickness of the scupper pipes complies with the requirements in **Table 12.6**.

13.4.2 Common Overboard Discharge

The number of scuppers, sanitary discharges and other similar openings in the shell plating is to be reduced to the minimum either by making each discharge serve for as many as possible of sanitary and other pipes, or in any other satisfactory manner. In general, however, different systems of overboard discharges are not to be connected to each other, unless specially approved by the Society.

13.4.3 Sanitary Discharges

Sanitary system is to comply with the requirements in **13.4.1** and **13.4.2**.

13.4.4 Ash-shoot and Rubbish-shoot

1. The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be provided with an efficient cover.

2. If the inboard opening prescribed in **-1** is situated below the freeboard deck, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the ash-shoot, rubbish-shoot, etc. in an easily accessible position above the tropical load line.

3. For ash-shoot and rubbish-shoot, two gate valves instead of the non-return valve with a positive means of closing from a position above the freeboard deck which comply with the following requirements are acceptable.

(1) Two gate valves are to be controlled from the working deck of the chute.

(2) The lower gate valve is to be controlled from a position above the freeboard deck. An interlock system between the two valves is to be arranged.

(3) The inboard end is to be located above the waterline formed by an 8.5° heel to port or starboard at a draft corresponding to the assigned summer freeboard, but not less than 1,000 *mm* above the summer waterline.

Where the inboard end exceeds $0.01L_f$ above the summer waterline, valve control from the freeboard deck is not required, provided the inboard gate valve is always accessible under service conditions.

4. A hinged weathertight cover at the inboard end of the chute together with a discharge flap may be acceptable in lieu of the upper and lower gate valves complying with the requirements in **-3**. In this case, the cover and flap are to be arranged with an interlock so that the discharge flap cannot be operated until the hopper cover is closed.

5. The controls for the gate valves and/or hinged covers are to be clearly marked: Keep closed when not in use.

6. For ships applied to damage stability requirements specified in, **Part 3** of the Rules, following requirements are to be satisfied where the inboard end of the chute is below the freeboard deck.

(1) The inboard end hinged cover/valve is to be watertight.

(2) The valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest load line.

(3) The screw-down non-return valve is to be controlled from a position above the bulkhead deck and provided with open/closed indicators. The valve control is to be clearly marked: Keep closed when not in use.

13.5 Bilge and Ballast Pipings

13.5.1 General

1. An efficient bilge pumping system is to be provided, capable of pumping from and draining any watertight compartment other than a space permanently appropriate for the carriage of liquid and for which other efficient means of pumping are provided, under all practical conditions.

2. An efficient ballast piping system is to be provided, capable of pumping ballast water into and from any tanks for carriage of ballast water under all practical conditions.

3. Where the fixed pressure water-spraying fire-extinguishing system or other fixed systems which will supply copious quantities of water are fitted for the cargo spaces as required by **19.3.1-3**, **19.3.9**, **20.2.1**, **20.5.1-1(3)**, **20.5.1-2** or **20.5.1-4, Part 6**, the bilge pumping systems for such cargo spaces are to comply with these requirements in addition the requirements in this Chapter.

4. Suitable measures are to be taken to the bilge pumping system to prevent the possibility of water passing from the sea to the watertight compartment and of bilge inadvertently passing from one compartment to another. To achieve this requirement, all bilge distribution boxes and manually operated valves in connection with the bilge pumping systems are to be in positions which are accessible under ordinary circumstances. All valves in the bilge distribution boxes are to be of non-return type.

5. Bilge suction pipes used for draining cargo holds, machinery room and shaft tunnels are to be entirely separate from pipes other than the bilge suction pipes.

6. Bilge pipes passing through deep tanks used exclusively for ballasting and bilge pipes and ballast pipes passing through deep tanks other than ballast tanks are to be led through an oiltight or watertight pipe tunnel or alternatively, are to be of sufficient thicknesses complying with the requirements in **Table 12.6** and all joints of them are to be welded.

7. Bilge pipes passing through double bottom tanks are to be led through oiltight or watertight pipe tunnel or alternatively, are to be of sufficient thickness complying with the requirements in **Table 12.6**.

8. Bilge pipes passing through double bottoms, side tanks, bilge hopper tanks or void spaces, where there is a possibility of damage of these pipes due to grounding or collision, are to be provided with non-return valves near the bilge suctions or stop valves capable of being closed from readily accessible positions.

9. Ballast piping system is to be provided with a suitable provision such as a non-return valve or a stop valve which can be kept closed any time excluding the time of ballasting and de-ballasting and which is provided with an indicator to show whether it is open or closed, in order to prevent the possibility of water inadvertently passing from the sea to the ballast tanks or of ballast passing from one ballast tank to another.

10. Where a hold is intended for carrying ballast water and cargo alternately, adequate provisions such as blank flange or spool piece are to be made in the ballast piping system to prevent inadvertent ingress of sea water through ballast pipes when carrying cargo and in the bilge piping system to prevent inadvertent discharge of ballast water through bilge pipes when carrying ballast water.

11. Where a tank is intended to be used both for fuel oil and ballast water, adequate provisions such as blank flange or spool piece are to be made to prevent mixing of fuel oil and ballast water in the ballast pipe when carrying fuel oil and in the fuel oil pipe when carrying ballast water.

13.5.2 Terminology

1. Main bilge line means a part of the bilge suction line which forms the main of bilge suction line connected to independent power driven bilge pumps specified in **13.5.4-1** and to which all the branch bilge suction pipes from bilge suctions specified in **13.5.5** and **13.5.7-1** to **-4** are connected.

2. Branch bilge suction pipe means a pipe connected to the main bilge line from the bilge suction of each compartment.

3. Direct bilge suction pipe means a bilge suction pipe which is connected directly to an independent power driven pump specified in **13.5.4-1** and arranged entirely separately from other pipes.

4. Emergency bilge suction pipe means a bilge suction pipe which is to be used in an emergency case and connected directly to an independent power driven pump specified in **13.5.7-6(1)** or **-7(1)**.

13.5.3 Sizes of Bilge Suction Pipes

1. Main bilge line, direct bilge suction pipes and branch bilge suction pipes from watertight compartments are to be of the internal diameter obtained from the following formulae **(1)** and **(2)** or the standard pipes of internal diameters nearest to the calculated diameter. In case where the internal diameter of such standard pipes is short of the calculated value by 13 *mm* or more, standard pipes of one grade higher diameter are to be used.

(1) For main bilge line and direct bilge suction pipes:

$$d = 1.68\sqrt{L_f(B+D)} + 25(mm)$$

(2) For branch bilge suction pipes:

$$d' = 2.15\sqrt{l(B+D)} + 25(mm)$$

where:

d: Internal diameter of main bilge line or direct bilge suction pipes (*mm*).

d: Internal diameter of branch bilge suction pipes (*mm*).

B and *D*: breadth and depth of ship, respectively (*m*)

L_f: Length (*m*) for freeboard specified in **1.2.3, Part 1 A**

However for ships to which the requirement **13.4.1-5(2)** is applied, "*D*" is to be considered as follows:

(a) For ships of which enclosed cargo spaces are extend for the full length of the ship, *D* is to be considered as the depth of ship measured to the next deck above the freeboard deck (*m*)

For ships of which enclosed cargo spaces are not extend for the full length of the ship, *D* is to be considered as the depth of ship plus $l' \times h/L_f\,(m)$

(b) where *l* and *h* are the aggregate length and height respectively of the enclosed cargo spaces

l: Length of the compartment to be served by the branch bilge suction pipes (*m*).

2. The internal diameter of main bilge line is not to be less than any one of those of the branch bilge suction pipes obtained from the formula in **-1(2)**.

3. The internal diameter of direct bilge suction pipes is also to comply with the requirements in **13.5.7-5(1)** and **(2)**.

4. Where bilge suctions are provided at the fore and after parts of cargo hold in accordance with the requirements in **13.5.5-1**, the internal diameter of the branch bilge suction pipe at the fore part may be reduced to 0.7 times that obtained from the formula in **-1(2)**.

5. Where the bilge pumps in engine room are exclusively used for bilge drainage in the engine room, the internal diameter of main bilge line and direct bilge suction pipes may be reduced to that obtained from the following formula:

$$d = \sqrt{2}\left(2.15\sqrt{l(B+D)} + 25\right)(mm)$$

where:

l: Length of engine room (*m*).

d, *B* and *D* : As defined in **-1**.

6. The internal diameter of branch bilge suction pipe is not to be less than 50 *mm* except that for drainage of a small compartment it may be reduced to 40 *mm*, where considered acceptable by the Society.

7. The internal sectional area of bilge suction pipes connecting two or more branch bilge suction pipes to the main bilge line is not to be less than the sum of internal sectional areas of the largest two branch bilge suction pipes, but need not exceed the internal sectional area of the main bilge line obtained from the formula in **-1(1)**.

8. The internal diameters of bilge suction pipes in fore and after peaks and shaft tunnels are not to be less than 65 *mm*, except that in ships less than 60 *m* in length, it may be reduced to 50 *mm*.

13.5.4 Bilge Pumps

1. Number of bilge pumps

(1) All ships are to be provided with at least two independent power bilge pumps connected to the main bilge suction pipes. In ships not more than 90 *m* in length, however, one of the required pumps may be driven by the main propulsion machinery.

(2) Ballast, sanitary and general service pumps driven by independent power may be accepted as independent power bilge pumps, provided that they are connected properly to the main bilge line.

(3) One of the independent power bilge pumps prescribed in **(1)** may be substituted by an educt in connection with a sea water pump other than bilge pump where considered acceptable by the Society. In this case, the capacity of the eductor is to comply with the requirement in **-2**.

2. Capacity of bilge pumps

Each pump specified in **-1** is to be capable of discharging bilge of not less than that obtained from the following formula through the main bilge line specified in 13.5.3:

$$Q = 5.66d^{2} \times 10^{-3}$$

where:

Q: Required quantity (m^3/hr).

d: Internal diameter of main bilge line specified in 13.5.3 (mm).

Where one of these pumps is of the capacity slightly less than the required, the deficiency may be made good by an excess capacity of the other pump.

3. Types of bilge pumps

All independent power bilge pumps prescribed in **-1** are to be of self-priming type or equivalent thereto and are to be so arranged that they are immediately operable when in use.

4. Connection of bilge pumps and suction pipes

All of the power pumps prescribed in **-1** are to be arranged for discharging bilge from all holds, engine room and shaft tunnel. Where, however, an eductor is used exclusively for bilge drainage in a hold, the bilge suction pipe of this hold need not be connected to the bilge pumps prescribed in **-1**. In this case, the eductor is to be so arranged as to be driven by two or more pumps. Capacity of the sea water pump for sending driving water to the eductor, capacity of the eductor, internal diameter of the suction pipe are to be considered appropriate by the Society.

13.5.5 Bilge Suction Arrangement in Holds

1. In ships having only one hold exceeding 33 *m* in length, bilge suctions are to be provided in suitable positions in the after half-length and in the forward half-length of the hold.

2. Where the inner bottom plating extends to the ship's sides, the bilge suctions are to be placed in wells at both wings and also at the center line if the top plating has an inverse camber.

3. Where close ceiling is fitted over the bilges of the holds, proper arrangement is to be made whereby water in the hold compartments may find its way to the suctions.

4. In the refrigerated chambers the insulation to bilge wells and bilge suction roses in bilge ways is to be of plug type and removable.

5. In the refrigerated chamber the insulation in way of bilge suction pipes is to be removable within the extent necessary for inspection.

13.5.6 Bilge Drainage from Top of Deep Tanks, Fore and After Peak Tanks and Chain Lockers

1. Bilge of fore and after peak tanks, deck forming the top of these tanks and chain lockers may be drained by eductors or hand pumps. These eductors or hand pumps are to be capable of being operated at any time from accessible positions above the load water line.

2. Efficient means are to be provided for draining bilge from top of the deep tanks and other watertight flat.

3. Drain from spaces above deep tanks may be led to bilge wells in the shaft tunnel or an accessible compartment.

In this case, these pipes are not to be more than 65*A* in nominal diameter and are to be provided with quick-acting self-closing valves located in an accessible position.

4. In case where a suction line is led through the collision bulkhead, it is to comply with the requirements in **13.2.5-2**.

13.5.7 Bilge Suction Arrangement in Engine Room

1. Where there is no double bottom in the engine room, at least two bilge suctions are to be provided near the centre line of the ship. One of these suctions is to be a suction for branch bilge suction pipe and the other is to be for a direct bilge suction pipe. If the rise of floor is less than 5 *degrees*, additional bilge suctions are to be provided at wings.

2. Where there is a double bottom in the engine room forming bilge ways at wings, one branch bilge suction and one direct bilge suction are to be provided at each wing.

3. Where the double bottom plating extends to the ships sides, bilge wells are to be placed at each side so far as is reasonable and practicable, and one branch bilge suction and one direct bilge suction are to be provided in each bilge well.

4. Where the engine room is separated by watertight bulkheads from a boiler compartment and auxiliary engine room, the bilge suction pipe arrangements in the boiler room and the auxiliary engine room are to comply with the requirements in **-1** in case of no double bottom construction, and are to comply with the requirements in **-2** or **-3** in case of double bottom construction. Only one direct bilge suction, however, will be accepted even in case of double bottom construction.

5. Direct bilge suction pipes are to comply with the following requirements.

(1) The internal diameter of direct bilge suction pipes is not to be less than that obtained from the formula in **13.5.3-1(1)**. Where a direct bilge suction pipe is provided on each side of the engine room in accordance with the requirements in **-2** or **-3**, the internal diameter of one of the direct bilge suction pipes may be reduced to that obtained from the formula in **13.5.3-1(2)**. In this case, the pipe reduced in diameter is to be located on the same side as the emergency bilge suction pipes specified in **-6** or **-7**.

(2) Notwithstanding the requirements in **(1)**, where the compartments are of small dimensions, the internal diameter of the direct bilge suction pipes may be adequately reduced.

6. Emergency bilge suction pipes for ships with steam turbine used as main propulsion machinery are to comply with the following requirements.

(1) In steam turbine ships, an emergency bilge suction pipe with a screw-down non-return valve having a hand wheel which is extended above the floor grating in the engine room, is to be fitted to the suction end of the main circulating pump, and the suction pipe of this pump is to be led to a suitable level in the engine room to discharge bilge in case of emergency. The internal diameter of such suction pipe is not to be less than two-thirds of the diameter of that of pump suction.

(2) Where the main circulating pump is not considered suitable for bilge discharge, the emergency bilge suction pipe may be led to the largest available power pump in the engine room other than the bilge pumps specified in **13.5.4-1** in lieu of the main circulating pump. The capacity of the pump is not to be less than that required by **13.5.4-2**. The internal diameter of such suction pipe is to be equal to that of pump suction.

(3) Where the pump prescribed in **(1)** or **(2)** is of self-priming type, the direct bilge suction arranged on the same side of the ship as the emergency bilge suction may be omitted.

7. Emergency bilge suction pipes for ships with diesel engine or gas turbine used as main propulsion machinery are to comply with the following requirements.

(1) In ships with diesel engine or gas turbine used as main propulsion machinery, an emergency bilge suction pipe with a screw-down non-return valve having a hand wheel which is extended above the lower platform in the engine room is to be fitted to the main cooling water pump, and the suction pipe is to be led to a suitable level in the engine room to discharge bilge in case of emergency. The internal diameter of such suction pipe is to be equal to that of pump suction.

(2) Where the main cooling water pump is not considered suitable for bilge discharge, the emergency bilge suction pipe may be led to the largest available power pump in the engine room other than the bilge pumps specified in **13.5.4-1** in lieu of the main cooling water pump. The capacity of the pump is not to be less than that required by **13.5.4-2**. The internal diameter of such a suction pipe is to be equal to that of pump suction.

(3) Where the pump prescribed in **(1)** or **(2)** is of self-priming type, the direct bilge suction arranged on the same side of the ship as the emergency bilge suction may be omitted.

13.5.8 Bilge Wells

1. The depth of bilge wells constructed in double bottom and the vertical distance between the bottom plating and the bottom of bilge wells are to comply with the requirements in **5.1.3-2, Part 2**.

2. The capacity of each bilge well is not to be less than 0.17 m^3.

3. The bilge wells may be substituted with steel bilge hats of reasonable capacity where the spaces to be drained are small or not capable of being provided with bilge wells of the volume prescribed in **-2**.

4. Where access manholes to the bilge well of cargo holds are necessary, they are to be located as near the bilge suctions as practicable. It is to be avoided, as far as practicable, to provide the above manholes on the fore and after bulkheads and inner bottom plating of the engine room.

13.5.9 Mud Boxes and Strum Boxes

1. Bilge suction pipes except for the emergency bilge suction pipes in engine room and shaft tunnels are to be provided with mud boxes, easily accessible from above the platform in the engine room, having covers easy to be opened or closed, and straight tail pipes to bilge wells are to be fitted to the suction side of the mud boxes.

2. The bilge suction ends in hold spaces are to be provided with strum boxes having perforation approximately 10 *mm* in diameter unless approved by the Society and having an open area of more than twice the area of the suction pipes, and the strum boxes are to be so constructed that they can be cleaned without disconnecting any joint of the suction pipes.

13.5.10 Dewatering Arrangements for Bulk Carriers, etc.

For bulk carriers defined in **28A.1.2 (1), Part 2**, bilge or ballast systems capable of being brought into operation from a readily accessible enclosed space, the location of which is accessible from the navigation bridge or continuously manned propulsion machinery control rooms without traversing exposed decks, are to be provided for draining and pumping the spaces specified in the following **(1)** and **(2)**.

(1) Ballast tanks forward of the collision bulkhead specified in **12.1.1, Part 2**

(2) Dry or void spaces other than chain lockers, any part of which extends forward of the foremost cargo hold and the volume of which exceeds 0.1% of the ship's maximum displacement volume.

13.6 Air Pipes

13.6.1 General

1. All tanks and cofferdams are to be provided with air pipes having sufficient cross sectional areas to permit easy venting from any part of the tanks and cofferdams.

2. Tanks having top plates not less than 7 *meters* either in length or in width are to be provided with two or more pipes arranged with a suitable distance. Tanks having inclined top plates, however, may be provided with one air pipe located at the highest part of the top plate.

3. Where the tanks or cofferdams are of complicated profile, special consideration is to be given to the number and positions of the air pipes.

4. Air pipes are to be arranged to be self-draining.

5. Vent pipes for fuel oil service, settling and lubrication oil tanks are to be located and arranged so as not to directly lead the risk of ingress of seawater splashes or rainwater in the event of a broken such pipe.

13.6.2 Open Ends of Air Pipes

1. The position of open ends of air pipes are to be in accordance with the following requirements **(1)** to **(4)** depending on the kinds and purpose of tanks.

(1) Air pipes to the following tanks and cofferdams are to be led above the bulkhead deck.

(a) Double bottom tanks

(b) Deep tanks

(c) Tanks which can be run up from the sea

(d) Cofferdams

(2) Air pipes to the following tanks and cofferdams are to be led to weather part.

(a) Fuel oil tanks and thermal oil tanks

(b) Cargo oil tanks

(c) Heated lubricating oil tanks and hydraulic oil tanks

(d) Tanks which can be pumped up (only for tanks which is situated outside machinery space and provided with no overflow pipe)

(e) Cofferdams adjacent to fuel oil tanks and cargo oil tanks.

(3) Air pipes to tanks which can be pumped up are to be led to a safe position where the equipment cannot suffer damages from the overflowing of liquid which may occur when the tank is being filled.

(4) Air pipes to tanks carrying combustible or flammable liquid are to be led to a safe position where there is no possibility of fire by the oil or gas issuing from the openings when tank is being filled.

2. All openings of air pipes leading above weather deck are to be provided with automatic closing devices.

3. The open ends of air pipes to fuel oil and cargo oil tanks are to be provided with a flame arresting wire gauze of corrosion resistant materials easy to clean and detach and having clear area through the mesh of not less than the required sectional area of the air pipe.

13.6.3 Sizes of Air Pipes

Sizes of air pipes are to be as follows:

(1) The total sectional area of air pipes to tanks which can be pumped up is not to be less than 1.25 times the total sectional area of filling pipes. Where the tank is provided with an overflow pipe specified in **13.7**, the internal diameter of the air pipes may be reduced to 50 *mm*.

(2) Provision is to be made for relieving vacuum when the tanks are being pumped out.

(3) The internal diameters of air pipes to cofferdams or tanks which form part of ship's structure is not to be less than 50 *mm*.

13.6.4 Height of Air Pipes

Where air pipes extend above the freeboard deck or superstructure deck, the exposed parts of the pipes are to be of substantial construction; the height from the upper surface of the deck to the point where water may have access below is to be at least:

760 *mm* on the freeboard deck, and

450 *mm* on the superstructure deck

Where these heights may interfere with the working of the ship, the height may be reduced to values appointed by the Society, provided that the Society is satisfied that the closing arrangement and other circumstances justify the lower height.

13.6.5 Additional Requirement for Air Pipes fitted on Exposed Fore Deck

For ships of 80 *m* or more in length L_1, specified in **14.2.1-1, Part 2**, where the height of the exposed deck in way of the item is less than $0.1L_1$ or 22 *m* above the designed maximum load line, whichever is the lesser, the air pipes which are located on the exposed deck over the forward $0.25L_1$ are to be of sufficient strength to resist green sea force.

13.7 Overflow Pipes

13.7.1 General

1. Where tanks which can be pumped up come under either one of the following categories, overflow pipes are to be provided:

(1) Where the sectional area of the air pipes does not comply with the requirements in **13.6.3(1);**

(2) Where there is any opening below the open ends of air pipes fitted to the tanks; and

(3) Fuel oil settling tanks and fuel oil service tanks.

2. Overflow pipes other than those to tanks for fuel oil, lubricating oil and other flammable oils are to be led to the open air, or alternatively, to proper positions where the overflows can be disposed of.

3. Overflow pipes are to be arranged to be self-draining.

4. In addition to **13.7**, overflow pipes for tanks for fuel oil, lubricating oil and other flammable oils are to comply with the requirements in **4.2.2(4), Part 6**.

13.7.2 Sizes of Overflow Pipes

1. The aggregated sectional area of overflow pipes which come under **13.7.1-1** is to be not less than 1.25 times the aggregated sectional area of filling pipes.

2. The internal diameter for overflow pipes is not to be less than 50 *mm*.

13.7.3 Overflow Pipes to Fuel Oil, Lubricating Oil and Other Flammable Oil tanks

1. Overflow pipes are to be led to an overflow tank of adequate capacity or to a storage tank having sufficient space reserved for overflow purposes.

2. Overflow pipes are to be provided with sight glasses at readily visible positions on the vertical pipes, unless an alarm device to give warning when the oil level rises to a predetermined point in the tanks, is installed.

13.7.4 Preventive Means of Counter-flow of Overflow

1. Where overflow pipes to deep tanks, which are used for alternate carriage of fuel oil, cargo oil, ballast water, general cargo, etc., are connected to an overflow main common to other tanks, arrangements are to be made to prevent the entering of liquid, gases, etc. from other tanks into the deep tank carrying general cargo, and to prevent the entering of a liquid of different quality to other tanks from the deep tank carrying the liquid.

2. Adequate means are to be provided on overflow pipes so that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through the overflow pipes.

3. Overflow pipes discharging through the ship's sides are to extend above the load line, and are to be provided with non-return valves fitted on the ship's sides. Where the overflow pipes do not extend above the freeboard deck, additional effective means are to be provided to prevent the sea water from passing inboard.

13.8 Sounding Pipes

13.8.1 General

1. All the tanks, cofferdams and areas the access to which is difficult are to be provided with a sounding pipe or a liquid level indicator.

2. Name plates are to be affixed to the upper ends of sounding pipes.

3. In addition to **13.8**, sounding pipes for tanks for fuel oil, lubricating oil and other flammable oils are to comply with the requirements in **4.2.2(3)(e), Part 6**.

13.8.2 Upper Ends of Sounding Pipes

Sounding pipes are to be led to positions above the bulkhead deck which are at all times readily accessible, and are to be provided with effective closing means at their upper ends. The sounding pipes, however, may be led to readily accessible positions from the platform of the machinery space provided that the closing means specified in **4.2.2(3)(e)** and **4.2.3(2), Part 6** are provided according to the kinds of tanks. Sounding pipes for tanks other than those for flammable oil and cofferdams may be led to readily accessible positions from the platform of the machinery space provided that sluice valves, cocks or screw caps attached to the pipes by chain are provided.

13.8.3 Construction of Sounding Pipes

1. Sounding pipes are to be as straight as practicable and if they are curved the curvature is to be sufficiently large.

2. Striking plates of adequate size and sufficient thickness are to be fitted on the bottom plating under the open ended sounding pipes to prevent the damage of plating by striking of the sounding rods. Where sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

3. The internal diameter of sounding pipes passing through a refrigerated chamber cooled down to 0 °*C* or below is not to be less than 65 *mm* and of other sounding pipes is not to be less than 32 *mm*.

13.8.4 Construction of Liquid Level Indicators

A liquid level indicator which is specified in **13.8.1** above is to be of a type approved one by the Society.

However, when a liquid level indicator conforms to a standard deemed approved by the Society or when it is provided with a certificate deemed by the Society, the requirements do not apply. The liquid level indicator for tanks for fuel oil, lubricating oil and other flammable oils are to comply with the requirements in 4.2, Part 6 of the Rules.

13.8.5 Water Level Detection and Alarm Systems for Bulk Carriers, etc.

1. For bulk carriers defined in 28A.1.2 (1), Part 2, water level detection and alarm systems are to be provided for giving audible and visual alarms in the navigation bridge, in accordance with the following **(1)** to **(4)**.

(1) In each cargo hold, the systems are to give alarms when the water level reaches the following **(a)** and (b) at the aft end of the cargo hold.

(a) a height of 0.5 *m* above the inner bottom

(b) a height not less than 15% of the depth of the cargo hold but not more than 2.0 *m*

(2) In any ballast tank forward of the collision bulkhead specified in 12.1.1, Part 2, the system is to give an alarm when the liquid in the tank reaches a level not exceeding 10% of the tank capacity.

(3) In any dry or void space other than chain locker, any Part of which extends forward of the foremost cargo hold and the volume of which exceeds 0.1% of the ship's maximum displacement volume, the system is to give an alarm at a water level of 0.1 *m* above the deck.

(4) The systems are to have constructions and functions deemed appropriate by the Society.

2. Alarms given by the water level detection and alarm systems specified in **-1** are to be capable of identifying the space where the water level reaches the alarm level and the water level specified in **-1(1)** at the navigation bridge.

The above alarms are also to be capable of being easily distinguishable from alarms given by other installations in the navigation bridge.

3. The water level detection and alarm systems specified in **-1** for ballast tanks and cargo holds which have been designed for carriage of water ballast may be provided with override devices deemed as appropriate by the Society.

4. Manuals documented operating and maintenance procedures for the water level detection and alarm systems specified in **-1** are to be kept on board.

13.8.6 Water Level Detection and Alarm Systems for Single Hold Cargo Ships

1. Cargo ships other than bulk carriers defined in 28A.1.2 (1), Part 2, having a length (L_f) of less than 80 *m* and a single cargo hold below the freeboard deck or cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to that deck, are to be fitted in such space or spaces with water level detection and alarm systems in accordance with the following **(1)** to **(3)**.

(1) The water level detection and alarm systems are to give an audible and visual alarm at the navigation bridge when the water level above the inner bottom in the cargo hold reaches a height of not less than 0.3 *m*, and another when such level reaches not more than 15% of the mean

(2) The systems are to be fitted at the aft end of the hold, or above its lowest Part where the inner bottom is not parallel to the designed waterline. Where webs or partial watertight bulkheads are fitted above the inner bottom, the fitting of additional detectors may be required.

(3) The systems are to have constructions and functions deemed appropriate by the Society.

2. Alarms given by the water level detection and alarm systems specified in **-1** are to be capable of identifying the space where the water level reaches the alarm level and the water level specified in **-1(1)** at the navigation bridge.

The above alarms are also to be capable of being easily distinguishable from alarms given by other installations in the navigation bridge.

3. Manuals documented operating and maintenance procedures for the water level detection and alarm systems specified in **-1** are to be kept on board.

4. Notwithstanding the provisions of **-1**, the water level detection and alarm systems need not to be fitted in ships complying with the requirements of **13.8.5**, or in ships having watertight side compartments each side of the cargo hold length extending vertically at least from inner bottom to freeboard deck having a breadth deemed as appropriate by the Society.

13.9 Fuel Oil Systems

13.9.1 General

1. The fuel oil systems in the machinery space where main propulsion machinery is installed and where a boiler is installed are to be such that easy maintenance and inspection are available. All valves or cocks are to be capable of being operated from above the platform.

2. Stop valves or cocks are to be fitted on both suction and delivery sides of fuel oil pumps.

3. Valves and pipe fittings with a design temperature above 60 *°C* and a design pressure above 1 *MPa* are to be suitable for use under a pressure of not less than 1.6 *MPa*. Valves and pipe fittings used for fuel oil transfer piping lines, fuel oil suction piping lines and other low pressure fuel oil piping lines are to be suitable for use under a pressure of not less than 0.5 *MPa*.

4. Union joints used for connection of fuel oil injection pipes of diesel engines or pipes of burning systems of boilers are to be of rigid construction and to have metal contact capable of providing sufficient oil tightness.

5. Where it is intended to carry fuel oil and ballast water in a same compartment alternately, the pipes are to be so arranged that the fuel oil can be pumped out from any compartment at the same time as the ballast water is being discharged from any other compartment. Where settling or service tanks are provided, each having a capacity sufficient to permit 12 *hours* normal service without replenishment, the above requirement may be modified.

6. Two fuel oil service tanks for each type of fuel used on board necessary for propulsion and vital systems or equivalent arrangements are to be provided.

7. The capacity of each fuel service tank required in **-6** is to be sufficient for at least 8 *hours* at maximum continuous rating of the main engine and normal operating load of the generators at sea.

8. In addition to **13.9**, fuel oil systems are to comply with the requirements in in **4.2, Part 6**.

13.9.2 Fuel Oil Filling Pipes

1. Fuel oil filling pipes from outboard are to be of exclusive use. The open ends of these pipes are to be led above decks as far as possible and to be provided with rigid covers.

2. Where fuel oil filling pipes are fitted not on nor near the top of the fuel oil tanks, non-return valves are to be fitted close to tanks, or alternatively, valves or cocks having remote control closing means specified in **4.2.2(3) (d), Part 6** are to be provided.

3. Notwithstanding the requirements in **-1**, where fuel oil filling pipes are connected to suction pipes, stop valves are to be provided on the filling pipes. Additional stop valves are to be provided where the tanks are situated on a higher position than the double bottom and fuel oil may pass to other fuel oil tanks through the filling pipes thereto and overflow from the openings of sounding pipes, etc.

13.9.3 Fuel Oil Transfer Pumps

In ships where power pumps are used for pumping up to the settling and service tanks, at least two independent power fuel oil transfer pumps are to be provided, and these pumps are to be connected ready for use. Where any suitable independent power driven fuel oil pump for other purposes is available as a fuel oil transfer pump, this pump may be used as a fuel oil transfer pump.

13.9.4 Drip Trays and Drainage System

1. Metallic drip trays with sufficient depth are to be provided under the equipment that are concerned with fuel oil such as diesel engines (except main propulsion machinery), burners, fuel oil pumps, fuel oil heaters, fuel oil coolers, fuel oil filters, and fuel oil tanks such as fuel oil settling and service tanks. Where it is not practicable to provide metallic drip trays, coamings are to be provided to keep spillage of oil.

2. Fuel oil settling tanks and service tanks are to be provided with drain valves or cocks for draining water from the bottom of the tanks.

3. The drain valves or cocks fitted to fuel oil tanks are to be of self-closing type.

4. Drainage arrangements are to comply with the following requirements:

(1) Oil in the drip trays or in the coamings prescribed in **-1**, **-2** and drains from drain valves or cocks fitted to fuel oil tanks are to be led to fuel oil drain tanks, or other suitable arrangement.

(2) The fuel oil drain tanks prescribed in **(1)** are not to form a part of an overflow system.

(3) Suitable appliances are to be provided for disposing fuel oil drains stored in the fuel oil drain tanks prescribed in **(1)**.

13.9.5 Fuel Oil Heaters

1. Where heaters are provided in fuel oil systems, they are to be provided with temperature controller and high temperature alarm devices or low flow alarm devices, unless where the oils would not be heated to the temperature within 10°C below the flash point of the fuel oil.

2. Double bottom tanks and deep tanks are not to be provided with electric heaters unless approved by the Society.

3. Electric heaters for heating fuel oil are to comply with the following requirements

(1) Heaters are to be provided with automatic temperature controlling devices.

(2) Safety switches with independent temperature sensor are to be provided. The safety switches are to cut off the electrical power supply to prevent the surface temperature of heating elements from rising 220 °*C* and above, and are to be provided with manual reset devices.

(3) Electric heaters are to be adequately protected against any mechanical damage at cleaning the tank.

13.9.6 Fuel Oil Systems for Diesel Engines

1. Number and capacity of fuel oil supply pumps for the main propulsion machinery

(1) The main propulsion machinery is to be provided with one main fuel oil supply pump of sufficient capacity to maintain the supply of the fuel oil at the maximum continuous output of the machinery, as well as one stand-by fuel oil supply pump of sufficient capacity to supply fuel under normal service condition. These pumps are to be connected ready for use.

(2) Where two or more main propulsion machinery is provided, and where each of them has a built-in main fuel oil supply pump and when it is possible to give a navigable speed even if one of them is out of use, stand-by fuel oil supply pump may be dispensed with on condition that one complete spare pump is carried on board.

2. Number and capacity of fuel oil supply pumps for diesel engines driving auxiliary machinery and electrical generators

(1) Diesel engines for driving electrical generators and auxiliary machinery for which duplication is required are to be provided with main and stand-by fuel oil supply pumps of sufficient capacity to maintain the supply of oil at the maximum continuous output of the engine. These pumps are to be connected ready for use.

(2) Where each engine prescribed in **(1)** is provided with an exclusive main fuel oil supply pump, the stand-by fuel oil supply pump may be omitted.

3. Driving system of stand-by fuel oil supply pumps and use of other pumps

(1) Stand-by fuel oil supply pumps are to be driven by independent power source.

(2) Where any fuel oil pump driven by independent power source and intended for other purposes is available as a stand-by fuel oil supply pump, this pump may be used as a stand by fuel oil supply pump.

4. Fuel oil filters

(1) Fuel oil filters are to be provided on fuel oil supply piping lines for diesel engines.

(2) Fuel oil filters for diesel engines used as main propulsion machinery are to be capable of being cleaned without stopping the supply of filtered oil. The filters are to be provided with valves or cocks for depressurizing before being opened.

5. Fuel oil heating devices and fuel oil purifying devices

Where low grade oil is used as fuel oil, suitable fuel oil heating devices and fuel oil purifying devices are to be provided.

13.9.7 Burning Systems for Boilers

1. Burning systems for main boilers

(1) Where the main boiler is provided with the combustion system of pressurized fuel injection type, at least two units of burning pumps and fuel oil heaters are to be provided respectively, each unit capable of supplying a sufficient amount of oil to generate steam at the maximum evaporation rate of the boiler even in the case of failure of one unit. These pumps are to be connected ready for use.

(2) Filters are to be provided on the suction and delivery sides of the fuel injection pumps. The filters are to be capable of being cleaned without stopping the supply of filtered oil.

(3) Fuel oil filters specified in the above **(2)** are to be provided with valves or cocks for depressurizing before being opened.

2. Burning systems for auxiliary boilers

(1) As for essential auxiliary boilers and other boilers to supply steam for fuel oil heating necessary for the operation of the main propulsion machinery or cargo heating that is required continuously, burning systems are to be provided in accordance with the requirements in **-1**. However, where alternative means are available to ensure the normal navigation and cargo heating with the burning system being out of operation, only one unit of burning system will be accepted.

(2) Where fuel oil is supplied to the burners by gravity, fuel oil filters capable of being cleaned without stopping the supply of filtered oil are to be provided.

3. Prevention of mixing of oil into steam pipes and air pipes

Where the removal of residual fuel oil in burners is conducted by means of steam or air, means are to be taken to prevent the mixing of oil into steam or air.

13.10 Lubricating Oil Systems and Hydraulic Oil Systems

13.10.1 General

1. The location, drip trays, drainage arrangements and heaters of lubricating oil systems are to comply with the requirements in **13.9.1-1**, **13.9.4-1** and **-4**, and **13.9.5** respectively (in these case the term “fuel oil” is to be read as “lubricating oil”).

2. The location, drip trays and drainage arrangements of the hydraulic oil systems are to comply with the requirements in **13.9.1-1**, **13.9.4-1** and **-4** (in these case the term “fuel oil” is to be read as “hydraulic oil”).

3. In addition to **13.10**, lubricating oil systems and hydraulic oil systems are to comply with the requirements in **4.2.3, Part 6** and **4.2.4, Part 6** respectively.

13.10.2 Lubricating Oil Pumps

1. Number and capacity of lubricating oil pumps for main propulsion machinery, propulsion shaftings and power transmission systems

(1) Main propulsion machinery, propulsion shaftings and their power transmission systems are to be provided with one main lubricating oil pump of sufficient capacity to maintain the supply of oil at the maximum continuous output of the machinery and one stand-by lubricating oil pump of sufficient capacity to supply oil under normal navigating condition. These pumps are to be connected ready for use.

(2) Where two or more main propulsion machinery, propulsion shafting and their power transmission systems are provided, and where each of them has a built-in main lubricating oil pump and when it is possible to give a navigable speed even if one of them is out of use, the stand-by lubricating oil pumps may be dispensed with on condition that one complete spare pump is carried on board.

2. Number and capacity of lubricating oil pumps for auxiliary machinery, electrical generators and their prime movers

(1) Electrical generators and auxiliary machinery for which duplication is required and their prime movers are to be provided with main and stand by lubricating oil pumps of sufficient capacity to maintain the supply of oil at the maximum continuous output of the machinery. These pumps are to be connected ready for use.

(2) Where each system prescribed in **(1)** is provided with an exclusive main lubricating oil pump, the stand by lubricating oil pump may be omitted.

3. Driving system of stand by lubricating oil pumps and use of other pumps

(1) Stand by lubricating oil pumps are to be driven by independent power source.

(2) Where any lubricating oil pump driven by independent power source and intended for other purposes is available as a stand by lubricating oil pump, this pump may be used as a stand by lubricating oil pump.

13.10.3 Stop Valves between Engine and Sump Tank

For ships of 100 *meters* and above in length, where a double bottom is used as a lubricating oil sump tank, a stop valve which can be easily operated from the engine room floor or suitable counterflow prevention device is to be provided.

13.10.4 Lubricating Oil Filters

1. Where forced lubrication system (including gravity supply from head tank) is adopted for lubrication of machinery installations, lubricating oil filters are to be provided.

2. The filters used for the lubricating oil systems of the main propulsion machinery, power transmission of propulsion shafting and controllable pitch propeller system are to be capable of being cleaned without stopping the supply of filtered oil.

3. Lubricating oil filters specified in the above **-2** are to be provided with valves or cocks for depressurizing before being opened.

13.10.5 Lubricating Oil Purifying Devices

Lubricating oil systems are to be provided with lubricating oil purifying system such as lubricating oil purifiers or filters in lieu of purifiers.

13.11 Thermal Oil Systems

13.11.1 General

The location and valves fitted to the pumps of thermal oil systems are to comply with the requirements in **13.9.1-1** and -**2**. The filling pipes from outside the ship are to comply with the requirements in **13.9.2-2**. Drip trays and drainage systems are to comply with the requirements in **13.9.4-1** and **-4**. In these cases the term "fuel oil" is to be read as "thermal oil". In addition to **13.11**, these systems are to comply with the requirements in **4.2.4, Part 6**.

13.11.2 Thermal Oil Systems

Thermal oil systems are to comply with the following requirements:

(1) Expansion tanks are to be provided with liquid level indicator.

(2) Circulating pumps are to be provided with a pressure measuring device at a suitable position on the delivery and suction sides.

(3) The inlet and outlet valves on thermal oil heaters are to be controllable from outside the compartment where they are installed, unless an arrangement for quick gravity drainage of thermal oil contained in the system into a collecting tank is made.

13.11.3 Pumps for Thermal Oil Heater

The thermal oil heater for important use is to be provided with two thermal oil circulating pumps and two fuel injection pumps. However, only one fuel injection pump may be accepted, where alternative means are available to ensure the normal navigation and cargo heating in case of failure of the pump.

(1) Thermal oil circulating pumps

(2) Fuel injection pumps

13.11.4 Heating of Liquid Cargoes with Flash Points Below 60 °C

Heating of liquid cargoes with flash points below 60 °*C* is to be arranged by means of a separate secondary system, located completely within the cargo area unless in the case as deemed appropriate by the Society.

13.12 Cooling Systems

13.12.1 Cooling Pumps

1. Number and capacity of cooling pumps for main propulsion machinery

(1) Main propulsion machinery is to be provided with a main cooling pump of sufficient capacity to maintain the supply of water (oil) at the maximum continuous output of the machinery as well as a stand by cooling pump of sufficient capacity to supply cooling water (oil) under the normal navigating condition. However, the capacity of stand-by circulating pumps of ships having steam turbines as main propulsion machinery will be considered in each case by the Society. These pumps are to be connected ready for use.

(2) In steam turbine ships, and adequately installed scoop arrangement may be used as the main cooling water pump.

In this case, the main condenser is to be so arranged as to be sufficiently cooled with other cooling systems, while ships run at low speed, in addition to the cooling system by stand by cooling water pumps prescribed in **(1)**.

(3) Where two or more main propulsion machinery are provided each of which has a built-in main cooling pump, and where it is possible to give a navigable speed in case of failure of one of the main propulsion machinery, the stand by cooling pumps may be dispensed with on condition that one complete spare pump is carried on board.

2. Number and capacity of cooling pumps for auxiliaries, electrical generators and their prime movers

(1) Electrical generators and auxiliaries for which duplication is required and their prime movers are to be provided with main and stand-by cooling pumps of sufficient capacity to maintain the supply of water (oil) at the maximum continuous output of the machinery. These pumps are to be connected ready for use.

(2) Where each prime mover prescribed in **(1)** is provided with an exclusive main cooling pump, the stand-by cooling pump may be omitted.

3. Drive system of stand by cooling pumps and use of other pumps

(1) Stand-by cooling pumps are to be driven by independent power source.

(2) Where a suitable pump driven by independent power source and intended for other purposes is available as a stand-by cooling pump, this pump may be used as a stand-by cooling pump.

13.12.2 Suction of Sea Water

Arrangement is to be provided to introduce cooling sea water from sea suction valves fitted on two or more sea chests or sea suctions.

13.12.3 Cooling Systems for Diesel Engines

Where sea water is used for the direct cooling of the propulsion machinery, or diesel engines driving electrical generators or auxiliary machinery for which duplication is required, strainers which are arranged to be capable of being cleaned without stopping the supply of filtered cooling water to the respective engines are to be provided between the sea suction valve and the cooling sea water pump.

13.13 Pneumatic Piping Systems

13.13.1 Arrangement of Air Compressors and Pressure Relief Systems

1. Air compressors are to be so arranged that entry of oil into inlet air may be minimized as practicable.

2. Each air compressor is to be provided with a relief valve to prevent the pressure from rising more than 10% above its maximum working pressure in cylinders.

3. Where water jackets of air coolers might be subject to dangerous excessive pressure due to leakage of compressed air into them, suitable pressure relief arrangement is to be provided for the water jackets.

13.13.2 Relief Devices and Other Fittings for Air Tanks

Relief devices and other fittings for air tanks are to comply with the requirements in **10.8**.

13.13.3 Number and Total Capacity of Air Compressors

1. Where the main propulsion machinery is designed for starting by compressed air, two or more starting air compressors are to be provided and arranged so as to be able to charge each air reservoir. Where, however, cylinders are provided with air charging valves, the charging valves will be considered as equivalent to an air compressor driven by the main propulsion machinery.

2. One of the air compressors prescribed in **-1** is to be driven by a prime mover other than the main propulsion machinery.

3. The total capacity of air compressors is to be sufficient to supply air in the air reservoirs from atmospheric pressure to the pressure required for the consecutive starts prescribed in **2.5.3-2** within one *hour*.

13.13.4 Emergency Air Compressors

1. Where prime movers driving air compressors specified in **13.13.3** are arranged for air starting, an independent power driven emergency air compressor is to be provided.

2. The prime movers driving the emergency air compressor are to be capable of starting without compressed air.

3. The capacity of the emergency air compressor is to be sufficient to start the prime movers of the air compressor prescribed in **13.13.3.** For this purpose, a small air reservoir for emergency air compressor may be provided.

13.13.5 Compressed Air Piping

1. Drainage system is to be provided to compressed air piping containing drain inside the pipes.

2. All discharging pipes to starting air reservoirs are to be led directly from starting air compressor.

3. Starting air pipes from the air reservoirs to the main propulsion machinery or auxiliary engines are to be entirely separate from the compressor discharge system prescribed in **-2**.

13.14 Steam Piping Systems and Condensate Systems

13.14.1 Drainage Arrangements

Drainage arrangements are to be installed at suitable locations in steam pipe lines.

13.14.2 Heating Coil for Oil

Where steam is used for heating of fuel oil or lubricating oil, the steam drain pipes are to be led to observation tanks or other oil detectors in a well-lighted and accessible position in machinery space.

13.14.3 Steam Pipes passing through Cargo Holds

In principle, steam pipes are not to be led through cargo holds, but where it is impracticable to avoid this arrangement, pipes are to be insulated and protected by steel plate and, all the joints are to be welded.

13.14.4 Condensate Systems

1. The main condenser is to be provided with at least two independent power driven condensate pumps and the arrangements to maintain vacuum in the condensers with capacity to deal with maximum designed rate of condensate from main condenser respectively. These arrangements may be omitted where considered unnecessary by the Society taking account of the type of the main condensers.

2. Suitable measures are to be taken to condensation systems of steam turbines for driving cargo oil pumps etc, so that the internal pressure of the condenser cannot exceed the design pressure in such a case of failure in the cooling system, and the measures are to be as deemed appropriate by the Society.

13.15 Feed Water Systems for Boilers

13.15.1 Feed Water Systems for Main Boilers

1. Two feed water systems are to be provided for the main boiler, each including a stop valve, a non-return valve specified in **9.9.5-1** and a feed pump. These feed water systems are to be capable of supplying feed water to the boiler with any one system being out of use.

2. Main boiler is to be provided with two or more feed water pumps which can supply feed water sufficient for maximum evaporation with any one pump being out of action. These feed pumps are to be connected ready for use.

3. Feed water pumps prescribed in **-2** are to be driven by independent prime movers.

4. Feed water systems are to be provided with feed water regulators capable of automatically controlling the feed water rate.

5. Feed pumps are not to be used for any other services than feeding the boilers.

13.15.2 Feed Water Systems for Auxiliary Boilers

Essential auxiliary boilers or other boilers intended to supply steam for fuel oil heating necessary for the operation of the main propulsion machinery or cargo heating that is required continuously are to be provided with feed water systems in accordance with **13.15.1**. The requirements in **13.15.1-1** and **-2** need not be applied provided that an alternative means is available to ensure the normal navigation and cargo heating with the feed water system being out of operation.

13.15.3 Distilling Plant

In ships using distilled water as feed water, at least one distilling plant with a sufficient capacity is to be provided.

13.15.4 Pipes passing through Tanks

Boiler feed water pipes are not to be led through tanks which contain oil, nor are oil pipes to be led through boiler feed water tanks.

13.16 Exhaust Gas Piping Arrangement

13.16.1 Exhaust Gas Pipes from Diesel Engines

1. In principle, exhaust gas pipes of two or more diesel engines are not to be connected together except in the following (1) and (2) cases.

(1) In cases where exhaust gas pipes of two or more diesel engines are connected to common silencers and effective means are provided to prevent any exhaust gas from returning into the cylinders of non-operating engines

(2) In cases where exhaust gas pipes of two or more diesel engines are connected to common exhaust gas cleaning systems deemed appropriate by the Society.

2. Exhaust gas piping lines led overboard near the water line are to be so arranged as to prevent water from being siphoned back to the cylinders.

3. Boiler uptakes and exhaust piping lines from diesel engines are not to be connected together except in the following (1) and (2),

(1) In cases where boilers are arranged to utilize waste heat from diesel engines.

(2) In cases where boiler uptakes and exhaust piping lines from diesel engines are connected to common exhaust gas cleaning systems deemed appropriate by the Society

13.16.2 Exhaust Gas Pipes from Boilers

In case where dampers are installed in the funnels or uptakes of boilers, their degree of opening is not to be reduced to 2/3 or less of the flue area when closed. They are to be capable of locking in any open position and the degree of opening is to be clearly indicated.

13.16.3 Exhaust Gas Pipes from Incinerators

A cleaning hole for maintenance is to be provided at the bending parts of the exhaust gas pipe from an incinerator.

13.17 Tests

13.17.1 Shop Tests

Auxiliaries and piping after the manufacture are to be tested in accordance with the requirements in **12.6**.

13.17.2 Tests on Board

1. Auxiliaries (excluding auxiliary machinery for specific use etc.) is to be subjected to running tests after installed on board. However, in the case of machinery having passed the running tests specified in **12.6.1-9**, the test methods on board may be suitably modified at the discretion of the Society.

2. Fuel oil piping systems, thermal oil piping systems, and heating coils in tanks are, after installed on board, to be subjected to a leak test at a pressure of 1.5 times the design pressure or 0.4 *MPa*, whichever is the greater.

Chapter 14 PIPING SYSTEMS

14.1 General

14.1.1 Scope

1. The requirements of this Chapter apply to the piping systems for tankers which have all the following features. The piping systems for other types of tankers will be considered by the Society in each case. The requirements especially provided in this Chapter are to apply in lieu of the requirements in **Chapters 12** and **13**.

(1) Crude oil, petroleum products having a vapour pressure (absolute pressure) less than 0.28 *MPa* at 37.8°C or other similar liquid cargoes are carried.

(2) Machinery spaces and cargo oil tanks (including slop tanks, the same being referred to hereinafter in this Chapter) are arranged in accordance with the requirements in **4.5.1-1, Part 6**

(3) Cargoes are loaded by land facilities and unloaded by cargo oil pumps on board the ship.

2. The piping systems for ships carrying dangerous chemicals in bulk are to comply with the requirements of this Chapter, except where specially required in *IBC Code IMO*. For this application, each wording cargo oil is to be read as cargo.

14.1.2 Drawings and Data

Drawings and data to be submitted for approval are generally as follows:

(1) Piping diagram of cargo oil pipes and instrumentation (with materials, dimensions, design pressures of pipes, valves, etc. and the arrangement of devices to prevent the passage of flame).

(2) Control system diagram (including safety and alarm systems) of integrated cargo and ballast systems driven by electrohydraulic power.

(3) Other drawings and data considered necessary by the Society.

14.2 Cargo Oil Pumps, Cargo Oil Piping Systems, Piping in Cargo Oil Tanks, etc.

14.2.1 Cargo Oil Pumps

1. Cargo oil pumps are to comply with the following requirements:

(1) Each pump is to be so designed as to minimize the risk of sparking and oil leakage at the seal.

(2) A stop valve is to be provided on the delivery side of the pump. However, such stop valve may be omitted, provided that the cargo oil pipe on the delivery side of the pump is provided with a stop valve in a proper position.

(3) Where a relief valve is provided on the delivery side of the pump, the arrangement is to be such that the escaped oil is led to the suction side of the pump.

(4) A pressure measuring device is to be fitted on the delivery side of each pump. Where the pump is driven by a prime mover which is installed in the space other than the pump room, an additional pressure measuring device is to be fitted at a suitable position visible from the controlling position.

(5) The requirements in **4.5.10(1), Part 6**.

2. Where prime movers, other than steam engines or hydraulic motors, for driving the cargo oil pumps are installed in the cargo oil pump room, descriptions and construction of the prime movers and the driving system are to be submitted for the approval by the Society.

3. Where deep well pumps, submerged pumps, etc. are installed, construction of the pumps and driving systems are to be submitted for approval by the Society.

4. In general, cargo oil pumps are not to be used for other purposes than transferring cargo oil or ballast in cargo oil tanks, transferring tank cleaning water for cargo oil tanks, discharging bilge as stipulated in **14.3.1-2** or discharging ballast as specified in **14.3.2-2**.

14.2.2 Arrangement of Cargo Oil Piping Systems

1. Cargo oil pipes are classified into Group III, except where considered necessary by the Society.

2. Each cargo oil tank is to be provided with a cargo oil suction pipe(s) so arranged that cargo unloading can be carried out with one of the cargo oil pumps out of use.

3. Cargo oil pipes are to be so arranged as to be capable of loading cargo oil to cargo oil tanks without passing through cargo oil pumps.

Where loading pipes are led directly to the tanks from above the deck, the opening ends of these pipes are to be led to the lower Part of the tanks as far as practicable to prevent the accident caused by the generation of static electricity.

4. Where sea suction pipes for ballasting purpose are connected to cargo oil pipes, stop valves are to be provided between the sea suction valves and the cargo piping.

5. Slip-on joints used in the cargo oil pipes are to comply with the requirements specified in **12.3.3**.

6. Sea suction pipes and discharge pipes for permanent ballast tanks are not to be connected to the sea suction pipes and discharge pipes for cargo oil tanks.

7. The earthing between independent cargo oil tanks and hull structures is to be required. All cargo piping systems (cargo oil pipes, vent pipes, tank washing pipelines, etc.) are to be electrically bonded to hull structures.

14.2.3 Alternative Use of Tanks

Where cargo oil tanks are so designed that they can also be used as ballast tanks or fuel oil tanks, the tanks are to be provided with devices which the Society requires, and approved drawings or documents having descriptions on a detailed operating manual for the alternative use are to be provided on board the ship.

14.2.4 Separation of Cargo Oil Pumps and Cargo Oil Pipes

1. Cargo oil pipes are to be entirely separated from other pipes, except where permitted in **14.2.2**, **14.3.1** and **14.3.2**.

2. Cargo oil pipes are not to be led through fuel oil tanks, engine room, accommodation spaces and any spaces where sources of vapour ignition are normally present. In addition, these pipes are not to be led to spaces forward the collision bulkhead or after the front bulkhead of the engine room.

3. Cargo oil pipes on the weather deck are to be arranged sufficiently apart from the accommodation spaces.

4. Where a ship is equipped for bow and/or stern loading and discharge of cargo oil outside the cargo area, the connections of the cargo lines leading to the cargo hose connection therein are to be of welded joints except valve connections and the cargo lines are to be clearly identified and segregated by following means of **(1)** or **(2)** situated in the cargo area. The open ends of the cargo lines are to be provided with a blank flange at the bow and/or stern end connections.

(1) Two valves which can be secured in the closed position and provided that the efficiency of the segregation can be checked

(2) One valve together with another closing appliances providing an equivalent standard of segregation such as a removable spool piece or spectacle flange

5. Cargo oil pipes and similar pipes to cargo oil tanks are not to pass through ballast tanks. However, these pipes may pass through the ballast tanks provided that these pipes in ballast tanks are of short length and the connections of these pipes are of welded joints or flanged joints which have no risk of leakage.

6. Notwithstanding preceding **-5**, for oil tankers other than double hull tankers, cargo oil pipes may pass through the ballast tanks provided that the connections of these pipes are of welded joints or flanged joints which have no risk of leakage. Expansion bends only, not glands, are permitted in these lines within ballast tanks.

14.2.5 Bulkhead Valves of Cargo Oil Piping Systems

1. Cargo oil pipes passing through oiltight bulkheads between cargo oil tanks and pump rooms are to be provided with stop valves as close to the bulkhead as practicable.

2. Where the valves prescribed in **-1** are located inside the pump room, they are to be made of steel and to be capable of being closed at the position of the valves and from a readily accessible position outside the compartment in which they are located. However, if the valves operated at a position above the deck are fitted on each cargo oil branch pipe, the valves located inside the pump room may be of cast iron without remote control device.

3. Where the valves prescribed in **-1** are located inside the tank, the valves may be of cast iron and need not be capable of being closed at the position of the valves, but they are to be provided with remote control devices, and the pipes are to be provided with another valve in the pump room.

4. Where the valves are required to be remote controlled according to the requirements in **-2** and **-3**, means are to be provided to show whether they are open or closed.

14.2.6 Valve Operation Rod penetrating through Decks

Stuffing boxes are to be provided at positions at which operating rods from cargo valves pass through gastight or oiltight decks.

14.2.7 Piping in Cargo Oil Tanks

1. Pipes other than cargo oil pipes, cargo oil heating pipes, ballast pipes of cargo tanks and pipes permitted in **-2** to **-4** are not to pass through cargo oil tanks nor to have any connection to these spaces.

2. Pipes for remote control of cargo oil piping systems, and vapour discharge pipes, tank cleaning pipes and sounding devices of cargo oil tanks may be led to cargo oil tanks.

3. Scupper pipes, sanitary pipes, etc. may be led through cargo oil tanks subject to the approval by the Society.

4. Ballast pipes and other pipes such as sounding and vent pipes to ballast tanks are not to pass through cargo oil tanks. However, these pipes may pass through the cargo oil tanks provided that these pipes in cargo oil tanks are of short length and the connections of these pipes are of welded joints or flanged joints which have no risk of leakage.

5. Notwithstanding preceding **-4**, for oil tankers other than double hull tankers, ballast pipes of ballast tanks adjacent to a cargo oil tank may pass through cargo oil tanks provided that the connections of these pipes are of welded joints or flanged joints which have no risk of leakage. Expansion bends only, not glands, are permitted in these lines within cargo oil tanks.

14.2.8 Sounding Devices of Cargo Oil Tanks

A suitable sounding device approved by the Society is to be fitted onto any cargo oil tank. The sounding device is to be designed or arranged to prevent any outflow of flammable vapours into spaces such as engine room, accommodation spaces, etc. where sources of vapour ignition are normally present.

14.2.9 Steam Pipes

1. The cargo oil heating steam supply and return pipes are not to penetrate the cargo oil tank plating, other than at the top of the tank, and the main supply pipes are to be run above the weather deck.

2. Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank.

3. The cargo oil heating steam return pipes are to be led to an observation tank or other oil detectors installed in a position as apart as possible from hot surfaces such as boilers and ignition sources, for the detection of contaminated oil in steam drain.

4. The steam temperature in the cargo area is not to exceed 220°C.

5. In the cargo oil pump rooms, drain pipes from steam or exhaust pipes or from the steam cylinders of the pumps are to terminate well above the bilge wells.

6. Each branch connection of cleaning steam pipes of cargo oil tanks or other tanks to which a cargo oil pipe is led is to be provided with a screw-down non-return valve or two stop valves.

14.2.10 Thermal Oil Pipes

1. The thermal oil piping arrangement for the cargo oil tanks is to comply with following requirements:

(1) All joints in the cargo oil tanks are to be of butt-welded type.

(2) Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the cargo oil tanks.
Where the thermal oil pipe penetrates the oiltight bulkhead between a cargo oil tank and the pump room, such shut-off valves or cocks may be installed as close to the bulkhead as practicable.

(3) The system is to be so arranged that the pressure in the coil is at least 3 *m* water head above the static head of the cargo when the circulating pump is not operating.

(4) For the ships only carrying oils having a flashpoint above 60°C, the requirement in **13.11.4** is to be applied.

2. The thermal oil temperature in the cargo area is not to exceed 220°C.

14.2.11 Integrated Cargo and Ballast Systems Driven by Electrohydraulic Power

Emergency stopping devices and control systems of integrated cargo and ballast systems driven by electrohydraulic power (hereinafter referred to as integrated systems) are to comply with the following requirements:

(1) Emergency stopping devices of integrated systems are to be independent from control systems. A single failure in the emergency stopping devices or the control systems is not to render the integrated system inoperative.

(2) Manual emergency stops of the cargo pumps are to be arranged in a way that they are not to cause the stop of the hydraulic power source.

(3) Emergency stopping devices and control systems are to be provided with backup power supply, which may be satisfied by a duplicate power supply from the main switch board. The failure of any power supply is to provide audible and visible alarm activation at each location where the control panel is fitted.

(4) Manual overriding or redundant arrangements are to be provided within the control systems to be made available for the operation of the integrated system in the event of failure of the automatic or remote control systems.

14.3 Piping Systems for Cargo Oil Pump Rooms, Cofferdams and Tanks adjacent to Cargo Oil Tanks

14.3.1 Bilge Piping Systems, etc. for Cargo Oil Pump Rooms and Cofferdams adjacent to Cargo Oil Tanks

1. Bilge piping system consisting of a power driven pump or eductor is to be provided to discharge bilge in the cargo oil pump room and cofferdams adjacent to a cargo oil tank. The bilge in these spaces is not to be led to the engine room.

2. Cargo oil pumps may be used for bilge drainage purpose specified in **-1**, provided that each bilge suction is provided with a screw-down non-return valve, and a stop valve or cock is fitted on the suction side of the pump and, in addition, a stop valve is fitted between the cargo oil pipe and the overboard discharge valve.

3. Bilge pipes for a cofferdam adjacent to a cargo oil tank are to be entirely separate from those for spaces not adjacent to a cargo oil tank. However, a common bilge pump (except cargo oil pump) may be used for bilge drainage purpose of these spaces subject to the approval by the Society, provided that the bilge pipe for spaces not adjacent to a cargo oil tank has a non-return valve.

4. Sounding pipes of cofferdams adjacent to a cargo oil tank is not to be less than 38 *mm* in internal diameter and unless otherwise approved by the Society to be led to above the weather deck.

14.3.2 Ballast Tanks adjacent to Cargo Oil Tanks

1. The requirements in **14.3.2** are also applied to ballast tanks used as cofferdams at the fore and after ends of cargo oil tanks in accordance with the requirements in **26.1.2-2(3), Part 2**. However, other requirements will be applied, if the fore ends of these ballast tanks are located forward of the collision bulkhead.

2. Dangerous ballast pipes (*see*, Note 2 of **Table 12.6(1)**) such as ballast pipes of ballast tanks adjacent to a cargo oil tank are to be separated from other pipes and are not to be led to the engine room. For this purpose, an exclusive pump for ballasting and de-ballasting these tanks is, generally, to be provided in the pump room. However, where specially approved by the Society, the cargo pumps may be used for the purpose of only de-ballasting in an emergency.

3. Slip joints used in the ballast pipes of ballast tanks adjacent to a cargo oil tank are to comply with the requirements specified in **12.3.3**.

4. Each air pipe to ballast tanks adjacent to a cargo oil tank is to be provided with easily renewable wire gauze to prevent the passage of flame at their outlets. In case where approved by the Society, the requirement in **13.6.3(1)** for the dimension of the air pipes will be properly modified.

5. Sounding pipes of ballast tanks adjacent to a cargo oil tank are to be led to above the weather deck, unless otherwise approved by the Society.

14.3.3 Fuel Oil Tanks adjacent to Cargo Oil Tanks

Sounding pipes of fuel oil tanks adjacent to a cargo oil tank are to be led to above the weather deck, unless otherwise approved by the Society.

14.3.4 Pump Arrangement of Forward Compartment

A pump used for bilge drainage or transfer of ballast water or fuel oil in a compartment forward of the cargo oil tanks is to be exclusive and unless otherwise approved by the Society to be installed in the forward part of the ship.

However, where approved by the Society, other suitable pumps than specified above may be used for the bilge drainage or transfer of ballast water in a compartment forward of the cargo oil tanks.

14.4 Ships only carrying Oils having a Flashpoint above 60°C

14.4.1 General

For the ships only carrying oils having a flashpoint above 60°C, the requirements in **14.1** to **14.3** will be partially modified in accordance with the following **(1)** to **(4)**.

(1) The requirements in **14.1.2** to **14.2.9** may be properly modified.

(2) Bilges of the cargo oil pump room and cofferdams adjacent to a cargo oil tank may be led to the engine room (*see*, **14.3.1**).

(3) Ballast pipes of ballast tanks adjacent to a cargo oil tank may be led to the engine room (*see*, **14.3.2-2**). The wire gauze to prevent the passage of flame required for the outlets of the air pipes to the cargo oil tanks may be omitted (*see*, **14.3.2-4**). The sounding pipes of these tanks may be arranged to have openings below the weather deck (*see*, **14.3.2-5**).

(4) The sounding pipes of fuel oil tanks adjacent to a cargo oil tank may not be led to above the weather deck (*see*, **14.3.3**).

14.5 Piping Systems for Combination Carriers

14.5.1 Scope

1. The requirements in **14.5** apply to piping systems and venting systems of ships designed to carry oil or alternatively solid cargoes in bulk.

2. For items especially provided in this **14.5**, the requirements in **14.5** are applied in lieu of the requirements in other Sections of this Part.

14.5.2 Terminology

The terms used in **14.5** are defined as follows:

(1) Combination carrier is an ore/oil carrier specified in **27.1.9, Part 2** and a *B/O* carrier specified in **28.8.1, Part 2**.

(2) Slop tank is a tank which is provided mainly for the carriage of tank washings and cargo oil and which is designed to be capable of loading oil whose flash point does not exceed 60°C when the ship is in the dry cargo mode.

(3) Solid cargo/oil hold is a compartment which is used as a solid cargo stowing hold when the ship is in the dry cargo mode and which is used as a cargo oil tank when the ship is not in the dry cargo mode.

(4) Ballast/solid cargo hold is a compartment which is used as an exclusive tank for ballast adjacent to a cargo oil tank when the ship is not in the dry cargo mode and which is used as a solid cargo stowing hold when the ship is in the dry cargo mode.

(5) Exclusive solid cargo hold is a compartment which is used as a void space adjacent to a cargo oil tank when the ship is not in the dry cargo mode and which is used as a solid cargo stowing hold when the ship is in the dry cargo mode.

(6) Oil/ballast tank is a tank which is used as a cargo oil tank when the ship is not in the dry cargo mode and which is used as a ballast tank or void space when the ship is in the dry cargo mode.

(7) Exclusive ballast tank is a compartment which is adjacent to a cargo oil tank when the ship is not in the dry cargo mode and which is used as an exclusive tank for ballast even when the ship is in or not in the dry cargo mode.

(8) Cargo hold is a general term for solid cargo/oil hold, ballast/solid cargo hold and exclusive solid cargo hold.

(9) Cargo oil tank is a general term for solid cargo/oil hold, oil/ballast tank and slop tank.

14.5.3 Bilge Piping Systems

1. Bilge piping systems for the cargo holds are not to be led to the engine room. The cargo oil pump may be used for the purpose of bilge suction on condition that the cargo oil piping systems in the cargo oil pump room used for the bilge suction comply with the requirements in **13.5.3** and **13.5.4**.

2. Bilge suction pipes for the cargo holds are to comply with the following requirements :

(1) Where two or more cargo oil piping systems (e.g. main and stripping lines) are provided or cargo oil piping systems are provided independently for the oil/ballast tanks and cargo holds and where these cargo oil piping systems are so arranged that liquid in all or selected oil/ballast tanks and cargo holds can be discharged (for the oil/ballast tanks, include the filling of ballasting water) simultaneously when the ship is in the dry cargo mode, these cargo oil pipes may be used as the bilge suction pipes for cargo holds. The diameter of these cargo oil pipes used as bilge suction pipes is not to be less than that specified for the bilge suction pipes.

(2) Where bilge suction pipes are provided for the exclusive use, an exclusive pump for bilge suction is to be provided in the cargo oil pump room or the bilge suctions are to be connected to the cargo oil pump

in the cargo oil pump room. Where cargo oil pumps are used as a bilge pump, a stop valve and a screw-down non-return valve are to be provided at the connection between the bilge pipe and cargo oil pump.

3. Bilge suctions in cargo holds are to comply with the following requirements:

(1) In general, one bilge suction is to be arranged on each side of the after end of the cargo hold. Where the length of cargo hold in ships having only one cargo hold exceeds 66 *m*, additional bilge suction is to be arranged in a suitable position in the forward half-length of the hold.

(2) Bilge wells are to be arranged at suitable positions so as to protect the cover plates from the direct strike of solid cargoes and to be provided with strum boxes or other suitable means so that the suction may not be choked by ore dust, etc.

(3) Bilge wells in solid cargo/oil holds and ballast/solid cargo holds, except where these bilge wells are also used as cargo oil suction wells, are to be provided with cover plates to blank off these wells or to be provided with blank flanges to blank off the open ends of the bilge suction pipes when the ship is not in the dry cargo mode.

4. For exclusive bilge suction pipes, branch bilge suction pipes are to comply with the requirements in **13.5** in addition to the requirements in **-3**. In calculating the inside diameter of the branch bilge suction pipes for draining cargo hold bilge of ore/oil carriers, the mean width of cargo hold may be used in lieu of *B*. Bilge suction pipes which are also used as a cargo oil pipe or which are connected to eductors are to be to the satisfaction of the Society in addition to comply with the requirements in **-2** and **-3**.

14.5.4 Cargo Oil Piping Systems

1. Cargo oil suctions in solid cargo/oil hold, except where these suctions are also used as bilge suctions, are to be provided with blank flanges to blank off the open end of the cargo oil suction pipes or to be provided with cover plates to blank off the cargo oil suction wells when the ship is in the dry cargo mode.

2. In addition to **14.5**, cargo oil piping systems for combination carriers are to comply with the requirements in **1.2.4** and **4.5.1-4, Part 6**.

14.5.5 Ventilating Systems

Ventilating systems for combination carriers are to comply with the requirements in **4.5.4-2, Part 6**.

14.6 Tests

14.6.1 Shop Tests

After the manufacture of piping systems of tankers and ships carrying dangerous chemical in bulk, tests are to be conducted in compliance with the requirements in **12.6**.

14.6.2 Tests after Installation on Board

1. Cargo oil pipes, after the completion of their piping, are to be subjected to a leak test at a pressure of 1.25 times the design pressure or greater.

2. Heating pipes inside cargo oil tanks are to be subjected to a leak test at a pressure of 1.5 times the design pressure or greater.

3. After installation inboard, auxiliaries and piping systems are to be subjected to the following tests:

(1) Function tests of cargo oil pumps

(2) Function tests of various systems concerning safety measures specified in this Chapter

Chapter 15 STEERING GEARS

15.1 General

15.1.1 Scope

1. The requirements in this Chapter apply to power-driven steering gears.

2. For items especially provided in this Chapter, the requirements in this Chapter are applied in lieu of the requirements in **Chapters 12** and **13**.

3. Electrical equipment and cables used for steering gears are to conform to the requirements of **Part 8** in addition to those specified in this Part.

4. Manual steering gears will be considered by the Society in each case.

15.1.2 Terminology

The terms used in this Chapter are defined as follows:

(1) Main steering gear is the machinery, rudder actuators, steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (tiller, etc) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

(2) Auxiliary steering gear is the equipment other than any Part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including tiller, etc.

(3) Steering gear power unit (hereinafter referred to as power unit) is:

(a) In the case of electric gear, an electric motor and its associated electrical equipment;

(b) In the case of electrohydraulic steering gear, a hydraulic pump, electric motor and its associated electrical equipment; and

(c) In the case of hydraulic steering gear other than those in **(b)**, a hydraulic pump and its driving engine.

(4) Power actuating system is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a power unit or units, together with the associated hydraulic pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e., tiller, etc.

(5) Rudder actuator is the component which converts directly hydraulic pressure into mechanical action to move the rudder.

(6) Control system is the equipment by which orders are transmitted from the navigating bridge to the power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

15.1.3 Drawings and Data

Drawings and data to be submitted are generally to be as follows:

(1) Drawings:

- (a) General arrangements of steering gear
- (b) Details of tiller, etc.
- (c) Assembly and details of power units
- (d) Assembly and details of rudder actuators
- (e) Piping diagram of hydraulic pipes ; Arrangements of control systems
- (f) Diagram of hydraulic and electrical systems (including alarm devices and automatic steering gear)
- (g) Arrangements and diagram of an alternative source of power
- (h) Diagram of a rudder angle indicator
- (i) Other drawings considered necessary by the Society

(2) Data:

- (a) Particulars
- (b) Operating instructions (including drawings showing the change-over procedure for power units and control systems, drawings showing the sequence of automatic supply of power from an alternative source of power, data showing the kind, particulars and an assembly of the power source in the case that the alternative source of power is an independent source of power and information about hydraulic fluid quality)
- (c) Manuals for countermeasures to be taken at the time of a single failure of the power actuating system;
- (d) Calculation sheet of the strength of essential parts.
- (e) Other data considered necessary by the Society.

15.1.4 Display of Operating Instructions, etc.

1. Simple operating instructions with a block diagram showing the change-over procedures for power units and control systems are to be permanently displayed on the navigating bridge and in the steering gear compartment for ships equipped with power-operated steering gears.

2. Where the system failure alarms according to 15.3.1-4. Are provided, appropriate instructions for emergency procedures when the alarm is activated, are to be provided on the navigation bridge.

15.1.5 Operating and Maintenance Instructions for Steering Gears

Operating and maintenance instructions and engineering drawings for steering gears are to be provided and written in a language understandable by her officers and crew members who are required to understand such information in the performance of their duties.

15.2 Performance and Arrangement of Steering Gears

15.2.1 Number of Steering Gears

1. Unless expressly provided otherwise, every ship is to be provided with a main steering gear and an auxiliary steering gear. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

2. Where the main steering gear comprises two or more identical power units, the auxiliary steering gear need not be fitted, provided that:

(1) The main steering gear is capable of operating the rudder as required by **15.2.2(1)** while operating with all power units;

(2) The main steering gear is so arranged that after a single failure in its piping system or in one of the power units the defect can be isolated so that steering capability can be maintained or speedily regained. Steering gears, other than of the hydraulic type, will be considered by the Society in each case.

15.2.2 Performance of Main Steering Gear

The main steering gear is to be:

(1) capable of putting the rudder over from 35 *degrees* on one side to 35 *degrees* on the other side with the ship at its load draught and running ahead at the speed specified in **1.2.8, Part 1A** and, under the same conditions, from 35 *degrees* on either side to 30 *degrees* on the other side in not more than 28 *seconds*;

(2) operated by power when the main steering gear has to meet the requirements in **(1)** or when the diameter of the upper stock is required in **Chapter 3, Part 2** to be over 120 *mm* (calculated with a material factor $K_s = 1$ where K_s is less than 1, and excluding the increase required for ships which have strengthening for navigation in ice, the same being referred hereinafter); and

(3) S_0 designed that they will not be damaged at maximum astern speed; however, this design requirements need not be proved by trials at maximum astern speed and maximum rudder angle.

15.2.3 Performance of Auxiliary Steering Gear

The auxiliary steering gear is to be:

(1) capable of putting the rudder over from 15 *degrees* on one side to 15 *degrees* on the other side in not more than 60 *seconds* with the ship at its load draught and running ahead at one half of the speed

specified in **1.2.8, Part 1A** or 7 *knots*, whichever is the greater, and capable of being brought speedily into action in an emergency; and

(2) operated by power where necessary to meet the requirement in **(1)** and in any case when the diameter of upper stock is required in **Chapter 3, Part 2** to be over 230 *mm*.

15.2.4 Piping

1. The hydraulic piping system is to be arranged so that transfer between power units can be readily effected.

2. Suitable arrangements to maintain the cleanliness of the hydraulic fluid are to be provided taking into consideration the type and design of the power actuating system.

3. Arrangements for bleeding air from the power actuating system are to be provided where necessary.

4. Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting pressure of the relief valves is not to be less than 1.25 times the maximum working pressure expected in the protected part. The minimum discharge capacity of the relief valves are not to be less than the total capacity of pumps which provide power for the actuator, increased by 10%. Under such conditions the rise in pressure is not to exceed 10% of the setting pressure. In this regard, due consideration is to be given to the extreme foreseen ambient conditions in respect of oil viscosity.

5. A low level alarm is to be provided for each hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. This alarm is to be audible and visual and to be given on the navigating bridge and at a position from which the main engine is normally controlled.

6. A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is operated by hydraulic power. The storage tank is to be permanently connected by piping in such a manner that the hydraulic system can be readily recharged from a position within the steering gear compartment and is to be provided with a contents gauge.

7. Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

15.2.5 Re-Start and Power-Failure Alarm of Power Units

Main and auxiliary steering gear power units are to be:

(1) Arranged to re-start automatically when power is restored after a power failure; and

(2) Capable of being brought into operation from a position on the navigating bridge. In the event of a power failure to any one of the power units, an audible and visual alarm is to be given on the navigating bridge.

15.2.6 Alternative Source of Power

Where the diameter of upper stock is required in **Chapter 3, Part 2** to be over 230 *mm*, an alternative source of power is to be provided in accordance with the following:

(1) The alternative source of power is to be either

(a) An emergency source of electric power; or

(b) An independent source of power located in the steering gear compartment and used only for this purpose.

(2) Any alternative source of power is to be capable of automatically supplying, within 45 *seconds*, alternative power to the power unit and its associated control system and the rudder angle indicator. In this case the alternative source of power is to be capable of giving sufficient power to the power unit so that the steering capability required by **15.2.3(1)** can be regained. In every ship of 10,000 *gross tonnage* and upwards, the alternative source of power is to have a capacity for at least 30 *minutes* of continuous operation of the steering gear and in any other ship for at least 10 *minutes*.

(3) The automatic starting arrangement for the generator or the prime mover of the pump used as the independent source of power specified in **(1)(b)** is to comply with the requirements for starting device and performance in **3.4.1, Part 8**.

15.2.7 Electrical Installations for Electric and Electrohydraulic Steering Gear

1. Cables used in power circuits required to be installed in duplicate by this Chapter are to be separated as far as practicable throughout the length.

2. Means for indicating that the power units are running is to be installed on the navigating bridge and at the position from which the main engine is normally controlled.

3. Each electric or electrohydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuits fed directly from the main switchboard. However, one of the circuits may be supplied through the emergency switchboard.

4. Any auxiliary electric or electrohydraulic steering gear associated with a main electric or electrohydraulic steering gear may be connected to one of the circuits supplying this main steering gear. The circuits are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

5. Short circuit protection and overload alarm are to be provided for such circuits and motors. The overload alarm is to be both audible and visible and to be situated in a conspicuous position in the place from which the main engine is normally controlled.

6. Protection against excess current, including starting current, if provided, is to be for not less than twice the full load current of the motor or circuit so protected, and to be arranged to permit the passage of the appropriate starting currents.

7. Where a three-phase supply is used an alarm is to be provided that will indicate failure of any one of the supply phases. The alarm is to be both audible and visible and to be situated in a conspicuous position in the place from which the main engine is normally controlled.

8. When in a ship of less than 1,600 *gross tonnage* any auxiliary steering gear which is required by **15.2.3(2)** to be operated by power is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Where such an electric motor primarily intended for other services is arranged to power such an auxiliary steering gear, the requirements in **-5** to **-7** may be waived by the Society if satisfied with the protection arrangement together with the requirements in **15.2.5** and **15.3.1-1(3)** applicable to auxiliary steering gear.

9. For ships with a gross tonnage less than 1,600 *tons* equipped with manual auxiliary steering gears, the power supply circuit from the main switchboard to the main steering gear may be one circuit.

15.2.8 Position of Steering Gears

1. The steering gear is to be installed in an enclosed compartment readily accessible and, as far as possible, separated from machinery spaces.

2. The steering gear compartment is to be provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

15.2.9 Means of Communication

A means of communication is to be provided between the navigating bridge and the steering gear compartment.

15.2.10 Rudder Angle Indictor

The angular position of rudder is to be:

(1) indicated on the navigating bridge. The rudder angle indicator is to be independent of the control system;

(2) recognizable in the steering gear compartment.

15.3 Controls

15.3.1 General

1. Steering gear control is to be provided:

(1) For the main steering gear, both on the navigating bridge and in the steering gear compartment;

(2) Where the main steering gear is arranged in accordance with the requirements in **15.2.1-2**, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.

(3) For any the auxiliary steering gear, in the steering gear compartment and, if power operated, it is also to be operable from the navigating bridge and to be independent of the control system for main steering gear.

2. Any main and auxiliary steering gear control system operable from the navigating bridge is to comply with the following:

(1) If electric, it is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit.

(2) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves.

(3) The system is to be capable of being brought into operation from a position on the navigating bridge.

(4) In the event of a failure of electrical power supply to the control system, an audible and visual alarm is to be given on the navigating bridge.

(5) Short circuit protection only is to be provided for steering gear control supply circuits.

3. Cables and pipes of control systems required to be in duplicate by this Chapter are to be separated as far as is practicable throughout their length.

4. For the steering gears which are so arranged that more than one system (either power or control) can be simultaneously operated, where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, is to be provided on navigation bridge.

15.3.2 Change-Over from Automatic to Manual Steering

The steering gears of a ship provided with an automatic pilot are to be capable of immediate change-over from automatic to manual steering.

15.4 Materials, Constructions and Strength of Steering Gears

15.4.1 Materials

1. Materials used in the steering gears are to be sound, flawless and adequate for their service conditions.

2. Materials used for cylinders and housings of rudder actuators, piping subjected to a hydraulic pressure and the components transmitting mechanical forces to the rudder stock are not to have a minimum elongation of less than 12% nor a specified tensile strength in excess of 650 N/mm^2. This does not apply to the materials for valves and bolts where approved by the Society.

3. Materials used for tillers are to be forged steels or cast steels tested in accordance with the requirements in **Part 10**.

4. Materials used for bosses and vanes of rotary vane type rudder actuators are to be forged steels, cast steels or nodular graphite cast irons tested in accordance with the requirements in **Part 10**.

5. Materials used for bolts for assembling split type tillers and bolts for securing the vanes to the bosses of rotary vane type rudder actuators are to be forged steels or rolled steels tested in accordance with the requirements in **Part 10**.

6. Materials used for major parts other than those mentioned in **-3** to **-5** are to comply with the requirements in recognized standards.

7. Materials other than those mentioned in **-2** to **-6** may be used where approved by the Society.

15.4.2 Welding

1. All welded joints of the parts used in power actuating systems are to be such that there are no incomplete penetration and other injurious defects.

2. Welded joints in parts subjected to the internal pressure of the power actuating system are to have sufficient strength.

15.4.3 General Construction of Steering Gear

1. Steering gears are to be of sufficient strength and reliability.

2. Configurations of major parts of the steering gear are to be determined to avoid local concentration of stress.

3. 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 specified in **15.2.2(1)**, taking into account any pressure which may exist in the low pressure side of the system. The design pressure is not to be less than the relief valve setting pressure.

4. Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component is, where appropriate, to utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which are to be permanently lubricated or provided with lubrication fittings.

5. Where considered necessary, fatigue analysis is to be carried out to the piping and components, taking into account pulsating pressure due to dynamic loads. Both the cases of high cycle and cumulative fatigue are to be considered.

15.4.4 Strength of Rudder Actuators

1. Strength of all components of rudder actuators subjected to an internal pressure, except for the allowable stress specified in this Chapter, is to comply with relevant requirements in **Chapter 10**.

2. In the strength calculations specified in **-1**, the allowable stress for the equivalent primary general membrane stress is to be not greater than the following values **(1)** or **(2)**, whichever is the smaller:

(1) $\frac{\delta_B}{A}$

$$\frac{\delta_Y}{B}$$

where:

δ_B: Specified tensile strength of the material (*N/mm*^{2})

δ_Y: Specified yield strength or 0.2% proof stress of the material (*N/mm*^{2})

A and *B*: As given in **Table 15.1**.

Table 15.1 *A* and *B*

	Roller or Forged Steel	Cast Steel	Nodular Cast Iron
A	3.5	4	5
B	1.7	2	3

15.4.5 Oil Seals in Rudder Actuators

1. Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.

2. Oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage will be accepted where approved by the Society.

15.4.6 Flexible Hose Assembly

Flexible hose assemblies specified in **12.3.4** are to be used in piping systems where flexibility is required.

15.4.7 Tillers, etc.

1. The scantlings of tillers, etc. of forged steels or cast steels which transfer power from the rudder actuator to the rudder stock, are to be so determined as the bending stress is not exceeding $118/K$ (N/mm^2) and the shearing stress is not exceeding $68/K$(N/mm^2) when the rudder torque T_R is applied.

where;

T_R: Rudder torque specified in **3.3, Part 2** (N-m).

K: Material coefficient of the tiller, specified in **3.1.2, Part 2**.

2. Notwithstanding the requirement specified in **-1**, the scantlings of rapson-slide type or trunk piston type tillers may be determined according to the following **(1)** to **(4)**.

(1) The vertical section of each side of tiller boss at the centre line of rudder stock is to comply with the following Formulae;

$$(D^2 - d^2)H \geq 170T_RK$$

$$H/d \geq 0.75$$

where;

D: Outer diameter of boss (mm).

d: Inner diameter of boss (mm).

H: Depth of boss (mm).

T_R: Rudder torque specified in **3.3, Part 2** (N-m).

K: Material coefficient of the tiller, specified in **3.1.2, Part 2**.

(2) The section modulus of arm about the vertical axis is to be not less than that obtained from the following formula;

$$Z_{TA} = 11\left(1 - \frac{r}{R_1}\right)T_R K$$

where;

Z_{TA}: Required section modulus of arm about the vertical axis (*mm*^{3}).

r: Distance from the centre of rudder stock to the section (*mm*).

R_1: Length of tiller arm measured from the centre of rudder stock to the point of application of the driving force (*mm*). In case where the length varies in accordance with rudder angle, R_1 is the maximum length within 35 *degrees* of rudder angle.

T_R: Rudder torque specified in **3.3, Part 2** (*N-m*).

K: Material coefficient of the tiller, specified in **3.1.2, Part 2**.

(3) The sectional area of arm at its outer end is to be not smaller than that obtained from the following formula;

$$A_R = 18.5\frac{T_R}{R_2}K$$

where;

A_R: Required sectional area of arm at its outer end (*mm*^{2}).

R_2: Length of tiller arm measured from the centre of rudder stock to the point of application of the driving force (*mm*). In case where the length varies in accordance with rudder angle, *R*2 is the length at 0 *degrees* of rudder angle.

T_R: Rudder torque specified in **3.3, Part 2** (*N-m*).

K: Material coefficient of the tiller, specified in **3.1.2, Part 2**.

(4) In the case of tiller having two arms, where power units are connected to each arm and these two power units are driven simultaneously, the scantlings of arms may be reduced from those required in **(2)** and **(3)** to the satisfaction of the Society.

3. Notwithstanding the requirement specified in **-1**., the scantlings of rotary vane type rudder actuator of forged steels or cast steels may be determined according to the following requirements, in addition to the requirements specified in **15.4.4**.

(1) Scantlings of the boss are to comply with the requirement specified in **-2(1)**.

(2) The section modulus about the vertical axis and the sectional area of vane is to be not less than that obtained from the following formulae;

$$Z_v = 11\left(\frac{B}{D+B}\right)\frac{T_R}{n}K$$

$$A_R = 37\left(\frac{1}{D+B}\right)\frac{T_R}{n}K$$

where;

Z_v: Required section modulus of vane about the vertical axis (*mm*3).

A_R: Required sectional area of vane (*mm*^{2}).

D: Outer diameter of boss (*mm*).

B: Height of vane measured from outer surface of boss (*mm*).

n: Number of vanes.

T_R: Rudder torque specified in **3.3, Part 2** (*N-m*).

K: Material coefficient of the vane, specified in **3.1.2, Part 2**.

4. Where tillers which are separated to two pieces are bolted, there are to be at least two bolts on each side of the head. The diameter of bolts at bottom of thread is not to be less than that obtained from the following formula. In such case, the thickness of coupling flange is to not less than three-fourth of the diameter of the bolts.

$$d_b = 1.45\sqrt{\frac{T_R}{nb}K}$$

where;

d_b : Required diameter of bolts at bottom of thread (*mm*).

T_R: Rudder torque specified in **3.3, Part 2** (*N-m*).

K: Material coefficient of the bolt, specified in **3.1.2, Part 2**

n: Number of bolts on each side of the head.

b: Distance from the centre of rudder stock to the centre of bolt (*cm*).

5. Tillers are to be coupled with rudder stock firmly using key by shrinkage fitting, force fitting or bolted method. However, tillers may be coupled without key, in the case where the fitting methods are in compliance to the satisfaction of the Society.

6. Scantlings of rotary vane type rudder actuator of nodular graphite cast iron are to be determined so as not to be applied with bending stress exceeding $94/K$ (N/mm^2) nor shearing stresses exceeding $54/K$ (N/mm^2) under the rudder torque T_R applied. Alternatively, the scantlings may be determined according to the requirements specified in **-3**, using 1.2 times the rudder torque *TR* specified in **3.3, Part 2**as rudder torque for calculating.

15.4.8 Stoppers

1. Tillers are to be provided with rudder stoppers.

2. Steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronized with the gear itself and not with the steering gear control. These arrangements, however, may be operated through a mechanical links such as floating levers

3. Suitable brake arrangements or ropes are to be provided to tillers to keep the rudder steady in the event of an emergency. In the case of hydraulic steering gear, where the rudder can be stopped safely by closing the oil pressure valves, this brake arrangement will not be required.

15.4.9 Buffers

Steering gears other than of hydraulic type are to be provided with spring buffers or other suitable buffer arrangements to relieve the gear from shocks given by the rudder.

15.5 Testing

15.5.1 Shop Tests

1. Pressure vessels and piping systems are to be subjected to tests in accordance with the requirements in 10.9, 12.6 and 13.17 in addition to the tests specified in 15.5.

2. All pressure parts are to be subjected to pressure tests with a pressure equal to 1.5 times the design pressure.

3. Each type of pumps used as a power unit is to be subjected to a running test for duration of not less than 100 *hours* the test arrangements are to be such that the pump may run in idle condition, and at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted.

After the test, the pump is to be disassembled to ascertain that there is no abnormality. The test may be waived for a power unit which has been proved to be reliable in marine service.

15.5.2 Tests after Installation on Board

1. Hydraulic piping systems are after installed on board to be subjected to a leak test at a pressure at least equal to the maximum working pressure.

2. The steering gear is, after installed on board, to be subjected to the running test.

3. Where the steering gear is designed to avoid hydraulic locking, this feature is to be demonstrated.

15.6 Additional Requirements concerning Tankers, Ships carrying Liquefied Gases in Bulk or Ships carrying Dangerous Chemicals in Bulk of 10,000 *Gross Tonnage* and upwards and Other Ships of 70,000 *Gross Tonnage* and upwards

15.6.1 Main steering Gears

1. In tankers, ships carrying liquefied gases in bulk or ships carrying dangerous chemicals in bulk of 10,000 *gross tonnage* and upwards and in every other ship of 70,000 *gross tonnage* and upwards, the main steering gear is to comprise two or more equivalent power units complying with the requirements in 15.2.1-2.

2. The steering gears in oil tankers, ships carrying liquefied gases in bulk or ships carrying dangerous chemicals in bulk of 10,000 *gross tonnage* and upwards is to comply with the following:

(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 system of the main steering gear, excluding failure in the tiller and seizure in the rudder actuator, steering capability is to be regained in not more than 45 *seconds* after the loss of one power actuating system;

(2) The main steering gear is to comprise either :

(a) two independent and separate power actuating systems, each capable of meeting the requirements in **15.2.2(1)** ; or

(b) at least two equivalent power actuating systems which, acting simultaneously in normal operation, are to be capable of meeting the requirements in **15.2.2(1)**. In this case, the following requirements of **i)** and **ii)** are also to be met :

i. Any loss of hydraulic fluid from one system is to be capable of being detected and the defective system automatically isolated so that the other actuating system or systems are to remain fully operational.

ii. In cases where necessary to obtain steering capability, interconnection of hydraulic power actuating systems is to be provided.

3. Steering gears other than of the hydraulic type will be considered by the Society in each case.

15.6.2 Controls

In the case of tankers, ships carrying liquefied gases in bulk or ships carrying dangerous chemicals in bulk of 10,000 *gross tonnage* or upwards, the modification for the hydraulic telemotor permitted in **15.3.1-1(2)** is not to be applied.

15.6.3 Number and Strength of Rudder Actuators

1. For tankers, ships carrying liquefied gases in bulk or ships carrying dangerous chemicals in bulk of 10,000 *gross tonnage* and upwards, but of less than 100,000 *tons deadweight*, a single rudder actuator may be permitted provided that:

(1) Following loss of steering capability due to a single failure of any Part of the piping system or in one of the power units, steering capability is to be regained within 45 *seconds*;

(2) Special consideration is to be given to stress analysis for the design including fatigue analysis and fracture mechanics analysis, as appropriate, to the material used, to the installation of sealing arrangements and to testing and inspection and to the provision of effective maintenance. In this case, the high cycle fatigue and cumulative fatigue are to be considered.

(3) Isolating valves are to be directly mounted on the rudder actuator so as to isolate the rudder actuator from the hydraulic oil in the piping systems; and

(4) Relief valves for protecting the rudder actuator against overpressure as required in **15.2.4-4** are to be provided.

2. For tankers, ships carrying liquefied gases in bulk or ships carrying dangerous chemicals in bulk of 10,000 *gross tonnage* and upwards, but less than 100,000 *tons deadweight* and equipped with a single rudder actuator, the strength of the rudder actuator is to comply with the following requirements in addition to those of **15.4.4**:

(1) A detailed calculation of the major parts of the rudder actuator is to be carried out to confirm their strength.

(2) A detailed stress analysis of the parts of rudder actuators subject to hydraulic pressure is to be carried out to confirm the strength sufficient to withstand the design pressure.

(3) Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis are to be carried out. In this case, the high cycle fatigue and cumulative fatigue are to be considered. In connection with these analysis, all foreseen dynamic loads are to be taken into account. Where considered necessary by the Society, experimental stress analysis may be required in addition to, or in lieu of, theoretical calculations.

(4) For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses are not exceed:

a) $\delta_m \leq f$

b) $\delta_1 \leq 1.5f$

c) $\delta_b \leq 1.5f$

d) $\delta_1 + \delta_b \leq 1.5f$

e) $\delta_m + \delta_b \leq 1.5f$

where;

δ_m : Equivalent primary general membrane stress (*N/mm*^{2})

δ_1: Equivalent primary local membrane stress (*N/mm*^{2})

δ_b: Equivalent primary bending stress (*N/mm*^{2})

f: $Lesser\ of\ \dfrac{\delta_B}{A}\quad or\quad \dfrac{\delta_Y}{B}$

δ_B: Specified tensile strength of material (*N/mm*^{2})

δ_Y: Specified minimum yield stress or 0.2% proof stress of material (*N/mm*^{2})

A and *B*: As given in **Table 15.2**.

(5) Where the parts of rudder actuators subject to hydraulic pressure are subjected to a burst test at the minimum bursting pressure specified below and they are confirmed to withstand this test, the detailed stress analysis required in **(2)** may be omitted. Where, however, considered necessary because of the design complexity or manufacturing procedures, the detailed stress analysis required in **(2)** is to be carried out notwithstanding the above.

$$P_b = PA\frac{\delta_{Ba}}{\delta_B}$$

where:

P_b: |Minimum bursting pressure (*MPa*)

P: Design pressure (*MPa*)

A: As given in **(4)**

δ_{Ba}: Actual tensile strength of the material (*N/mm*^{2})

δ_B: Specified minimum tensile strength of the material (*N/mm*^{2})

Table 15.2 *A* and *B*

	Roller or Forged Steel	Cast Steel	Nodular Cast Iron
A	4	4.6	5.8
B	2	2.3	3.5

15.6.4 Shop Tests

For tankers, ships carrying liquefied gases in bulk or ships carrying dangerous chemicals in bulk of 10,000 *gross tonnage* and upwards, but less than 100,000 *tons deadweight* and equipped with a single rudder actuator, the rudder actuator are to be subjected to suitable and complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria for the non-destructive testing will be considered by the Society in each case. Where considered necessary, fracture mechanics analysis is to be used for determining maximum allowable flaw size.

Chapter 16 WINDLASSES AND MOORING WINCHES

16.1 General

16.1.1 Scope

1. The requirements herein Chapter 16 apply to those windlasses and mooring winches driven by electric power, hydraulic power or steam.

2. Any windlasses and mooring winches other than those specified in **-1** are to be subject to approval by the Society.

16.2 Windlasses

16.2.1 Drawings and data

Drawings and data listed below are to be submitted.

(1) Drawings:
- (a) Particulars and applied internationally recognized standards
- (b) General arrangement
- (c) Material specification of essential parts
- (d) Other drawings considered necessary by the Society

(2) Data:
- (a) Production test procedure
- (b) Calculated strength for essential parts
- (c) Other data considered necessary by the Society

16.2.2 Construction and performance

1. The windlasses are to be capable of continuous operation over a period of 30 *minutes* while exerting the working load defined in **(1)** and at least two *minutes* overload pull defined in **(2)**.

(1) Working load is to be decided depending on grade of chains below.
- (a) Grade 1 cable : $37.5d^2$ (N)
- (b) Grade 2 cable : $42.5d^2$ (N)
- (c) Grade 3 cable : $47.5d^2$ (N)

where d is the chain cable diameter (mm)

(2) Overload is to be 1.5 times of working load.

2. The windlass is to be fitted brake for safe stopping of anchor and anchor chain. Such brake is to be capable of holding the below-mentioned load sufficiently.

(1) with chain cable stopper : 0.45 X the breaking load of chain cable

(2) without chain cable stopper : 0.8 X the breaking load of chain cable

3. Windlasses and their beds with other accessories and facilities are to be installed effectively and securely onto the deck.

4. For ships of 80 *m* or more in length L_1 specified in **14.2.1-1, Part 2**, where the height of the exposed deck in way of the item is mounted is less than $0.1L_1$ or 22 *m* above the designed maximum load line, whichever is the lesser, windlass mounts on the exposed deck over the forward $0.25L_1$ are to be of sufficient strength.

5. The strength of above deck framing and hull structure supporting the windlass and its securing bolt is to be according to the requirements in **9.7.1, Part 2**.

6. Prime movers and gearing are to be provided following devices and parts for protection against excessive torque or shock and for safety on board.

(1) Over pressure protection device

(2) Slipping clutch between electric motor and gearing

(3) Torque limiting device, (electrically driven windlass only)

(4) Cover for opened gearing

(5) Cover for hot surface of steam cylinders

7. Windlasses are to be capable of lifting chain cable (3 links or more in length) which are paid into the sea. Then mean lifting speed is to be at least 0.15 *m/s*.

16.2.3 Tests

1. Shop Tests

(1) Before assembly hydrostatic pressure test for following components is to be carried out in accordance with the requirement **12.6.1**. Test pressure is to be 1.5 times designed pressure. However test pressure for steam cylinder may be 1.5 times working pressure.

- (a) Housings with covers for hydraulic motors and pumps
- (b) Hydraulic pipes
- (c) Valves and fittings
- (d) Pressure vessels
- (e) Steam cylinders

(2) Load test, over load tests, operation tests and chain wheel brake test with prime mover are to be carried out. Where windlass has been recognized by the Society, such tests may be reduced.

(3) Where windlass has been given approval of the Society several tests required in above requirement **(2)** may be dispensed with.

2. Tests after installation on board

Required tests in **2.3.1 of Part 1B** are to be carried out at the sea trial.

16.3 Mooring winches

16.3.1 Structure etc.

1. Mooring winches are to comply with the recognized standards.

2. Mooring winches and their beds and other accessory facilities are to be installed effectively and securely onto the deck.

3. The mounts of mooring winches which are integrated with windlasses is to be in accordance with the requirements in **16.2.2-4** and **-5**.

16.3.2 Tests

All mooring winches are to be subjected to the following tests after their installation on board.

(1) Confirmation of abnormality for mooring winches being operated for 15 *minutes* in each direction at maximum speed under no load.

(2) Functioning test of the drum brake under the operating condition specified in **(1)**.

(3) Notwithstanding the requirements of **(1)** and **(2)** in **-2** above, where there are a plurality of units of the same type, the period of testing and number of units to be tested may be reduced.

Chapter 17 REFRIGERATING MACHINERY AND CONTROLLED ATMOSPHERE SYSTEMS

17.1 General

17.1.1 Scope

1. The requirements in this chapter apply to the refrigerating machinery using the primary refrigerants listed below and forming the refrigerating cycle used for refrigeration, air conditioning, etc., as well as to the controlled atmosphere systems for the cargo holds. However, the refrigerating machinery with compressors of 7.5 kW or less and the refrigerating machinery using primary refrigerants other than those listed below are to be as deemed appropriate by the Society.

$R22$: $CHCIF_2$

$R134\,a$: CH_2FCF_3

$R404\,A$: $R125/R143a/R134a$ $(44/52/4\,wt\,\%)$ $CHF_2CF_3/CH_3CF_3/CH_2FCF_3$

$R407\,C$: $R32/R125/R134\alpha$ $(23/25/52\,wt\,\%)$ $CH_2F_2/CHF_2CF_3/CH_2FCF_3$

$R410\,A$: $R32/R125$ $(50/50\,wt\,\%)$ CH_2F_2/CHF_2CF_3

$R507\,A$: $R125/R143a$ $(50/50\,wt\,\%)$ CHF_2CF_3/CH_3CF_3

2. For items especially provided in this Chapter, the requirements in this Chapter are applied in lieu of the requirements in **Chapters 10**, **12** and **13**.

17.1.2 Drawings and Data

Drawings and data to be submitted for approval are generally as follows:

(1) Drawings (with materials, scantlings, kinds, design pressure, design temperature, etc. of the pipes, valves, etc.)

- (a) Piping diagrams of refrigerating systems for provision chamber and air conditioning installations
- (b) Drawings of pressure vessels exposed to a pressure of the primary refrigerant
- (c) Drawings of controlled atmosphere systems
- (d) Other drawings considered necessary by the Society

(2) Data

- (a) The particulars of refrigerating machinery
- (b) The specifications of controlled atmosphere systems
- (c) Other drawings considered necessary by the Society

17.2 Design of Refrigerating Machinery

17.2.1 General

The design pressure of pressure vessels and piping systems and the class of pipes used for refrigerating machinery are as follows:

(1) The design pressure of the pressure vessels and piping systems used for the refrigerating machinery and exposed to a pressure of the refrigerant is not to be less than the pressure in **Table 17.1** depending on the kind of the refrigerants.

(2) Pipes for the refrigerants specified in **Table 17.1** are to be classified into Group III.

17.2.2 Location

Refrigerating machinery compartments are to be provided with efficient arrangements of drainage and ventilation, and separated by gastight bulkheads from the adjacent refrigerated chambers.

17.2.3 Materials

1. Materials used for the refrigerating machinery are to be suitable for the refrigerant used, the design pressure, the minimum working temperature, etc.

2. Materials used for the primary refrigerant pipes, valves and their fittings are to comply with the requirements in **12.1.4** to **12.1.6** according to the classes of pipes specified in **17.2.1(2).**

3. Materials used for the pressure vessels exposed to the refrigerant pressure (condensers, receivers and other pressure vessels) are to comply with the requirements in **10.2** according to the classes of pressure vessels specified in **10.1.3**.

4. The following materials are not to be used for the parts of refrigerating machinery.

(1) Aluminum alloy containing magnesium over 2% for parts to be contacted with primary refrigerants.

(2) Pure aluminum less than 99.7% for parts to be usually contacted with water without corrosion protection.

5. The service limitations of valves made of iron castings are shown in **Table 17.2**. Although utilizing of iron castings is permitted by the Table, they are not to be used for valves in pipings having a design temperature below 0°C or exceeding 220°C. However, where the normal working pressure of the pipig is not exceeding 1/2.5 times the design pressure, the temperature limitations may be lowered to -50°C.

Table 17.1 Design Pressure of Pressure Vessels and Piping Systems for Refrigerating Machinery

Refrigerants	High Pressure side[1] (*MPa*)	Low Pressure side[2] (*MP*a)
*R*22	1.9	1.5
*R*134*a*	1.4	1.1
*R*404*A*	2.5	2.0
*R*407*C*	2.4	1.9
*R*410*A*	3.3	2.6
*R*507*A*	2.5	2.0

Note:

1 High Pressure side: The pressure part from the compressor delivery side to the expansion valve.

2 Low Pressure side: The pressure part from the expansion valve to the compressor suction valve. In case where a multistage compression system is adopted, the pressure part from the lower-stage delivery side to the higher-stage suction side is to be included.

Table 17.2 Service Limitation of Valves made of Iron Castings

Kind of valves	Materials	Application
Stop valves	Gray iron casting with specified tensile strength not exceeding 200 N/mm^2 or equivalent thereto	Not to be used
	Gray iron carting other than those specified in above, Spheroidal graphite iron castings, Melleable iron casting or equivalent thereto	(1) May be used for design pressure not exceeding 1.6 *MPa* (2) May be used for design pressure exceeding 1.6 *MPa* but not exceeding 6.6 *MPa*, provided nominal diameter does not exceed 100 mm and design temperatures is 150ºC or below
Relief valves	Any iron casting	Not to be used
Automatic control valves	Gray iron casting with specified tensile strength not exceeding 200 N/mm^2 or equivalent thereto	Not to be used
	Gray iron casting other than those specified in above or equivalent thereto	(1) May be used for design pressure not exceeding 1.6 *MP*. (2) May be used for design pressure exceeding 1.6 *MPa* but not exceeding 2.6 *MPa*, provided nominal diameter does not exceed 100mm and design temperature is 150ºC or below
	Spheroidal graphite iron casting, Malleable iron castings or equivalent thereto	Not to be used for design pressure exceeding 3.2 *MPa*

17.2.4 Pressure Relief Devices

1. Relief valves is to be provided between compressor cylinder and gas delivery stop valve, the discharge being led to suction side of the compressor. However, compressors of 11 kW or less for the refrigerating installation may be provided with a pressure control switch in lieu of the above safety device.

2. Relief valves are to be fitted to the pressure vessels which may be isolated and store the primary refrigerants in a liquid condition. The discharged gases from the relief valves are to be led to the atmosphere in a safe place above the weather deck or to the low pressure parts of the equipment.

3. Where the discharged gases from relief valves on high pressure parts of primary refrigerants are led to low pressure parts before being relieved to the atmosphere, the operation of the relief valves are not to be interrupted by back pressure accumulation.

4. Relief valves are to be provided to the cooling liquid side of condenser and brine side of evaporator except where the pump connected is so constructed that the pressure does not exceed the design pressure.

17.3 Controlled Atmosphere Systems

17.3.1 General

Controlled atmosphere zones and the relevant requirements are to be arranged as follows;

(1) Each controlled atmosphere zone is to be made as air-tight as possible, and is to be arranged to keep the internal pressure normal.

(2) Gas freeing systems are to be provided to discharge the gas from each controlled atmosphere zone, and ventilators are to be provided for enclosed spaces adjacent to controlled atmosphere zones.

(3) Closing appliances of entrances, etc. of controlled atmosphere zones are to be so constructed as to be capable of preventing from easy opening due to mis-handling, etc. under the controlled atmosphere.

(4) Fixed nitrogen generators are to be installed in a dedicated room, airtight from the adjacent spaces. This nitrogen generator room is to be fitted with an exhaust mechanical ventilation system of a sufficient capacity.

(5) Each controlled atmosphere zone is to be provided with warning alarm which will be given before injection of nitrogen into the controlled atmosphere zone.

(6) Fixed oxygen alarm devices are to be provided at a fixed nitrogen gas generation room and each enclosed spaces adjacent to controlled atmosphere zones in order to alarm at each place in the event of low level oxygen content.

(7) A means of two-way communication is to be provided between controlled atmosphere zones and the nitrogen release control station. A suitable number of portable oxygen measuring instruments with alarm are to be provided on board for the safe entrance to dangerous zone. Further, medical first-aid equipment including oxygen resuscitation equipment is to be provided on board.

17.4 Tests

17.4.1 Shop Tests

Refrigerating machinery is, to be tested according to the following:

(1) Pressure vessels exposed to a pressure of the primary refrigerant are to be subjected to a hydrostatic test at a pressure of 1.5 times the design pressure and a tightness test at a pressure equal to the design pressure.

(2) Cylinders and crank cases of the compressors of the refrigerator are to be subjected to a hydrostatic test at a pressure of 1.5 times the design pressure and a tightness test at a pressure equal to the design pressure.

17.4.2 Tests after Installation on Board

1. The piping systems which are exposed to a pressure of the primary refrigerant are, after installed on board, to be subjected to a leak test at a pressure of 90% of the design pressure.

2. All Installations and equipment connected with controlled atmosphere systems are to be tested by operation tests, etc, to verify that they operate normally.

Chapter 18 AUTOMATIC AND REMOTE CONTROL

18.1 General

18.1.1 Scope

1. The requirements in this Chapter apply to the systems of automatic or remote control which are used to control the following machinery and equipment.

(1) Main propulsion machinery (in this Chapter, propulsion generating set in electric propulsion ships are excluded),

(2) Controllable pitch propeller

(3) Steam generating set

(4) Electric generating set (in this Chapter, propulsion generating set in electric propulsion ships are included)

(5) Auxiliary machinery associated with machinery and equipment listed in **(1)** to **(4)**

(6) Fuel oil systems

(7) Bilge systems

(8) Deck machinery

2. Where considered necessary by the Society, the requirements in this Chapter are correspondingly applied to the systems of automatic or remote control which are used for controlling machinery and equipment not listed in **-1(1)** to **(8)**.

18.1.2 Terminology

Terms used in this Chapter are defined as follows:

(1) Monitoring station (excluding control station) is a position where measuring instruments, indicators, alarms, etc. for the machinery and equipment are centralized and necessary information to grasp the operating condition of them can be obtained. Where, however, a monitoring station is provided with the ship in addition to a control station mentioned in (2) below, the requirements of the Rules relating to a monitoring station do not apply to the monitoring station concerned.

(2) Control station is a position which has a function as a monitoring station and from which the machinery and equipment can be controlled.

(3) Main control station is a control station provided with equipment necessary and sufficient to control the main propulsion machinery (this equipment will be referred to as main control equipment in this **(3)** and **(4)**) and from which the main propulsion machinery is normally controlled, of the ship which provides the main control equipment at the outside of the navigation bridge.

(4) Main control station on bridge is a navigation bridge of the ship which provides main control equipment at the navigation bridge and that the main propulsion machinery is normally controlled there.

(5) Sub-control station is such a control station at which the main propulsion machinery is capable of being controlled, except for local control station for the main propulsion machinery that is provided in the machinery space of the ship provided with a main control station on bridge.

(6) Bridge control devices are remote control devices for the main propulsion machinery or controllable pitch propellers provided on a navigation bridge or a main control station on bridge.

(7) Sequential control is a pattern of control that can be carried out automatically in the predetermined sequence.

(8) Program control is a pattern of control that desired values can be changed in the predetermined schedule.

(9) Local control is direct manual control of the machinery and equipment performed at or near their locations, receiving the necessary information from the measuring instruments, indicators and so on.

(10) Safety system is a system which operates automatically, in order to prevent damages to the machinery and equipment in case where serious impediments to functioning should occur on them during operation so that one of the following actions will take place.

- (a) Starting of stand-by machinery or equipment
- (b) Reduction of outputs of the machinery or equipment
- (c) Shutting off the fuel or power supplies, thereby stopping the machinery or equipment

18.1.3 Drawings and Data

Drawings and data to be submitted are generally, as follows:

(1) Drawings and data concerning automation

- (a) List of measuring points
- (b) List of alarm points
- (c) Control devices and safety devices
  - i) List of controlled objects and controlled variables
  - ii) Kinds of sources of control energy (self-actuated, pneumatic, electric, etc.)
  - iii) List of conditions for emergency stopping, speed reduction (automatic or demand for reduction), etc.

(2) Following drawings and data for the automatic control devices and remote control devices for main propulsion machinery or controllable pitch propellers.

- (a) Operating instructions of main propulsion machinery such as starting and stopping, change-over of direction of revolution, increase and decreased of output, etc.
- (b) Arrangements of safety devices (including those attached to the engines) and pilot lamps
- (c) Controlling diagrams

(3) Following drawings and data for the automatic control devices and remote control devices for boilers:

- (a) Operating instructions of sequential control, feed water control, pressure control, combustion control and safety devices.
- (b) Diagrams for automatic combustion control devices and automatic feed water control devices

(4) Diagrams and operating instructions for automatic control devices for electric generating sets (automatic load sharing devices, preference tripping devices, automatic starting devices, automatic synchronous making devices, sequential starting devices, etc.)

(5) Panel arrangements of monitoring panels, alarming panels and control stands at respective control stations

(6) Drawings and data for the computers and computerized systems specified in **18.2.7**.

18.2 System Design

18.2.1 System Design

1. Control systems, alarm systems and safety systems are to be so designed that one fault does not result in other faults as far as practicable and the extent of the damage could be kept to a minimum.

2. Control systems, alarm systems and safety systems are to be designed on the fail-to-safe principle. The characteristic of fail-to-safe is to be evaluated on the basis not only of the respective systems themselves and associated machinery and equipment, but also the total safety of the ship.

3. Systems of automatic or remote control are to be sufficiently reliable under service conditions.

4. Cables for signals are to be installed in such a manner that harmful induced interference can be avoided.

18.2.2 Supply of Power

1. Supply of electrical power

The supply of electrical power is to be in accordance with the following:

(1) Electrical supply circuits to control systems, alarm systems and safety systems are not to branch off from the power circuits and lighting circuits, except that the electrical power to the control systems, alarm systems and safety systems may be supplied from the power circuits to the machinery and equipment they serve.

(2) The electrical power to alarm systems and safety systems for electric generating sets is also to be supplied from an accumulator battery.

2. Supply of oil pressure

The supply of control oil pressure is to be in accordance with the following:

(1) Sources of oil pressure are to be capable of supplying stably necessary pressure and quantity of purified oil.

(2) Overpressure preventive devices are to be provided on the delivery side of oil pressure pumps.

(3) Two or more sets of oil pressure pumps for the control of main propulsion machinery and main shaftings are to be provided and they are to be so arranged that in case where one of the pumps in operation becomes out of operation stand-by pump(s) may start automatically or may be readily remotely started. In this case, the oil pressure pumps are not to be used for the control of other machinery and equipment than main propulsion machinery and main shafting.

3. Supply of pneumatic pressure

The supply of control air is to be in accordance with the following:

(1) Control systems are to be provided with an air reservoir having a capacity capable of supplying air to control devices at least for 5 *minutes* in the event of failure of the control air compressor.

(2) Where starting air reservoirs for diesel engines used as main propulsion machinery are used as control air reservoirs, pressure reducing valves are to be duplicated or a spare pressure reducing valve is to be provided on board.

(3) There are to be two or more sets of air compressors which may be used as a source of control air. Each air compressor is to have redundant capacity even in the event of failure of either one of them.

(4) Control air is to pass through a filter and, if necessary, a drier so that solid, oil and water may be removed to a minimum.

(5) Control air pipes are to be independent of general service air pipes and starting air pipes.

18.2.3 Environmental Conditions

Systems of automatic or remote control are to be capable of withstanding the environmental conditions of the places where they are installed.

18.2.4 Control Systems

1. Independency of control systems

Control systems for main propulsion machinery or controllable pitch propellers, boilers, electric generating sets and auxiliary machinery essential for main propulsion of the ship are to be independent each other. However, when the propulsion generator plant and the main generating plant are connected to the same bus line, their control systems may be made common to them.

2. Interconnection devices

In case of plural main propulsion machinery or controllable pitch propellers, electric generating sets, or auxiliary machinery (excluding auxiliary machinery for specific use, etc.) which are designed to be operated simultaneously in multiple under the same condition, interconnection devices may be provided between the control devices of these installations.

3. Control characteristics

Remote control devices and automatic control devices are to have control characteristics in conformity with the dynamic properties of the machinery and equipment they serve and to be considered not to invite malfunction and hunting due to disturbance.

4. Interlock

Control devices are to be provided with suitable interlocking arrangements in order to prevent damages to the machinery and equipment due to anticipated malfunction and mal-operation of the machinery and equipment.

5. Change-over to manual operating

Change-over to manual operating is to comply with the following requirements:

(1) Main propulsion machinery or controllable pitch propellers, boilers, electric generating sets and auxiliary machinery essential for main propulsion of the ship are to be so arranged as to be manually started, operated and controlled even in the event where automatic control devices become out of operation.

(2) Automatic control devices are generally to be provided with provisions to stop manually the automatic function of these devices.

(3) The provisions specified in **(2)** are to be capable of stopping the automatic function of the automatic control devices, even where any part of the automatic control devices become out of operation.

6. Cancellation of remote control function

For remote control devices, the function of remote control is to be capable of being manually cancelled.

7. Indication of control locations

In cases where the machinery and equipment are capable of being operated from more than one station, the following requirements in **(1)** and **(2)** are to be complied with. However, this requirement need not be complied with in cases where the safety of the machinery and equipment and the safety at the time of maintenance work can be obtained by means of other measures considered appropriate by the Society.

(1) At each control station there is to be an indicator showing which station is in control of the machinery and equipment.

(2) Control of the machinery and equipment is to be possible only from one station at a time.

18.2.5 Alarm Systems

1. Function of alarm systems is to comply with the following requirements:

(1) In case where an abnormal condition is detected, devices to issue a visual and audible alarm (hereinafter referred to as alarm devices in this Part) are to operate.

(2) In case where arrangements are made to silence audible alarms they are not to extinguish visual alarms.

(3) Two or more faults are to be indicated at the same time.

(4) Audible alarms for machinery and equipment are to be clearly distinguishable from other audible alarms such as general alarm, fire alarm, CO_2 flooding alarm, etc.

2. Function of the alarm systems provided in the monitoring station for main propulsion machinery or controllable pitch propellers is to comply with the following requirements, in addition to the requirements in **-1**:

(1) The visual indication of the alarm is to remain until the fault has been corrected.

(2) The acceptance of any alarm is not to inhibit another alarm.

(3) If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, alarm devices are again to operate.

(4) Manual stopping of each alarm system is to be clearly indicated.

3. Visual alarms are to be so arranged that each abnormal condition of the machinery and equipment is readily distinguishable and that acknowledgement is clearly noticeable.

18.2.6 Safety Systems

1. Constitution of systems

Constitution of safety systems is to comply with the following requirements:

(1) Safety systems are to be, as far as practicable, provided independently of control systems and alarm systems.

(2) Safety systems for the main propulsion machinery, boilers, electric generating sets and auxiliary machinery essential for main propulsion of the ship are to be independent each other.

2. Function of safety systems

Function of the safety systems is to comply with the following requirements:

(1) Alarm systems which have functions prescribed in **18.2.5** are to operate when safety systems are put into action.

(2) In case where safety systems are put into action and the operation of the machinery or equipment is stopped, it is not to automatically restart before manual reset is made.

3. Override arrangements

Where arrangements are provided for overriding a safety system, the following requirements **(1)** and **(2)** are to be complied with:

(1) A visual indication is to be given at the relevant control stations of the machinery and equipment when an override is operated.

(2) The override arrangements are to be such that inadvertent operation is prevented.

18.2.7 Computers and Computerized Systems

1. Computerized control systems, alarm systems and safety systems are divided into three categories as shown in **Table 18.1** based upon the impact a single failure has on human and vessel safety, and the environment. These systems are to comply with the requirements in this chapter and the following **-2** through **-4**.

Table 18.1 Computerized System Categories

Category	Effects in case of failure	System functionality
I	Those systems which will not lead to dangerous situations for human safety, safety of the vessel and threat to the environment	-Systems related with informational or administrative tasks
II	Those systems which could eventually lead to dangerous situations for human safety, safety of the vessel and threat to the environment	-Alarm systems -Control system which are necessary to maintain the ship in normal operational and habitable conditions
III	Those systems which could immediately lead to dangerous situations for human safety, afety of the vessel and threat to the environment	-Control systems for maintaining the vessel`s propulsion and steering -Safety systems

2. Computers used for the control systems, alarm systems and safety systems for the machinery and equipment, considered necessary by the Society, are to comply with the following.

(1) Reliability and maintainability

The reliability and maintainability of the computerized systems are not to be inferior to those of the systems not relying upon computers.

(2) Requirements for Computers

(a) The composition of computers is to be so planned that the extent of effect due to a failure of part of circuits or components is limited to a minimum as far as possible.

(b) Each component is to be protected against overvoltage (electric noise) which may intrude from an input or output terminal.

(c) Central processing units and important associating apparatus are to have self-monitoring function.

(d) Important programs and data are to be made not to come to extinction in case where electrical supply from outside may temporarily stop.

(e) Computers are to be so composed as to re-start in a short time in accordance with the planned order when electrical power is restored after a power failure.

(f) Spare parts for important composing elements which require special technique for repair work, are to be supplied by easily replaceable units.

(g) Change-over to the back-up means is to be easily and surely possible.

(3) Back-up means

(a) Where one computer simultaneously performs fuel control (governor control, electronic injection control, etc.) and remote control of main propulsion machinery in diesel or turbine ships, or output control (rotational speed control, load control, etc.) and remote control of main propulsion machinery in electric propulsion ships, one of the following systems is to be provided in case of a computer failure. However, where this requirement is impracticable, the systems are to comply with the requirements deemed appropriate by the Society.

i) Stand-by computer

ii) Governor controlled back-up systems operated at the main control station

(b) Important safety systems utilizing computers are to be provided with back-up means which can be used in a short time in the event of failure of the computer in service.

(c) Where visual display units (VDU) are adopted as the indicators for the alarm systems stipulated in this chapter, at least two VDUs are to be installed or other arrangements deemed appropriate by the Society are to be considered.

(4) Components of computerized systems

The separation of computerized control systems and safety systems are to comply with the requirements in **18.2.4-1** and **18.2.6-1** respectively. However, where these requirements are impracticable, the systems are to comply with the requirements deemed appropriate by the Society.

3. The communication links for transferring data between separated terminals of the systems categorized in Categories II and III in **Table 18.1** are to comply with the following.

(1) Where the failure of a single component of the data communication link results in loss of data communication, means are to be provided for the automatic restoration of the link.

(2) Where the data communication link covers two or more systems from among control systems, alarms systems and safety systems specified in this chapter, the link including cables is to be installed in duplicate; unless there are alternate means of performing the same functions without the use of the link.

(3) The data communication link is to be self-checking and visual and audible alarms are to be activated when failures in the link are detected.

4. Where system specifications are modified, the following items are to be complied with.

(1) The systems categorized in Categories II and III in **Table 18.1** are to be protected against program modification by end users.

(2) For the systems categorized in Category III in **Table 18.1**, modifications of parameters by manufacturers are tobe approved by the Society.

(3) Any modifications made after shipment are to be documented and traceable.

18.3 Automatic and Remote Control of Main Propulsion Machinery or Controllable Pitch Propellers

18.3.1 General

The devices for remote or automatic control by which the main propulsion machinery or controllable pitch propellers are controlled are to comply with the requirements in this **18.3**.

18.3.2 Remote Control Devices for Main Propulsion Machinery or Controllable Pitch Propellers

1. General

Remote control devices for main propulsion machinery or controllable pitch propellers are to be complied with the following requirements:

(1) Remote control devices for main propulsion machinery or controllable pitch propellers are to be capable of controlling the propeller speed and the direction of thrust (the blade angle of propellers in the case of controllable pitch propellers) by means of a simple operation.

(2) Remote control devices for main propulsion machinery or controllable pitch propellers are to be provided for each propeller. Where multiple propellers are designed to operate simultaneously, they may be control by one control device.

(3) In case where the speed of the diesel engines used as main propulsion machinery is controlled by governors, the governors are to be adjusted so that main propulsion machinery may not exceed 103% of the maximum continuous revolutions. The governors are to be capable of maintaining the safe minimum speed.

(4) In case where a program control is adopted, the program for increase and decrease of output is to be so designed that undue mechanical stresses and thermal stresses do not occur in any parts of machinery.

(5) In the remote control stations or monitoring stations and at the manoeuvring platform for the main propulsion machinery or controllable pitch propellers, the following instruments are to be provided.

(a) Indicators for propeller speed and direction of rotation in the case of solid propellers.

(b) Indicators for propeller speed and pitch position in the case of controllable pitch propeller.

(6) In remote control stations for main propulsion machinery or controllable pitch propellers, alarm devices necessary for the control of main propulsion machinery or controllable pitch propellers are to be provided.

2. Transfer of control

Remote control devices for main propulsion machinery or controllable pitch propellers are to comply with the following requirements with respect to transfer of control:

(1) Each control station for main propulsion machinery or controllable pitch propellers is to be provided with means to indicate which of them is in control.

(2) Remote control of main propulsion machinery or controllable pitch propellers is to be possible only from one location at a time.

(3) Transfer of control is to be possible only with order by the serving station and acknowledgement by the receiving station except for the following cases:

(a) Transfer of control between local control station for main propulsion machinery or controllable pitch propellers and main control station or sub-control station; and

(b) Transfer of control during the stopping condition of the main propulsion machinery.

(4) In cases where main propulsion machinery or controllable pitch propellers is controlled from the navigation bridge or the main control station on bridge, the transfer of control is to be possible from the local control station for main propulsion machinery or controllable pitch propellers, main control station or the sub-control station with no order of the transfer of control from the navigation bridge or the main control station on bridge.

(5) Means are to be provided to prevent the propelling thrust from altering significantly when transferring control from one location to another except for the transfer of control described in **(3)(a)** and **(4)**.

3. Failure of remote control systems of main propulsion machinery or controllable pitch propellers

The following requirements are to be complied with in case of failure of remote control devices for main propulsion machinery or controllable pitch propellers:

(1) In the remote control stations for main propulsion machinery or controllable pitch propellers alarm devices which operate in the event of failure of the remote control devices for main propulsion machinery or controllable pitch propellers are to be provided.

(2) In the event of failure of the remote control devices for main propulsion machinery or controllable pitch propellers, the main propulsion machinery or the controllable pitch propellers is to be possible to control-locally. It is alto to be possible to control the auxiliary machinery, essential for the propulsion and safety of the ship, at or near the machinery concerned.

(3) In the event of failure of the remote control devices for main propulsion machinery or controllable pitch propellers, the preset speed and direction of the propeller thrust are to be maintained until the control is

in operation at the main control station, the sub-control station or the local control station for the main propulsion machinery or controllable pitch propellers, unless this is considered impracticable by the Society.

(4) In the event of failure of any of the remote control devices for main propulsion machinery or controllable pitch propellers, the transfer of control to the main control station, the sub-control station or the local control station for the main propulsion machinery or controllable pitch propellers is to be possible by a simple operation.

(5) Remote control stations for main propulsion machinery or controllable pitch propellers are to be provided with independent emergency stopping devices for the main propulsion machinery, which are effective in the event of failure of the remote control devices for the main propulsion machinery or the controllable pitch propellers.

4. Remote starting of main propulsion machinery in diesel ships

Starting by means of remote control devices for main propulsion machinery is to comply with the following:

(1) The number of starting of main propulsion machinery is to satisfy the number specified in **2.5.3**.

(2) Remote control devices for main propulsion machinery arranged to automatically start are to be so designed that the number of automatic consecutive attempts which fail to produce a start is limited to three times. In the event of failure of starting, a visual and audible alarm is to be issued at the relevant control station as well as the main control station on bridge, the main control station or the monitoring station (where the main control station on bridge and the main control station are not provided) for the main propulsion machinery or the controllable pitch propellers.

(3) Where compressed air is used for starting of the main propulsion machinery, alarm devices to indicate the low starting air pressure are to be provided at the remote control station and the monitoring station for the main propulsion machinery.

(4) The low starting air pressure mentioned in **(3)** for the operation of alarm devices is to be set at a level to permit further main propulsion machinery starting operations.

18.3.3 Bridge Control Device

Bridge control devices are to comply with the following requirements as well as those in **18.3.2**.

(1) Even in cases where main propulsion machinery or controllable pitch propellers is controlled from the navigation bridge or the main control station on bridge, the telegraph orders at the navigation bridge or the main control station on bridge are to be indicated in the main or sub-control stations respectively and at the maneuvering platform which are capable of controlling main propulsion machinery or controllable pitch propellers.

  (a) Sub-control station or local control station for main propulsion machinery or controllable pitch propellers for ships provided with main control station on bridge ; or

  (b) Main control station for ships not provided with main control station on bridge.

(2) Bridge control devices are to be provided with either one of the following devices in order to prevent prolonged running of main propulsion machinery in critical speed range:

(a) Devices to make to pass automatically and rapidly through the critical speed range :

(b) Alarm devices which operate in case where the main propulsion machinery operates exceeding a predetermined period in the critical speed range.

(3) The bridge control devices are to be provided with visual and audible alarms which inform the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency of threshold warnings of impending or imminent actions of the safety systems of main propulsion machinery specified in 18.1.2(10) **(b)** or **(c)**.

(4) The bridge control devices are to be provided with an override arrangement specified in 18.2.6-3 for the following safety systems of main propulsion machinery.

(a) The system which takes the actions specified in 18.1.2(10) **(b)**.

(b) The system which takes the actions specified in 18.1.2(10) **(c)**. (except for cases where total failure of the main propulsion machinery will be resulted within a short period of time.)

18.3.4 Safety Measures

1. Safety measures for main propulsion machinery or controllable pitch propellers

Safety measures for main propulsion machinery or controllable pitch propellers are to comply with the following requirements:

(1) The following safety measures are to be taken to remote control devices for main propulsion machinery or controllable pitch propellers:

(a) Necessary interlocking devices are to be provided to prevent serious damage due to operational error.

(b) Where the auxiliary machinery essential for main propulsion of the ship are driven by electric motors, the main propulsion machinery is to be so designed as to stop automatically in the event of failure of the main source of electrical power or to be capable of being stopped.

(c) The main propulsion machinery is to be so arranged as not to restart automatically when electrical power is restored after the failure of the main source of electrical power whereas the main propulsion machinery was stopped.

(d) The remote control devices for main propulsion machinery or controllable pitch propellers are to be so designed that the engine may not be abnormally overloaded in the event of failure of them.

(2) Stopping devices for main propulsion machinery are to be provided at the monitoring station for main propulsion machinery or controllable pitch propellers.

2. Safety systems of main propulsion machinery

Safety systems of main propulsion machinery are to comply with the following requirements:

(1) A device to shut off the fuel or steam supply (this device hereinafter being referred to as safety device) for the main propulsion machinery is not to be automatically activated except in cases which could lead to complete breakdown, serious damage or explosion.

(2) The safety systems for the main propulsion machinery are to be so designed as not to lose their function or as to fail-to-safe, even in the event of failure of main electrical source or air source.

3. Self-reversing diesel engines

At least the following safety measures are to be taken to the remote control devices for self-reversing diesel engines:

(1) Starting operation is to be possible only when the camshaft is surely at the position of “Ahead” or “Astern”.

(2) During reversing operation, fuel is not to be injected.

(3) Reversing operation is to be conducted after “Ahead” revolution is reduced to a predetermined value.

4. Main propulsion machinery of a multi-engines coupled to a single shaft ship.

At least the following safety measures are to be taken to the remote control devices for multi-engines coupled to a single shaft:

(1) Each main propulsion machinery is to be provided with an overload preventive device.

(2) Each main propulsion machinery is not to be subjected to an abnormally unbalanced load.

5. Main propulsion machinery with clutch

At least the following safety measures are to be taken to the remote control devices for engines with clutch:

(1) The clutch equipped to a main propulsion machinery in a multi-engines coupled to a single shaft is to be disengaged when the main propulsion machinery is stopped in an emergency. While multi-engines are operating in different directions of rotation their clutches are not to be engaged simultaneously.

(2) Engaging and disengaging of clutches are to be carried out below a predetermined revolutions of the main propulsion machinery.

(3) An over speed protective device specified in 2.4.1-2, 3.3.1-1 or 4.3.1-1 is to be provided.

(4) In case where there is fear that the speed of the propulsion motor would exceed 125% of the rated revolutions when the clutch is disengaged, an over speed protective device as deemed appropriate by the Society is to be provided.

6. Main propulsion machinery driving controllable pitch propellers

At least the following safety measures are to be taken to the remote control devices for engines driving controllable pitch propellers:

(1) An overload preventive device is to be provided.

(2) Starting of engines or engaging of clutches is to be performed while the propeller blades are in a neutral position.

(3) An over speed protective device as specified in 2.4.1-2, 3.3.1-1 or 4.3.1-1is to be provided.

(4) In case where there is fear that the speed of the propulsion motor would exceed 125% of the rated revolutions when the propeller pitch is altered, an over speed protective device as deemed appropriate by the Society is to be provided.

18.4 Automatic and Remote Control of Boilers

18.4.1 General

1. The systems of automatic control for both combustion and feed water of oil-fired boilers are to comply with the requirements in **18.4.2** to **18.4.5** respectively.

2. The systems of automatic control for either combustion or feed water of oil-fired boilers are to comply with the relevant requirements in **18.4.2** or **18.4.3** as well as the requirements in **18.4.4** and **18.4.5**.

3. Automatic control of boilers other than oil-fired boilers or having a special feature is to be deemed appropriate by the Society.

4. In case where boilers are remotely controlled, control devices and monitoring devices necessary for the operation of the boilers are to be provided at the relevant control stations.

5. Remote water level indicators are to comply with the requirements in **9.9.8**.

18.4.2 Automatic Combustion Control Systems

1. General

Automatic combustion control systems are to comply with the following requirements:

(1) The automatic combustion control systems are to be able to control so as to obtain planned steam amount, steam pressure and steam temperature and to secure stable combustion.

(2) The devices to control the fuel supply to meet the load imposed are to be capable of ensuring stable combustion in the controllable range of fuel supply.

(3) Where combustion control is carried out according to the pressure of the boiler, the upper limit of this pressure is to be lower than the set pressure of the safety valves.

2. Combustion control devices for intermittent operation

The combustion control devices for intermittent operation are to comply with the following requirements and they are to operate according to the planned sequence:

(1) Before ignition on the pilot burner or before ignition on the main burner if the pilot burner is not fitted, the combustion chamber and the flue are to be prepurged by air of not less than 4 times the volume of the combustion chamber and the flue up to the boiler uptake. For small boilers with only one burner, prepurge for not less than 30 *seconds* will be accepted.

(2) In case of direct ignition which is a method of ignition that the main burner is fired by ignition spark, opening of the fuel valve is not to precede the ignition spark.

(3) In case of indirect ignition which is a method of ignition that the main burner is fired by the pilot burner, opening of the fuel valve for the pilot burner (hereinafter referred to as ignition fuel valve in this part) is not to precede the ignition spark, and opening of the fuel valve for the main burner (hereinafter referred to as main fuel valve in this part) is not to precede opening of the ignition fuel valve.

(4) Firing is to be surely carried out within the planned period. Main fuel valve is to be so designed as to close after opening of the valve not exceeding 10 *seconds* in the case of direct ignition and 15 *seconds* in the case of indirect ignition if the firing on the main burner has failed.

(5) Firing on the main burners is to be carried out at their low firing position.

(6) After closure of the main fuel valve, post-purge is to be carried out for not less than 20 *seconds* to ensure adequate combustion air to completely burn all fuel oil remaining between the fuel oil valve and the burner nozzle. This requirement need not to be complied with in the case of auxiliary boilers where deemed appropriate by the Society.

3. Combustion control devices for the control of the number of firing burners

The combustion control devices for the control of the number of firing burners are to comply with the following requirements:

(1) Each burner is to be fired and extinguished according to the planned sequence. However, the base burner may be fired by manual operation and other burners may be fired by flame of a burner(s) already fired.

(2) The remaining fuel in the extinguished burner is to be automatically burnt up in order not to interfere the restarting. However, while the pilot burner is not fired, the remaining fuel in the base burner is not to be removed by steam or air when it is in place.

(3) The burners for main boilers are to be capable of being fired and extinguished from the main control station or the main control station on bridge, except for the firing of base burner.

4. Other combustion control devices

Other combustion control devices are to be deemed appropriate by the Society, as well as they are to comply with the relevant requirements in **-2** and **-3**.

18.4.3 Automatic Feed Water Control Devices

1. Automatic feed water control devices are to be capable of controlling automatically the feed water in order to maintain the water level in the boilers in a predetermined range.

2. Main boilers are to be provided with not less than three water level detectors used for a feed water control device, a remote water level indicator, a low-water level safety device and a low-water level alarm device.

18.4.4 Safety Measures

1. Safety devices

Safety devices are to comply with the requirements in **9.9.10-1**.

2. Heating of fuel oil

In case where heated fuel oil is used, an automatic temperature control device is to be provided to the heater and the boiler is to be provided with a device to shut off automatically the fuel supply to the burners or an alarm device which operates when the temperature of fuel oil falls below a predetermined value.

18.4.5 Alarms

Alarm devices are to comply with the requirements in **9.9.10-2**.

18.5 Automatic and Remote Control of Electric Generating Sets

18.5.1 General

1. Electric generating sets arranged to be automatically or remotely started are to be provided with interlocking devices necessary for safe operation.

2. Electric generating sets (other than those used for emergency source of electrical power) arranged to be automatically started are to be so designed that the number of automatic consecutive attempts which fail to produce a start is limited to two times and to be provided with an alarm device which operate at the time of the failure of starting.

3. In case where a diesel engine to drive a propulsion generator is remote started the number of starting is to conform to the required number specified in **2.5.3**.

4. Where automatic start of the stand-by generating set with automatic connection to the switchboard busbars is provided, automatic closure on to the busbars is to be limited to one attempt in the event of the original power failure being caused by short circuit.

5. Automatic control and remote control systems for the electric generating set, whose generator is driven by the main propulsion machinery and supplies electrical power to the electrical installations relating to the services specified in **3.1.2(1), Part 8** and is operated while the main propulsion machinery is controlled by the bridge control devices are to comply with the requirements in **3.2.1, Part 8**, in addition to those in this **18.5**.

18.5.2 Emergency Source of Electric Power

Automatic or remote control devices for diesel engines to drive emergency generators for non-emergency purposes are to be complied with the following requirements:

(1) Alarm devices to be activated in the event of the abnormal conditions given in **Table 18.2** are to be provided.

(2) Devices referred to in **(1)** are to provide alarms at both local and control positions. The visual alarms at control positions may be of group indication.

(3) Each diesel engine with a maximum continuous output of 220 *kW* or over is to be provided with an over speed protective device specified in **2.4.1-4**.

(4) When devices to shut down the diesel engines are provided other than those referred to in **(3)**, means are to be provided to override those devices automatically during navigation.

(5) The silencing of the audible alarms from the control positions is not to cause the silencing of the audible alarm at local position.

Table 18.2 Alarms for Diesel Engines to Drive Emergency Generators

Monitored Variables		Alarms	Remarks
Temperature	L.O. inlet	H	Applicable to engines with maximum continuous output of 220 kW or over.
	Cooling water or air outlet	H	
Pressure	L.O. inlet	L	
	Cooling water inlet	L	Applicable to engines with a maximum continuous output of 220 kW or over. Low flow may be accepted
Other	Oil mist concentration in crankcase	H	Applicable to engines with a maximum continuous output of 2,250 kW or over, or a cylinder bore of more than 300 mm
	Leakage from F.O. burning pipe, level in leakage tunk	○	
	Oversped	○	Applicable to engines with maximum continuous output of 220 kW or cover.

Note: "H" and "L" mean high and low. "○"means abnormal condition occurred.

18.6 Automatic and Remote Control of Auxiliary Machinery

18.6.1 Automatic Operation of Air Compressors

In cases where air compressors for starting and air compressors for controlling are automatically operated, alarm devices are to be provided to indicate pressure drop in air reservoirs.

18.6.2 Automatic Starting and Stopping of Bilge Pumping Arrangements

In cases where the bilge pumps are capable of being started and stopped automatically, alarm devices are to be provided to indicate high level of bilge in the relevant bilge wells and running of pumps for a long time.

18.6.3 Thermal Oil Installations

Thermal oil installations arranged to be automatically controlled are to comply with the following:

(1) Control devices

Control devices are to comply with **18.4.2-1** and **-2**, also with **9.12.2-1** and **-2**.

(2) Safety devices

Safety devices are to comply with **9.12.1** and **9.12.2-5**.

(3) Alarm devices

Thermal oil installations are to be provided with alarm devices which operate in the following cases:

(a) When the safety devices required in **(2)** have operated.

(b) When the temperature of the fuel at the inlet of burner has fallen.

18.6.4 High Temperature Alarm for Oil Heaters

In case where a temperature for fuel oil and lubricating oil is automatically controlled, high temperature alarm devices are to be provided, except where oils are not heated above the flashpoints.

18.6.5 Opening and Closing Devices for Sea Valves

In cases where sea valves to be fitted on the shell plating below the load water line are remotely or automatically controlled, other opening and closing devices which can be easily operated even in the event of failure of the automatic or remote control devices are to be provided.

18.6.6 Liquid Level Alarm Systems for Fuel Oil Tanks

In case where fuel transfer to fuel oil tanks is automatically controlled, the receiving tanks are to be provided with a high and low level alarm.

18.6.7 Mooring Arrangements

In cases where mooring arrangements are provided with remote control devices, the mooring arrangements are to be capable of being locally operated.

18.6.8 Fuel Oil Filling Arrangements

In case where arrangements for filling fuel oil into respective fuel oil tanks from the outside of the ships (hereinafter referred to as fuel oil filling arrangements in this Part) are provided with remote control devices, the fuel oil filling arrangements are to be such as not to interfere with filling of fuel even in the event of failure of the remote control devices.

18.6.9 Diesel Engines

1. With respect to the safety measures for auxiliary machinery driven by diesel engines, the requirements specified in **2.4.5** are to be applied.

2. The requirements in **18.5.2** apply correspondingly to the automatic or remote control devices for emergency diesel engines used for non-emergency purposes other than those mentioned in **18.5.2**.

18.7 Tests

18.7.1 Shop Tests

After constructed, the systems of automatic or remote control of the machinery and equipment, considered necessary by the Society, are to be subjected to the following tests.

(1) Environmental tests

Devices, units and sensors (hereinafter referred to as “automatic devices” in this Part) and automatic equipment composed of automatic devices are to be subject to the following tests at the manufactures works. The procedures of the tests are to be deemed appropriate by the Society.

(a) External examination

(b) Operation test and performance test

(c) Electrical power supply failure test (to be applied to electrical/electronic devices, etc.)

(d) Electrical power supply fluctuation test (to be applied to electrical/electronic devices, etc.)

(e) Power supply fluctuation test (to be applied to hydraulic/pneumatic devices, etc.)

(f) Insulation resistance test (to be applied to electrical/electronic devices, etc.)

(g) High voltage test (to be applied to electrical/electronic devices, etc.)

(h) Pressure test (to be applied to hydraulic/pneumatic devices, etc.)

(i) Dry heat test

(j) Damp heat test

(k) Vibration test

(l) Inclination test (to be applied to equipment with moving parts)

(m) Cold test

(n) Salt mist test (to be applied to devices installed in unenclosed spaces such as open decks)

(o) Electrostatic discharge immunity test (to be applied to electronic devices)

(p) Radiated radio frequency immunity test (to be applied to electronic devices)

(q) Conducted low frequency immunity test (to be applied to electronic devices)

(r) Conducted high frequency immunity test (to be applied to electronic devices)

(s) Burst/Fast transient immunity test (to be applied to electronic devices)

(t) Surge immunity test (to be applied to electronic devices)

(u) Radiated emission test (to be applied to electronic devices that emit the electromagnetic wave)

(v) Conducted emission test (to be applied to electronic devices that emit the electromagnetic wave)

(w) Flame retardant test (to be applied to flammable enclosures of equipment)

(x) Other tests considered necessary by the Society

(2) Completion tests of automatic equipment

The automatic devices which have passed through the environmental tests specified in **(1)** are to be subjected to the following tests after completion of assembly as automatic equipment. The procedures of the tests are to comply with the requirements deemed appropriate by the Society.

(a) External examination

(b) Operation tests and performance tests

(c) Insulation resistance tests and high voltage tests (to be applied to electric/electronic devices etc.)

(d) Pressure tests (to be applied to hydraulic/pneumatic devices etc.)

(e) Confirmation of the effective implementation of quality control of software and documentation of software modification history.

(f) Other tests deemed necessary by the Society.

18.7.2 Approval of Use

1. Where the automatic devices and automatic equipment have passed the environmental tests specified in 18.7.1, they will obtain the approval of use and made public, upon request from the manufacturer.

2. With respect to the automatic devices and automatic equipment which have already obtained the approval of use by the Society, a part or all of the environmental test specified in 18.7.1(1) may be dispensed with.

18.7.3 Tests after Installation on Board

After installed onboard the systems of automatic or remote control of the machinery and equipment are to be confirmed that they operate effectively, under as far practical condition as possible. However, part of these tests may be carried out during sea trials.

Chapter 19 SPARE PARTS, TOOLS AND INSTRUMENTS

19.1 General

19.1.1 Scope

1. The requirements in this Chapter apply to spare parts, tools and instruments for the machinery installations.

2. Term of machinery installations used in this chapter is defined as follows :

(1) Diesel engines for main propulsion

(2) Diesel engines to drive generators or auxiliary machinery essential for main propulsion

(3) Steam turbines for main propulsion

(4) Steam turbines drive generators or auxiliary machinery essential for main propulsion

(5) Main propulsion shafting

(6) Boilers

(7) Pumps and air compressors

3. Since the requirements for spare parts and tools vary depending on regulations of registered country, purpose of ships engaged, kinds of machinery installations, navigation routes and others, the requirements in this Chapter may not be applicable in all cases. However, as a rule, spare parts and tools specified in this Chapter are to be provided in engine room, boiler room or any other convenient places in a ship.

4. The spare parts, tools and instruments for machinery installations not specified in this Chapter are to be as deemed appropriate by the Society.

5. The spare parts and tools for electrical installations are to comply with the requirements in **3.8 in Part 8**.

19.1.2 Documentation

The ship's owner or shipbuilder is to submit, for approval, the list showing the number of specified spare parts, tools and instruments for machinery installation, actually provided on board.

19.2 Spare Parts, Tools and Instruments

19.2.1 Spare Parts

1. The spare parts for a diesel engine for main propulsion are given in **Table 19.1**.

2. The spare parts for a diesel engine to drive a generator (except emergency generator) or auxiliary machinery essential for main propulsion are given in **Table 19.2**.

3. The spare parts for a steam turbine for main propulsion and a steam turbine to drive a generator (except emergency generator) or auxiliary machinery essential for main propulsion are given in **Table 19.3**.

4. The spare parts for a main propulsion shafting are given in **Table 19.4**.

5. The spare parts for a main boiler, an essential auxiliary boiler, a boiler to supply steam for fuel oil heating necessary for operation of main propulsion machinery or cargo heating required continuously, and a thermal oil installation for essential use are given in **Table 19.5**. However, no spare parts are required, provided that stand-by means which ensure to keep the normal service condition of a ship or heating of cargoes ar

6. e provided, in case of failure of boilers other than main boiler or thermal oil installations.

7. The spare parts for a pump and an air compressor (other than emergency use) which are classified as auxiliary machinery essential for main propulsion, and a bilge pump are given in **Table 19.6**.

8. The spare parts for the machinery installations listed in the **Tables 19.1** to **19.6** are those required for each one set of the machinery installations. In case where the ship is installed with two or more sets of the machinery installations of the same type for the same service, only one set of spare parts for the machinery installations may be acceptable.

However, the number of water gauge glasses of round type and flat type is required to be the number in **Table 19.5** for each boiler, and the number of flat type water gauge frames is required to be one for each two boilers.

9. Notwithstanding the requirement specified in **-7**. no spare parts are required for the machinery installations specified in following **(1)** and **(2)**.

(1) The machinery installations whose number exceeds the Rule required number and each capacity is adequate under the normal service condition of the ship.

(2) The pumps classified as auxiliary machinery essential for main propulsion, which have stand-by pumps of adequate capacity under normal service condition of the ship.

19.2.2 Tools and Instruments

The tools and instruments for each one ship are given in **Table 19.7**.

Table 19.1(a) Spare Parts for Diesel Engines for Main Propulsion

Item	Spare parts	Number required
Main bearing	Main bearing or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1 set
Cylinder liner	Cylinder liner, complete with joint rings and gaskets	1
Cylinder cover	Cylinder cover, complete with all valves, joint rings and gaskets For engine without cylinder cover, the respective valves	1
	Cylinder cover bolts and nuts, for one cylinder	1/2 set
Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set
	Starting air valve, complete with casing, seat, springs and other fittings	1
	Relief valve, complete with casting, springs and other fittings	1
	Fuel valves, complete with castings, springs and other fittings for one engine *Note: Engines with three or more fuel valves per cylinder: two fuel valves complete per cylinder, and other valves excluding casings.	1 set*
Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bots and nuts	1 set
	Top end bearing or shells of each size and type fitted, complete with shims, bolts and nuts.	1 set
Pistons	Crosshead type: Piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod	1
		1
Pistons rings	Piston rings for one cylinder	1 set
Piston cooling	Telescopic cooling pipes and fittings or equivalent for one cylinder unit	1 set
Chain for camshaft drives	Chain drive: separate links with pins and rollers of each size and type fitted	6
Cylinder lubricator	Lubricator, complete, of the largest size, with its driving chain or gear wheel	1
Fuel injection pumps	Fuel injection pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.)	1

Table 19.1(b) Spare Parts for Diesel Engines for Main Propulsion

Fuel injection piping	High pressure fuel pipe of each size shape fitted, complete with couplings	1
Scavenge blowers (including turbo chargers)	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if other type (see Note)	1 set
Scavenging system	Suction and delivery valves for one pump of each type fitted, complete.	1 set
Reduction and or reversing gear	Complete bearing brush of each size fitted in the gear case assembly	1 set
	Roller or ball bearing, complete, of each size fitted in the gear case assembly	1 set
Gaskets and packings	Special gaskets and packings of each size and type fitted for cylinder cover and cylinder liner for one cylinder	-

Note:

The spare parts for scavenge blowers may be omitted where it has been demonstrated, at the builder s test bench, for one engine of the type concerned, that the engine can be maneuvered satisfactorily with one blower out of action. In this case, however, the requisite blanking and blocking arrangements for running with one blower out of action are to be available on board.

Table 19.2 Spare Parts for Diesel Engines to Drive Generators or Auxiliary Machinery Essential for Main Propulsion

Item	Spare parts	Number required
Main Bearings	Main bearings of shell of each size and type fitted, complete with shims, bolts and nuts	1 set
Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set
	Staring air valve, complete with casting, seat, springs and other fittings	1
	Relief valve, complete with casing, springs and other fittings	1
	Fuel valves of each size and type fitted, complete with casings, springs and other fittings for one engine	1/2 set
Connecting rod bearing	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts for one cylinder	1 set
	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts for one cylinder	1 set
	Trunk piston type: Gudgeon pin with bush for one cylinder	1 set
Piston rings	Piston rings, for one cylinder	1 set
Piston cooling	Telescopic cooling pipes and fittings or their equivalent for one cylinder	1 set
Fuel injection pumps	Fuel injection pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc)	1
Fuel injection piping	High pressure fuel pipe of each size and shape fitted, complete with couplings	1
Gaskets and packings	Special gaskets and packings of each size and type fitted, for cylinder cover and cylinder liner for one cylinder.	1 set

Table 19.3 Spare Parts for Steam Turbines

Item	Spare parts	Number required
Main bearing	Bearing of each size for rotor shaft and reduction gear shaft	1 set of each shaft
Rotor thrust bearing	Pads (including adjusting lines and rings) for one face	1 set*
Turbine shaft sealing rings	Carbon sealing rings, with springs, for each size and type	1 set
Oil filtters	Strainer baskets or inserts for filtters of each size and type Applicable to those of special design	1 set

*Note:

For a main steam turbine, when the pads of one face differ from those of the other, complete set of pads is to be provided.

Table 19.4 Spare Parts for Main Shaftings

Spare parts	Number required
Main thrust bearing:	
Pads for one face of Michell type thrust block	1 set for each size*
Complete thrust shoe for one face of solid ring type	1 for each size*
Inner and outer race with rollers of roller thrust bearing	1 for each size

*Note:

When the pads of one face differ from those of the other, complete set of pads is to be provided.

Table 19.5 Spare Parts for Boilers and Thermal Oil Installations

Spare parts	Number required
Safety valve spring of each size including superheater safety valve spring	1
Oil burner nozzles, complete for one boiler	1 set
Round type water gauge glasses including packings	12
Flat type water gauge glasses	2
Flat type water gauge frame	1

Table 19.6 Spare Parts for Pumps and Air Compressors

Item	Spare parts	Number required
Piston pumps	Valves with seats and springs of each size fitted	1 set
	Piston rings of each and size for one piston	1 set
Centrifugal and gear type pumps	Bearing of each type and size	1
	Rotor sealing of each type and size (Parts liable to deteriorate, such as packings, sleeves)	1
Air Compressors	Piston rings of each type and size	1 set
	Suction and delivery valves and their springs of each size	1/2 set

Notes:

1. Pumps and air compressors include those for remote or automatic control system.
2. Gear type pumps include vane pumps and screw pumps.

Table 19.7 Tools and Instruments

Description	Spare parts	Number required
Boiler required spare parts in the requirement in **19.2.1-5**	Tube stoppers or plugs of each size, including those for superheater tubes and economizer tubes *Note: In the case of cylindrical boiler, half of them are to be those which can be used from burner side	For water tube boiler: 12 for each size
		For other type boiler: 12 in total*
All boilers	Standard pressure gauge *Note: Gauge tester will be acceptable	1*
	Water tester *Note: Two salinometers will be acceptable	1 set*
Special tools and instruments for maintenance of repair work or the machinery installations		1 set

Chapter 20 SPECIAL REQUIREMENTS FOR MACHINERY INSTALLED IN SHIPS WITH RESTRICTED AREA OF SERVICE AND SMALL SHIPS

20.1 General

20.1.1 Scope

The requirements in this Chapter apply to machinery to be installed in ships with a gross tonnage less than 500 *tons* and intended for registry with restricted areas of service in place of the relevant requirements in Chapters up to the preceding **Chapter 19**.

20.2 Modified Requirements

20.2.1 Ships with Class Notation "*Coasting Service*" or Equivalent

1. For the following machinery, provisions of spare one may be omitted provided that the total capacity of machinery is sufficient enough to obtain the maximum continuous output of the main propulsion machinery or the maximum evaporative capacity of the main and essential auxiliary boiler, and two sets of machinery in nearly the same capacity and whose capacity of either one set is sufficient enough to obtain navigable speed of the ships, are installed on board ship.

(1) The source of pressure to drive the clutch of power transmission systems for main propulsion specified in **5.2.4-3** above.

(2) Pumps for hydraulic pumps for pitch control gears of controllable pitch propellers specified in **7.2.2-8** above.

(3) Fuel oil supply pumps specified in **13.9.6-1** and **-2** above.

(4) Burning systems for boilers specified in **13.9.7-1** and **-2** above.

(5) Lubricating oil pumps specified in **13.10.2-1** and **-2** above.

(6) Cooling water (oil) pumps for main propulsion machinery specified in **13.12.1-1** and **-2** above.

(7) Feed water systems specified in **13.15.1-1** and **-2** above.

2. In the requirements specified in **13.9.6-1(2), 13.10.2-1(2),** and **13.12.1-1(3),** the requirements to provide a complete set of the spare pump do not apply.

3. The requirement specified in **15.3.1-4.** is not necessary to apply.

4. For ships with the Class Notation "*Coasting Service*" or equivalent, which are not engaged in international voyages, or whose gross tonnage is less than 500 *tons*, the following requirements may be complied with in addition to the requirements in **-1** to **-3** above.

(1) The requirements specified in **1.3.1-5** are not necessary to apply.

(2) The requirements specified in **1.3.8** are not necessary to apply. (for ships not engaged in international voyages only)

(3) The requirements specified in **1.3.9** are not necessary to apply.

(4) Any other appropriate unit specified in 5.2.4-3 may be replaced with emergency fixing bolts for clutch to enable the ship to have a navigable speed.

(5) Other suitable device specified in 7.2.2-8 above, may be replaced with a propeller pitch-fixing device to enable the ship to have a navigable speed.

(6) The requirements specified in 13.5.10, 13.6.1-5, 13.8.5, 13.9.1-6 and 13.9.1-7 are not necessary to apply.

(7) The requirements specified in 15.1.5 are not necessary to apply.

(8) The requirements specified in 15.2.4-5 and -6 need not apply (excluding those cases where any provision of auxiliary steering gear has been omitted according to the requirements in 15.2.1-2).

(9) The requirements for an alternative source of power specified in 15.2.6 above is not necessary to apply.

(10) The requirements in 15.2.7-1 and -7 above are not necessary to apply.

(11) The requirements for overload for circuits and motors specified in 15.2.7-5 above is not necessary to apply.

(12) A means of communication between the navigating bridge and the steering gear compartment specified in 15.2.9 above may be replaced with an appropriate alternative means.

(13) The requirements in 15.3.1-3 above is not necessary to apply.

20.2.2 Ships with the Class Notation "*Smooth Water Service*" or equivalent

1. The buffer arrangements specified in 15.4.9 above may be omitted, in addition to complying with the requirements specified in 20.2.1-1, -2 and -3 above.

2. For ships with a diameter of the upper stock according to Chapter 3, Part 2 not more than 120 *mm* (calculated with a material factor K_s = 1where K_s = is less than 1), the provisions of the auxiliary steering gear specified in 15.2.1 above may be omitted where spare parts for consumables, such as packing and bearings, are provided for the power-driven main steering gear or where spare steering wires are provided for the hand-powered main steering gear.

3. For ships with the Class Notation "*Smooth Water Service*" or equivalent which are not engaged in international voyages, or whose gross tonnage is less than 500 *tons*, the following requirements may apply in addition to the requirements specified in 20.2.1-1 to -4, 20.2.2-1 and -2.

(1) Notwithstanding the requirements in 1.3.1-4 above, provisions of one unit or one set each of the machinery specified in 20.2.1-1(1) to (7) may be accepted, provided that each has such a capacity sufficient for the main propulsion machinery to obtain the maximum continuous output and for the main and essential auxiliary boiler to obtain the maximum evaporative capacity.

(2) The requirements for fuel oil transfer pumps specified in 13.9.3 may be modified to one set of a pump driven by an independent source of power.

(3) Notwithstanding the requirement in 1.3.1-3, the requirements for two or more starting air compressors specified in 13.13.3 may be modified to one starting air compressor driven by an independent source of power.

20.2.3 Ships with a Gross Tonnage less than 500 *tons*, etc.

1. For ships with a gross tonnage less than 500 *tons*, the requirements specified in **20.2.1-3** and **-4(1)**, **(3)** and **(6)** through **(13)** above may be complied with. Moreover, the buffer arrangements specified in **15.4.9** above may be omitted.

2. For ships which are not engaged on international voyages or whose gross tonnage is less than 500 *tons*, the requirements specified in **13.4.1-4** and **13.8.6** need not to apply.

3. For ships which are not engaged on international voyages and whose gross tonnage is not less than 500 *tons*, where deemed appropriate by the Society taking account of various conditions of such ships related to the navigation, the requirements specified in **13.8.5** need not to be applied to.

20.3 Spare Parts, Tools and Instruments for ships with Restricted Areas of Service

20.3.1 Spare Parts, Tools and Instruments and etc. for Ships with Class Notation "*Coasting Service*" or equivalent

Spare parts for the machinery installed in ships with a Class Notation of "*Coasting Service*" or equivalent may be in compliance with the requirements specified in **Table 20.1**. Further, for ships equipped with 2 or more diesel engines or steam turbines for main propulsion and for ships equipped with 2 or more main generators, spare parts for diesel engines or steam turbines for main propulsion or to drive main generators are not to be required, respectively.

20.3.2 Spare Parts for Ships with Class Notation "*Smooth Water Service*" or equivalent

Spare parts for the machinery installed in ships with a Class Notation of *Smooth Water Service* may be in compliance with the requirements specified in **Table 20.2**. Further, for ships equipped with 2 or more diesel engines or steam turbines for main propulsion and for ships equipped with 2 or more main generators, spare parts for diesel or steam turbines for main propulsion or to drive main generators are not to be required, respectively.

Table 20.1 Spare Parts for Ships of Coasting Service

<table>
<tr><th>Area of service</th><th>Table No. In Chapter 19</th><th colspan="2">Items and types of spares</th><th>Quantity</th></tr>
<tr><td rowspan="12">Coasting Service</td><td rowspan="5">Table 19.1
Table 19.2</td><td colspan="2">Cylinder liner, cylinder cover, piston, camshaft driving gear, cylinder lubricator, scavenging air blower (including turbocharger) scavenging air system, reduction gear, reversing gear</td><td rowspan="3">Omitted</td></tr>
<tr><td colspan="2">Main bearing, piston cooling system</td></tr>
<tr><td rowspan="2">Cylinder-mounted valve</td><td>Starting air valve, relief valve</td></tr>
<tr><td>Exhaust gas valve, fuel injector</td><td>For one cylinder</td></tr>
<tr><td colspan="2">Connecting rod bearing</td><td>Lower half of small end bearing metal, upper half of big end bearing metal, one piece each</td></tr>
<tr><td>Table 19.3 and Table 19.4</td><td colspan="2">All items and all types</td><td>Omitted</td></tr>
<tr><td rowspan="2">Table 19.5</td><td colspan="2">Cylindrical water gauge glass</td><td>6 pieces</td></tr>
<tr><td colspan="2">Flat water gauge glass</td><td>One piece</td></tr>
<tr><td>Table 19.6</td><td colspan="2">Centrifugal pump, gear pump, air compressor</td><td rowspan="2">Omitted</td></tr>
<tr><td rowspan="3">Table 19.7</td><td colspan="2">Standard pressure gauge</td></tr>
<tr><td rowspan="2">Tube plug</td><td>Water tube boiler</td><td>4 pieces each</td></tr>
<tr><td>Other types of boiler</td><td>4 pieces in total</td></tr>
</table>

Table 20.2 Spare Parts for Ships of Smooth Water Service

<table>
<tr><th>Area of service</th><th>Table No. in Chapter 21</th><th colspan="2">Items and types of spares</th><th>Quantity</th></tr>
<tr><td rowspan="10">Smooth Water Service</td><td rowspan="2">Table 19.1
and Table 19.2</td><td colspan="2">Connecting rod bearing</td><td>Lower half of small end bearing metal, upper half of big end bearing metal, one piece each</td></tr>
<tr><td colspan="2">All items excluding connecting rod bearing</td><td rowspan="3">Omitted</td></tr>
<tr><td>Table 19.3 and Table 19.4</td><td colspan="2">All items and all types</td></tr>
<tr><td rowspan="3">Table 19.5</td><td colspan="2">Safety valve spring, complete set of oil burner</td></tr>
<tr><td colspan="2">Cylindrical water gauge glass</td><td>3 pieces</td></tr>
<tr><td colspan="2">Flat water gauge glass</td><td>One piece</td></tr>
<tr><td>Table 19.6</td><td colspan="2">Centrifugal pump, gear pump, air compressor</td><td rowspan="2">Omitted</td></tr>
<tr><td>Table 19.7</td><td colspan="2">Standard pressure gauge</td></tr>
<tr><td>Table 21.7</td><td>Tube plug</td><td>Water tube boiler</td><td>2 pieces for each type</td></tr>
<tr><td></td><td></td><td>Other types of boiler</td><td>2 pieces in total</td></tr>
</table>