PART
4

CHAPTER 4 Boilers, Pressure Vessels and Fired Equipment

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SECTION 1 Boilers and Pressure Vessels and Fired Equipment

1 General

1.1 Application *(2008)*

Regardless of the system in which they formed a part, boilers, fired and unfired heaters, pressure vessels and heat exchangers of the following categories are to be subjected to the provisions of this section:

i) Boilers and steam generators with design pressure over 3.5 bar (3.6 kgf/cm^2, 50 psi).

ii) Fired heaters for oil with design pressure over 1 bar (1 kgf/cm^2, 15 psi).

iii) Independent pressure vessel tanks for the carriage of liquefied gases, defined in Section 5C-8-4.

iv) *(2008)* Accumulators, regardless of their diameters, see 4-6-7/3.5.4.

v) Other pressure vessels and heat exchangers of 150 mm (6 in.) diameter and over, having design pressure, temperature and volume as defined in 4-4-1/Table 1. Pressure vessels and heat exchangers under 150 mm (6 in.) in diameter are not required to comply with the provisions of this section. Acceptance of them will be based on manufacturer's guarantee of physical properties and suitability for the intended service, provided the installation is carried out to the satisfaction of the Surveyor.

vi) Boilers and fired heaters not included above, fired inert gas generators and incinerators are subject to the provisions of 4-4-1/15 only.

TABLE 1
Pressure Vessels Covered in Part 4, Chapter 4

	Pressure				*Temperature*			*Volume*	
	bar	*kgf/cm^2*	*psi*		*°C*	*°F*		*m^3*	*ft^3*
a) Pressure vessels and heat exchangers for toxic and corrosive substances (see 4-1-1/1.9.5)	>1.0	>1.0	>15	–	all	all	–	all	all
b) Pressure vessels, heat exchangers and heaters other than a)	>6.9	>7	>100	–	all	all	–	all	all
c) Pressure vessels, heat exchangers and heaters other than a) and b)	>1.0	>1.0	>15	*and*	>149 [(1)] >66 [(2)] >90 [(3)]	>300 [(1)] >150 [(2)] >200 [(3)]	*and*	>0.14	> 5

Notes

1 Applicable to steam, gas or vapor; and to liquids other than fuel oil, lubricating oil, hydraulic oil and thermal oil.

2 Applicable to fuel oil.

3 Applicable to lubricating oil, hydraulic oil and thermal oil.

1.3 Definitions

1.3.1 Design Pressure

Design Pressure is the gauge pressure to be used in the design of the boiler or pressure vessel. It is to be at least the most severe condition of coincidental pressure and temperature to be expected in normal operation. For pressure vessels having more than one chamber, the design pressure of the inner chamber is to be the maximum difference between the inner and outer chambers.

1.3.2 Maximum Allowable Working Pressure

The *Maximum Allowable Working Pressure* (MAWP) of a boiler or pressure vessel is the maximum pressure permissible at the top of the boiler or pressure vessel in its normal operating condition and at the designated coincidental temperature specified for that pressure. It is the least of the values found for MAWP for any pressure-bearing parts, adjusted for the difference in static head that may exist between the part considered and the top of the boiler or pressure vessel. MAWP is not to exceed the design pressure.

1.3.3 Design Temperature

The maximum temperature used in design is not to be less than the mean metal temperature (through the thickness) expected under operating conditions. The minimum metal temperature used in design is to be the lowest expected in service, except when lower temperatures are permitted by the Rules of the recognized code or standard.

1.5 Recognized Codes or Standards

All boilers and pressure vessels required to be certified by 4-4-1/1.1 are to be designed, constructed and tested in accordance with Appendix 4-4-1A1 of this section. Alternatively, they may comply with a recognized code or standard. The following are some of the national standards that are considered recognized for the purpose of this section:

Boilers:

- ASME Boiler and Pressure Vessel Code Section I
- British Standard BS 1113 Design and manufacture of water tube steam generating plant (including superheaters, reheaters and steel tube economizers)
- British Standard BS 2790 Specifications for the design and manufacture of shell boilers of welded construction

Pressure vessels and heat exchangers:

- ASME Boiler and Pressure Vessel Code Section VIII Div. 1; or Section VIII Div. 2
- Standards of Tubular Exchanger Manufacturers Association
- British Standard BS 5500 Specification for unfired fusion welded pressure vessels
- Japanese Industrial Standard JIS B8270 *et al* for Pressure vessels

Other national standards or codes will be considered, provided that they are no less effective.

1.7 Grouping of Boilers and Pressure Vessels

For purpose of specifying the degree of inspection and testing during the certification process, boilers and pressure vessels are categorized as in 4-4-1/Table 2.

1.9 Certification

All boilers and pressure vessels within the scope of 4-4-1/1.1 are to be certified by the Bureau. Mass-produced pressure vessels, including seamless extruded cylinders and fluid power cylinders, may be certified by alternative means as described in 4-4-1/1.11. 4-4-1/Table 3 provides important elements of the certification process for each group of boilers and pressure vessels. Columns 1, 2 and 3 in the table are to be complied with for all boilers and pressure vessels regardless of the chosen standard or code of compliance. Fabrication and inspection details in column 4 (see Section 2-4-3) are to be complied with also, except that considerations will be given to alternative provisions in the chosen standard or code of compliance.

TABLE 2
Grouping of Boilers and Pressure Vessels

Grp	*Type*	*Pressure*				*Temperature*			*Volume*			*Thickness*	
		bar	*kgf/cm^2*	*psi*		*°C*	*°F*		*m^3*	*ft^3*		*mm*	*in.*
I	a) Boilers and steam generators	>3.5	>3.6	>50	–	all	all	–	all	all	–	all	all
	b) Pressure vessels and heat exchangers, other than d) and e) (6).	>41.4	>42.2	>600	*or*	>371 (1) >204 (2)	>700 (1) >400 (2)	*and*	all	all	*or*	>38	>1.5
	c) Fired heaters for oil	>41.4	>42.2	>600	–	all	all	–	all	all	–	all	all
	d) Liquefied gas pressure vessel cargo tanks (6)	≥2.1	≥2.1	≥30	–	all	all	–	all	all	–	all	all
	e) Pressure vessels and heat exchangers for toxic or corrosive substances (6)	>1.0	>1.0	>15	–	all	all	–	all	all	–	all	all
II	a) Fired heater for oil	≤41.4 and >1.0	≤42.2 and >1.0	≤600 and >15	–	all	all	–	all	all	–	all	all
	b) Pressure vessels and heat exchangers, other than Group I b (6)	≤41.4 and >6.9	≤42.2 and >7	≤600 and >100	*and*	≤371 (1) ≤204 (2)	≤700 (1) ≤400 (2)	*and*	all	all	*and*	≤38	≤1.5
	c) Pressure vessels and heat exchangers, other than Group II b (6)	≤6.9 and >1.0	≤7 and >1.0	≤100 and >15	*and*	>149 (3) >66 (4) >90 (5)	>300 (3) >150 (4) >200 (5)	*and*	>0.14	>5	*and*	≤38	≤1.5

Notes

1 Steam, gas or vapor, other than toxic or corrosive substances.

2 Liquids, other than toxic and corrosive substances.

3 Steam, gas or vapor, and liquids excluding fuel oil, lubricating oil and thermal oil; other than toxic or corrosive substances.

4 Fuel oil.

5 Lubricating oil and thermal oil.

6 Internal diameter ≥ 150 mm (6 in.). Vessels with smaller diameter are outside the scope of this section.

TABLE 3
Certification Details

	1	2	3	4			
	Design approval	Survey during fabrication	Material test witnessed by Surveyor	Full radiography	Post-weld heat treatment	Production test plate	Charpy V-notch test
Group I	x	x	x	x	x	x	as required
Group II	x	x	-	-	-	-	as required

1.11 Special Cases

1.11.1 Independent Cargo Pressure Vessels

Pressure vessels independent of the vessel's hull and intended for the carriage of liquefied gases as cargo are, in addition to the provisions of this section, to comply with Section 5C-8-4.

Pressure vessels intended for carriage of other cargoes, such as bulk cement, which require compressed air for loading and discharging, are subject to the provisions of this section if the operating pressure and volume of the vessels exceed that indicated in 4-4-1/Table 1 item c.

1.11.2 Mass-produced Boilers and Pressure Vessels *(2003)*

Mass-produced boilers, pressure vessels and heat exchangers may be certified on the basis of the ABS Type Approval Program (see 1-1-4/7.7, 4-1-1/Table 5 and 1-1-A3/5), subject to their designs being approved by the Bureau in each case.

Consideration will be given to accepting Group II pressure vessels and heat exchangers based on certification by an independent agency in accordance with the intent of this section, and the certificate of compliance being submitted to the Surveyor for verification. Each of such units is to have a permanently affixed nameplate traceable to the certificate. Further design evaluation and testing may be required if doubt arises as to the integrity of the unit.

1.11.3 Pressure Vessels Included in Self-contained Equipment *(2007)*

Pressure vessels and heat exchangers, which form part of an independently manufactured and assembled unit (for example, a self contained air conditioning or ship's stores refrigeration unit, etc.), are not subject to the requirements of this Section, provided the independently assembled unit does not form part of a ship's piping system covered under Part 4, Chapters 6, 7 and 9 and Part 6, Chapter 2.

1.11.4 Seamless Pressure Vessels for Gases

Mass-produced pressurized cylinders for storage of industrial gases such as carbon dioxide, oxygen, acetylene, etc., which are of extruded seamless construction, are to be designed, manufactured and tested in accordance with a recognized standard for this type of pressure vessel. Their acceptance will be based on their compliance with the standard as verified by either the Bureau or an agency recognized by a national authority (in the country of manufacture) having jurisdiction over the safety of such pressure vessels. The certificate of compliance, traceable to the cylinder's serial number, is to be presented to the Surveyor for verification in each case.

1.11.5 Fluid Power Cylinders

Hydraulic cylinders for steering gears, regardless of diameter, are to meet 4-3-4/7 and 4-3-4/19. For other hydraulic and pneumatic cylinders, regardless of diameter, see 4-6-7/3.5.5.

1.13 Plans and Data to be Submitted

1.13.1 Boilers

General arrangement

Design data: heating surface, evaporative capacity, design and working pressure and temperature, superheater header and tube mean wall temperatures, estimated pressure drop through the superheaters, safety relief valve settings and capacities, draft requirements at design conditions, number and capacity of forced draft fans.

Materials of all pressurized parts and their welded attachments

Sectional assembly

Seating arrangements

Steam and water drums, and header details

Waterwall details

Steam and superheater tubing including the maximum expected mean wall temperature of the tube wall, and the tube support arrangements

Economizer arrangement, header details, and element details

Casing arrangement

Typical weld joint designs

Post-weld heat treatment and nondestructive examination

Boiler mountings including safety valves and relieving capacities, blow-off arrangements water-gauges and try cocks, etc.

Integral piping

Reheat section (when fitted)

Fuel oil burning arrangements including burners and registers

Forced draft system

Boiler instrumentation, monitoring and control systems

1.13.2 Pressure Vessels and Heat Exchangers

General arrangements

Design data: design pressures and temperatures, fluid name, degree of radiographic examination, corrosion allowance, heat treatment (or lack of it), hydrostatic test pressure, setting of safety relief valve

Material specifications including heat treatment and mechanical properties

Shell and head details, and shell to head joint details

Nozzles, openings, manways, etc., and their attachment details; flanges and covers, as applicable

Tubes, tube sheets, heads, shell flanges, covers, baffles, tube to tubesheet joint details, packings, as applicable

Support structures, seating, etc.

1.13.3 Thermal Oil Heaters

In addition to the arrangements and details and construction details of pressure parts as required for steam boilers and heat exchangers, as appropriate, the following are to be submitted:

Thermal oil characteristics, including flash point; thermal oil deterioration testing routines and facilities

Thermal oil plant design parameters: thermal oil circulation rate; circulating pump head/capacity; designed maximum oil film temperature

Arrangement and details of appurtenances; relief valve capacities

Schematic of thermal oil piping system

Fire extinguishing fixtures for the furnace space

Instrumentation, monitoring and control systems

1.13.4 Calculations

Calculations in accordance with a recognized standard or code.

1.13.5 Fabrication

Welding procedure specifications and procedure qualification records; post-weld heat treatment procedure; nondestructive examination plan, where applicable. Welder qualification records are to be submitted to the Surveyor.

3 Materials

3.1 Permissible Materials

3.1.1 General

Pressure parts of boilers and pressure vessels are to be constructed of materials conforming to specifications permitted by the applicable boiler or pressure vessel code. Boiler and pressure vessel material specifications provided in Section 2-3-1 may be used in connection with the provisions of Appendix 4-4-1A1. Materials for non-pressure parts are to be of a weldable grade (to be verified by welding procedure qualification, for example) if such parts are to be welded to pressure parts.

3.1.2 Materials for High Temperature Service

Materials of pressure parts subjected to service temperatures higher than room temperature are to have mechanical and metallurgical properties suitable for operating under stress at such temperatures. Material specifications concerned are to have specified mechanical properties at elevated temperatures, or alternatively, the application of the materials is to be limited by allowable stresses at elevated temperatures as specified in the applicable boiler or pressure vessel standard. The use of materials specified in Section 2-3-1 is to be in accordance with the allowable stresses specified in Appendix 4-4-1A1.

3.1.3 Materials for Low Temperature Service

Materials of pressure parts subjected to low service temperatures are to have suitable notch toughness properties. Permissible materials, the allowable operating temperatures, the tests that need be conducted and the corresponding toughness criteria are to be as specified in the applicable pressure vessel standard.

3.3 Permissible Welding Consumables

Welding consumables are to conform to recognized standards. Welding consumables tested, certified and listed by the Bureau in its publication *Approved Welding Consumables* for meeting a standard may be used in all cases. See Section 2-4-3.

Welding consumables not so listed but specified by the manufacturer as conforming with a standard (e.g., AWS) may be used in Group II pressure vessels. Such consumables are to have been proven in qualifying the welding procedures intended to be used in the fabrication of the boiler or pressure vessel, or are to be of a make acceptable to the Surveyor. For Group I boilers and pressure vessels, such consumables are to be further represented by production test pieces taken from representative butt welds to prove the mechanical properties of the metal.

3.5 Material Certification and Tests

Materials, including welding consumables, entered into the construction of boilers and pressure vessels are to be certified by the material manufacturers as meeting the material specifications concerned. Certified mill test reports, traceable to the material concerned, are to be presented to the Surveyor for information and verification in all cases. In addition, where so indicated in 4-4-1/Table 3, materials of the main pressure parts, namely, steam and water drums, shell and heads, headers, shell flange, tubes, tubesheets, etc. are required to have their materials tested in the presence of a Surveyor to verify their compliance with the corresponding material specifications. Welding consumables, in these instances, are to have their mechanical strength verified by the testing of production test pieces.

5 Design

All boilers, steam generators, fired heaters, pressure vessels and heat exchangers required to be certified by 4-4-1/1.1 are to be designed in accordance with Appendix 4-4-1A1. Alternatively, a recognized code or standard (see 4-4-1/1.5) may be used for this purpose. All such designs are to be submitted for approval before proceeding with the fabrication.

7 Fabrication, Testing and Certification

7.1 Material Tests

Material tests are to be in accordance with 4-4-1/3.5.

7.3 Welded Fabrication

Welding of pressure parts and of non-pressure parts to pressure parts is to be performed by means of qualified welding procedures and by qualified welders. The qualification of welding procedures is to be conducted in accordance with Section 2-4-3 or the applicable boiler or pressure vessel standard or code. Welding procedure specifications and their qualification records are to be submitted for review as indicated in 4-4-1/1.13.5. The Surveyor is to have the option of witnessing the conduct of the qualification test, and may request additional qualification tests if there are reasons to doubt the soundness of the qualified procedure. Similarly, qualification of welders is to be in accordance with the applicable code and is to be to the satisfaction of the Surveyor.

7.5 Dimensional Tolerances

Parts to be welded are to be aligned within the tolerances specified in Section 2-4-2 or the applicable standard or code. The fitting of the main seams is to be examined by the Surveyor prior to welding. The conformance of formed heads to the theoretical shape and the out-of-roundness of the finished shells are to be within specified tolerances and are to be verified to the satisfaction of the Surveyor.

7.7 Nondestructive Examination

Radiographic examinations are to be in accordance with 2-4-2/23 or the applicable standard or code. All Group I boilers and pressure vessels are to have their butt seams fully radiographed. See 4-4-1/1.9. Group II pressure vessels are to be radiographed to the extent as required by the designed joint-efficiency. The radiography standard and acceptance criteria, along with the degree of other nondestructive examination, such as ultra-sonic, dye penetrant, or magnetic particle, are to be in accordance with the chosen standard or code. Radiographic films are to be submitted to the surveyor for review.

7.9 Preheat and Postweld Heat Treatment

Preheat and postweld heat treatment are to be in accordance with 2-4-2/11 through 2-4-2/17 or the applicable standard or code. All Group I boilers and pressure vessels are to be postweld heat treated. See 4-4-1/1.9. In addition, postweld heat treatment is to be carried out where required by, and in accordance with the applicable boiler or pressure vessel code or standard. The postweld heat treatment procedure is to be submitted to the Surveyor for review prior to the heat treatment.

7.11 Hydrostatic Tests *(1 July 2003)*

7.11.1 Boilers

The Surveyor is to witness hydrostatic tests on all boilers. The test pressure is not to be less than 1.5 times the maximum allowable working pressure or at such pressures as specified by the standard or code of compliance.

7.11.2 Pressure Vessels

The Surveyor is to witness hydrostatic tests on all pressure vessels. The test pressure is not to be less than 1.3 times the maximum allowable working pressure or at such pressures as specified by the standard or code of compliance. Where hydrostatic tests are impracticable, alternative methods of pressure tests, such as a pneumatic pressure test, may be considered for pressure vessels, subject to such test procedures being submitted for consideration in each case.

7.13 Manufacturer’s Documentation

The manufacturer is to submit documentation of fabrication records, including but not limited to material certificates, welding procedure qualification records, welder qualification records, heat treatment reports, nondestructive examination reports and dimensional check reports, as applicable, to the Surveyor for final review and acceptance.

9 Boiler Appurtenances

9.1 Safety Valves

9.1.1 General

9.1.1(a) Boiler (2004). Each boiler (including exhaust gas boiler) and steam generator is to be fitted with at least one safety valve and where the water-heating surface is more than 46.5 m^2 (500 ft^2), two or more safety valves are to be provided. The valves are to be of equal size as far as practicable and their aggregate relieving capacity is not to be less than the evaporating capacity of the boiler under maximum operating conditions. In no case, however, is the inlet diameter of any safety valve for propulsion boiler and superheaters used to generate steam for main propulsion and other machinery to be less than 38 mm (1.5 in.) nor more than 102 mm (4 in.). For auxiliary boilers and exhaust gas economizers, the inlet diameter of the safety valve must not be less than 19 mm ($^3/_4$ in.) nor more than 102 mm (4 in.).

9.1.1(b) Superheater. Each superheater, regardless of whether it can be isolated from the boiler or not, is to be fitted with at least one safety valve on the superheater outlet. See also 4-4-1/9.1.2(b).

9.1.1(c) Economizers. Each economizer, where fitted with a bypass, is to be provided with a sentinel relief valve, unless the bypass arrangement will prevent a buildup of pressure in the economizer when it is bypassed.

9.1.2 Minimum Relieving Capacity

9.1.2(a) Boiler. In all cases, the safety-valve relieving capacity is to be determined on the basis of the boiler heating surface and water-wall heating surface along with the fuel-burning equipment, and is not to be less than that given in the following table. Where certification by the boiler manufacturer of the evaporative capacity of the boiler under maximum operating conditions indicates a higher capacity, the higher capacity is to be used.

Minimum mass of steam per hour per heating surface area of oil-fired boilers, kg/h/m² (lb/h/ft²)		
Boiler Type	*Boiler Heating Surface*	*Waterwall Surface*
Fire-tube	39.1 (8)	68.3 (14)
Water-tube	48.8 (10)	78.1 (16)

9.1.2(b) Boilers with integral superheaters. Where a superheater is fitted as an integral part of a boiler with no intervening valve between the superheater and the boiler, the relieving capacity of the superheater safety valve, based on the reduced pressure, may be included in determining the total relieving capacity of the safety valves for the boiler as a whole. In such a case, the relieving capacity of the superheater safety valve is not to be credited for more than 25% of the total capacity required. The safety valves are to be so set and proportioned that, under any relieving condition, sufficient steam will pass through the superheater to prevent overheating the superheater. Specially designed full-flow superheater valves, pilot-operated from the steam drum, may be used.

9.1.2(c) Exhaust gas boiler. Minimum required relieving capacity of the safety valve is to be determined by the manufacturer. If auxiliary firing is intended in combination with exhaust gas heating, the relieving capacity is to take this into consideration. If auxiliary firing is intended only as an alternative to exhaust gas heating, the relieving capacity is to be based on the higher of the two.

9.1.2(d) Pressure rise during relieving. For each boiler, the total capacity of the installed safety valves is to be such that the valves will discharge all steam that can be generated by the boiler without allowing the pressure to rise more than 6% above the maximum allowable working pressure. See 4-4-1/9.1.8.

9.1.3 Pressure Settings

9.1.3(a) Boiler drum. At least one safety valve on the boiler drum is to be set at or below the maximum allowable working pressure. If more than one safety valve is installed, the highest setting among the safety valves is not to exceed the maximum allowable working pressure by more than 3%. The range of pressure settings of all the drum safety valves is not to exceed 10% of the highest pressure to which any safety valve is set.

In no case is the relief pressure to be greater than the design pressure of the steam piping or that of the machinery connected to the boiler plus the pressure drop in the steam piping.

9.1.3(b) Superheater. Where a superheater is fitted, the superheater safety valve is to be set to relieve at a pressure no greater than the design pressure of the steam piping or the design pressure of the machinery connected to the superheater plus pressure drop in the steam piping. In no case is the superheater safety valve to be set at a pressure greater than the design pressure of the superheater.

In connection with the superheater, the safety valves on the boiler drum are to be set at a pressure not less than the superheater-valve setting plus 0.34 bar (0.35 kgf/cm^2, 5 psi), plus approximately the normal-load pressure drop through the superheater. See also 4-4-1/9.1.3(a).

9.1.4 Easing Gear

Each boiler and superheater safety valve is to be fitted with an efficient mechanical means by which the valve disc may be positively lifted from its seat. This mechanism is to be so arranged that the valves may be safely operated from the boiler room or machinery space platforms, either by hand or by any approved power arrangement.

9.1.5 Connection to Boiler

Safety valves are to be connected directly to the boiler, except that they may be mounted on a common fitting; see 4-4-1/9.3. However, they are not to be mounted on the same fitting as that for the main or auxiliary steam outlet. This does not apply to superheater safety valves, which may be mounted on the fitting for the superheater steam outlet.

9.1.6 Escape Pipe

The area of the escape pipe is to be at least equal to the combined outlet area of all of the safety valves discharging into it. The pipe is to be so routed as to prevent the accumulation of condensate and is to be so supported that the body of the safety valve is not subjected to undue load or moment.

9.1.7 Drain Pipe

Safety valve chests are to be fitted with drain pipes leading to the bilges or a suitable tank. No valve or cock is to be fitted in the drain pipe.

9.1.8 Pressure Accumulation Test

Safety valves are to be set under steam and tested with pressure accumulation tests in the presence of the Surveyor. The boiler pressure is not to rise more than 6% above the maximum allowable working pressure when the steam stop valve is closed under full firing condition for a duration of 15 minutes for firetube boilers and 7 minutes for watertube boilers. During this test, no more feed water is to be supplied than that necessary to maintain a safe working water level. The popping point of each safety valve is not to be more than 3% above its set pressure.

Where such accumulation tests are impractical because of superheater design, an application to omit such tests may be approved, provided the following are complied with:

- All safety valves are to be set in the presence of the Surveyor.
- Capacity tests have been completed in the presence of the Surveyor on each valve type.
- The valve manufacturer supplies a certificate for each safety valve stating its capacity at the maximum allowable working pressure and temperature of the boiler.
- The boiler manufacturer supplies a certificate stating the maximum evaporation of the boiler.
- Due consideration is given to back pressure in the safety valve steam escape pipe.

9.1.9 Changes in Safety Valve Setting

Where, for any reason, the maximum allowable working pressure is lower than that for which the boiler and safety valves were originally designed, the relieving capacity of the valves under lower pressure is to be checked against the evaporating capacity of the boiler. For this purpose, a guarantee from the manufacturer that the valve capacity is sufficient for the new conditions is to be submitted for approval, or it is to be demonstrated by a pressure accumulation test, as specified in 4-4-1/9.1.8, conducted in the presence of a Surveyor.

9.3 Permissible Valve Connections on Boilers

9.3.1 Connection Method

All valves of more than 30 mm (1.25 in.) nominal diameter are to be connected to the boiler with welded or flanged joints. Where the thickness of the shell plate is over 12.7 mm (0.5 in.), or where the plate has been reinforced by welded pads, valves 30 mm (1.25 in.) nominal diameter and under may be attached by short, extra-heavy screwed nipples.

For studded connections, stud holes are not to penetrate the whole thickness of the shell plate and the depth of the thread is to be at least equal to 1.5 times the diameter of the stud.

9.3.2 Valve Materials

All valves attached to a boiler, either directly or by means of a distance piece, are to be forged or cast steel, except where the pressure does not exceed 24.1 bar (24.6 kgf/cm^2, 350 psi) and the steam temperature does not exceed 232°C (450°F), nodular cast iron Grade 60-40-18 (see 2-3-10/1) may be used.

Where temperature does not exceed 208°C (406°F), valves may be made of Type 1 bronze complying with 2-3-14/1. Where high temperature bronze is used, the temperature limit may be 288°C (550°F).

9.3.3 Valve Design

Valves are to comply with a recognized national standard, and are to be permanently marked in accordance with the requirements of the standard. Valves not complying with a recognized national standard are to be approved in each case. See 4-6-2/5.15.

9.5 Main Steam and Feed Valve Connections

9.5.1 General

All steam and feedwater connections to boilers are to have stop valves connected directly to the boilers. A distance piece between the boiler and the valve is permissible if the piece is as short as possible. The stop valves are to be arranged to close against boiler pressure, except that the stop valves on feedwater connections may close against feed water pressure. Screw down valves are to close with a clockwise motion of the hand when facing the top of the stem.

9.5.2 Steam Stop Valves

Main and auxiliary steam stop valves are to be fitted to each boiler. Where a superheater is fitted, main and auxiliary stop valves are to be located at the superheater to insure a flow of steam through the superheater at all times, except that where the total superheat temperature is low, alternative arrangement may be considered. Each steam stop valve exceeding 150 mm (6 in.) nominal diameter is to be fitted with a by-pass valve for plant warm-up purposes.

9.5.3 Feed Valves

9.5.3(a) Temperature differential. For boilers with a design pressure of 27.6 bar (28 kgf/cm^2, 400 psi) or over, the feed-water connection to the drum is to be fitted with a sleeve or other suitable device to reduce the effects of metal temperature differentials between the feed pipe and the shell or head of the drum.

Feed water is not to be discharged into a boiler in such a manner that it impinges directly against surfaces exposed to hot gases or the radiant heat of the fire.

9.5.3(b) Feed stop valve. A feed stop valve is to be fitted to each feedwater line to the boiler and is to be attached directly to the boiler. If an economizer forms a part of the boiler, the feedwater stop valve may be attached directly on the economizer. Consideration will be given to locating the valve near an operating platform, provided that the pipe between the economizer and the valve is a seamless steel pipe having all joints welded.

For feed water system requirements, see 4-6-6/5.

9.5.3(c) Feed stop check valve. In addition and adjacent to the stop valve in 4-4-1/9.5.3(b), a stop check valve is to be fitted, or as close thereto as practicable. A feedwater regulator may be interposed between the stop valve and the stop check valve if a by-pass is also fitted.

9.5.3(d) Feed water line between economizer and boiler. Boilers fitted with economizers are to be provided with a check valve located in the feed water line between the economizer and the boiler drum. This check valve is to be located as close to the boiler drum feed water inlet nozzle as possible. When a by-pass is provided for the economizer, the check valve is to be of the stop-check type.

9.7 Instrument Connections for Boilers

9.7.1 Water Gauges

9.7.1(a) Number of gauges. Each boiler is to have at least two approved independent means of indicating the water level, one of which is to be a direct reading gauge glass. On double-ended fire-tube boilers and on boilers with drums more than 4 m in length and with drum axis athwartships, these water-level indicators are to be fitted on or near both ends.

9.7.1(b) Gauge details. Water gauges are to be fitted with shutoff valves, top and bottom, and drain valves. Shutoff valves are to be of through-flow construction and are to have a means for clearly indicating whether they are open or closed. Shutoff valves for water columns are to be attached directly to the boilers, and the pipes to the columns are not to lead through smoke boxes or uptakes unless they are completely enclosed in open-ended tubes of sufficient size to permit free air circulation around the pipes. Glass water gauges are to be so located that the lowest visible level in the glass is either not lower than 51 mm (2 in.) above the lowest permissible water level specified in 4-4-1/9.7.1(c) below.

9.7.1(c) Lowest permissible water level. The lowest permissible water level referred to in 4-4-1/9.7.1(b) is to be as follows.

- Water tube boilers: the lowest permissible water level is to be just above [usually 25 mm (1 in.) above] the top row of tubes when cold; for boilers with tubes not submerged when cold, the manufacturer is to submit a lowest permissible level for consideration. In all cases, the lowest permissible level is to be submitted with the boiler design in each case for approval.
- Internally fired fire-tube boilers with combustion chambers integral with the boiler: 51 mm (2 in.) above the highest part of the combustion chamber.
- Vertical submerged-tube boilers: 25 mm (1 in.) above the upper tube sheet.
- Vertical fire-tube boilers: one half the length of the tubes above the lower tube sheet.

9.7.1(d) Marking of furnace top. The level of the highest part of the effective heating surface, e.g., the furnace crown of a vertical boiler and the combustion chamber top of a horizontal boiler, is to be clearly marked in a position adjacent to the water gauge glass.

9.7.2 Pressure Gauges

Each boiler is to be provided with a steam pressure gauge, which is to indicate pressure correctly up to at least 1.5 times the pressure at which the safety valves are set. Double-ended boilers are to have one such gauge at each end. Gauges are to be located where they can be easily seen and the highest permissible working pressure is to be specially marked.

9.9 Miscellaneous Connections

9.9.1 Try Cocks

Try cocks, when fitted, are to be attached directly to the head or shell of a boiler, except that in the case of water-tube boilers, they may be attached to the water column. The lowest try cock is to be located 51 mm (2 in.) higher than the lowest visible part of the gauge glass. Try cocks may only be considered one of the required means for determining the water level where the boiler is an auxiliary installation with a maximum allowable working pressure of not more than 10.3 bar (10.5 kgf/cm^2, 150 psi) and where the steam is not used for main propulsion.

9.9.2 Test Connections

At least one valve is to be fitted to each boiler for boiler-water testing. They are to be directly connected to the boiler in a convenient location, but are not to be connected to the water column or gauge.

9.9.3 Blow-off Arrangements

Each boiler is to have at least one blow-off valve attached to the boiler drum, either at the lowest part of the boiler or fitted with an internal pipe leading to the lowest part. Where this is not practicable for water tube boilers, the valve may be suitably located outside the boiler casing and attached to a pipe led to the lowest part of the boiler. This pipe is to be well supported, and where it may be exposed to direct heat from fire, it is to be protected by refractory or other heat resisting material so arranged that the pipe may be inspected and is not constrained against expansion.

Where a surface blow is fitted, the valve is to be located within the permissible range of the water level or fitted with a scum pan or pipe at this level.

9.9.4 Superheater Drain and Vent

Superheaters are to have valves or cocks fitted to permit drainage of headers. Arrangements are to be made for venting the superheater, and to permit steam circulation through the superheater when starting the boiler.

9.11 Inspection Openings

All boilers are to be provided with sufficient manholes or handholes for inspection and cleaning. The clear opening of manholes is to be not less than 300 mm by 400 mm (12 in. by 16 in.). A handhole opening in a boiler shell is not to be less than 60 mm by 90 mm (2.25 in. by 3.5 in.). Where, due to size or interior arrangement of a boiler, it is impractical to provide a manhole or other suitable opening for direct access, there are to be two or more handholes or other suitable openings through which the interior can be inspected. Consideration will be given to alternative provisions in other boiler standards or codes.

9.13 Dampers

When dampers are installed in the funnels or uptakes of vessels using oil, they are not to obstruct more than two-thirds of the flue area when closed, and they are to be capable of being locked in the open position when the boilers are in operation. In any damper installation, the position of the damper and the degree of its opening is to be clearly indicated. Where fitted, power-operated dampers for the regulation of superheater steam temperatures are to be submitted for approval in each case.

9.15 Guidance for Spare Parts

While spare parts are not required for class, the spare parts listed below are for unrestricted service and are provided as a guidance to assist in ordering spare parts which may be appropriate for the intended service. The maintenance of spare parts aboard each vessel is the responsibility of the owner.

- 1 set of springs and one set of studs and nuts for one safety valve of each size
- 12 gauge glasses with packings per boiler if of the round gauge glass type
- 2 gauge glasses with packings per boiler and 1 frame for each of 2 boilers if of the flat-gauge-glass type
- 1 boiler pressure gauge or gauge-testing apparatus

- 24 tube stoppers, but need not be more than the number necessary to plug 5% of each size of generator, waterwall, economizer and superheater tube for one boiler
- Tube material, welding machine, special welding rods and other materials needed to make weld repairs on welded wall boiler tubes. This equipment would replace tube stoppers needed for water walls
- Necessary special tools

9.17 Additional Requirements for Shell Type Exhaust Gas Economizers *(2007)*

9.17.1 Application

This requirement is applicable to shell type exhaust gas economizers that are intended to be operated in a flooded condition and that can be isolated from the steam piping system.

9.17.2 Design and Construction

Design and construction of shell type exhaust gas economizers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

9.17.3 Pressure Relief

9.17.3(a) Number of Valves. The shell type exhaust gas economizer is to be provided with at least one safety valve, and when it has a total heating surface of 46.5 m^2 (500 ft^2) or more, it is to be provided with at least two safety valves in accordance with 4-4-1/9.1.1

9.17.3(b) Discharge Pipe. To avoid the accumulation of solid matter deposits on the outlet side of safety valves, the discharge pipes and safety valve housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the shell type exhaust gas economizers where it will not pose threats to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements.

9.17.4 Pressure Indication

Every shell type exhaust gas economizer is to be provided with a means of indicating the internal pressure. A means of indicating the internal pressure is to be located so that the pressure can be easily read from any position from which the pressure may be controlled.

9.17.5 Lagging

Every shell type exhaust gas economizer is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

9.17.6 Feed Water

Every shell type exhaust gas economizer is to be provided with arrangements for pre-heating and de-aeration, addition of water treatment or combination thereof to control the quality of feed water to within the manufacturer's recommendations.

9.17.7 Operating Instructions

The manufacturer is to provide operating instructions for each shell type exhaust gas economizer which is to include reference to:

i) Feed water treatment and sampling arrangements.

ii) Operating temperatures – exhaust gas and feed water temperatures.

iii) Operating pressure.

iv) Inspection and cleaning procedures.

v) Records of maintenance and inspection.

vi) The need to maintain adequate water flow through the economizer under all operating conditions.

vii) Periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly.

viii) Procedures for using the exhaust gas economizer in the dry condition.

ix) Procedures for maintenance and overhaul of safety valves.

11 Boiler Control

11.1 Local Control and Monitoring

Suitable means to effectively operate, control and monitor the operation of oil fired boilers and their associated auxiliaries are to be provided locally. Their operational status is to be indicated by conventional instruments, gauges, lights or other devices to show the functional condition of the fuel system, feed water and steam systems. For details of these piping systems, see Section 4-6-6.

11.3 Manual Emergency Shutdown

Boiler forced-draft or induced-draft fans and fuel oil service pumps are to be fitted with remote means of control situated outside the space in which they are located so that they may be stopped in the event of fire arising in that space.

11.5 Control of Fired Boilers

11.5.1 Automatic Shutdown

All boilers, regardless of duties and degree of automation, are to be fitted with the following automatic shutdowns:

11.5.1(a) Burner Flame Scanner. Each burner is to be fitted with a flame scanner designed to automatically shut off the fuel supply to the burner in the event of flame failure. The shutoff is to be achieved within 6 seconds following flame extinguishment. In the case of failure of the flame scanner, the fuel to the burner is to be shut off automatically.

11.5.1(b) High and low water level sensors. High and low water level sensors are to be provided. A low water condition is to automatically shut off the fuel supply to the burners. The low water sensor is to be set to operate when the water level falls to a minimum safe level but at a level no lower than that visible in the gauge glass. Additionally, the water level sensor is to be located to minimize the effects of roll and pitch, or is to be provided with a short-time delay (approximately 5 seconds) to prevent trip-out due to transients or to the vessel's motion.

For auxiliary boilers intended for non-automatic operation under local supervision, a high water level sensor need not be fitted.

11.5.1(c) Forced draft. Forced draft failure is to automatically shut off the fuel supply to the burners.

11.5.1(d) Boiler control power. Loss of boiler control power is to automatically shut off the fuel supply to the burners.

11.5.1(e) Burners. Burners are to be arranged so that they cannot be withdrawn unless the fuel supply to the burners is cut off.

11.5.2 Alarms *(2002)*

11.5.2(a) Fuel oil shutoff. Actuation of any of the fuel shut-offs specified in 4-4-1/11.5.1 is to alert the boiler operator at the appropriate control station of such condition by means of visual and audible alarms.

11.5.2(b) Air supply and flue. Means are to be fitted to detect and alarm at an early stage in case of fire in the boiler air supply and the exhaust duct. In the absence of an air casing for small boilers, a heat (temperature) detector fitted in the windbox would meet this requirement.

4-4-1/Table 4 provides a summary of the required alarms and shutdowns.

TABLE 4
List of Alarms and Shutdowns – Fired Boilers *(2002)*

Monitored Parameter		*Alarm*	*Automatic Shutdown with Alarm*	*Notes*
A1	Boiler drum water level – low	x		4-4-1/11.5.1(b)
A2	Boiler drum water level – low-low		x	4-4-1/11.5.1(b)
A3	Boiler drum water level – high	x		4-4-1/11.5.1(b)
B1	Forced draft fan – failure		x	4-4-1/11.5.1(c)
B2	Air Supply Casing – fire	x		4-4-1/11.5.2(b)
C1	Burner flame – failure		x	4-4-1/11.5.1(a)
C2	Flame scanner – failure		x	4-4-1/11.5.1(a)
D1	Atomizing medium – off-limit condition	x		4-4-1/11.5.3(e)
E1	Uptake gas temperature – high	x		4-4-1/11.5.2(b)
F1	Control power supply – loss		x	4-4-1/11.5.1(d)

11.5.3 Automatic Boiler Control

Regardless of duties, boilers fitted with automatic control are to comply with 4-4-1/11.5.1 and 4-4-1/11.5.2 and the following.

11.5.3(a) Automatic boiler purge. Where boilers are fitted with an automatic ignition system, a timed boiler purge with all air registers open is required prior to ignition of the initial burner. The boiler purge may be initiated manually or automatically. The purge time is to be based on a minimum of four air changes of the combustion chamber and furnace passes. It is to be proven that the forced draft fan is operating and the air registers and dampers are open before the purge time commences.

11.5.3(b) Trial-for-ignition period. Means provided to temporarily by-pass the flame-scanner control system during a trial-for-ignition period is to be limited to 15 seconds from the time the fuel reaches the burners. Except for this trial-for-ignition period, there is to be no means provided to by-pass one or more of the burner flame scanner systems unless the boiler is being locally controlled.

11.5.3(c) Automatic burner light-off. Where boilers are fitted with an automatic ignition system, and where residual fuel oil is used, means are to be provided for lighting off the burners with igniters lighting properly-heated residual fuel oil. Alternatively, the burners may be lighted off with a light oil used as a pilot to ignite residual fuel oil. If all burners experience a flame failure, the initial burner is to be brought back into automatic service only in the low-firing position. To avoid the possibility of a false indication due to the failure of the flame scanner in the “flame-on” mode, the initial light-off burner is to be fitted with dual scanners or a scanner of the self-checking type.

11.5.3(d) Post purge. Immediately after normal shutdown of the boiler, an automatic purge of the boiler equal to the volume and duration of the pre-purge is to occur. Following closing of the master fuel valve due to safety actions, the post purge is not to automatically occur; it is to be carried out under manual control.

11.5.3(e) Atomizing medium. Off-limit condition of burner primary-air pressure or atomizing-steam pressure is to be alarmed.

11.7 Control for Waste Heat Boilers

In general, control of waste heat boilers is to be as for fired boilers, as applicable. The following specific requirements are also applicable.

11.7.1 Boilers not Designed to Operate with Low Water Level *(2002)*

11.7.1(a) Smoke tube type. A low water level condition is to be alarmed. Arrangements are to be provided to divert the exhaust gas in a low water level condition, either manually or automatically. Automatic diversion of exhaust gas is also to be alarmed.

Note: The above requirements for by-pass/diversion arrangements are not applicable to waste heat boilers designed for dry condition operations.

11.7.1(b) Water tube type. A condition of low water flow in the tubes is to be alarmed. Arrangements are to be provided to automatically start a standby feed water pump

4-4-1/Table 5 provides a summary of the required alarms.

TABLE 5
List of Alarms – Waste Heat Boilers *(2002)*

(not designed to operate with low water level)

Monitored Parameter		*Alarm*	*Notes*
Smoke tube type			
A1	Boiler drum water level – low	x	4-4-1/11.7.1(a)
B1	Exhaust gas automatic diversion	x	4-4-1/11.7.1(a)
C1	Exhaust gas temperature at outlet – high	x	4-4-1/11.5.2(b)
Water tube type			
D1	Water flow in the tubes – low	x	4-4-1/11.7.1(b)
E1	Exhaust gas temperature at outlet – high	x	4-4-1/11.5.2(b)

11.7.2 Soot Cleaning

Waste heat boilers with extended surface tubes are to be provided with soot cleaning arrangements, which are to be available while the boiler is in operation.

11.9 Control for Fired Water Heaters *(2002)*

In general, control of fired water heaters is to be as for fired boilers, as applicable.

4-4-1/Table 6 provides a summary of the required alarms and shutdowns.

TABLE 6
List of Alarms and Shutdowns – Fired Water Heaters *(2002)*

Monitored Parameter		*Alarm*	*Automatic Shutdown with Alarm*	*Notes*
A1	Heater water level – low	x		4-4-1/11.5.1(b)
A2	Heater water level – low-low		x	4-4-1/11.9 [4-4-1/11.5.1(b)]
A3	Heater water level – high	x		4-4-1/11.5.1(b)
B1	Forced draft fan – failure		x	4-4-1/11.9 [4-4-1/11.5.1(c)]
B2	Air supply casing – fire	x		4-4-1/11.5.2(b)
C1	Burner flame – failure		x	4-4-1/11.9 [4-4-1/11.5.1(a)]
C2	Flame scanner – failure		x	4-4-1/11.9 [4-4-1/11.5.1(a)]
D1	Atomizing medium – off limit condition	x		4-4-1/11.9 [4-4-1/11.5.3(e)]
E1	Uptake gas temperature – high	x		4-4-1/11.5.2(b)
F1	Control power supply – loss		x	4-4-1/11.9 [4-4-1/11.5.1(d)]

13 Thermal Oil Heaters

13.1 Appurtenances

13.1.1 Relief Valve

Each fired or exhaust gas heater for thermal oil is to be fitted with a suitable liquid relief valve. The relief valve is to be arranged to discharge into a suitable collection tank.

13.1.2 Sampling

Means are to be fitted to allow samples of thermal oil to be taken periodically for testing. Facilities are to be provided onboard for carrying out the necessary tests.

13.1.3 Expansion Tank

Vents from the thermal oil expansion tank and thermal oil storage tank are to be led to the weather. The pipe connection between the heater and the expansion tank is to be fitted with a valve at the tank capable of local manual operation and remote shutdown from outside the space where the tank is located.

13.3 Thermal Oil Heater Control

13.3.1 Local Control and Monitoring

Suitable means to effectively operate, control and monitor the operation of oil fired thermal oil heaters and their associated auxiliaries are to be provided locally. Their operational status is to be indicated by conventional instruments, gauges, lights or other devices to show the functional condition of fuel system, thermal oil circulation system, forced-draft system and flue gas system.

13.3.2 Automatic Control

In general, the thermal oil heating system is to be operated with an automatic burner and flow regulation control capable of maintaining the thermal oil at the desired temperature for the full range of operating conditions.

13.3.3 Monitoring and Automatic Shutdown *(2002)*

The requirements of 4-4-1/11.5.1(a), 4-4-1/11.5.1(c), 4-4-1/11.5.1(d) and 4-4-1/11.5.1(e) for boilers are also applicable for thermal oil heaters. In addition, automatic fuel shut-off is to be fitted for the conditions as indicated in 4-4-1/Table 7:

TABLE 7
List of Alarms and Shutdowns – Fired Thermal Oil Heaters *(2002)*

Monitored Parameter		*Automatic Shutdown with Alarm*	*Notes*
A1	Burner flame – failure	x	4-4-1/13.3.3 [4-4-1/11.5.1(a)]
A2	Flame scanner – failure	x	4-4-1/13.3.3 [4-4-1/11.5.1(a)]
B1	Forced draft system – failure	x	[4-4-1/11.5.1(c)]
C1	Control power supply – loss	x	[4-4-1/11.5.1(d)]
D1	Thermal oil expansion tank level – low	x	4-4-1/13.3.3
D2	Thermal oil temperature at oil outlet – high	x	4-4-1/13.3.3
D3	Thermal oil pressure or flow in circulation system – low	x	4-4-1/13.3.3
E1	Flue gas temperature – high	x	4-4-1/13.3.3

13.3.4 Remote Shutdown

Thermal oil circulating pumps, fuel oil service pumps and forced-draft fans are to be fitted with local means of operation and remote means of stopping from outside the space in which these equipment are located.

13.3.5 Valve Operation

The thermal oil main inlet and outlet are to be provided with stop valves arranged for local manual operation and for remote shutdown from outside the space in which the heater is located. Alternatively, arrangements are to be provided for quick gravity discharge of the thermal oil to a collection tank.

13.3.6 Fire Extinguishing System

The furnaces of thermal oil heaters are to be fitted with a fixed fire extinguishing system capable of being actuated locally and remotely from outside the space in which the heater is located.

13.5 Exhaust-gas Thermal Oil Heaters *(2002)*

Exhaust-gas thermal oil heaters are to comply with the following additional requirements:

i) The heater is to be so designed and installed that the tubes may be easily and readily examined for signs of corrosion and leakage.

ii) A high temperature alarm is to be provided in the exhaust gas piping for fire detection purposes.

iii) A fixed fire extinguishing and cooling system is to be installed within the exhaust gas piping. This may be a water drenching system, provided arrangements are made below the heater to collect and drain the water.

4-4-1/Table 8 provides a summary of the required alarms and shutdown.

TABLE 8
List of Alarms and Shutdowns – Exhaust-gas Thermal Oil Heaters *(2002)*

Monitored Parameter		*Alarm*	*Automatic Shutdown with Alarm*	*Notes*
A1	Thermal oil expansion tank level – low		x	4-4-1/13.5 (4-4-1/13.3.3)
A2	Thermal oil temperature at oil outlet – high		x	4-4-1/13.5 (4-4-1/13.3.3)
A3	Thermal oil pressure or flow in circulation system – low		x	4-4-1/13.5 (4-4-1/13.3.3)
B1	Exhaust gas temperature – high	x		4-4-1/13.5 ii)

15 Incinerators

15.1 Local Control and Monitoring

Suitable means to effectively operate, control and monitor the operation of incinerators and their associated auxiliaries are to be provided locally. Their operational status is to be indicated by conventional instruments, gauges, lights or other devices to show the functional condition of the fuel system, furnace temperature, forced-draft system and flue gas system. The provisions of 4-6-6/7 pertaining to the boiler fuel oil service piping system are also applicable to the incinerator fuel oil system.

15.3 Emergency Shutdown

Fuel oil service pumps and forced-draft fans are to be fitted with local means of operation and remote means of stopping from outside the space in which they are located.

15.5 Automatic Shutdowns

The requirements of 4-4-1/11.5.1(a), 4-4-1/11.5.1(c), 4-4-1/11.5.1(d) and 4-4-1/11.5.1(e) for boilers are also applicable for incinerator. In addition, automatic fuel shut-off is to be fitted for the following conditions:

- Flue gas temperature high
- Furnace temperature high

17 Pressure Vessel and Heat Exchanger Appurtenances

17.1 Pressure Relief Valve

Every pressure vessel and each chamber of every heat exchanger which can be subjected to a pressure greater than its design pressure is to be fitted with a pressure relief valve of suitable capacity. The relief valve is to be set at not more than the maximum allowable working pressure and is to be sized to prevent the pressure in the vessel from rising more than 10% or 0.21 bar (0.21 kgf/cm^2, 3 psi), whichever is greater, above the maximum allowable working pressure. Consideration will be given to the installation of the pressure relief valve in the piping system connected to the pressure vessel, provided that this relief valve is of the required capacity and that it cannot be isolated from the pressure vessel by the intervening valve. Attention is also to be directed to the requirements of the safety relief valve in the code or standard of compliance.

17.3 Inspection Openings

17.3.1 Diameter Over 915 mm (36 in.)

All pressure vessels and heat exchangers over 915 mm (36 in.) inside diameter are to be provided with a manhole or at least two handholes. An elliptical or obround manhole is not to be less than 279 mm by 381 mm (11 in. by 15 in.) or 254 mm by 406 mm (10 in. by 16 in.). A circular manhole is not be less than 381 mm (15 in.) inside diameter and a handhole is not to be less than 102 mm by 152 mm (4 in. by 6 in.).

17.3.2 Diameter Over 457 mm (18 in.)

At least two inspection openings, closed by pipe plugs of not less than 50 mm (2 in.) nominal, will be acceptable for vessels with diameters of 915 mm (36 in.) or less and over 457 mm (18 in.).

17.3.3 Diameter Over 305 mm (12 in.)

For vessel diameters 457 mm (18 in.) or less and over 305 mm (12 in.), at least two pipe plugs of not less than 40 mm (1.5 in.) nominal may be used.

17.3.4 Diameter 305 mm (12 in.) or Less

For vessel diameters 305 mm (12 in.) or less, at least two pipe plugs of not less than 20 mm ($^3/_4$ in.) nominal may be used.

17.3.5 Alternative Arrangements

Consideration will be given to alternative arrangements which can be shown to provide for an equivalent degree of internal inspection. Flanged and/or threaded connections from which piping instruments or similar attachments can be removed may be an acceptable alternative, provided that the connections are at least equal to the size of the required openings and the connections are sized and located to afford at least an equal view of the interior as the required openings.

17.5 Drain

Pressure vessels subject to corrosion are to be fitted with a suitable drain opening at the lowest point practicable; or a pipe may be used extending inward from any location to the lowest point.

19 Installation and Shipboard Trials

19.1 Seating Arrangements

Boilers, pressure vessels and other pressurized or fired equipment are to be properly secured in position on supports constructed in accordance with approved plans. Structural supports for fired equipment are not to be of heat sensitive material.

19.3 Boiler Installation

19.3.1 Bottom Clearance

The distance between the boiler and the floors or inner bottom is not to be less than 200 mm (8 in.) at the lowest part of a cylindrical boiler. This distance is not to be less than 750 mm (30 in.) between the bottom of the furnace (or boiler pan) and tank top (or floor) in the case of water-tube boilers. See also 3-2-4/1.1 and 3-2-4/9.5.

19.3.2 Side Clearance

The distance between boilers and vertical bulkheads is to be sufficient to provide access for maintenance of the structure; and, in the case of bulkheads in way of fuel oil and other oil tanks, the clearance is to be sufficient to prevent the temperature of the bulkhead from approaching the flash point of the oil. This clearance, generally, is to be at least 750 mm (30 in.).

19.3.3 Top Clearance

Sufficient head room is to be provided at the top of boiler to allow for adequate heat dissipation. This clearance is, generally, not to be less than 1270 mm (50 in.). No fuel oil or other oil tank is to be installed directly above any boiler.

19.3.4 Tween Deck Installation

Where boilers are located on tween decks in machinery spaces and boiler rooms are not separated from a machinery space by watertight bulkheads, the tween decks are to be provided with coamings at least 200 mm (8 in.) in height. This area may be drained to the bilges.

19.3.5 Hot Surfaces

Hot surfaces likely to come into contact with the crew during operation are to be suitably guarded or insulated. Where the temperature of hot surfaces are likely to exceed 220°C (428°F), and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid is likely to come into contact with such surfaces, they are to be suitably insulated with materials impervious to such liquid. Insulation material not impervious to oil is to be encased in sheet metal or an equivalent impervious sheath.

19.3.6 Ventilation

The spaces in which the oil fuel burning appliances are fitted are to be well ventilated.

19.3.7 Fire Protection

Boiler space is to be considered a machinery space of category A and is to be provided with fixed fire extinguishing system and other fire fighting equipment, as specified in 4-7-2/1.1.

19.5 Installation of Thermal Oil Heaters and Incinerators

In general, the installation of thermal oil heaters, incinerators and other fired equipment is to be in accordance with 4-4-1/19.3. Consideration should be given to installing thermal oil heaters in a space separated from the propulsion machinery space. Where fired equipment is installed in a space which is not continuously manned, it is also to be protected by a fire detection and alarm system.

19.7 Shipboard Trials

19.7.1 Boilers

All boilers are to be functionally tested after installation in the presence of a Surveyor. The test is to include proof of actuation of all safety devices. Safety valves are to be tested by boiler pressure accumulation test or its equivalent; see 4-4-1/9.1.8.

19.7.2 Pressure Vessels and Heat Exchangers

Pressure vessels and heat exchangers are to be functionally tested with the systems in which they form a part.

19.7.3 Thermal Oil Heaters and Incinerators

Thermal oil heaters, incinerators and other fired equipment are to be functionally tested after installation in the presence of a Surveyor.

PART

4

CHAPTER 4 Boilers, Pressure Vessels and Fired Equipment

SECTION 1 Appendix 1 – Rules for Design

1 General

1.1 Application

These requirements apply to the design and fabrication of boilers and pressure vessels. They are based on ASME Boiler and Pressure Vessel Code Section I and Section VIII Div. 1. As an alternative to these requirements, codes and standards indicated in 4-4-1/1.5 may be used.

1.3 Loads Other than Pressure

All boilers and pressure vessels designed with the provisions of this appendix are to take into account the hydrostatic head when determining the minimum thickness. Although not provided in the design rules of this appendix, additional stresses imposed by effects other than pressure or static head which increase the average stress by more than 10% of the allowable working stress are also to be taken into account. These effects include the static and dynamic weight of the unit and its content, external loads from connecting equipment, piping and support structure, thermal stress, fluctuating temperature or pressure conditions, as well as loads during hydrostatic testing.

1.5 Deformation Testing

Where the use of these Rules is impracticable due to the shape of a proposed pressure vessel, a submission may be made for approval of maximum allowable working pressure determined from a hydrostatic deformation test made on a full-sized sample. Consideration will be given to maximum allowable working pressure determined means of empirical equations and hydrostatic deformation test data in accordance with a recognized standard.

1.7 Plate and Pipe Thickness Tolerance

Plate and pipes are to be ordered not thinner than design thickness. Vessels made of plate furnished with mill under tolerance of not more than the smaller value of 0.25 mm (0.01 in.) or 6% of the ordered thickness may be used at the full design pressure for the thickness ordered.

3 Cylindrical Shell Under Internal Pressure

3.1 General Equations

Seamless and fusion-welded shells are to be in accordance with the following equations. The equations to be used are subject to 4-4-1A1/3.3 for boiler shells and to 4-4-1A1/3.5 for pressure vessel shells.

$$W = \frac{fSE(T-C)}{R+(1-y)(T-C)} \quad \text{or} \quad T = \frac{WR}{fSE-(1-y)W} + C \qquad (1)$$

$$W = \frac{fSE\left\{(R_o - C)^2 - R^2\right\}}{(R_o - C)^2 + R^2} \qquad (2)$$

$$W = \frac{2fSE(T-C)}{D-2y(T-C)} \quad \text{or} \quad T = \frac{WD}{2fSE+2yW} + C \quad \text{for } W \geq 6.9 \text{ bar} \qquad (3)$$

where

f = factor for units of measure = 10 (100, 1) for SI (MKS, US) units respectively

W = maximum allowable working pressure; bar (kgf/cm^2, psi)

For equation (3), W is not to be taken as less than 6.9 (7, 100) respectively for any condition of service or steel material

S = maximum allowable working stress at the design temperature material, to be obtained from 4-4-1A1/Table 2; in N/mm^2 (kgf/mm^2, psi)

E = efficiency of longitudinal joint or efficiency of ligaments between tube holes or efficiency of other closely spaced openings, whichever is the least; dimensionless; see 4-4-1A1/3.3.4, 4-4-1A1/3.3.5 and 4-4-1A1/3.5.4.

T = minimum thickness of shell, mm (in.)

R = inside radius of the weakest course of the shell; mm (in.)

R_o = outside radius of the above shell under consideration; mm (in.)

D = outside diameter of header or drum, mm (in.)

C = corrosion allowance, see 4-4-1A1/3.3.6 and 4-4-1A1/3.5.2; mm (in.)

y = coefficient having values as follows (values between temperatures may be interpolated):

	≤482°C 900°F	*510°C 950°F*	*538°C 1000°F*	*566°C 1050°F*	*593°C 1100°F*	*≥621°C 1150°F*
Ferritic steel	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic steel	0.4	0.4	0.4	0.4	0.5	0.7

3.3 Boiler Shells

3.3.1 Thickness Less than One-half the Inside Radius

Where the thickness is less than one-half the inside radius, drums and headers are to be in accordance with Equation (1) or (3).

3.3.2 Thickness Greater than One-half the Inside Radius

The maximum allowable working pressure for parts of boilers of cylindrical cross section designed for temperatures up to that of saturated steam at critical pressure (374.1°C, 705.4°F) is to be determined using Equation (2).

3.3.3 Minimum Thickness

The minimum thickness of any boiler plate under pressures is to be 6.4 mm (0.25 in.), or when pipe over 127 mm (5 in.) OD is used in lieu of plate for the shell of cylindrical components under pressure, its minimum wall is to be 6.4 mm (0.25 in.).

3.3.4 Weld Seam Efficiency

The value of E is to be as follows and is to be used for calculations for the corresponding part of the shell.

- *Seamless shells:* E = 1.00.
- *Welded shells:* longitudinal and circumferential weld seams of boiler shells are to be accomplished by double-welded butt type, or equivalent, and are to be examined for their full length by radiography, E = 1.00.

3.3.5 Ligament Efficiency

3.3.5(a) Longitudinal ligament. When tube holes parallel to the longitudinal axis are such that the pitch of the tube on every row is equal, as in 4-4-1A1/Figure 1, E is to be given by the equation:

$$E = \frac{p - d}{p}$$

When the pitch of the tube holes on any one row is unequal, as in 4-4-1A1/Figures 2 and 3, E is to be given by the equation:

$$E = \frac{p_1 - nd}{p_1}$$

where

p, p_1 = pitch of tubes; mm (in.)

d = diameter of tube holes, mm (in.)

n = number of tube holes in pitch p_1

3.3.5(b) Diagonal ligament efficiency. Where the tube holes are as shown in 4-4-1A1/Figure 4, the efficiency of such ligaments is to be determined from 4-4-1A1/Figure 5. When the diagonal efficiency is less than the efficiency determined from 4-4-1A1/3.3.5(a), it is to be used in calculating the minimum shell thickness.

FIGURE 1
Example of Tube Spacing With Pitch of Holes Equal in Every Row

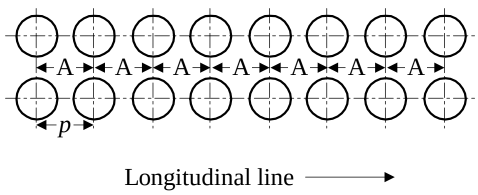


FIGURE 2
Example of Tube Spacing with Pitch of Holes Unequal in Every Second Row

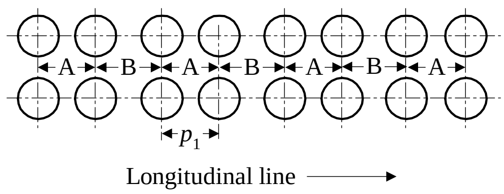


FIGURE 3
Example of Tube Spacing with Pitch of Holes Varying in Every Second Row

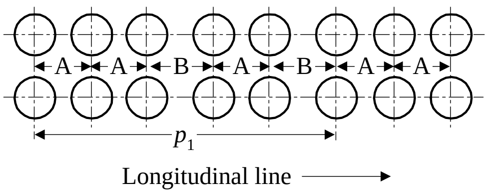


FIGURE 4
Example of Tube Spacing with Tube Holes on Diagonal Lines

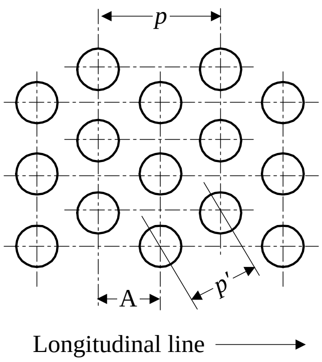
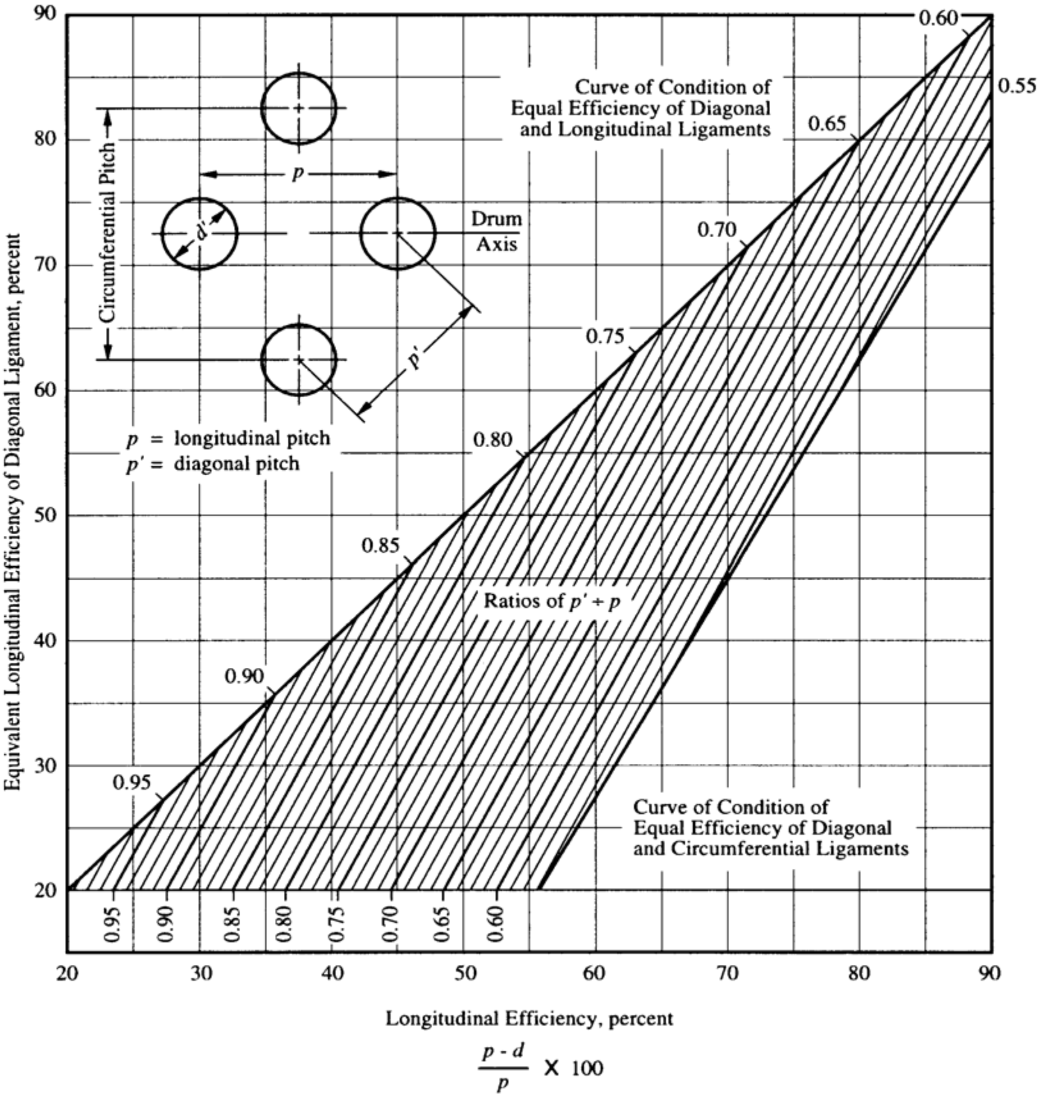


FIGURE 5
Diagram for Determination of Diagonal Efficiency



3.3.5(c) Unsymmetrical ligament efficiency. When tubes or holes are unsymmetrically spaced, the average ligament efficiency is to be not less than that given by the following requirements, which apply to ligaments between tube holes and not to single openings. This procedure may give lower efficiencies in some cases than those for symmetrical groups which extend a distance greater than the inside diameter of the shell as covered under 4-4-1A1/3.3.5(a) and 4-4-1A1/3.3.5(b). When this occurs, the efficiencies computed under 4-4-1A1/3.3.5(a) and 4-4-1A1/3.3.5(b) are to be used.

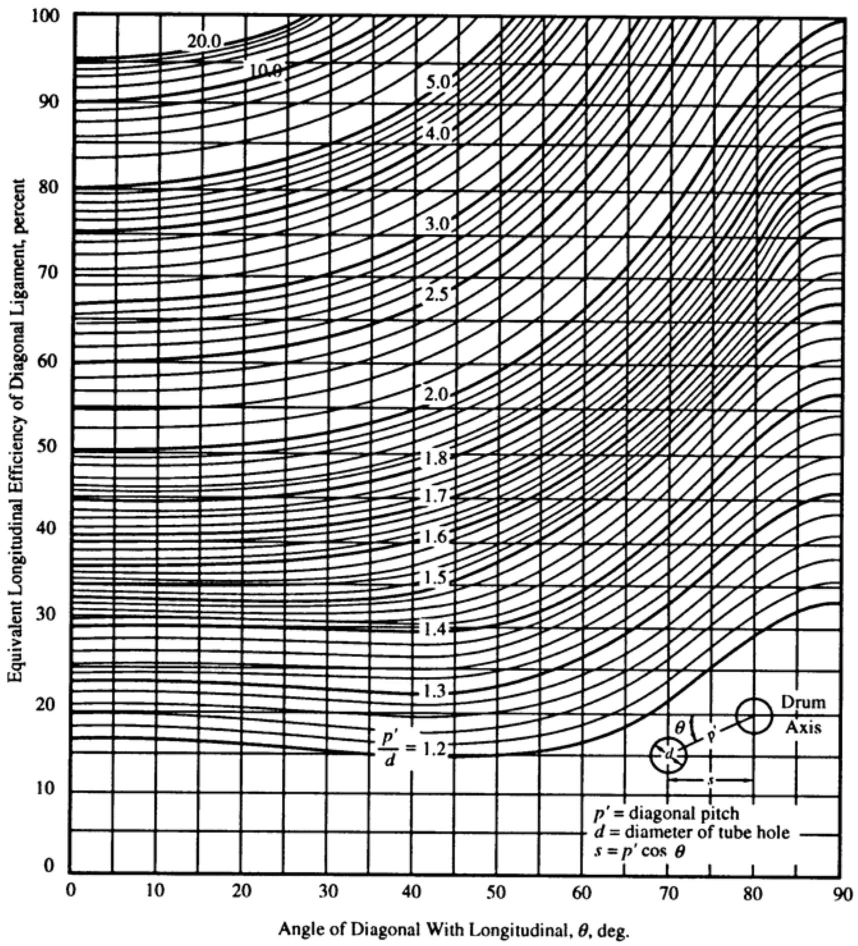
i) For a length equal to the inside diameter of the drum for the position which gives the minimum efficiency, the efficiency is to be not less than that on which the maximum allowable pressure is based. When the diameter of the drum exceeds 1525 mm (60 in.), the length is to be taken as 1525 mm (60 in.) in applying this requirement.

ii) For a length equal to the inside radius of the drum for the position which gives the minimum efficiency, the efficiency is to be not less than 80% of that on which the maximum allowable pressure is based. When the radius of the drum exceeds 762 mm (30 in.), the length is to be taken as 762 mm (30 in.) in applying this requirement.

iii) For holes placed longitudinally along a drum but which do not come in a straight line, the above Rules for calculating efficiency are to hold, except that the equivalent longitudinal width of a diagonal ligament is to be used. To obtain the equivalent width, the longitudinal pitch of the two holes having a diagonal ligament is to be multiplied by the efficiency of the diagonal ligament as given in 4-4-1A1/Figure 6.

3.3.5(d) Circumferential ligament efficiency. The efficiency of circumferential ligaments is to be determined in a manner similar to that of the longitudinal ligaments in 4-4-1A1/3.3.5(a) and is to be equal to at least one-half the efficiency of the latter.

FIGURE 6
Diagram for Determining Efficiency of Diagonal Ligaments in Order to Obtain Equivalent Longitudinal Efficiency



3.3.6 Corrosion Allowance, *C*

A corrosion allowance is to be added if corrosion or erosion is expected. The value is to be specified in the submitted plans.

3.5 Pressure Vessel Shells

3.5.1 Maximum Allowable Working Pressure

The maximum allowable working pressure is to be determined using Equation (1) when W does not exceed 3.85SE (SI units), 38.5SE (MKS units), or 0.385SE (US units) or when the thickness does not exceed one half of the inside radius. Where the thickness of the shell exceeds one-half of the inside radius, or when W exceeds 3.85SE (SI units) pressure vessels designed for pressures above 207 bar (210 kgf/cm^2, 3000 psi), Equation (2) is to be used.

3.5.2 Corrosion Allowance

A corrosion allowance, C, of not less than one-sixth of the calculated thickness is to be used in determining the thickness of pressure vessels intended for air, steam or water or any combination thereof when they are designed with S values taken from 4-4-1A1/Table 2 and the minimum required thickness is less than 6.4 mm (0.25 in.), except that the sum of the calculated thickness and corrosion allowance need not exceed 6.4 mm (0.25 in.). This corrosion allowance is to be provided on the surface in contact with the substance. A corrosion allowance may be omitted for the following cases:

- When 0.8 of the S values taken from 4-4-1A1/Table 2 are used in the design or,
- When values of E in column (c) of 4-4-1A1/Table 1 are used in the design, or
- When seamless vessel parts are designed with E = 0.85.

3.5.3 Minimum Thickness

Plates are not to be less than 2.4 mm ($^3/_{32}$ in.) thick after forming and without allowance for corrosion.

3.5.4 Weld Joint Efficiency

Efficiencies for welded, unfired pressure vessels are to be determined from 4-4-1A1/Table 1. For Group I pressure vessels, longitudinal and circumferential weld seams of shell are to be accomplished by double-welded butt type, or equivalent, and are to be examined for their full length by radiography, in which case, E = 1.00.

5 Unstayed Heads

5.1 Torispherically and Hemispherically Dished Heads

5.1.1 Minimum Thickness

The minimum thickness for heads without manholes or handholes and having the pressure on the concave side is to be determined by the following equation. See 4-4-1A1/Figures 7u and 7v. For heads having pressure on the convex side, see 4-4-1A1/5.1.7.

$$T = \frac{WRM}{2fSE - 0.2W} + C$$

$$M = 0.25\left(3 + \sqrt{\frac{R}{r}}\right)$$

M = 1.00 for hemispherically dished heads

where

T = minimum thickness of the head; mm (in.)

W = maximum working pressure; bar (kgf/cm^2, psi)

R = radius to which the head is dished, measured on the concave side, see 4-4-1A1/5.1.2; mm (in.)

r = knuckle radius of head, see 4-4-1A1/5.1.3; mm (in.)

S = maximum allowable working stress, see 4-4-1A1/5.1.4; N/mm^2 (kgf/mm^2, psi)

E = lowest efficiency of any joint in the head, see 4-4-1A1/5.1.5

C = corrosion allowance, see 4-4-1A1/5.1.6; mm (in.)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

5.1.2 Dish Radius

The radius to which a head is dished is to be not greater than the outside diameter of the flanged portion of the head.

5.1.3 Knuckle Radius

The inside radius of the flange formed on any head for its attachment to the shell plate is to be

- Not less than three (3) times the thickness of the head, and
- In the case of dished heads, not less than 6% of the outside diameter of the flanged portion of the head.

5.1.4 Maximum Allowable Working Stress

The maximum allowable working stress may be taken from 4-4-1A1/Table 2, except that in the case of pressure vessels where spot radiography is not carried out the maximum allowable unit working stress is not to exceed 0.85 of the appropriate *S* value in 4-4-1A1/Table 2.

5.1.5 Joint Efficiency

For boilers and Group I pressure vessels, weld seams in the heads are to be of the double-welded butt type and are to be fully radiographed, thus, $E = 1$. For seamless heads, use $E = 1.00$. For Group II pressure vessels, use *E* values in 4-4-1A1/Table 1.

Head to shell seams are to be considered circumferential seams of shell and are to be dealt with as in 4-4-1A1/3.3.4 for boiler and 4-4-1A1/3.5.4 for Group I pressure vessels. However, for hemispherical heads without a skirt, where the attachment of the head to the shell is at the equator, the head to shell joint is to be included in evaluating the joint efficiency of the head.

5.1.6 Corrosion Allowance

The values of the corrosion allowance are to be in accordance with 4-4-1A1/3.3.6 for boilers and 4-4-1A1/3.5.2 for pressure vessels.

5.1.7 Heads Having Pressure on the Convex Side

The minimum thickness of a dished head having pressure on the convex side is not to be less than the thickness calculated by the equation in 4-4-1A1/5.1.1 using $1.67 \times W$, where *W* is the maximum working pressure on the convex side.

5.3 Ellipsoidal Heads

5.3.1 Heads with Pressure on the Concave Side

The minimum thickness of a dished head of an ellipsoidal form having pressure on the concave side is to be in accordance with the following equation:

$$T = \frac{WDK}{2fSE - 0.2W} + C$$

$$K = \frac{1}{6}\left[2 + \left(\frac{D}{2h}\right)^2\right]$$

where

h = inside depth of the head not including the skirt; mm (in.) (see 4-4-1A1/Figure 7t)

D = inside diameter of the head skirt; mm (in.) (see 4-4-1A1/Figure 7t)

T, *W*, *S*, *E*, *C* and *f* are as defined in 4-4-1A1/5.1.

5.3.2 Heads with Pressure on the Convex Side

The minimum thickness of a dished head having pressure on the convex side is not to be less than the thickness calculated by the equation in 4-4-1A1/5.3.1 using 1.67 × *W*, where *W* is the maximum working pressure on the convex side.

5.5 Heads with Access Openings

5.5.1 Torispherically- and Hemispherically-dished Heads

When a dished head has a manhole or other access opening exceeding 152 mm (6 in.) in any dimension and it is not reinforced in accordance with 4-4-1A1/7, the head thickness determined by 4-4-1A1/3.1, using $M = 1.77$, is to be increased by 15%, but in no case by less than 3.2 mm (0.125 in.).

5.5.2 Ellipsoidal Heads

If a flanged-in manhole is placed in an ellipsoidal head, the thickness is to be the same as for a spherically dished head with a dish radius equal to 0.8 of the inside diameter of the shell and with added thickness for the manhole as called for in 4-4-1A1/5.5.1.

5.5.3 Manhole Flange Depth

A flanged-in manhole opening in a dished head is to be flanged to a depth of not less than three times the required thickness of the head for plate up to 38 mm (1.5 in.) in thickness. For plate exceeding 38 mm (1.5 in.), the depth is to be the required thickness of the plate plus 76 mm (3 in.). The flange depth is to be measured from the outside of the opening along the major axis.

5.5.4 Reinforced Access Openings

When an access opening is reinforced in accordance with 4-4-1A1/7.3, the head thickness may be the same as for a blank head.

5.7 Unstayed Flat Heads

5.7.1 General

The minimum thickness for unstayed flat heads is to conform to the provisions of 4-4-1A1/5.7. These provisions apply to both circular and noncircular heads and covers. Some acceptable types of flat heads and covers are shown in 4-4-1A1/Figure 7. In this figure, the dimensions of the component parts and the dimensions of the welds are exclusive of extra metal required by corrosion allowance.

5.7.2 Definitions of Symbols Used

B = total bolt load, as further defined hereunder; N (kgf, lbf)

C = corrosion allowance, see 4-4-1A1/3.3.6 for boilers and 4-4-1A1/3.5.2 for pressure vessels

D = long span of noncircular heads or covers measured perpendicular to short span; m (in.)

d = diameter, or short span, measured as indicated in 4-4-1A1/Figure 7, mm (in.)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

h_g = gasket moment arm, equal to the radial distance from the center line of the bolts to the line of the gasket reaction, as shown in 4-4-1A1/Figures 7j and 7k; mm (in.)

K = factor depending on the method of attachment of the head; on the shell, pipe or header dimensions; and on other items as listed in 4-4-1A1/5.7.3(d) below, dimensionless

L = perimeter of noncircular bolted head measured along the centers of the bolt holes; mm (in.)

ℓ = length of flange of flanged heads, measured from the tangent line of knuckle, as indicated in 4-4-1A1/Figure 7a, c-1 and c-2; mm (in.)

m = t_r/t_s

r = inside corner radius on the head formed by flanging or forging; mm (in.)

S = maximum allowable stress value from 4-4-1A1/Table 2; N/mm^2 (kgf/mm^2, psi)

t = minimum required thickness of flat head or cover; mm (in.)

t_e = minimum distance from beveled end of drum, pipe or header, before welding, to outer face of head, as indicated in 4-4-1A1/Figure 7i; mm (in.)

t_f = actual thickness of the flange on a forged head, at the large end, as indicated in 4-4-1A1/Figure 7b-1, mm (in.)

t_h = actual thickness of flat head or cover; mm (in.)

t_ℓ = throat dimension of the closure weld, as indicated in 4-4-1A1/Figure 7r; mm (in.)

t_r = required thickness of seamless shell, pipe or header, for pressure; mm (in.)

t_s = actual thickness of shell, pipe or header; mm (in.)

t_w = thickness through the weld joining the edge of a head to the inside of a drum, pipe or header, as indicated in 4-4-1A1/Figure 7g; mm (in.)

W = maximum allowable working pressure; bar (kgf/cm^2, psi)

Z = factor for noncircular heads and covers that depends on the ratio of short span to long span, as given in 4-4-1A1/5.7.3(c).

FIGURE 7
Some Acceptable Types of Unstayed Heads and Covers

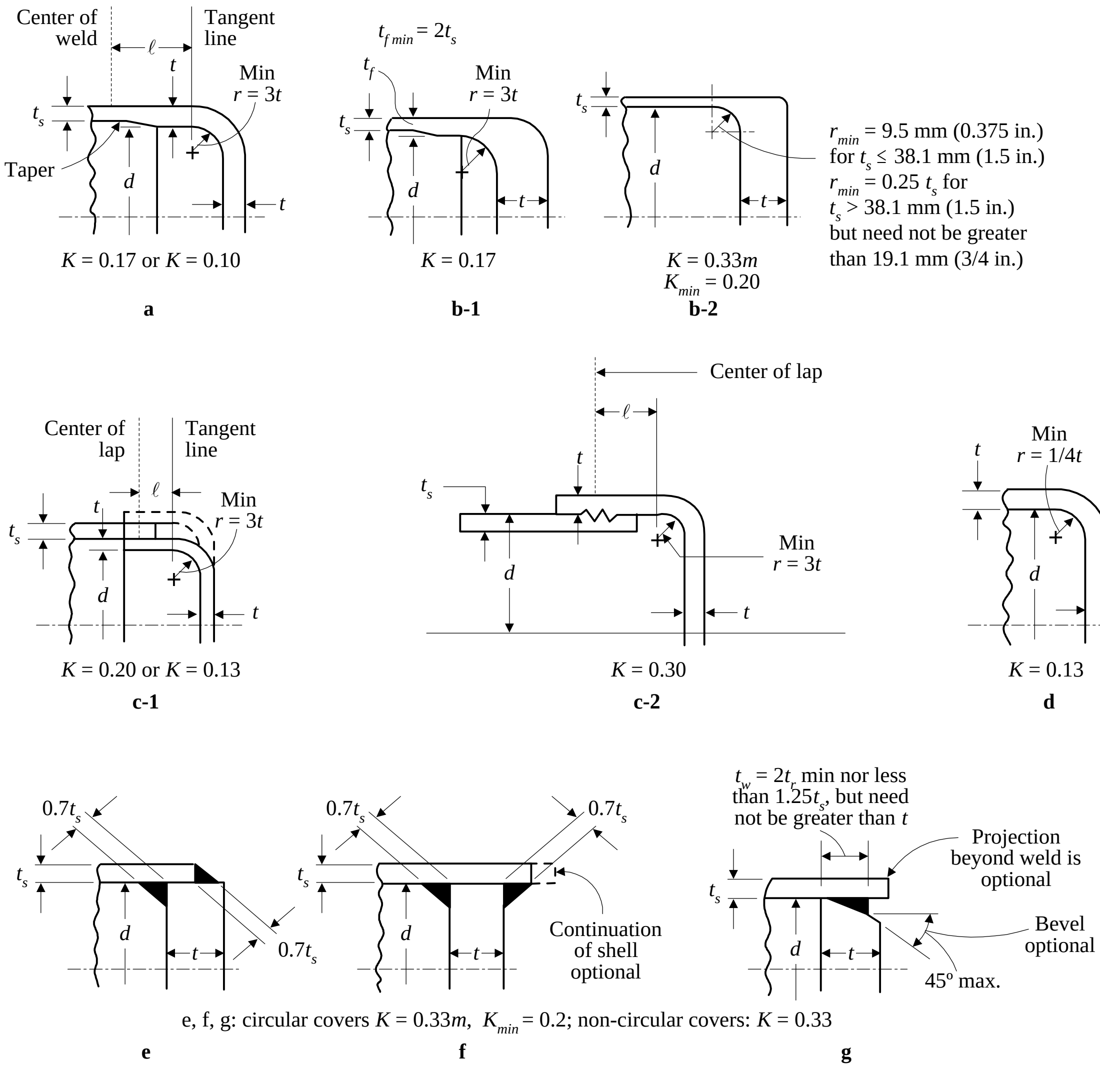
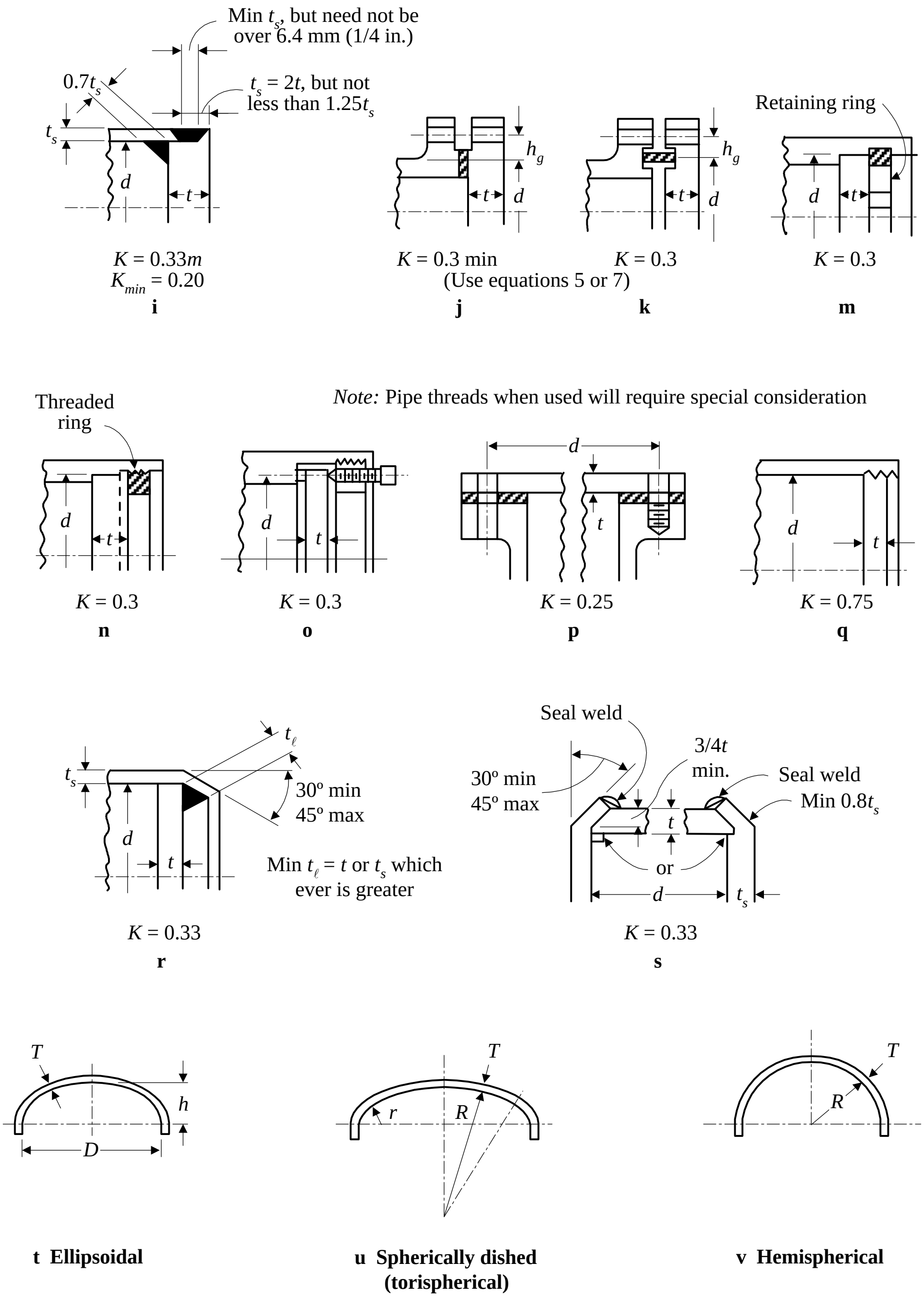


FIGURE 7 (continued)
Some Acceptable Types of Unstayed Heads and Covers



5.7.3 Equations for Minimum Thickness

The following provisions are to be used to evaluate the minimum required thickness for flat unstayed heads, covers, and blind flanges. The equations in 4-4-1A1/5.7.3(b) through 4-4-1A1/5.7.3(d) allow for pressure and bolt loading only. Greater thickness may be necessary if deflection would cause leakage at threaded or gasketed joints.

5.7.3(a) Standard blind flanges. Circular blind flanges of ferrous materials conforming to ANSI B16.5 will be acceptable for the pressure-temperature ratings specified in the Standard. These flanges are shown in 4-4-1A1/Figures 7j and 7k. Blind flanges complying with other compatible recognized national or international standards may be submitted for approval.

5.7.3(b) Circular heads. The minimum required thickness of flat unstayed circular heads, covers and blind flanges is to be calculated by the following equation:

$$t = d\sqrt{\frac{KW}{fS}} + C \qquad (4)$$

except when the head, cover or blind flange is attached by bolts causing an edge moment (see 4-4-1A1/Figures 7j and 7k), in which case the thickness is to be calculated by the following equation:

$$t = d\sqrt{\frac{KW}{fS} + \frac{1.9Bh_g}{Sd^3}} + C \qquad (5)$$

When using Equation 5, the thickness t is to be calculated for both initial tightening and design conditions, and the greater of the two values is to be used. For initial tightening conditions, the value for S at room temperature is to be used, and B is to be the average of the required bolt load and the load available from the bolt area actually used. For design conditions, the value for S at design temperature is to be used, and B is to be the sum of the bolt loads required to resist the end-pressure load and to maintain tightness of the gasket.

5.7.3(c) Noncircular heads. Flat unstayed heads, covers or blind flanges may be square, rectangular, elliptical, obround, segmental or otherwise noncircular. Their required thickness is to be calculated by the following equations:

$$t = d\sqrt{\frac{ZKW}{fS}} + C \qquad (6)$$

$$Z = 3.4 - 2.4\frac{d}{D} \quad \text{with } Z \le 2.5$$

except where the noncircular heads, covers, or blind flanges are attached by bolts causing a bolt edge moment (see 4-4-1A1/Figures 7j and 7k), in which case the required thickness is to be calculated by the following equation:

$$t = d\sqrt{\frac{ZKW}{fS} + \frac{6Bh_g}{SLd^2}} + C \qquad (7)$$

When using Equation 7, the thickness t is to be calculated for both initial tightening and design conditions, as prescribed for Equation 5.

5.7.3(d) K values. For the types of construction shown in 4-4-1A1/Figure 7, the values of K to be used in Equations 4, 5, 6, and 7 are to be as follows.

i) *4-4-1A1/Figure 7a*: K = 0.17 for flanged circular and noncircular heads, forged integral with or butt-welded to the shell, pipe or header. The inside corner radius is not to be less than three times the required head thickness, with no special requirement with regard to the length of the flange. Welding is to meet all of the requirements for circumferential joints given in Section 2-4-2.

K = 0.10 for circular heads, when the flange length for heads of the above design is not less than that given in the following equation and the taper is no greater than 1:3:

$$\ell = \left(1.1 - \frac{0.8t_s^2}{t_h^2}\right)\sqrt{dt_h} \quad \text{.......... (8)}$$

ii) *4-4-1A1/Figure 7b-1*: K = 0.17 for circular and noncircular heads, forged integral with or butt-welded to the shell, pipe or header. The corner radius on the inside is not less than three times the thickness of the flange and welding meets all of the requirements for circumferential joints given in Section 2-4-2.

iii) *4-4-1A1/Figure 7b-2*: $K = 0.33m$ but not less than 0.20 for forged circular and noncircular heads integral with or butt welded to the vessel, where the flange thickness is not less than the shell thickness and the corner radius on the inside is not less than the following.

r_{min} = 9.5 mm (0.375 in.) for $t_s \le 38.1$ mm (1.5 in.)

r_{min} = $0.25t_s$ for $t_s > 38.1$ mm (1.5 in.) but need not be >19.1 mm (0.75 in.)

The welding is to comply with the requirements for circumferential joints given in Section 2-4-2.

iv) *4-4-1A1/Figure 7c-1*: K = 0.13 for circular heads lapwelded or brazed to the shell with the corner radius not less than $3t$ and ℓ not less than required by Equation 8 and where the welds meet the requirements of 2-4-2/7.11.

K = 0.20 for circular and noncircular lapwelded or brazed construction as above, but with no special requirement with regard to ℓ.

v) *4-4-1A1/Figure 7c-2*: K = 0.30 for circular flanged plates screwed over the end of the shell, pipe or header, with the inside corner radius not less than $3t$, in which the design of the threaded joint against failure by shear, tension or compression, resulting from the end force due to pressure, is based on a factor of safety of at least four (4), and the threaded parts are at least as strong as the threads for standard piping of the same diameter. Seal welding may be used, if desired.

vi) *4-4-1A1/Figure 7d*: K = 0.13 for integral flat circular heads when the dimension d does not exceed 610 mm (24 in.), the ratio of thickness of the head to the dimension d is not less than 0.05 nor greater than 0.25, the head thickness t_h, is not less than the shell thickness t_s, the inside corner radius is not less than $0.25t$, and the construction is obtained by special techniques of upsetting and spinning the end of the shell, pipe or header, such as employed in closing header ends.

vii) *4-4-1A1/Figure 7e, f and g*:

$K = 0.33m$ but not less than 0.2 for circular plates, welded to the inside of a drum, pipe or header, and otherwise meeting the requirements for the respective types of fusion-welded boiler drums, including stress relieving when required for the drum, but omitting radiographic examination. If m is smaller than 1, the shell thickness t_s is to extend to a length of at least $2\sqrt{dt}$ from the inside face of the head. The throat thickness of the fillet welds in 4-4-1A1/Figure 7e and f is to be at least $0.7t_s$. The size of the weld t_w in 4-4-1A1/Figure 7g is to be not less than two times the required thickness of a seamless shell nor less than 1.25 times the nominal shell thickness, but need not be greater than the head thickness. The weld is to be deposited in a welding groove with the root of the weld at the inner face of the head as shown in the figure. Radiographic examination is not required for any of the weld joints shown in the figures.

K = 0.33 for noncircular plates, welded to the inside of a drum, pipe or header, and otherwise meeting the requirements for the respective types of fusion-welded boiler drums, including stress-relieving when required for the drum, but omitting radiographic examination. The throat thickness of the fillet welds in 4-4-1A1/Figure 7e and f is to be at least $0.7t_s$. The size of the weld t_w in 4-4-1A1/Figure 7g is to be not less than two times the required thickness of a seamless shell nor less than 1.25 times the nominal shell thickness, but need not be greater than the head thickness. The weld is to be deposited in a welding groove with the root of the weld at the inner face of the head as shown in the figure. Radiographic examination is not required for any of the weld joints shown in the figures.

viii) *4-4-1A1/Figure 7i*: $K = 0.33m$ but not less than 0.2 for circular plates welded to the end of the drum, pipe or header, when an inside weld with minimum throat thickness of $0.7t_s$ is used, and when the beveled end of the drum, pipe or header is located at a distance not less than $2t_r$ nor less than $1.25t_s$ from the outer face of the head. The width at the bottom of the welding groove is to be at least equal to t_s, but need not be over 6.4 mm (0.25 in.). Radiographic examination is not required for any of the weld joints shown in the figure.

ix) *4-4-1A1/Figure 7j and k*: $K = 0.3$ for circular and noncircular heads and covers bolted to the shell, flange or side plate, as indicated in the figures. Note that Equation 5 or 7 is to be used because of the extra moment applied to the cover by the bolting. When the cover plate is grooved for a peripheral gasket, as shown in 4-4-1A1/Figure 7k, the net cover-plate thickness under the groove or between the groove and the outer edge of the cover plate is to be not less than:

$$d\sqrt{\frac{1.9Bh_g}{Sd^3}}$$ for circular heads and covers,

nor less than

$$d\sqrt{\frac{6Bh_g}{SLd^2}}$$ for noncircular heads and covers.

x) *4-4-1A1/Figure 7m, n and o*: $K = 0.3$ for a circular plate inserted into the end of a shell, pipe or header, and held in place by a positive mechanical locking arrangement, and when all possible means of failure either by shear, tension, compression or radial deformation, including flaring, resulting from pressure and differential thermal expansion, are resisted with a factor of safety of at least four (4). Seal welding may be used, if desired.

xi) *4-4-1A1/Figure 7p*: $K = 0.25$ for circular and noncircular covers bolted with a full-face gasket to shells, flanges or side plates.

xii) *4-4-1A1/Figure 7q*: $K = 0.75$ for circular plates screwed into the end of a shell, pipe or header, having an inside diameter d not exceeding 305 mm (12 in.); or for heads having an integral flange screwed over the end of a shell, pipe or header, having an inside diameter d not exceeding 305 mm (12 in.); and when the design of the threaded joint against failure by shear, tension, compression or radial deformation, including flaring, resulting from pressure and differential thermal expansion, is based on a factor of safety of at least four (4). A tapered pipe thread will require special consideration. Seal welding may be used, if desired.

xiii) *4-4-1A1/Figure 7r*: $K = 0.33$ for circular plates having a dimension d not exceeding 457 mm (18 in.), inserted into the shell, pipe or header, and welded as shown, and otherwise meeting the requirements for fusion-welded boiler drums, including stress-relieving but omitting radiographic examination. The end of the shell, pipe or header, is to be crimped over at least 30° but not more than 45°. The crimping is to be done cold only when this operation will not injure the metal. The throat of the weld is to be not less than the thickness of the flat head or the shell, pipe or header, whichever is greater. Radiographic examination is not required for any of the weld joints shown in the figure.

xiv) *4-4-1A1/Figure 7s*: K = 0.33 for circular beveled plates having a diameter d not exceeding 457 mm (18 in.), inserted into a shell, pipe or header, the end of which is crimped over at least 30° but not more than 45°, and when the undercutting for seating leaves at least 80% of the shell thickness. The beveling is to be not less than 75% of the head thickness. The crimping is to be done when the entire circumference of the cylinder is uniformly heated to the proper forging temperature for the material used. For this construction, the ratio t_s/d is to be not less than the ratio:

$$\frac{W}{10S} \left(\frac{W}{100S}, \frac{W}{S}\right)$$ for SI (MKS, US) units, respectively, nor less than 0.05.

The maximum allowable working pressure, W, for this construction is not to exceed:

$$\frac{50.8S}{d} \left(\frac{508S}{d}, \frac{S}{5d}\right)$$ for SI (MKS, US) units respectively.

Radiographic examination is not required for any of the weld joints shown in the figure.

5.9 Stayed Flat Heads

5.9.1 General

Surfaces required to be stayed include flat plates such as heads or portions thereof, wrapper sheets, furnace plates, side sheets, tube plates, combustion chamber plates, etc., also curved plates with pressure on the convex side which are not self supporting. No plates less than 7.9 mm ($^5/_{16}$ in.) in thickness are to be used in stayed surface construction.

5.9.2 Plates Supported by Stay Bars

The minimum required thickness of plates supported by stay bars is to be determined by the following equation:

$$T = p\sqrt{\frac{KW}{fS}}$$

where

T = minimum thickness of the plate; mm (in.)

W = maximum working pressure; bar (kgf/cm^2, psi)

p = maximum pitch measured between the centers of stays in different rows, which may be horizontal and vertical, or radial and circumferential; mm (in.)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

S = maximum allowable working stress; N/mm^2 (kgf/mm^2, psi)

K = factor depending on the kind of service to which the plate is subjected and the method of construction, as given below:

i) *For plates exposed to products of combustion:*

K = 0.23 for plates under 11.1 mm ($^7/_{16}$ in.)

= 0.22 for plates 11.1 mm ($^7/_{16}$ in.) and over

= 0.21 for plates under 11.1 mm ($^7/_{16}$ in.) reinforced by doubling strips, the width of the doubling strip to be not less than $^2/_3$ of the maximum pitch of the stays and the thickness is to be not less than $^2/_3$ of the thickness of the plate

= 0.20 for plates 11.1 mm ($^7/_{16}$ in.) and over reinforced by doubling strips, the width of the doubling strip to be not less than $^2/_3$ of the maximum pitch of the stays and the thickness is to be not less than $^2/_3$ of the thickness of the plate *ii)* *For plates not exposed to products of combustion:*

K = 0.20 for plates under 11.1 mm ($^7/_{16}$ in.)

= 0.19 for plates 11.1 mm ($^7/_{16}$ in.) and over

= 0.18 for plates under 11.1 mm ($^7/_{16}$ in.) reinforced by doubling strips, the width of the doubling strip to be not less than $^2/_3$ of the maximum pitch of the stays and the thickness is to be not less than $^2/_3$ of the thickness of the plate

= 0.17 for plates 11.1 mm ($^7/_{16}$ in.) and over reinforced by doubling strips, the width of the doubling strip to be not less than $^2/_3$ of the maximum pitch of the stays and the thickness is to be not less than $^2/_3$ of the thickness of the plate

5.9.3 Plates Supported by Stay Tubes

The minimum required thickness of plates supported by stay tubes is to be determined by the following equation:

$$T = \sqrt{\frac{KW}{fS}\left(p^2 - \frac{\pi}{4}d_o{}^2\right)}$$

where

d_o = outside diameter of the tube; mm (in.)

T, p, K, W, f and S are as defined above.

5.9.4 Tube Plates Subjected to Compressive Stresses

For flat tube plates having the ligaments subjected to compressive stresses, such as tube plates of combustion chambers with the tops supported by girders, the minimum required thickness of plates is to be determined by the following equation:

$$T = \frac{LPW}{2fS(P-d)}$$

where

P = least horizontal pitch of tubes, mm (in.)

L = total length of the combustion chamber over the tube plate and back sheet, mm (in.)

d = inside diameter of plain tube, mm (in.)

T, W, S and f are as defined above.

5.9.5 Stays

The minimum required cross sectional area of stays is to be determined by the following equation:

$$A_r = \frac{1.1AW}{fS}$$

where

A_r = required cross sectional area of stay, mm^2 (in^2)

A = area supported by the stay, mm^2 (in^2)

W = maximum working pressure, bar (kgf/cm^2, psi)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

S = maximum allowable working stress, N/mm^2 (kgf/mm^2, psi)

7 Openings and Reinforcements

7.1 General

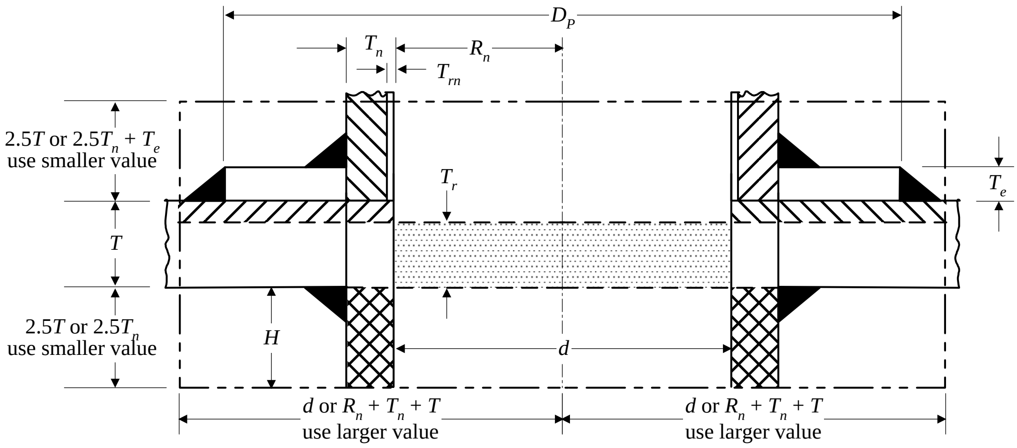
7.1.1 Application

The following apply to all openings in shells, headers or heads, except as otherwise provided in 4-4-1A1/7.1.2. The reinforcement requirements apply to openings not exceeding the following dimensions.

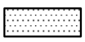
- For shells 1525 mm (60 in.) diameter or less, $^1/_2$ the shell diameter but not over 508 mm (20 in.).
- For shells over 1525 mm (60 in.) diameter, $^1/_3$ the shell diameter but not over 1016 mm (40 in.).

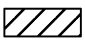
Reinforcement of larger openings is to be submitted for specific approval.

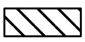
FIGURE 8
Example of Reinforced Opening

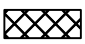


Without Reinforcing Element

 $= A$ $= d \times T_r \times F$

 $= A_1$ $= (ET - FT_r)(d - R_n)2 = (ET - FT_r)d$
or
$= (ET - FT_r)(R_n + T_n + T - R_n)2 = (ET - FT_r)(T_n + T)2$

 $= A_2$ $= (T_n - T_{rn})2.5T \times 2 = (T_n - T_{rn})5T$
or
$= (T_n - T_{rn})2.5T_n \times 2 = (T_n - T_{rn})T_{rn}5T_n$

 $= A_3$ $= (T_n)2H$

 $= A_4$ = Area of welds

If $A_1 + A_2 + A_3 + A_4 \geq A$
If $A_1 + A_2 + A_3 + A_4 < A$

With Reinforcing Element

A_1, A_2, A_3, A_4 same as without reinforcing element.
2.5T_n is measured from the top surface of the reinforcing element.
A_2 becomes the smaller of $(T_n - T_{rn})5T$ or $(T_n - T_{rn})(5T_n - 2T_e)$.
Area of reinforcing element = $(D_P - d - 2T_n)T_e = A_5$
If $A_1 + A_2 + A_3 + A_4 + A_5 \geq A$ opening is adequately reinforced.

7.1.2 Openings in Definite Pattern

Openings in a definite pattern such as tube holes may be designed in accordance with the requirements of 4-4-1A1/3.3.5, provided the largest hole in the group does not exceed that permitted by the following equations.

$$d = 8.08 \cdot \sqrt[3]{DT(1-K)} \quad \text{mm} \qquad \text{or} \qquad d = 2.75 \cdot \sqrt[3]{DT(1-K)} \quad \text{in.}$$

subject to the following:

i) $d \le 203$ mm (8 in.)

ii) $K = \dfrac{WD}{1.6\,fST}$ when design with 0.8 of S value from 4-4-1A1/Table 2

iii) $K = \dfrac{WD}{1.82\,fST}$ when design with actual S values from 4-4-1A1/Table 2

iv) if $DT > 129{,}000$ mm^2 (200 in^2), use $DT = 129{,}000$ mm^2 (200 in^2)

where

d = maximum allowable diameter of opening; mm (in.)

D = outside diameter of shell; mm (in.)

T = thickness of plate; mm (in.)

W = maximum working pressure; bar (kgf/cm^2, psi)

S = maximum allowable working stress from 4-4-1A1/Table 2; N/mm^2 (kgf/mm^2, psi)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

See also 4-4-1A1/7.11.3 concerning reinforcement between tube holes.

7.1.3 Calculations

Calculations demonstrating compliance with 4-4-1A1/7.3 are to be made for all openings, except:

i) Where there are single openings in the shell or headers with the diameter of the opening less than that permitted by the equation in 4-4-1A1/7.1.2, or

ii) Where single openings of not larger than 50 mm (2 in.) nominal pipe size are made in shells or headers having an inside diameter not less than four times the diameter of the opening.

Tube holes arranged in a definite pattern are also to comply with 4-4-1A1/7.3 when the tube hole diameter is greater than that permitted by the equation in 4-4-1A1/7.1.2.

7.1.4 Openings in or Adjacent to Welds

Any opening permitted in these Rules may be located in a welded joint that has been stress-relieved and radiographed.

7.3 Reinforcement Requirements

7.3.1 Shells and Formed Heads

Reinforcement is to be provided in amount and distribution such that the area requirements for reinforcement are satisfied for all planes through the center of the opening and normal to the vessel surface. The total cross-sectional area of reinforcement in any given plane is to be not less than obtained from the following equation:

$$A = FdT_r$$

where

A = required reinforcement (see 4-4-1A1/Figure 8); mm^2 (in^2)

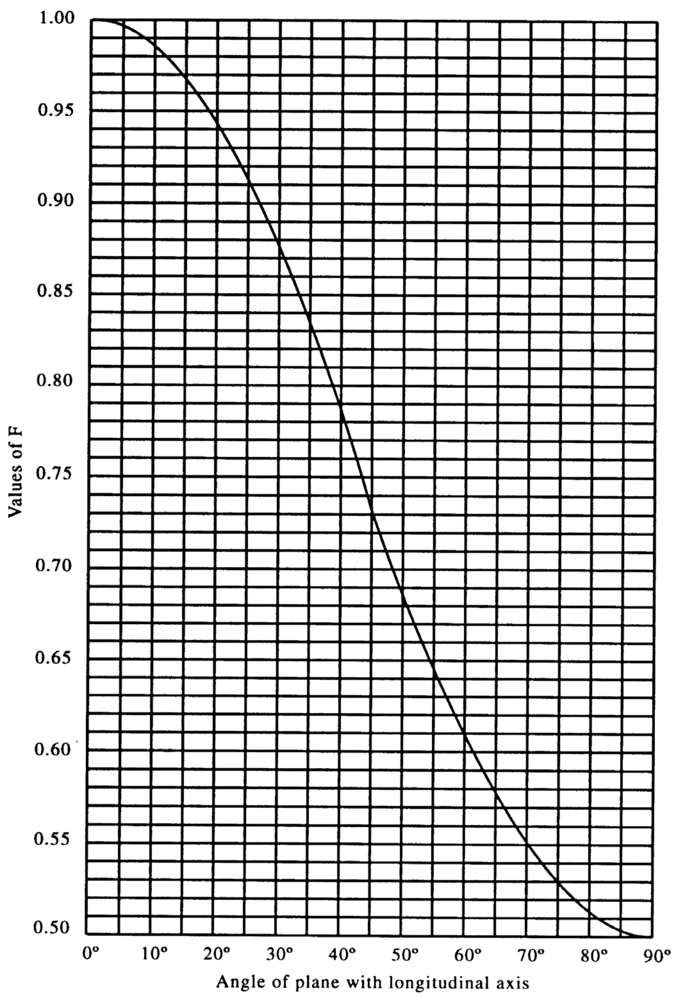
F = a correction factor which compensates for the variation in pressure stresses on different planes with respect to the axis of a vessel. A value of 1.0 is to be used if the chosen plane containing the opening (or the nozzle) axis coincides with the vessel's longitudinal axis. Otherwise, the values of F is to be as given in 4-4-1A1/Figure 9.

d = diameter of the finished opening in the given plane; mm (in.)

T_r = the minimum required thickness, exclusive of the corrosion allowance, C, of a seamless shell, header, formed head or flat head, as calculated by formulas in 4-4-1A1/3.1, 4-4-1A1/5.1, 4-4-1A1/5.3, or 4-4-1A1/5.7 as appropriate, using E = 1; mm (in.), except that:

- for dished heads when the opening and its reinforcement are entirely within the spherical portion, T_r is the thickness exclusive of the corrosion allowance required by the equation given in 4-4-1A1/5.1 using M = 1; and
- for elliptical heads as defined in 4-4-1A1/5.3 when the opening and its reinforcement are located entirely within a circle, the center of which coincides with the center of the head and the diameter of which is 0.8 of the inside shell diameter, T_r is the thickness, exclusive of the corrosion allowance required by the equation given in 4-4-1A1/5.1 using M = 1 and R = 0.9 of the inside diameter of the shell

FIGURE 9
Chart for Determining Value of *F*



7.3.2 Flat Heads

Flat heads that have an opening with a diameter that does not exceed one-half of the head diameter, or shortest span, are to have a total cross-sectional area of reinforcement not less than that given by the following:

$$A = 0.5dT$$

where

A = required reinforcement; mm^2 (in^2)

d = diameter of the finished opening in the given plane; mm (in.)

T = minimum required thickness of plate, exclusive of corrosion allowance, as determined from 4-4-1A1/5.7; mm (in.)

As an alternative, the thickness of flat heads may be increased to provide the necessary reinforcement by using 2K in Equations 4 and 6 given in 4-4-1A1/5.7.3. However, the value of 2K to be used in the equations need not exceed 0.75. For the types of construction indicated in 4-4-1A1/Figures 7j and 7k, the quantity under the square-root of Equations 5 and 7 given in 4-4-1A1/5.7.3 is to be doubled.

Flat heads that have an opening with a diameter that exceeds one-half of the head diameter, or shortest span, are to be designed as a flange in accordance with bolted flange-connection practice.

7.5 Reinforcement Limits

Metal in the vessel and nozzle walls, exclusive of corrosion allowance, over and above the thickness required to resist pressure may be considered as reinforcement within the reinforcement limits as specified below.

7.5.1 Limits Along Wall

The limits of reinforcement measured along the vessel wall are to be at a distance on each side of the axis of the opening (or nozzle) equal to the greater of the following requirements:

i) The diameter of the finished opening.

ii) The radius of the finished opening plus the thickness of the vessel wall, plus the thickness of the nozzle wall

7.5.2 Limits Normal to Wall

The limits of reinforcement measured normal to the pressure vessel wall are to be parallel to the contour of the vessel surface and at a distance from each surface equal to the smaller of the following requirements:

i) 2.5 times the shell thickness

ii) 2.5 times the nozzle wall thickness, plus the thickness of any added reinforcement exclusive of the weld metal on the side of the shell under consideration

7.7 Metal Having Reinforcement Value

7.7.1 Reinforcement Available in Vessel Wall

Metal in the vessel wall, exclusive of corrosion allowance, over and above the thickness required to resist pressure may be considered as reinforcement within the reinforcement limits given in 4-4-1A1/7.5. The cross-sectional area of the vessel wall available as reinforcement is the larger of the A_1 values given by the following equations.

$$A_1 = (ET - FT_r)d$$

$$A_1 = 2(ET - FT_r)(T + T_n)$$

where

A_1 = area in the excess thickness in the vessel wall available for reinforcement; mm^2 (in^2)

E = weld joint efficiency, to be taken as:

- The longitudinal weld joint efficiency when any part of the opening passes through a longitudinal weld joint; or
- 1.0 when the opening is made in the seamless plate or when the opening passes through a circumferential joint in a shell (exclusive of head to shell joints)

T = thickness of the vessel wall, less corrosion allowance; mm (in.)

F = a factor, as defined in 4-4-1A1/7.3.1

T_r = the minimum required thickness of a seamless shell or head as defined in 4-4-1A1/7.3.1

T_n = thickness of the nozzle wall, exclusive of corrosion allowance; mm (in.)

d = diameter of the finished opening (or internal diameter of the nozzle) less corrosion allowance, in the plane under consideration; mm (in.)

7.7.2 Reinforcement Available in Nozzles

7.7.2(a) Nozzles extending outside the vessel. The nozzle wall, exclusive of corrosion allowance, over and above the thickness required to resist pressure, and in that part of the nozzle extending outside the pressure vessel wall, may be considered as reinforcement within the reinforcement limits given in 4-4-1A1/7.5. The maximum area on the nozzle wall available as reinforcement is the smaller of the values of A_2 given by the following equations.

$$A_2 = (T_n - T_{rn})5T$$

$$A_2 = (T_n - T_{rn})(5T_n + 2T_e)$$

where

A_2 = area of excess thickness in the nozzle wall available for reinforcement; mm^2 (in^2)

T_{rn} = the minimum required thickness of a seamless nozzle wall, excluding corrosion allowance, found by the equation used for T_r for shell; mm (in.)

T_e = thickness of reinforcing element; mm (in.)

T = thickness of vessel wall, less corrosion allowance; mm (in.)

T_n = thickness of nozzle wall, exclusive of the corrosion allowance; mm (in.); which is not to be less than the smallest of the following:

- The minimum required thickness of the seamless shell or head;
- Thickness of standard-wall pipe; or
- The minimum required thickness of a pipe based on 41.4 bar (42.2 kgf/cm^2, 600 psi) internal pressure.

7.7.2(b) Nozzles extending inside the vessel. All metal exclusive of corrosion allowance in the nozzle wall extending inside the pressure vessel and within the reinforcement limits specified in 4-4-1A1/7.5 may be included as reinforcement.

7.7.3 Added Reinforcement

Metal added as reinforcement and metal in attachment welds, provided they are within the reinforcement limits, may be included as reinforcement.

7.9 Strength of Reinforcement

7.9.1 Material Strength

In general, material used for reinforcement is to have an allowable stress value equal to or greater than that of the material in the vessel wall. Where material of lower strength is used, the area available for reinforcement is to be proportionally reduced by the ratio of the allowable stresses. No credit, however, is to be taken for the additional strength of any reinforcement having a higher allowable stress than the vessel wall. Deposited weld metal used as reinforcement is to be assumed to have an allowable stress value equal to the weaker of the materials connected by the weld.

7.9.2 Required Strength of Nozzle Attachment Weld

In the plane normal to the vessel wall and passing through the center of the opening, the strength of the weld attaching the nozzle and reinforcement element to the vessel wall is to be at least equal to the smallest of the following:

$$V = dT_rS$$

$$V = [d_uT_r - (2d - d_u)(T - T_r) + A_s]S$$

$$V = [d_uT_r - 2T(T - T_r) + A_s]S$$

where

V	=	the required strength (through load-carrying paths; see e.g., 4-4-1A1/Figure 10) to be provided by weldment or by the combination of weldment and nozzle wall to resist shear from pressure loading; N (kgf, lbf)
d_u	=	diameter of the unfinished opening prior to nozzle installation; mm (in.)
A_s	=	total stud hole cross-section area where stud holes are tapped into the vessel wall; mm^2 (in^2)
S	=	allowable stress of the vessel wall material from 4-4-1A1/Table 2; N/mm^2 (kgf/mm^2, psi)

d, T_r, T are as defined in 4-4-1A1/7.7.1.

7.9.3 Calculating the Strength of Attachment Weld

Sufficient welding is to be deposited to develop the strength (through load-carrying paths, see 4-4-1A1/Figure 10) of the reinforcing parts through shear or tension in the weld and nozzle wall, as applicable. The combined strength of the weld or nozzle wall or both, as applicable, is to be computed and is not to be less than the value of V specified in 4-4-1A1/7.9.2. The weld shear areas to be used in the computation are to be in accordance with the following provisions:

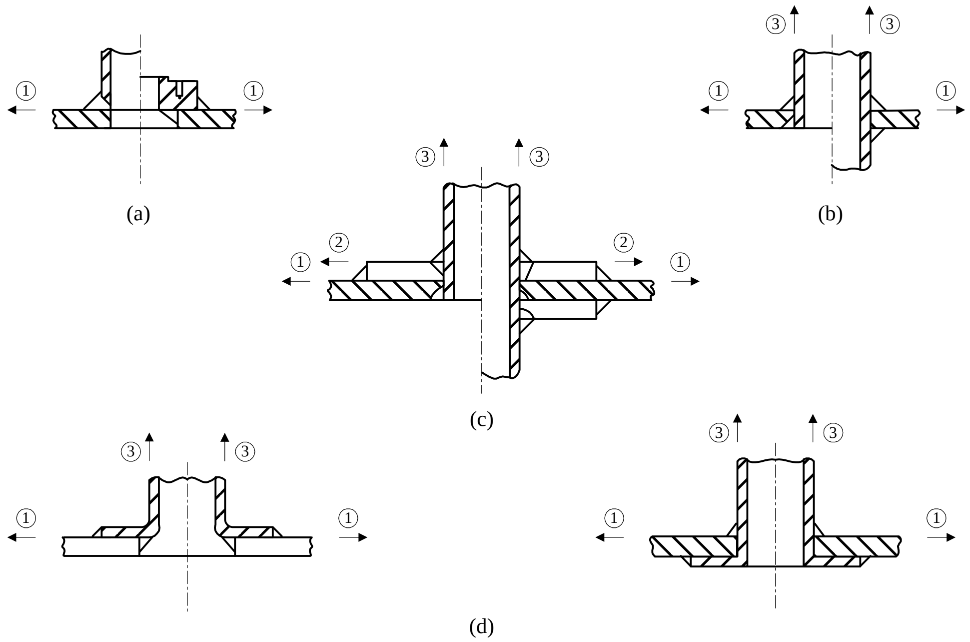
i) The strength of the groove welds is to be based on half of the area subjected to shear, as applicable, computed using the minimum weld depth dimension at the line of load-carrying path in the direction under consideration. The diameter of the weld is to be taken as the inside diameter of the weld when calculating path number three (see 4-4-1A1/Figure 10), or the mean diameter of the weld when calculating path number one or two (see 4-4-1A1/Figure 10).

ii) The strength of the fillet weld is to be based on half of the area subject to shear, computed on the inside diameter of the weld when calculating path number 3, or the mean diameter of the weld when calculating path number one or two, using weld leg dimension in the direction under consideration.

The allowable stress values for groove and fillet welds and for shear in nozzle necks, in percentages of stress value for the vessel material, are as follows:

Nozzle wall shear	70%
Groove weld tension	74%
Groove weld shear	60%
Fillet weld shear	49%

FIGURE 10
Load-carrying Paths in Welded Nozzle Attachments



(1) Denotes the load-carrying path acting perpendicular to the nozzle centerline about the nozzle at the face of the vessel.

(2) Denotes the load-carrying path acting perpendicular to the nozzle centerline about the nozzle at the face of the external pad.

(3) Denotes the load-carrying path about the nozzle acting parallel to the nozzle centerline.

7.11 Reinforcement of Multiple Openings

7.11.1 Spacing of Openings

Two adjacent openings are to have a distance between centers not less than $1^1/_3$ times their average diameter.

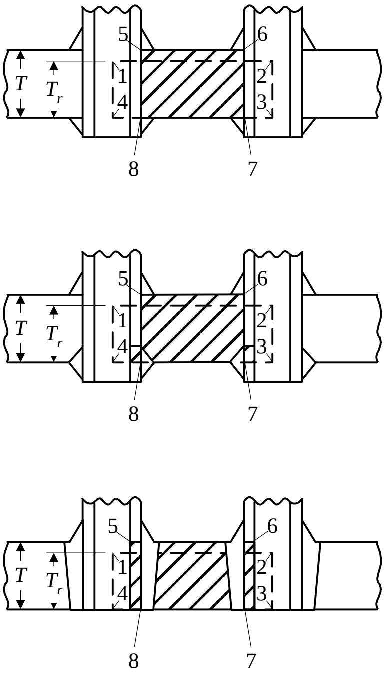
7.11.2 Reinforcement Overlapping

When adjacent openings are so spaced that their limits of reinforcement overlap, the opening is to be reinforced in accordance with 4-4-1A1/7.3 with a reinforcement that has an area equal to the combined area of the reinforcement required for the separate openings. No portion of the cross section is to be considered as applying to more than one opening or be evaluated more than once in a combined area.

7.11.3 Reinforcement of Holes Arranged in a Definite Pattern

When a shell has a series of holes in a definite pattern, the net cross-sectional area between any two finished openings within the limits of the actual shell wall, excluding the portion of reinforcing part not fused to the shell wall, is to equal at least $0.7F$ of the cross-sectional area obtained by multiplying the center-to-center distance of the openings by T_r, the required thickness of a seamless shell, where the factor F is taken from 4-4-1A1/Figure 9 for the plane under consideration. See illustration of these requirements in 4-4-1A1/Figure 11.

FIGURE 11
Illustration of Rules Given in 4-4-1A1/7.11.3



The cross-section area represented by 5, 6, 7, 8, shall be at least equal to the area of the rectangle represented by 1, 2, 3, 4 multiplied by 0.7*F*, in which *F* is a value from 4-4-1A1/Figure 9 and T_r is the required thickness of a seamless shell

9 Boiler Tubes

9.1 Materials

Tubes for water-tube boilers, superheaters and other parts of a boiler, where subjected to internal pressure, are to be of seamless steel or electric-resistance-welded tubing.

9.3 Maximum Allowable Working Pressure

The maximum allowable working pressure and the minimum required thickness are to be in accordance with the following equations:

$$W = fS\left[\frac{2T - 0.01D - 2e}{D - (T - 0.005D - e)}\right]$$

$$T = \frac{WD}{2fS + W} + 0.005D + e$$

where

D	=	outside diameter of tube; mm (in.)
T	=	minimum thickness of tube wall; mm (in.)
W	=	maximum working pressure; bar (kgf/cm^2, psi)

S = maximum allowable working stress; N/mm^2 (kgf/mm^2, psi); at not less than the maximum expected mean wall temperature, *m*, of the tube wall, which in no case is to be taken as less than 371°C (700°F) for tubes absorbing heat. For tubes which do not absorb heat, the wall temperature may be taken as the temperature of the fluid within the tube, but not less than the saturation temperature. Appropriate values of *S* are to be taken from 4-4-1A1/Table 2.

m = sum of outside and inside surface temperatures divided by 2

e = 1 mm (0.04 in.) over a length at least equal to the length of the seat plus 25 mm (1 in.) for tubes expanded into tube seats, see 4-4-1A1/9.5.

= 0 for tubes strength-welded to headers and drums

f = factor for units of measure, 10 (100, 1) for SI (MKS, US) units, respectively.

9.5 Tube-end Thickness

The thickness of the ends of tubes strength-welded to headers or drums need not be made greater than the run of tube as determined from 4-4-1A1/9.3. However, the thickness of tubes, where expanded into headers or drums, is to be no less than the minimum thickness required by 4-4-1A1/9.3 for each diameter for which a working pressure is tabulated. The minimum thickness of tubes or nipples for expanding into tube seats may be calculated from 4-4-1A1/9.3 with *e* equal to zero, provided the thickness at the end of the tubes to be expanded is made a minimum of:

i) 2.40 mm (0.095 in.) for tubes 32 mm (1.25 in.) outside diameter.

ii) 2.67 mm (0.105 in.) for tubes more than 32 mm (1.25 in.) outside diameter and up to 51 mm (2 in.) outside diameter inclusive.

iii) 3.05 mm (0.120 in.) for tubes more than 51 mm (2 in.) outside diameter and up to 76 mm (3 in.) outside diameter inclusive.

iv) 3.43 mm (0.135 in.) for tubes more than 76 mm (3 in.) outside diameter and up to 102 mm (4 in.) outside diameter inclusive.

v) 3.81 mm (0.150 in.) for tubes more than 102 mm (4 in.) outside diameter and up to 127 mm (5 in.) outside diameter inclusive.

9.7 Tube-end Projection

The ends of all tubes and nipples used in water-tube boilers are to project through the tube plate or header, not less than 6.4 mm (0.25 in.) nor more than 19 mm (0.75 in.). They are to be expanded in the plate and then either bell-mouthed or beaded. Where tubes are to be attached to tube sheets by means of welding, details are to be submitted for approval.

11 Joint Designs

Welded joints are to be designed in accordance with 2-4-2/7 and 2-4-2/9.

13 Joint and Dimensional Tolerances

Joint and dimensional tolerances are to be in accordance with 2-4-2/5.

15 Weld Tests

Welding procedure and welder/welding operator qualification tests are to be in accordance with Section 2-4-3.

17 Radiography and Other Nondestructive Examination

Radiography of butt-welded seams is to be in accordance with 2-4-2/23.

19 Preheat and Postweld Heat Treatment

Preheat and postweld heat treatments are to be in accordance with 2-4-2/11 through 2-4-2/21.

21 Hydrostatic Tests *(1 July 2003)*

21.1 Boilers

All completed boilers (after all required nondestructive examination and after postweld heat treatment) are to be subjected to a hydrostatic test at not less than 1.5 times the design pressure or the maximum allowable pressure (the pressure to be stamped on the nameplate is to be used) in the presence of a Surveyor. The pressure gauge used in the test is to have a maximum scale of about twice the test pressure, but in no case is the maximum scale to be less than 1.5 times the test pressure. Following the hydrostatic test, the test pressure may be reduced to the design or the maximum allowable working pressure, and an inspection is to be made by the Surveyor of all joints and connections.

21.3 Pressure Vessels

All completed pressure vessels (after all required non-destructive examination and after postweld heat treatment) are to be subjected to a hydrostatic test at not less than 1.3 times the design pressure or the maximum allowable pressure (the pressure to be stamped on the nameplate is to be used) in the presence of a Surveyor. The pressure gauge used in the test is to have a maximum scale of about twice the test pressure, but in no case is the maximum scale to be less than 1.3 times the test pressure. Following the hydrostatic test, the test pressure may be reduced to the design or the maximum allowable working pressure, and an inspection is to be made by the Surveyor of all joints and connections.

TABLE 1
Joint Efficiencies for Welded Joints *(2007)*

Type of Joint	Limitation	*Degree of Radiography*		
		(a) Full (1)	*(b) Spot* (1)	*(c) None* (2)
(a) Butt joints as attained by double welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surfaces. Welds using metal backing strips which remain in place are excluded	None	1.00	0.85 (4)	0.70
(b) Single welded butt joint with backing strip other than those included above	None, except 15.9 mm (0.625 in.) maximum thickness in circumferential butt welds having one plate offset as shown in 2-4-2/Figure 1.	0.90	0.80	0.65
(c) Single-welded butt joint without use of backing strip	Circumferential joints only, not over 15.9 mm (0.625 in.) thick and not over 610 mm (24 in.) outside diameter.			0.60
(d) Double full-fillet lap joint	Longitudinal joints not over 9.5 mm (0.375 in.) thick. Circumferential joints not over 15.9 mm (0.625 in.) thick.			0.55
(e) Single full-fillet lap joints with plug welds	Circumferential joints for attachment of heads, not over 610 mm (24 in.) outside diameter to shell not over 12.7 mm (0.5 in.) thick (3).			0.50
(f) Single full-fillet lap joints without plug welds	i) For the attachment of heads convex to pressure to shell not over 15.9 mm (0.625 in.) required thickness, only with use of fillet weld on the inside of shell. Or ii) For attachment of heads having pressure on either side to shells not over 610 mm (24 in.) inside diameter and not over 6.4 mm (0.25 in.) required thickness with fillet weld on outside of head flange only.			0.45

Notes

1 Full and spot radiograph requirements covered in 2-4-2/23.

2 The maximum allowable joint efficiencies shown in this column are the weld-joint efficiencies multiplied by 0.8 (and rounded off to the nearest 0.05) to effect the basic reduction in allowable stress required by the Rules for welded vessels that are not spot examined. This value may only be used provided that a maximum allowable unit working stress not exceeding 0.8 of the appropriate S value in 4-4-1A1/Table 2 is used in all other design calculations except for stress S for unstayed flat heads and covers in 4-4-1A1/5.7, and stresses used in flange designs.

3 Joints attaching hemispherical heads to shells are excluded.

4 *(2007)* Seamless vessel sections and heads with circumferential butt joints, excluding hemispherical heads, that are spot radiographed are to be designed for circumferential stress using the appropriate S value in 4-4-1A1/Table 2. Where seamless vessel sections and heads with circumferential butt joints are not spot radiographed, they are to be designed for circumferential stress using stress value not to exceed 0.85 of the appropriate S value in 4-4-1A1/ Table 2. This stress reduction is not applicable to T_r and T_{rn} in reinforcement calculations.

TABLE 2 (SI units)
Maximum Allowable Stress Values for Ferrous Materials – N/mm^2 *(2003)*

Stress values shown in italics are permissible, but use of these materials at these temperatures is not current practice.

The stress values in this table may be interpolated to determine values for intermediate temperatures.

Stress values for other materials may be the same as given in the ASME Boiler and Pressure Vessel Code.

ABS Gr.	ASTM Gr.	Nominal Comp.	Min. Tensile strength	Note	Metal temperature (°C) not exceeding –29 to 149	204	260	316	343	371	399	427	454	482	510	538	566	593	621	649
	Plate steels – Section 2-3-2																			
MA	A285 Gr.A	C	310	1,4	88.9	88.9	88.9	84.8	82.0	79.3	*73.8*	*57.2*	*45.5*	*34.5*						
MB	A285 Gr.B	C	345	1,4	98.6	98.6	98.6	95.1	91.7	86.2	*75.8*	*64.8*	*50.3*	*34.5*						
MC	A285 Gr.C	C	379	1,4	108.2	108.2	108.2	105.5	102.0	98.6	*89.6*	*74.5*	*60.0*	*40.7*						
MD	A515 Gr.55	C Si	379	1	108.2	108.2	108.2	105.5	102.0	98.6	*89.6*	*74.5*	*60.0*	*40.7*	*27.6*	*17.2*				
ME	A515 Gr.60	C	414	1	117.9	117.9	117.9	113.1	108.9	105.5	*89.6*	*74.5*	*60.0*	*40.7*	*27.6*	*17.2*				
MF	A515 Gr.65	C	448	1	128.2	128.2	128.2	123.4	119.3	115.1	*95.8*	*78.6*	*60.0*	*40.7*	*27.6*	*17.2*				
MG	A515 Gr.70	C	483	1	137.9	137.9	137.9	133.8	129.6	124.8	*102.0*	*82.7*	*64.1*	*46.2*	*27.6*	*17.2*				
H	A204 Gr.A	C-1/2 Mo	448	2	128.2	128.2	128.2	128.2	128.2	128.2	128.2	126.9	123.4	*94.5*	*56.5*	*33.1*				
I	A204 Gr.B	C-1/2 Mo	483	2	137.9	137.9	137.9	137.9	137.9	137.9	137.9	137.2	133.1	*94.5*	*56.5*	*33.1*				
J	A204 Gr. C	C-1/2 Mo	517	2	147.5	147.5	147.5	147.5	147.5	147.5	147.5	147.5	142.7	*95.5*	*56.5*	*33.1*				
K	A516 Gr.55	C	379	1	108.2	108.2	108.2	105.5	102.0	98.6	*89.6*	*74.5*	*60.0*	*40.7*	*27.6*	*17.2*				
L	A516 Gr. 60	C	414	1	117.9	117.9	117.9	113.1	108.9	105.5	*89.6*	*74.5*	*60.0*	*40.7*	*27.6*	*17.2*				
M	A516 Gr. 65	C	448	1	128.2	128.2	128.2	123.4	119.3	115.1	*95.8*	*78.6*	*60.0*	*40.7*	*27.6*	*17.2*				
N	A516 Gr. 70	C	483	1	137.9	137.9	137.9	133.8	129.6	124.8	*102.0*	*82.7*	*64.1*	*46.2*	*27.6*	*17.2*				
	Forged steel drum – Section 2-3-3																			
A	A266 Cl-1		414	1	117.9	117.9	112.4	105.5	102.0	98.6	*89.6*	*74.5*	*60.0*	*40.7*	*27.6*	*17.2*				
B	A266 Cl-2		483	1	137.9	137.9	135.1	126.9	122.7	118.6	*102.0*	*82.7*	*64.1*	*46.2*	*27.6*	*17.2*				
	Castings – Sections 2-3-9 and 2-3-10																			
3	A216.WCA	C	414	1,7	117.9	117.9	112.4	105.5	102.0	98.6	*89.6*	*74.5*	*60.0*	*40.7*	*27.6*	*17.2*				
4	A216 WCB	C	483	1,7	137.9	137.9	135.1	126.9	122.7	118.6	*102.0*	*82.7*	*64.1*	*46.2*	*27.6*	*17.2*				
60-40-18	A395	Nodular iron	414	7	82.7															
	Tubes – Section 2-3-5																			
D	A178 Gr.A	C-Mn	324	1,3,5,6	92.4	92.4	92.4	91.7	88.3	85.5	*73.8*	*62.1*	*49.0*	*34.5*	*17.9*	*9.0*				
F	A178 Gr.C	C-Mn	414	1,3,5	117.9	117.9	117.9	117.9	117.9	107.6	*89.6*	*74.5*	*60.0*	*34.5*	*23.4*	*14.5*				
G	A226	C-Mn	324	1,5,6	92.4	92.4	92.4	91.7	88.3	85.5	*73.8*	*62.1*	*49.0*	*34.5*	*20.7*	*10.3*				
H	A192	C-Mn	324	1,6	92.4	92.4	92.4	91.7	88.3	85.5	*73.8*	*62.1*	*49.0*	*34.5*	*31.0*	*17.2*				
J	A210 Gr.A-1	C-Mn	414	1	117.9	117.9	117.9	117.9	117.9	107.6	*89.6*	*74.5*	*60.0*	*40.7*	*27.6*	*17.2*				
K	A209 Gr.T1	C-Mn-1/2 Mo	379	2	108.2	108.2	108.2	108.2	108.2	108.2	106.2	102.7	100.0	94.5	*56.5*	*33.1*				
L	A209 Gr.T1a	C-Mn-1/2 Mo	414	2	117.9	117.9	117.9	117.9	117.9	115.8	113.1	109.6	106.2	94.5	*56.5*	*33.1*				
M	A209 Gr.T1b	C-Mn-1/2 Mo	365	2	104.1	104.1	104.1	104.1	103.4	101.4	98.6	96.5	93.1	89.6	*56.5*	*33.1*				
N	A213 Gr.T11	1-1/4 Cr - 1/2 Mo	414		123.4	115.8	111.7	108.2	106.2	104.1	102.0	99.3	96.5	*93.8*	*64.1*	*43.4*	*30.0*	*19.3*	*13.1*	*8.3*
O	A213 Gr.T12	1 Cr - 1/2 Mo	414		113.8	113.8	113.8	112.4	110.3	108.9	106.9	105.5	102.7	*100.0*	*77.9*	*77.2*	*31.0*	*19.3*	*12.4*	*7.6*
P	A213 Gr.T22	2-1/4 Cr - 1 Mo	414		114.5	114.5	114.5	114.5	114.5	114.5	114.5	114.5	114.5	*93.8*	*74.5*	*55.2*	*39.3*	*26.2*	*16.5*	*9.7*

Notes

1 Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite.

2 Upon exposure to temperatures above about 470°C, the carbide phase of carbon-molybdenum steel may be converted to graphite.

3 Only killed steel is to be used above 482°C.

4 Flange quality in this specification not permitted above 454°C.

5 Above 371°C these stress values include a joint efficiency factor of 0.85. When material to this specification is used for pipe, multiply the stress values up to and including 371°C by a factor of 0.85.

6 Tensile value is expected minimum.

7 To these values a quality factor of 0.80 is to be applied unless nondestructive testing (NDT) is carried out beyond that required by material specification. See UG 24 of ASME Code, Section VIII, Division 1.

TABLE 2 (MKS units) Maximum Allowable Stress Values for Ferrous Materials – kgf/mm^2 *(2003)*

Stress values shown in italics are permissible, but use of these materials at these temperatures is not current practice.

The stress values in this table may be interpolated to determine values for intermediate temperatures.

Stress values for other materials may be the same as given in the ASME Boiler and Pressure Vessel Code.

ABS Gr.	ASTM Gr.	Nominal Comp.	Min. Tensile strength	Note	Metal temperature (°C) not exceeding															
					–29 to 149	204	260	316	343	371	399	427	454	482	510	538	566	593	621	649
Plate steels – Section 2-3-2																				
MA	A285 Gr.A	C	31.6	1,4	9.07	9.07	9.07	8.65	8.37	8.09	*7.52*	*5.84*	*4.64*	*3.52*						
MB	A285 Gr.B	C	35.2	1,4	10.05	10.05	10.05	9.70	9.35	8.79	*7.73*	*6.61*	*5.13*	*3.52*						
MC	A285 Gr.C	C	38.7	1,4	11.04	11.04	11.04	10.76	10.41	10.05	*9.14*	*7.59*	*6.12*	*4.15*						
MD	A515 Gr.55	C Si	38.7	1	11.04	11.04	11.04	10.76	10.41	10.05	*9.14*	*7.59*	*6.12*	*4.15*	*2.81*	*1.76*				
ME	A515 Gr.60	C	42.2	1	12.02	12.02	12.02	11.53	11.11	10.76	*9.14*	*7.59*	*6.12*	*4.15*	*2.81*	*1.76*				
MF	A515 Gr.65	C	45.7	1	13.08	13.08	13.08	12.58	12.16	11.74	*9.77*	*8.01*	*6.12*	*4.15*	*2.81*	*1.76*				
MG	A515 Gr.70	C	49.2	1	14.06	14.06	14.06	13.64	13.22	12.73	*10.41*	*8.44*	*6.54*	*4.71*	*2.81*	*1.76*				
H	A204 Gr.A	C-1/2 Mo	45.7	2	13.08	13.08	13.08	13.08	13.08	13.08	13.08	12.94	12.59	*9.63*	*5.77*	*3.37*				
I	A204 Gr.B	C-1/2 Mo	49.2	2	14.06	14.06	14.06	14.06	14.06	14.06	14.06	13.99	13.57	*9.63*	*5.77*	*3.37*				
J	A204 Gr. C	C-1/2 Mo	52.7	2	15.05	15.05	15.05	15.05	15.05	15.05	15.05	15.05	14.55	*9.36*	*5.77*	*2.27*				
K	A516 Gr.55	C	38.7	1	11.04	11.04	11.04	10.76	10.41	10.05	*9.14*	*7.59*	*6.12*	*4.15*	*2.81*	*1.76*				
L	A516 Gr. 60	C	42.2	1	12.02	12.02	12.02	11.53	11.11	10.76	*9.14*	*7.59*	*6.12*	*4.15*	*2.81*	*1.76*				
M	A516 Gr. 65	C	45.7	1	13.08	13.08	13.08	12.58	12.16	11.74	*9.77*	*8.01*	*6.12*	*4.15*	*2.81*	*1.76*				
N	A516 Gr. 70	C	49.2	1	14.06	14.06	14.06	13.64	13.22	12.73	*10.41*	*8.44*	*6.54*	*4.71*	*2.81*	*1.76*				
Forged steel drum – Section 2-3-3																				
A	A266 Cl-1		42.2	1	12.02	12.02	11.46	10.76	10.41	10.05	*9.14*	*7.59*	*6.12*	*4.15*	*2.81*	*1.76*				
B	A266 Cl-2		49.2	1	14.06	14.06	13.78	12.94	12.51	12.09	*10.41*	*8.44*	*6.54*	*4.71*	*2.81*	*1.76*				
Castings – Sections 2-3-9 and 2-3-10																				
3	A216.WCA	C	42.2	1,7	12.02	12.02	11.46	10.76	10.41	10.05	*9.14*	*7.59*	*6.12*	*4.15*	*2.81*	*1.76*				
4	A216 WCB	C	49.2	1,7	14.06	14.06	13.78	12.94	12.51	12.09	*10.41*	*8.44*	*6.54*	*4.71*	*2.81*	*1.76*				
60-40-18	A395	Nodular iron	42.2	7	8.44															
Tubes – Section 2-3-5																				
D	A178 Gr.A	C-Mn	33.0	1,3,5,6	9.42	9.42	9.42	9.35	9.00	8.72	*7.52*	*6.34*	*4.99*	*3.52*	*1.83*	0.91				
F	A178 Gr.C	C-Mn	42.2	1,3,5	12.02	12.02	12.02	12.02	12.02	10.96	*9.14*	*7.59*	*6.12*	*3.16*	*2.39*	*1.48*				
G	A226	C-Mn	33.0	1,5,6	9.42	9.42	9.42	9.35	9.00	8.72	*7.52*	*6.33*	*4.99*	3.52	2.11	1.05				
H	A192	C-Mn	33.0	1,6	9.42	9.42	9.42	9.35	9.00	8.72	*7.52*	*6.33*	*4.99*	3.52	*3.16*	1.76				
J	A210 Gr.A-1	C-Mn	42.2	1	12.02	12.02	12.02	12.02	12.02	10.97	*9.14*	*7.59*	*6.12*	*4.15*	*2.81*	1.76				
K	A209 Gr.T1	C-Mn-1/2 Mo	38.7	2	11.04	11.04	11.04	11.04	11.04	11.04	10.83	10.46	10.19	9.63	*5.77*	*3.37*				
L	A209 Gr.T1a	C-Mn-1/2 Mo	42.2	2	12.02	12.02	12.02	12.02	12.02	11.81	11.53	11.18	10.83	9.63	*5.77*	*3.37*				
M	A209 Gr.T1b	C-Mn-1/2 Mo	37.3	2	10.62	10.62	10.62	10.62	10.55	10.36	10.05	9.82	9.49	9.14	*5.77*	*3.37*				
N	A213 Gr.T11	1-1/4 Cr - 1/2 Mo	42.2		12.02	11.81	11.39	11.04	10.83	10.62	10.41	10.12	9.84	*9.56*	*6.54*	*4.43*	*2.95*	*1.97*	*1.34*	*0.84*
O	A213 Gr.T12	1 Cr - 1/2 Mo	42.2		11.60	11.60	11.60	11.46	11.25	11.11	10.90	10.76	10.48	*10.19*	*7.94*	*5.06*	*3.16*	*1.97*	*1.27*	*0.77*
P	A213 Gr.T22	2-1/4 Cr - 1 Mo	42.2		11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	*9.56*	*7.59*	*5.62*	*4.00*	*2.67*	*1.69*	*0.98*

Notes

1 Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite.

2 Upon exposure to temperatures above about 470°C, the carbide phase of carbon-molybdenum steel may be converted to graphite.

3 Only killed steel is to be used above482°C.

4 Flange quality in this specification not permitted above 454°C.

5 Above 371°C these stress values include a joint efficiency factor of 0.85. When material to this specification is used for pipe, multiply the stress values up to and including 371°C by a factor of 0.85.

6 Tensile value is expected minimum.

7 To these values a quality factor of 0.80 is to be applied unless nondestructive testing (NDT) is carried out beyond that required by material specification. See UG 24 of ASME Code, Section VIII, Division 1.

TABLE 2 (US units)
Maximum Allowable Stress Values for Ferrous Materials – ksi *(2003)*

Stress values shown in italics are permissible, but use of these materials at these temperatures is not current practice.

The stress values in this table may be interpolated to determine values for intermediate temperatures.

Stress values for other materials may be the same as given in the ASME Boiler and Pressure Vessel Code.

ABS Gr.	ASTM Gr.	Nominal Comp.	Min. Tensile strength	Note	Metal temperature (°F) not exceeding															
					–20 to 300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
	Plate steels – Section 2-3-2																			
MA	A285 Gr.A	C	45	1,4	12.9	12.9	12.9	12.3	11.9	11.5	*10.7*	*8.3*	*6.6*	*5.0*						
MB	A285 Gr.B	C	50	1,4	14.3	14.3	14.3	13.8	13.3	12.5	*11.0*	*9.4*	*7.3*	*5.0*						
MC	A285 Gr.C	C	55	1,4	15.7	15.7	15.7	15.3	14.8	14.3	*13.0*	*10.8*	*8.7*	*5.9*						
MD	A515 Gr.55	C Si	55	1	15.7	15.7	15.7	15.3	14.8	14.3	*13.0*	*10.8*	*8.7*	*5.9*	*4.0*	*2.5*				
ME	A515 Gr.60	C	60	1	17.1	17.1	17.1	16.4	15.8	15.3	*13.0*	*10.8*	*8.7*	*5.9*	*4.0*	*2.5*				
MF	A515 Gr.65	C	65	1	18.6	18.6	18.6	17.9	17.3	16.7	*13.9*	*11.4*	*8.7*	*5.9*	*4.0*	*2.5*				
MG	A515 Gr.70	C	70	1	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	*9.3*	*6.7*	*4.0*	*2.5*				
H	A204 Gr.A	C-1/2 Mo	65	2	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.4	17.9	*13.7*	*8.2*	*4.8*				
I	A204 Gr.B	C-1/2 Mo	70	2	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	19.3	*13.7*	*8.2*	*4.8*				
J	A204 Gr. C	C-1/2 Mo	75	2	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	20.7	*13.7*	*8.2*	*4.8*				
K	A516 Gr.55	C	55	1	15.7	15.7	15.7	15.3	14.8	14.3	*13.0*	*10.8*	*8.7*	*5.9*	*4.0*	*2.5*				
L	A516 Gr. 60	C	60	1	17.1	17.1	17.1	16.4	15.8	15.3	*13.0*	*10.8*	*8.7*	*5.9*	*4.0*	*2.5*				
M	A516 Gr. 65	C	65	1	18.6	18.6	18.6	17.9	17.3	16.7	*13.9*	*11.4*	*8.7*	*5.9*	*4.0*	*2.5*				
N	A516 Gr. 70	C	70	1	20.0	20.0	20.0	19.4	18.8	18.1	*14.8*	*12.0*	*9.3*	*6.7*	*4.0*	*2.5*				
	Forged steel drum – Section 2-3-3																			
A	A266 Cl-1		60	1	17.1	17.1	16.3	15.3	14.8	14.3	*13.0*	*10.8*	*8.7*	*5.9*	*4.0*	*2.5*				
B	A266 Cl-2		70	1	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	*9.3*	*6.7*	*4.0*	*2.5*				
	Castings – Sections 2-3-9 and 2-3-10																			
3	A216.WCA	C	60	1,7	17.1	17.1	16.3	15.3	14.8	14.3	*13.0*	*10.8*	*8.7*	*5.9*	*4.0*	*2.5*				
4	A216 WCB	C	70	1,7	20.0	20.0	19.6	18.4	17.8	17.2	*14.8*	*12.0*	*9.3*	*6.7*	*4.0*	*2.5*				
60-40-18	A395	Nodular iron	60	7	12.0															
	Tubes – Section 2-3-5																			
D	A178 Gr.A	C-Mn	47	1,3,5,6	13.4	13.4	13.4	13.3	12.8	12.4	*10.7*	*9.0*	*7.1*	*5.0*	*2.6*	*1.3*				
F	A178 Gr.C	C-Mn	60	1,3,5	17.1	17.1	17.1	17.1	17.1	15.6	*13.0*	*10.8*	*8.7*	*5.0*	*3.4*	*2.1*				
G	A226	C-Mn	47	1,5,6	13.4	13.4	13.4	13.3	12.8	12.4	*10.7*	*9.0*	*7.1*	*5.0*	*3.0*	*1.5*				
H	A192	C-Mn	47	1,6	13.4	13.4	13.4	13.3	12.8	12.4	*10.7*	*9.0*	*7.1*	*5.0*	*4.5*	*2.5*				
J	A210 Gr.A-1	C-Mn	60	1	17.1	17.1	17.1	17.1	17.1	15.6	*13.0*	*10.8*	*8.7*	*5.9*	*4.0*	*2.5*				
K	A209 Gr.T1	C-Mn-1/2 Mo	55	2	15.7	15.7	15.7	15.7	15.7	15.7	15.4	14.9	14.5	13.7	*8.2*	*4.8*				
L	A209 Gr.T1a	C-Mn-1/2 Mo	60	2	17.1	17.1	17.1	17.1	17.1	16.8	16.4	15.9	15.4	13.7	*8.2*	*4.8*				
M	A209 Gr.T1b	C-Mn-1/2 Mo	53	2	15.1	15.1	15.1	15.1	15.0	14.7	14.3	14.0	13.5	13.0	*8.2*	*4.8*				
N	A213 Gr.T11	1-1/4 Cr - 1/2 Mo	60		17.1	16.8	16.2	15.7	15.4	15.1	14.8	14.4	14.0	*13.6*	*9.3*	*6.3*	*4.2*	*2.8*	*1.9*	*1.2*
O	A213 Gr.T12	1 Cr - 1/2 Mo	60		16.5	16.5	16.5	16.3	16.0	15.8	15.5	15.3	14.9	*14.5*	*11.3*	*7.2*	*4.5*	*2.8*	*1.8*	*1.1*
P	A213 Gr.T22	2-1/4 Cr - 1 Mo	60		16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	*13.6*	*10.8*	*8.0*	*5.7*	*3.8*	*2.4*	*1.4*

Notes

1 Upon prolonged exposure to temperatures above 800°F, the carbide phase of carbon steel may be converted to graphite.

2 Upon exposure to temperatures above about 875°F, the carbide phase of carbon-molybdenum steel may be converted to graphite.

3 Only killed steel is to be used above 900°F.

4 Flange quality in this specification not permitted above 850°F.

5 Above 700°F these stress values include a joint efficiency factor of 0.85. When material to this specification is used for pipe, multiply the stress values up to and including 700°F by a factor of 0.85.

6 Tensile value is expected minimum.

7 To these values a quality factor of 0.80 is to be applied unless nondestructive testing (NDT) is carried out beyond that required by material specification. See UG 24 of ASME Code, Section VIII, Division 1.

PART

4

CHAPTER 5 Deck and Other Machinery

CONTENTS

PART

4

CHAPTER 5 Deck and Other Machinery

SECTION 1 Anchor Windlass

1 General

1.1 Application

The provisions of Part 4, Chapter 5, Section 1 (referred to as Section 4-5-1) apply to windlasses used for handling anchors and chains required by Part 3, Chapter 5.

1.3 Standards of Compliance *(2002)*

The design, construction and testing of windlasses are to conform to an acceptable standard or code of practice. To be considered acceptable, the standard or code of practice is to specify criteria for stresses, performance and testing.

The following are examples of standards presently recognized by the Bureau:

SNAME T & R Bulletin 3-15 - Guide to the Design and Testing of Anchor Windlasses for Merchant Ships

ISO 7825	Deck machinery general requirements
ISO 4568	Windlasses and anchor capstans Sea-going Vessels
JIS F6710	Steam Anchor Windlasses
JIS F6712	AC Electrical Anchor Windlasses
JIS F6713	Hydraulic Anchor Windlasses
JIS F6714	Windlasses
BS MA35	Specifications for Ship Deck Machinery Windlass

1.5 Plans and Particulars to be Submitted

The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, are to be submitted to the Bureau for evaluation:

- Windlass design specifications; anchor and chain cable particulars; performance criteria; standard of compliance.
- Windlass arrangement plan showing all of the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery; brakes; controls; etc.
- Dimensions, materials, welding details, as applicable, of all torque-transmitting (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load bearing (shaft bearings, cable lifter, sheaves, drums, bed-frames, etc.) components of the windlass and of the winch, where applicable, including brakes, chain stopper (if fitted) and foundation.
- Hydraulic piping system diagram along with system design pressure, relief valve setting, bill of materials, typical pipe joints, as applicable.

- Electric one line diagram along with cable specification and size; motor controller; protective device rating or setting; as applicable.
- Control, monitoring and instrumentation arrangements.
- Engineering analyses for torque-transmitting and load-bearing components demonstrating their compliance with recognized standards or codes of practice. Analyses for gears are to be in accordance with a recognized standard.
- Windlass foundation structure, including under deck supporting structures, and holding down arrangements.
- *(2003)* Plans and data for windlass electric motors including associated gears rated 100 kW (135 hp) and over.
- *(1 July 2008)* Calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity are to be submitted if the "load testing" including "overload" capacity of the entire windlass unit is not carried out at the shop [see 4-5-1/7ii)].

3 Materials and Fabrication

3.1 Materials

Materials entered into the construction of torque-transmitting and load-bearing parts of windlasses are to comply with material specifications in Part 2, Chapter 3 or of a national or international material standard. The proposed materials are to be indicated in the construction plans and are to be approved in connection with the design. All such materials are to be certified by the material manufacturers and are to be traceable to the manufacturers' certificates.

3.3 Welded Fabrication

Weld joint designs are to be shown in the construction plans and are to be approved in association with the approval of the windlass design. Welding procedures and welders are to be qualified in accordance with Part 2, Chapter 4. Welding consumables are to be type-approved by the Bureau or are to be of a type acceptable to the Surveyor. The degree of nondestructive examination of welds and post-weld heat treatment, if any, are to be specified and submitted for consideration.

5 Design

Along with and not withstanding the requirements of the chosen standard of compliance, the following requirements are also to be complied with. In lieu of conducting engineering analyses and submitting them for review, approval of the windlass mechanical design may be based on a type test, in which case the testing procedure is to be submitted for consideration. At the option of the manufacturers, windlass designs may be approved based on the Type Approval Program (see 1-1-A3/5).

5.1 Mechanical Design

5.1.1 Design Loads *(2002)*

5.1.1(a) Holding Loads. Calculations are to be made to show that, in the holding condition (single anchor, brake fully applied and chain cable lifter declutched), and under a load equal to 80% of the specified minimum breaking strength of the chain cable (see 2-2-2/Table 2 and 2-2-2/Table 3), the maximum stress in each load bearing component will not exceed yield strength (or 0.2% proof stress) of the material. For installations fitted with a chain cable stopper, 45% of the specified minimum breaking strength of the chain cable may instead be used for the calculation.

5.1.1(b) Inertia Loads. The design of the drive train, including prime mover, reduction gears, bearings, clutches, shafts, wildcat and bolting is to consider the dynamic effects of sudden stopping and starting of the prime mover or chain cable so as to limit inertial load.

5.1.2 Continuous Duty Pull

The windlass prime mover is to be able to exert for at least 30 minutes a continuous duty pull (e.g., 30-minute short time rating as per 4-8-3/3.3.2 and 4-8-3/Table 4; or corresponding to S2-30 min. of IEC 60034-1), Z_{cont}, corresponding to the grade (see 3-5-1/Table 1) and diameter, d, of the chain cables as follows:

Grade of chain	Z_{cont}		
	N	*kgf*	*lbf*
1	$37.5d^2$	$3.82d^2$	$5425.7d^2$
2	$42.5d^2$	$4.33d^2$	$6149.1d^2$
3	$47.5d^2$	$4.84d^2$	$6872.5d^2$
Unit of d	mm	mm	in.

The value of Z_{cont} is based on the hoisting of one anchor at a time, and that the effects of buoyancy and hawse pipe efficiency (assumed to be 70%) have been accounted for. In general, stresses in each torque-transmitting component are not to exceed 40% of yield strength (or 0.2% proof stress) of the material under these loading conditions.

5.1.3 Overload Capability

The windlass prime mover is to be able to provide the necessary temporary overload capacity for breaking out the anchor. This temporary overload capacity or “short term pull” is to be at least 1.5 times the continuous duty pull applied for at least 2 minutes.

5.1.4 Hoisting Speed

The mean speed of the chain cable during hoisting of the anchor and cable is to be at least 9 m/min. For testing purposes, the speed is to be measured over two shots of chain cable and initially with at least three shots of chain (82.5 m or 45 fathoms in length) and the anchor submerged and hanging free.

5.1.5 Brake Capacity

The capacity of the windlass brake is to be sufficient to stop the anchor and chain cable when paying out the chain cable. Where a chain cable stopper is not fitted, the brake is to produce a torque capable of withstanding a pull equal to 80% of the specified minimum breaking strength of the chain cable without any permanent deformation of strength members and without brake slip. Where a chain cable stopper is fitted, 45% of the breaking strength may instead be applied.

5.1.6 Chain Cable Stopper

Chain cable stopper, if fitted, along with its attachments is to be designed to withstand, without any permanent deformation, 80% of the specified minimum breaking strength of the chain cable.

5.1.7 Support Structure *(2002)*

See 3-5-1/11.3.

5.3 Hydraulic Systems

Hydraulic systems where employed for driving windlasses are to comply with the provisions of 4-6-7/3.

5.5 Electrical Systems

5.5.1 Electric Motors *(2003)*

Electric motors are to meet the requirements of 4-8-3/3 and those rated 100 kW and over are to be certified by the Bureau. Motors installed in the weather are to have enclosures suitable for their location as provided for in 4-8-3/1.11. Where gears are fitted, they are to meet the requirements of Section 4-3-1 and those rated 100 kW (135 hp) and over are to be certified by the Bureau. The Surveyor’s presence for material tests referred to in 4-3-1/3.1.2 and 4-3-1/3.3 is not required, subject to compliance with 4-5-1/3.1.

5.5.2 Electrical Circuits

Motor branch circuits are to be protected in accordance with the provisions of 4-8-2/9.17 and cable sizing is to be in accordance with 4-8-2/7.7.6. Electrical cables installed in locations subjected to the sea are to be provided with effective mechanical protection as provided for in 4-8-4/21.15.

7 Shop Inspection and Testing *(1 July 2006)*

Windlasses are to be inspected during fabrication at the manufacturers' facilities by a Surveyor for conformance with the approved plans. Acceptance tests, as specified in the specified standard of compliance, are to be witnessed by the Surveyor and include the following tests, as a minimum.

i) *No-load test.* The windlass is to be run without load at nominal speed in each direction for a total of 30 minutes. If the windlass is provided with a gear change, additional run in each direction for 5 minutes at each gear change is required.

ii) *Load test (1 July 2008).* The windlass is to be tested to verify that the continuous duty pull, overload capacity and hoisting speed as specified in 4-5-1/5.1 can be attained.

Where the required "load testing" including "overload" capacity of the entire windlass unit at the shop is not possible or practical, the manufacturer may submit powering calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity. These calculations are to be validated through testing of an anchor windlass unit. Once these calculations are validated, they may be used in place of the load tests within the scope of the calculations. Further, in addition to other testing requirements, each prime mover is to be tested at the shop to verify its ability to meet the calculated power requirements. Where the prime mover is a hydraulic motor, in addition to the hydraulic motor, the hydraulic pump is also to be tested at the shop. During the testing, the input/output torque, speed, delivery pressures and flow rates of the pump and the hydraulic motor are to be measured, as appropriate.

iii) *Brake capacity test.* The holding power of the brake is to be verified either through testing or by calculation.

At the option of the manufacturers, windlass designs and the manufacturing facilities may be approved under the Type Approval Program (see Appendix 1-1-A3).

9 On-board Tests *(2002)*

See 3-7-2/1.

PART
4

CHAPTER 6 Piping Systems

CONTENTS

PART

4

CHAPTER 6 Piping Systems

SECTION 1 General Provisions

1 General

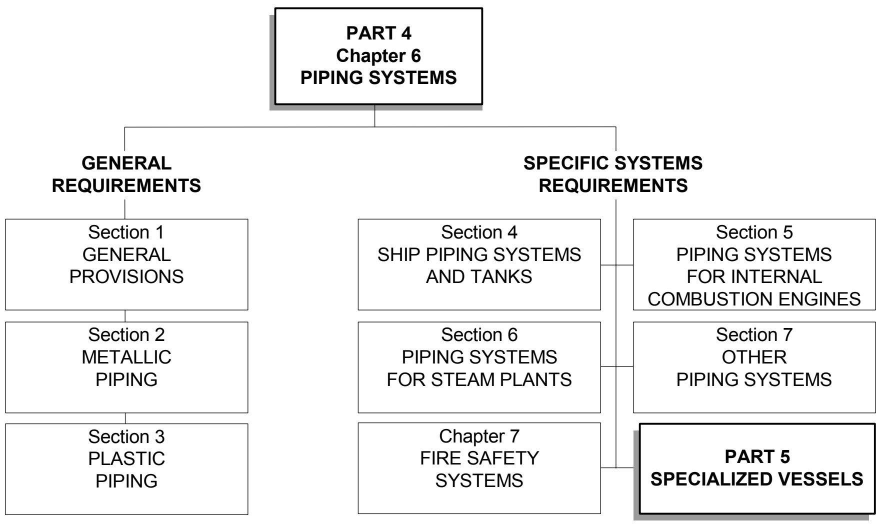
1.1 Application

The provisions of Part 4, Chapter 6, Section 1 (referred to as Section 4-6-1) apply to all piping systems. These include piping systems covered in Section 4-6-2 through Section 4-6-7, as well as to piping systems in Part 4, Chapter 7 "Fire Safety Systems", and to piping systems of specialized types of vessels in the applicable sections of Part 5C.

1.3 Organization of Piping Systems Requirements

4-6-1/Figure 1 shows the organization of the provisions for piping systems. These requirements are divided into:

FIGURE 1
Organization of the Provisions for Piping Systems



i) General requirements, which include:

- Definitions of terms used throughout these sections, certification requirements of system components and plans to be submitted for review;
- Metallic piping design, pipe components, piping fabrication and testing and general shipboard installation details;
- Plastic piping design, plastic pipe components, plastic piping fabrication and testing.

ii) Specific systems requirements, which include:

- Bilges and gravity drains piping systems, and piping systems serving tanks (other than cargo tanks); piping systems for storage, transfer and processing of fuel oil and lubricating oil;
- Piping systems relating to the operation of internal combustion engines;
- Piping systems relating to the operation of steam turbine and steam generating plants;
- Other piping systems, such as hydraulic piping system, oxygen-acetylene piping system, etc.;
- Fire extinguishing systems, which are provided in Part 4, Chapter 7;
- Cargo piping systems and other piping systems specific to specialized vessel types, which are provided in various chapters in Part 5C.

3 Definitions

3.1 Piping

The term *Piping* refers to assemblies of piping components and pipe supports.

3.3 Piping System

Piping System is a network of piping and any associated pumps, designed and assembled to serve a specific purpose. Piping systems interface with, but exclude, major equipment, such as boilers, pressure vessels, tanks, diesel engines, turbines, etc.

3.5 Piping Components

Piping Components include pipes, tubes, valves, fittings, flanges, gaskets, bolting, hoses, expansion joints, sight flow glasses, filters, strainers, accumulators, instruments connected to pipes, etc.

3.7 Pipes

Pipes are pressure-tight cylinders used to contain and convey fluids. Where the word 'pipe' is used in this section, it means pipes conforming to materials and dimensions as indicated in Section 2-3-12, Section 2-3-13, Section 2-3-16 and Section 2-3-17, or equivalent national standards such as ASTM, BS, DIN, JIS, etc.

3.9 Pipe Schedule

Pipe Schedules are designations of pipe wall thicknesses as given in American National Standard Institute, ANSI B36.10. Standard and extra heavy (extra strong) pipes, where used in these sections, refer to Schedule 40 and Schedule 80, up to maximum wall thicknesses of 9.5 mm (0.375 in.) and 12.5 mm (0.5 in.), respectively. For a listing of commercial pipe sizes and wall thicknesses, see 4-6-2/Table 8.

3.11 Tubes

Tubes are generally small-diameter thin-wall pipes conforming to an appropriate national standard. Tubes are to meet the same general requirements as pipes.

3.13 Pipe Fittings

Pipe Fittings refer to piping components such as sleeves, elbows, tees, bends, flanges, etc., which are used to join together sections of pipe.

3.15 Valves

The term *Valve* refers to gate valves, globe valves, butterfly valves, etc., which are used to control the flow of fluids in a piping system. For the purpose of these Rules, test cocks, drain cocks and other similar components which perform the same function as valves are considered valves.

3.17 Design Pressure

Design Pressure is the pressure to which each piping component of a piping system is designed. It is not to be less than the pressure at the most severe condition of coincidental internal or external pressure and temperature (maximum or minimum) expected during service. However, the Rules do impose in some instances a specific minimum design pressure that exceeds the maximum expected service pressure, see for example 4-6-4/13.7 for heated fuel oil systems.

3.19 Maximum Allowable Working Pressure

The *Maximum Allowable Working Pressure* is the maximum pressure of a piping system determined, in general, by the weakest piping component in the system or by the relief valve setting. The maximum allowable working pressure is not to exceed the design pressure.

3.21 Design Temperature

The *Design Temperature* is the maximum temperature at which each piping component is designed to operate. It is not to be less than the temperature of the piping component material at the most severe condition of temperature and coincidental pressure expected during service. For purposes of the Rules, it may be taken as the maximum fluid temperature.

For piping used in a low-temperature application, the design temperature is to include also the minimum temperature at which each piping component is designed to operate. It is not to be higher than the temperature of the piping component material at the most severe condition of temperature and coincidental pressure expected during service. For the purposes of the Rules, it may be taken as the minimum fluid temperature.

For all piping, the design temperature is to be used to determine allowable stresses and material testing requirements.

3.23 Flammable Fluids

Any fluid, regardless of its flash point, liable to support a flame is to be treated as a flammable fluid for the purposes of Section 4-6-1 through Section 4-6-7. Aviation fuel, diesel fuel, heavy fuel oil, lubricating oil and hydraulic oil (unless the hydraulic oil is specifically specified as non-flammable) are all to be considered flammable fluids.

3.25 Toxic Fluids *(2002)*

Toxic fluids are those that are liable to cause death or severe injury or to harm human health if swallowed or inhaled or by skin contact.

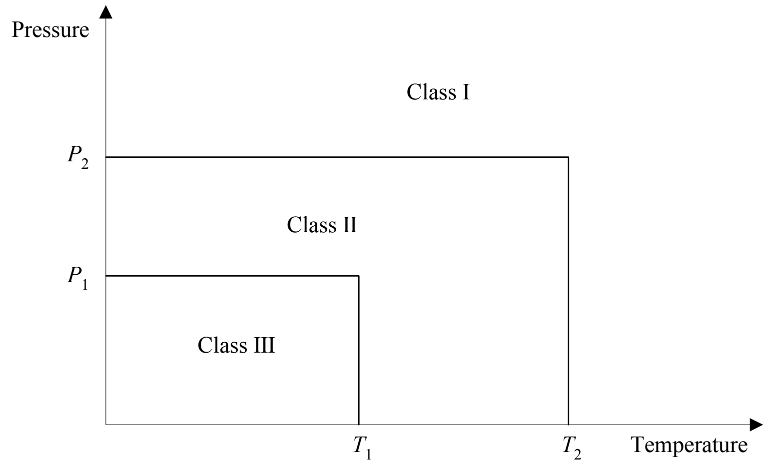
3.27 Corrosive Fluids *(2002)*

Corrosive fluids, excluding seawater, are those possessing in their original state the property of being able through chemical action to cause damage by coming into contact with living tissues, the vessel or its cargoes, when escaped from their containment.

5 Classes of Piping Systems

Piping systems are divided into three classes according to service, design pressure and temperature, as indicated in 4-6-1/Table 1. Each class has specific requirements for joint design, fabrication and testing. The requirements in this regard are given in Section 4-6-2 for metallic piping. For plastic piping, see Section 4-6-3.

TABLE 1
Classes of Piping Systems *(2002)*



Piping Class →	*Class I* $P > P_2$ *OR* $T > T_2$		*Class II Bounded by Class I and Class III - see chart above*		*Class III* $P \leq P_1$ *AND* $T \leq T_1$	
Piping System ↓	*bar, (kgf/cm², psi)*	*°C (°F)*	*bar, (kgf/cm², psi)*	*°C (°F)*	*bar, (kgf/cm², psi)*	*°C (°F)*
Corrosive fluids	Without special safeguards		With special safeguard		Not applicable	
Toxic fluids	All		Not applicable		Not applicable	
Flammable liquids heated to above flash point or having flash point 60°C or less	Without special safeguards		With special safeguards		Open-ended piping	
Liquefied gas	Without special safeguards		With special safeguards		Open-ended piping	
Steam	16 (16.3, 232)	300 (572)	See chart		7 (7.1, 101.5)	170 (338)
Thermal oil	16 (16.3, 232)	300 (572)	See chart		7 (7.1, 101.5)	150 (302)
Fuel oil Lubricating oil Flammable hydraulic oil	16 (16.3, 232)	150 (302)	See chart		7 (7.1, 101.5)	60 (140)
Cargo oil piping in cargo area	Not applicable		Not applicable		All	
Other fluids (including water, air, gases, non-flammable hydraulic oil)	40 (40.8, 580)	300 (572)	See chart		16 (16.3, 232)	200 (392)
Open ended pipes (drains, overflows, vents, exhaust gas lines, boilers escapes pipes)	Not applicable		Not applicable		All	

Notes:

1. The above requirements are not applicable to piping systems intended for liquefied gases in cargo and process areas.
2. The above requirements are also not applicable to cargo piping systems of vessels carrying chemicals in bulk.
3. Safeguards are measures undertaken to reduce leakage possibility and limiting its consequences, (e.g., double wall piping or equivalent, or protective location of piping etc.)

7 Certification of Piping System Components

7.1 Piping Components

Piping components are to be certified in accordance with 4-6-1/Table 2 and the following.

7.1.1 ABS Certification

Where indicated as 'required' in 4-6-1/Table 2, the piping component is to be certified by the Bureau. This involves design approval of the component, as applicable, and testing in accordance with the standard of compliance at the manufacturer's plant. Such components may also be accepted under the Type Approval Program, see 4-6-1/7.5.

7.1.2 Design Approval

Design approval is a part of the ABS certification process and where indicated as 'required' in 4-6-1/Table 2, the piping components are to meet an applicable recognized standard, or are to be design-approved by the Bureau. For the latter purpose, pipe fittings and valves are to be evaluated for their adequacy for the rated pressures and temperatures, and, as applicable, type inspection and testing are to be conducted as part of the design evaluation process. See also 4-6-1/7.5, 4-6-2/5 and 4-6-3/5.

7.1.3 Manufacturer's Certification

Where indicated as 'required' in 4-6-1/Table 2, the manufacturer is to certify that the piping component complies with the standard to which the component is designed, fabricated and tested, and to report the results of tests so conducted. For Class III components, manufacturer's trademark, pressure/temperature rating and material identification, as applicable, stamped or cast on the component and verifiable against the manufacturer's catalog or similar documentation will suffice.

7.1.4 Identification

Where indicated as 'permanent' in 4-6-1/Table 2, the piping component is to bear permanent identification, such as manufacturer's name or trademark, standard of compliance, material identity, pressure rating, etc., as required by the standard of compliance or the manufacturer's specification. Such markings may be cast or forged integral with, stamped on, or securely affixed by nameplate on the component, and are to serve as a permanent means of identification of the component throughout its service life.

Where indicated as 'temporary', the pipe is to have identification for traceability during fabrication.

TABLE 2
Piping Classes and Certification

Piping Component	*Class*	*ABS Certification* (1)	*Design Approval* (1)	*Manufacturer's Certification* (1)	*Identification* (1)
Pipes	I, II	Required (2)	Not applicable (3)	Required	Temporary (3)
	III	Not required (3)	Not applicable (3)	Required	Temporary (3)
Pipe fittings	I, II	Not required	Required (4, 6)	Required	Permanent
	III	Not required	Not required (5 ,6)	Required	Permanent
Valves	I, II	Not required	Required (4)	Required	Permanent
	III	Not required	Not required (5)	Required	Permanent

Notes:

1 See 4-6-1/7.1.1, 4-6-1/7.1.2, 4-6-1/7.1.3 and 4-6-1/7.1.4.

2 Except hydraulic piping.

3 Except for plastic piping. See Section 4-6-3.

4 Where not in compliance with a recognized standard.

5 Documentary proof of pressure/temperature rating is required. See 4-6-2/5.15.

6 Design of flexible hoses and mechanical pipe joints is to be approved in each case. See 4-6-2/5.7 and 4-6-2/5.9, respectively.

7.3 Pumps

7.3.1 Pumps Requiring Certification

The pumps listed below are to be certified by a Surveyor at the manufacturers' plants:

i) Pumps for all vessels (500 gross tonnage and over):

- Fuel oil transfer pumps
- Hydraulic pumps for steering gears (see also 4-3-4/19.5), anchor windlasses, controllable pitch propellers
- Fire pumps, including emergency fire pumps
- Bilge pumps
- Ballast pumps

ii) Pumps associated with propulsion diesel engine and reduction gears (for engines with bores > 300 mm only):

- Fuel oil service pumps, booster pumps, etc.
- Sea water and freshwater cooling pumps
- Lubricating oil pumps

iii) Pumps associated with steam propulsion and reduction gears:

- Fuel oil service pumps
- Main condensate pumps
- Main circulating pumps
- Main feed pumps
- Vacuum pumps for main condenser
- Lubricating oil pumps

iv) Pumps associated with propulsion gas turbine and reduction gears:

- Fuel oil service pumps
- Lubricating oil pumps

v) Cargo pumps associated with oil carriers, liquefied gas carriers and chemical carriers.

vi) *(2006)* Cargo vapor compressors associated with liquefied gas carriers (high and low duty gas compressors).

vii) Pumps associated with inert gas systems:

- Fuel oil pumps for boilers/inert gas generators
- Cooling water pumps for flue gas scrubber

7.3.2 Required Tests

The following tests are to be carried out at the manufacturer's plant in the presence of the Surveyor.

7.3.2(a) Hydrostatic tests. The pumps are to be hydrostatically tested to a pressure of at least $1.5P$, where P is the maximum working pressure of the pump. If it is desired to conduct the hydrostatic test on the suction side of the pump independently from the test on the discharge side, the test pressure on the suction side is to be at least $1.5P_s$, where P_s is the maximum pressure available from the system at the suction inlet. In all cases, the test pressure for both the suction and the discharge side is not to be less than 4 bar.

7.3.2(b) Capacity tests. Pump capacities are to be checked with the pump operating at design conditions (rated speed and pressure head). For centrifugal pumps, the pump characteristic (head-capacity) design curve is to be verified to the satisfaction of the Surveyor. Capacity tests may be waived if previous satisfactory tests have been carried out on similar pumps.

7.3.2(c) Relief valve capacity test (2005). For positive displacement pumps with an integrated relief valve, the valve's setting and full flow capacity corresponding to the pump maximum rating is to be verified. The operational test for relief valve capacity may be waived if previous satisfactory tests have been carried out on similar pumps.

7.5 Certification Based on the Type Approval Program

7.5.1 Pipes *(2003)*

For pipes which are required to be ABS certified in accordance with 4-6-1/Table 2, the manufacturer may request that the Bureau approve and list them under the Type Approval Program described in Appendix 1-1-A3. Upon approval under 1-1-A3/5.5 (PQA) and listing under this program, the pipes will not be required to be surveyed and certified each time they are manufactured for use onboard a vessel.

To be considered for approval under this program, the manufacturer is to operate a quality assurance system that is certified for compliance with a recognized quality standard. In addition, quality control of the manufacturing processes is to cover all of the provisions of inspection and tests required by the Rules and applicable pipe standard, in accordance with 1-1-A3/5.5.

7.5.2 Pipe Fittings and Valves *(2003)*

For pipe fittings and valves which are not required to be certified but are required to be design approved in accordance with 4-6-1/Table 2, the manufacturer may request that the Bureau approve and list the component as a Design Approved Product described in 1-1-A3/5.1. The design is to be evaluated in accordance with 4-6-1/7.1.2. Upon approval and listing, and subject to renewal and updating of the certificates as required by 1-1-A3/5.7, it will not be necessary to submit the design of the component for approval each time it is proposed for use onboard a vessel.

The manufacturer may also request that the product be approved and listed under the Type Approval Program. In this case, in addition to the design approval indicated above, the manufacturer is to provide documented attestation that the product will be manufactured to consistent quality and to the design and specifications to which it is approved. See 1-1-A3/5.3 (AQS)/(RQS) or 1-1-A3/5.5 (PQA).

7.5.3 Pumps *(2003)*

As an alternative to certification specified in 4-6-1/7.3.2 for mass-produced pumps, the manufacturer may request that the Bureau approve and list the pump under the Type Approval Program. To be approved under this program:

i) A sample of the pump type is to be subjected to hydrostatic and capacity tests specified in 4-6-1/7.3.2; and

ii) The manufacturer is to operate a quality assurance system which is to be certified for compliance with a quality standard in accordance with 1-1-1A3/5.3 (AQS)/(RQS) or 1-1-A3/5.5 (PQA). The quality control plan is to have provision to subject each production unit of the pump to a hydrostatic test specified in 4-6-1/7.3.2(a) and the manufacturer is to maintain record of such tests.

The manufacturer has the option to request approval for the pump design in accordance with 4-6-1/7.5.3i) above only, in which case the pump type may be listed as an approved product as described in 1-1-A3/5.1. Certification of a production unit will be based on its being subjected to the hydrostatic test specified in 4-6-1/7.3.2(a) in the presence of a Surveyor.

9 Plans and Data to be Submitted

9.1 System Plans

The following plans are to be submitted for review:

- Propulsion machinery space arrangement, including locations of fuel oil tanks
- Booklet of standard details (see 4-6-1/9.5)
- Ballast system
- Bilge and drainage systems
- Boiler feed water and condensate systems
- Compressed air system
- Cooling water systems
- Exhaust piping (for boilers, incinerators and engines)
- Fixed oxygen-acetylene system
- Fuel oil systems, including storage tanks, drip trays and drains
- Helicopter refueling system, fuel storage tank and its securing and bonding arrangements
- Hydraulic and pneumatic systems
- Lubricating oil systems
- Sanitary system
- Sea water systems
- Vent, overflow and sounding arrangements
- Steam systems
- Steam piping analyses (as applicable)
- Tank venting and overflow systems
- All Class I and Class II piping systems not covered above

9.3 Contents of System Plans

Piping system plans are to be diagrammatic and are to include the following information:

- Types, sizes, materials, construction standards, and pressure and temperature ratings of piping components other than pipes
- Materials, outside diameter or nominal pipe size, and wall thickness or schedule of pipes
- Design pressure and design temperature, test pressure
- Maximum pump pressures and/or relief valve settings
- Flash point of flammable liquids
- Instrumentation and control
- Legend for symbols used

9.5 Booklet of Standard Details

The booklet of standard details, as indicated in 4-6-1/9.1, is to contain standard practices to be used in the construction of the vessel, typical details of such items as bulkhead, deck and shell penetrations, welding details, pipe joint details, etc. This information may be included in the system plans, if desired.

PART

4

CHAPTER 6 Piping Systems

SECTION 2 Metallic Piping

1 Application

The provisions of Part 4, Chapter 6, Section 2 (referred to as Section 4-6-2) cover metallic piping. They include requirements for piping materials, design, fabrication, inspection and testing. They also include general requirements for shipboard installation practices. Requirements for plastic piping are provided in Section 4-6-3.

3 Materials

While references are made to material specifications in Section 2-3-12, Section 2-3-13, Section 2-3-16 and Section 2-3-17, equivalent materials complying with a national or international standard will be considered for acceptance.

3.1 Ferrous

3.1.1 Steel Pipes

3.1.1(a) Material specifications. Material specifications for acceptable steel pipes are in Section 2-3-12. Materials equivalent to these specifications will be considered.

3.1.1(b) Application of seamless and welded pipes. The application of seamless and welded pipes is to be in accordance with the following table:

	Seamless Pipes	*Electric Resistance Welded Pipes*	*Furnace Butt Welded Pipes*
Class I	permitted	permitted	not permitted
Class II	permitted	permitted	not permitted
Class III	permitted	permitted	permitted [1]

Note: 1 Except for flammable fluids.

3.1.2 Forged and Cast Steels

Material specifications for steel forgings and steel castings are given in Section 2-3-7 and Section 2-3-9, respectively. There is no service limitation except as indicated in 4-6-2/3.1.5 and 4-6-2/3.1.6.

3.1.3 Gray Cast Iron *(2002)*

Material specifications for gray cast iron (also called ordinary cast iron) are given in Section 2-3-11. Cast iron components should not be used in systems that are exposed to pressure shock, vibration or excessive strain. In general, gray cast iron pipes, valves and fittings may be used only in Class III piping systems. Specifically, gray cast iron is not to be used for the following applications:

- Valves and fittings for temperatures above 220°C (428°F)
- Valves connected to the collision bulkhead (see 4-6-2/9.7.3)
- Valves connected to the shell of the vessel (see 4-6-2/9.13.2)
- Valves fitted on the outside of fuel oil, lubricating oil, cargo oil and hydraulic oil tanks where subjected to a static head of oil [see, for example, 4-6-4/13.5.3(a)]

- Valves mounted on boilers except as permitted for heating boilers (see 4-4-1/9.3.2)
- Pipes, valves and fittings in cargo oil piping on weather decks for pressures exceeding 16 bar (16.3 kgf/cm^2, 232 psi) [see 5C-1-7/3.3.2(e)]
- Pipes, valves and fittings in cargo oil manifolds for connection to cargo handling hoses [see 5C-1-7/3.3.2(e)]
- Fixed gas fire extinguishing systems

3.1.4 Nodular (Ductile) Iron

Material specifications for nodular iron are given in Section 2-3-10. Nodular iron is not permitted for the construction of valves and fittings for temperatures of 350°C (662°F) and above.

Nodular iron may be used for Classes I and II piping systems and for valves listed in 4-6-2/3.1.3 provided it has an elongation of not less than 12% in 50 mm (2 in.).

3.1.5 Elevated Temperature Applications

In general, carbon and carbon-manganese steel pipes, valves and fittings for pressure service are not to be used for temperatures above 400°C (752°F) unless their metallurgical behavior and time dependent strengths are in accordance with national or international codes or standards and that such behavior and strengths are guaranteed by the steel manufacturers.

Consideration is to be given to the possibility of graphite formation in the following steels:

- Carbon steel above 425°C (797°F)
- Carbon-molybdenum steel above 470°C (878°F)
- Chrome-molybdenum steel (with chromium under 0.60%) above 525°C (977°F)

3.1.6 Low Temperature Applications

Ferrous materials used in piping systems operating at lower than -18°C (0°F) are to have adequate notch toughness properties. Specifications of acceptable materials are in Section 2-3-13. Materials for piping systems of liquefied gas carriers are to comply with 5C-8-5/2.6.

3.3 Copper and Copper Alloys

Material specifications for copper and copper alloy pipes and castings are given in Section 2-3-14, Section 2-3-16 and Section 2-3-17.

Copper and copper alloys are not to be used for fluids having a temperature greater than the following:

Copper-nickel:	300°C (572°F)
High temperature bronze:	260°C (500°F)
All other copper and copper alloys:	200°C (392°F)

Copper and copper alloy pipes may be used for Classes I and II systems, provided they are of the seamless drawn type. Seamless drawn and welded copper pipes are acceptable for Class III systems.

5 Design

5.1 Pipes

The wall thickness of a pipe is not to be less than the greater of the value obtained by 4-6-2/5.1.1 or 4-6-2/5.1.3. However, 4-6-2/5.1.2 may be used as an alternative to 4-6-2/5.1.1.

5.1.1 Pipes Subject to Internal Pressure *(2002)*

The minimum wall thickness is not to be less than that calculated by the following equations or that specified in 4-6-2/5.1.3, whichever is greater. Units of measure are given in the order of SI (MKS, US) units, respectively. The use of these equations is subject to the following conditions:

- The following requirements apply for pipes where the outside to inside diameter ratio does not exceed a value of 1.7.
- Ferrous materials are to be those that have specified elevated temperature tensile properties required below.

$$t = (t_0 + b + c)m$$

$$t_0 = \frac{PD}{KSe + P}$$

where

t = minimum required pipe wall thickness (nominal wall thickness less manufacturing tolerance) ; mm (in.)

t_0 = minimum required pipe wall thickness due to internal pressure only; mm (in.)

P = design pressure; bar (kgf/cm^2, psi)

D = outside diameter of pipe; mm (in.)

K = 20 (200, 2) for SI (MKS, US) units of measure, respectively

S = permissible stress; N/mm^2 (kgf/mm^2, psi); to be determined by a) or b) below:

a) Carbon steel and alloy steel pipes with a specified minimum elevated temperature yield stress or 0.2% proof stress: S is to be the lowest of the following three values:

$$\frac{\sigma_T}{2.7} \qquad \frac{\sigma_Y}{1.8} \qquad \frac{\sigma_R}{1.8}$$

where

σ_T = specified minimum tensile strength at room temperature, i.e., 20°C (68°F).

σ_Y = specified minimum yield strength at the design temperature.

σ_R = average stress to produce rupture in 100,000 hours at the design temperature.

b) Copper and copper alloys: S is to be in accordance with 4-6-2/Table 2.

e = efficiency factor, to be equated to:

1.0 for seamless pipes

1.0 for electric-resistance welded pipes manufactured to a recognized standard

0.6 for furnace butt-welded pipes

For other welded pipes, the joint efficiency is to be determined based on the welding procedure and the manufacturing and inspection processes.

b = allowance for bending; mm (in.). The value for b is to be chosen in such a way that the calculated stress in the bend, due to the internal pressure only, does not exceed the permissible stress. When the bending allowance is not determined by a more accurate method, it is to be taken as:

$$b = 0.4\frac{D}{R}t_0$$

R = mean radius of the bend; mm (in.)

c = corrosion allowance; mm (in.); to be determined as follows:

- For steel pipes, the value for c is to be in accordance with 4-6-2/Table 3.
- For non-ferrous metal pipes (excluding copper-nickel alloys containing 10% or more nickel), c = 0.8 mm (0.03 in.).
- For copper-nickel alloys containing 10% or more nickel, c = 0.5 mm (0.02 in.).
- Where the pipe material is corrosion resistant with respect to the media, e.g., special alloy steel, c = 0.

m = coefficient to account for negative manufacturing tolerance when pipe is ordered by its nominal wall thickness, calculated as follows:

$$= \frac{100}{100 - a}$$

a = percentage negative manufacturing tolerance, or 12.5% where a is not available

5.1.2 Pipes Subject to Internal Pressure – Alternative Equation

As an alternative to 4-6-2/5.1.1, for steel pipe specifications in Section 2-3-12, the minimum wall thickness may be determined by the following equations or that specified in 4-6-2/5.1.3, whichever is greater. Units of measure are given in the order of SI (MKS, US) units, respectively.

$$t = \frac{PD}{KS + MP} + c$$

where

P, D, K, t are as defined in 4-6-2/5.1.1; and

P = for calculation purpose, not to be taken as less then 8.6 bar, 8.8 kgf/cm^2 (125 psi)

S = allowable stress from 4-6-2/Table 1; N/mm^2 (kgf/mm^2, psi).

M = factor, from 4-6-2/Table 1.

c = allowance for threading grooving or mechanical strength, and is to be as given below:

- Plain end pipe ≤ 100 mm (4 in.) NB: 1.65 mm (0.065 in.)
- Plain end pipe ≤ 100 mm (4 in.) NB for hydraulic oil service: 0
- Plain end pipe > 100 mm (4 in.) NB: 0
- Threaded pipe ≤ 9.5 mm ($^3/_8$ in.) NB: 1.27 mm (0.05 in.)
- Threaded pipe > 9.5 mm ($^3/_8$ in.) NB: [0.8 × (mm per thread)] or [0.8 ÷ (threads per in.)]
- Grooved pipe: depth of groove

The above method of calculation may also be used for determining required wall thickness for pipes of other materials. In such cases, the value of S may be obtained from ANSI B31.1 *Code for Power Piping*.

5.1.3 Minimum Pipe Wall Thickness and Bending *(2005)*

Not withstanding 4-6-2/5.1.1 or 4-6-2/5.1.2, the minimum wall thickness of pipes is not to be less than that indicated in 4-6-2/Table 4 for steel pipes, and 4-6-2/Tables 5A and 5B for other metal pipes. The wall thicknesses listed in these tables are nominal wall thicknesses. When using the tables, no allowances need be made to account for negative tolerance or reduction in thickness due to bending.

Pipe bending is to be in accordance with 2-3-12/25 of the *Rules for Materials and Welding (Part 2).* Alternatively, bending in accordance with a recognized standard (e.g., ASME B31.1 - Section 129.1 and 129.3) or other approved specifications to a radius that will result in a surface free of cracks and substantially free of buckles may be acceptable.

5.3 Pipe Branches

Pipe branches may be made by the use of standard branch fittings or by welded fabrication. In the case of welded fabrication, the main pipe is weakened by the hole that must be made in it to accommodate the branch pipe. The opening is to be compensated as follows:

- Excess wall thickness, over and above the minimum required wall thickness of the main pipe and the branch required for pressure service (disregarding corrosion allowance and manufacturing tolerances) determined by the equation in 4-6-2/5.1.1 or 4-6-2/5.1.2 may be considered for this purpose.
- The opening may be compensated with reinforcement pads.

The opening and its compensation may be designed in accordance with the criteria of opening reinforcement of a pressure vessel. See, for example, 4-4-1A1/7.

5.5 Pipe Joints *(2006)*

5.5.1 Butt Welded Joints

Butt welded joints, where complete penetration at the root is achieved, may be used for all classes of piping. Degree of verification of sound root penetration is to be in accordance with 2-4-4/5 and 2-4-4/11.

5.5.2 Socket Welded Joints *(2006)*

Socket welded joints using standard fittings may be used for Classes I and II piping up to and including 80 mm (3 in) nominal diameter, except in toxic and corrosive fluid services (see 4-6-1/3.25 and 4-6-1/3.27) or services where fatigue, severe erosion or crevice corrosion is expected to occur. Socket welded joints using standard fittings may be used for Class III piping without limitation. The fillet weld leg size is to be at least 1.1 times the nominal thickness of the pipe. See 4-6-2/Figure 1.

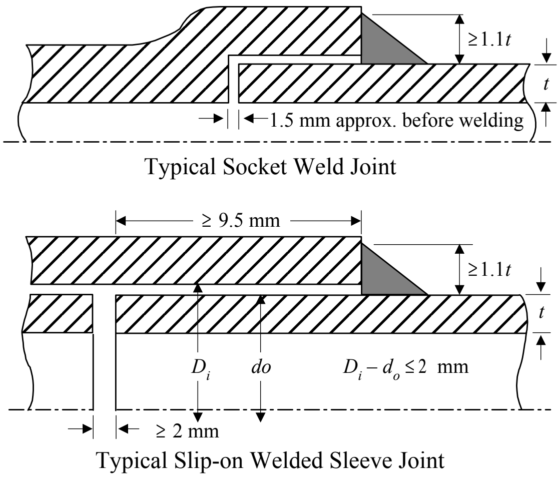
5.5.3 Slip-on Welded Sleeve Joints *(2006)*

Slip-on welded sleeve joints may be used for Classes I and II piping up to and including 80 mm (3 in.) nominal diameter except in toxic and corrosive fluid services (see 4-6-1/3.25 and 4-6-1/3.27) or services where fatigue, severe erosion or crevice corrosion is expected to occur, provided that:

- The inside diameter of the sleeve is not to exceed the outside diameter of the pipe by more than 2 mm (0.08 in.).
- The depth of insertion of the pipe into the sleeve is to be at least 9.5 mm (0.375 in.).
- The gap between the two pipes is to be at least 2 mm (0.08 in.).
- The fillet weld leg size is as per 4-6-2/5.5.2, see 4-6-2/Figure 1.

Slip-on welded sleeve joints may be used for Class III piping without size limitation. In such cases, joint design and attachment weld sizes may be in accordance with a recognized alternative standard.

FIGURE 1
Socket Welded and Slip-on Welded Sleeve Joints



5.5.4 Flanged Joints

Flanges of all types (see 4-6-2/Table 6 for typical types) conforming to and marked in accordance with a recognized national standard may be used within the pressure-temperature ratings of the standard, subject to limitations indicated in 4-6-2/Table 7. For flanges not conforming to a recognized standard, calculations made to a recognized method are to be submitted for review. Non-standard flanges are to be subjected to the same limitations indicated in 4-6-2/Table 7.

Flanges conforming to a standard are to be attached to pipes by welding or other acceptable means as specified in the standard. For example, slip-on flanges conforming to ASME B16.5 are to be attached to pipes by a double fillet weld having throat size of not less than 0.7 times the wall thickness of the pipe. Non-standard flanges are to be attached to pipes by a method approved with the design.

5.5.5 Threaded Joints

5.5.5(a) Taper-thread joints. Threaded joints having tapered pipe threads complying with a recognized standard are not to be used for toxic and corrosive fluid services and for all services of temperatures exceeding 495°C (923°F). They may be used for Classes I and II piping subject to limitations indicated in the table below. They may be used for Class III piping without limitation. For hydraulic oil system, see 4-6-7/Table 1.

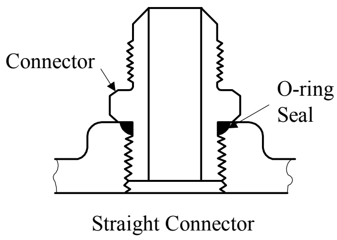
Pipe Nominal Diameter, d		*Maximum Pressure Permitted*		
mm	*in.*	*bar*	*kgf/cm^2*	*psi*
$d > 80$	$d > 3$	Not permitted for Classes I & II		
$80 \geq d > 50$	$3 \geq d > 2$	27.6	28.1	400
$50 \geq d > 25$	$2 \geq d > 1$	41.4	42.2	600
$25 \geq d > 20$	$1 \geq d > 0.75$	82.8	84.4	1200
$d \leq 20$	$d \leq 0.75$	103	105.5	1500

5.5.5(b) Taper-thread joints for hydraulic oil system. Taper-thread joints up to 80 mm (3 in.) nominal diameter may be used without pressure limitation for connection to equipment only, such as pumps, valves, cylinders, accumulators, gauges and hoses. When such fittings are used solely to join sections of pipe, they are to be in accordance with 4-6-2/5.5.5(a). However, hydraulic systems for the following services are to comply with 4-6-2/5.5.5(a) in all respects:

- Steering gear hydraulic systems
- Controllable pitch propeller hydraulic systems
- Hydraulic systems associated with propulsion or propulsion control

5.5.5(c) Straight-thread 'o'-ring joints. For hydraulic oil piping, straight thread 'o'-ring type fittings (see 4-6-2/Figure 2) may also be used for connections to equipment, without pressure and service limitation, but are not to be used for joining sections of pipe.

FIGURE 2
Straight-thread 'O'-Ring Joints



5.7 Flexible Hoses *(2006)*

5.7.1 Definition

A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

5.7.2 Scope

The requirements of 4-6-2/5.7.3 to 4-6-2/5.7.6 apply to flexible hoses of metallic or non-metallic material intended for a permanent connection between a fixed piping system and items of machinery. The requirements also apply to temporary connected flexible hoses or hoses of portable equipment.

Flexible hose assemblies as defined in 4-6-2/5.7.1 are acceptable for use in oil fuel, lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems, and Class III steam systems where they comply with 4-6-2/5.7.3 to 4-6-2/5.7.6.

Flexible hoses are not acceptable in high pressure fuel oil injection systems.

These requirements for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

5.7.3 Design and Construction

5.7.3(a) Hose material. Flexible hoses are to be designed and constructed in accordance with recognized National or International standards acceptable to the Bureau. Flexible hoses constructed of rubber or plastics materials and intended for use in bilge, ballast, compressed air, oil fuel, lubricating, hydraulic and thermal oil systems are to incorporate a single or double closely woven integral wire braid or other suitable material reinforcement. Where rubber or plastics materials hoses are to be used in oil supply lines to burners, the hoses are to have external wire braid protection in addition to the integral reinforcement. Flexible hoses for use in steam systems are to be of metallic construction.

5.7.3(b) Hose end fittings. Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. Flanged end connections are to comply with 4-6-2/5.5.4 and threaded end connections with 4-6-2/5.5.5, as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses in piping systems for steam, flammable media, starting air or for sea water where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar (5.1 kgf/cm^2, 72.5 psi) and provided there are at least two stainless steel hose clamps at each end connection. The hose clamps are to be at least 12 mm (0.5 in.) wide and are not to be dependent upon spring tension to remain fastened.

5.7.3(c) Fire resistance. Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media and sea water systems where failure may result in flooding, are to be of a fire-resistant type*. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

* *Note:* The installation of a shutoff valve immediately upstream of a sea water hose does not satisfy the requirement for fire-resistant type hose.

5.7.3(d) Hose application. Flexible hose assemblies are to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and other relevant requirements of this Section.

Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 4-6-2/5.7.5 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

5.7.4 Installation

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

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

The number of flexible hoses, in piping systems is to be kept to minimum and is to be limited for the purpose stated in 4-6-2/5.7.2.

Where flexible hoses are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other similar protection.

Flexible hoses are to be installed in clearly visible and readily accessible locations.

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

- Orientation
- End connection support (where necessary)
- Avoidance of hose contact that could cause rubbing and abrasion
- Minimum bend radii

5.7.5 Tests

5.7.5(a) Test procedures. Acceptance of flexible hose assemblies is subject to satisfactory type testing. Type test programs for flexible hose assembles are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

The tests are, as applicable, to be carried out on different nominal diameters of hose type complete with end fittings for pressure, burst, impulse resistance and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable.

- ISO 6802 – Rubber and plastics hoses and hose assemblies with wire reinforcement – Hydraulic impulse test with flexing.
- ISO 6803 – Rubber and plastics hoses and hose assemblies – Hydraulic-pressure impulse test without flexing.
- ISO 15540 – Ships and marine technology – Fire resistance of hose assemblies – Test methods.
- ISO 15541 – Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench.
- ISO 10380 – Pipework – Corrugated metal hoses and hose assemblies.

Other standards may be accepted where agreed.

5.7.5(b) Burst test. All flexible hose assemblies are to be satisfactorily type burst tested to an international standard to demonstrate they are able to withstand a pressure not less than four (4) times its design pressure without indication of failure or leakage.

Note: The international standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 × MWP.

5.7.6 Marking

Flexible hoses are to be permanently marked by the manufacturer with the following details:

- Hose manufacturer's name or trademark.
- Date of manufacture (month/year).
- Designation type reference.
- Nominal diameter.
- Pressure rating
- Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

5.8 Expansion Joints

5.8.1 Molded Expansion Joints *(2004)*

5.8.1(a) Molded Nonmetallic Expansion Joints. Where molded expansion joints made of reinforced rubber or other suitable nonmetallic materials are proposed for use in Class III circulating water systems in machinery spaces, the following requirements apply:

- The expansion joint is to be oil resistant.
- The maximum allowable working pressure is not to be greater than 25% of the hydrostatic bursting pressure determined by a burst test of a prototype expansion joint. Results of the burst test are to be submitted.
- Plans of molded or built-up expansion joints over 150 mm (6 in.), including internal reinforcement arrangements, are to be submitted for approval. Such joints are to be permanently marked with the manufacturer's name and the month and year of manufacture.

5.8.1(b) Molded Expansion Joints of Composite Construction. Where molded expansion joints of composite construction utilizing metallic material, such as steel or stainless steel or equivalent material, with rubberized coatings inside and/or outside or similar arrangements are proposed for use in oil piping systems (fuel, lubricating or hydraulic oil), the following requirements apply:

- Expansion joint ratings for temperature, pressure, movements and selection of materials are to be suitable for the intended service.
- The maximum allowable working pressure of the system is not to be greater than 25% of the hydrostatic bursting pressure determined by a burst test of a prototype expansion joints. Results of the burst test are to be submitted.
- The expansion joints are to pass the fire resistant test specified in 4-6-2/5.7.3(c).
- The expansion joints are to be permanently marked with the manufacturer's name and the month and year of manufacture.

Molded expansion joints may be Type Approved; see 1-1-A3/1.

5.8.2 Metallic Bellow Type Expansion Joints

Metallic bellow type expansion joints may be used in all classes of piping, except that where used in Classes I and II piping, they will be considered based upon satisfactory review of the design. Detailed plans of the joint are to be submitted along with calculations and/or test results verifying the pressure and temperature rating and fatigue life.

5.9 Mechanical Joints *(2006)*

5.9.1 Design

These requirements are applicable to pipe unions, compression couplings and slip-on joints, as shown in 4-6-2/Table 9. The approval is to be based upon the results of testing of the actual joints in association with the following requirements. Mechanical joints similar to those indicated in 4-6-2/Table 9 and complying with these requirements will be specially considered.

5.9.1(a) General (1 July 2007). The application and pressure ratings of mechanical joints are to be approved by the Bureau. The approval is to be based upon the testing specified in 4-6-2/5.9.2, as required for the service conditions and intended application.

5.9.1(b) Impact on Wall Thickness. 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.

5.9.1(c) Operational Conditions. 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 onboard.

5.9.1(d) Materials. Material of mechanical joints is to be compatible with the piping material and internal and external media.

5.9.1(e) Burst Testing. Mechanical joints are to be tested to a burst pressure of four (4) times the design pressure. For design pressures above 200 bar (204 kgf/cm^2, 2900 psi), the required burst pressure will be specially considered by the Bureau.

5.9.1(f) Fire Testing. Mechanical joints are to be of fire resistant type, as required by 4-6-2/Table 10.

5.9.1(g) Locations. 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.

5.9.1(h) Application. 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.

5.9.1(i) Joints. 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.

5.9.1(j) Support and Alignment. 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.

5.9.1(k) Slip-on Joints. Slip-on joints are to be accessible for inspection. Accordingly, slip-on joints are not to be used in pipelines in cargo holds, tanks and other spaces that are not easily accessible, unless approved by the Bureau. Application of these joints inside tanks may be permitted only for the same media that is 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.

5.9.1(l) Application. Application of mechanical joints and their acceptable use for each service is indicated in 4-6-2/Table 10. Dependence upon the Class of piping, pipe dimensions, working pressure and temperature is indicated in 4-6-2/Table 11. In particular cases, sizes in excess of those mentioned above may be accepted by the Bureau if in compliance with a recognized national or international standard.

5.9.1(m) Testing. Mechanical joints are to be tested in accordance with a program approved by the Bureau, which is to include at least the following:

i) Tightness test

ii) Vibration (fatigue) test (where necessary)

iii) Pressure pulsation test (where necessary)

iv) Burst pressure test

v) Pull out test (where necessary)

vi) Fire endurance test (where necessary)

vii) Vacuum test (where necessary)

viii) Repeated assembly test (where necessary)

5.9.1(n) Joints Assembly. 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.

5.9.2 Testing of Mechanical Joints *(2007)*

5.9.2(a) General. These requirements describe the type testing for the approval of mechanical joints intended for use in marine piping systems. The Bureau may specify more severe testing conditions and additional tests if considered necessary to ensure the intended reliability and also accept alternative testing in accordance with national or international standards where applicable to the intended use and application. See 1-1-A3/1 for general requirements for Type Approval Certification.

5.9.2(b) Scope. This specification is applicable to mechanical joints defined in 4-6-2/5.9.1 including compression couplings and slip-on joints of different types for marine use.

5.9.2(c) Documentation. Following documents and information are to be submitted by the Manufacturer for assessment and/or approval:

i) Product quality assurance system implemented.

ii) Complete description of the product.

iii) Typical sectional drawings with all dimensions necessary for evaluation of joint design.

iv) Complete specification of materials used for all components of the assembly.

v) Proposed test procedure as required in 4-6-2/5.9.2(e) and corresponding test reports or other previous relevant tests.

vi) Initial information:

- Maximum design pressures (pressure and vacuum)
- Maximum and minimum design temperatures
- Conveyed media
- Intended services
- Maximum axial, lateral and angular deviation, allowed by manufacturer
- Installation details

5.9.2(d) Materials. The materials used for mechanical joints are to comply with the requirements of 4-6-2/5.9.1(d). The manufacturer is to submit evidence to substantiate that all components are adequately resistant to working the media at design pressure and temperature specified.

5.9.2(e) Testing, procedures and requirements. The aim of these tests is to demonstrate the ability of the pipe joints to operate satisfactory under intended service conditions. The scope and type of tests to be conducted e.g. applicable tests, sequence of testing, and the number of specimen, is subject to approval and will depend on joint design and its intended service in accordance with the requirements of 4-6-2/5.9.1 and 4-6-2/5.9.2, unless otherwise specified, water or oil is to be used as the test fluid.

i) *Test program*. Testing requirements for mechanical joints are as indicated in 4-6-2/Table 12.

ii) *Selection of Test Specimen.* Test specimens are to be selected from the production line or at random from stock. Where there are various sizes from the type of joints requiring approval, a minimum of three separate sizes representative of the range, from each type of joints are to be subject to the tests listed in 4-6-2/Table 12.

iii) *Mechanical Joint Assembly.* Assembly of mechanical joints should consist of components selected in accordance with 4-6-2/5.9.2(e)ii) and the pipe sizes appropriate to the design of the joints. Where pipe material would affect the performance of mechanical joints, the selection of joints for testing is to take the pipe material into consideration. Where not specified, the length of pipes to be connected by means of the joint to be tested is to be at least five times the pipe diameter. Before assembling the joint, conformity of components to the design requirements, is to be verified. In all cases the assembly of the joint shall be carried out only according to the manufacturer's instructions. No adjustment operations on the joint assembly, other than that specified by the manufacturer, are permitted during the test.

iv) *Test Results Acceptance Criteria.* Where a mechanical joint assembly does not pass all or any part of the tests in 4-6-2/Table 12, two assemblies of the same size and type that failed are to be tested and only those tests which the mechanical joint assembly failed in the first instance, are to be repeated. In the event where one of the assemblies fails the second test, that size and type of assembly is to be considered unacceptable. The methods and results of each test are to be recorded and reproduced as and when required.

v) *Methods of tests.*

1. *Tightness test.* In order to ensure correct assembly and tightness of the joints, all mechanical joints are to be subjected to a tightness test, as follows.

   a. *(1 July 2007)* Mechanical joint assembly test specimen is to be connected to the pipe or tubing in accordance with the requirements of 4-6-2/5.9.2(e)iii) and the manufacturers instructions, filled with test fluid and de-aerated. Mechanical joints assemblies intended for use in rigid connections of pipe lengths, are not to be longitudinally restrained. Pressure inside the joint assembly is to be slowly increased to 1.5 times of design pressure. This test pressure is to be retained for a minimum period of 5 minutes. In the event where there is a drop in pressure or there is visual indication of leakage, the test (including fire test) is to be repeated for two test pieces. If during the repeat test, one test piece fails, the testing is regarded as having failed. Other alternative tightness test procedures, such as a pneumatic test, may be accepted.

b. For compression couplings a static gas pressure test is to be carried out to demonstrate the integrity of the mechanical joints assembly for tightness under the influence of gaseous media. The pressure is to be raised to maximum pressure or 70 bar (71.4 kg/cm^2, 1,015 psi) which ever is less.

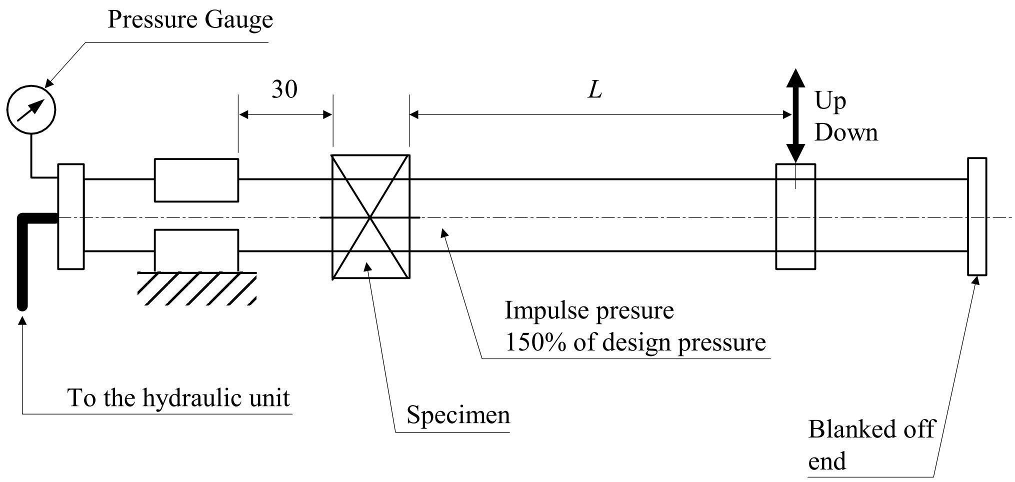
c. Where the tightness test is carried out using gaseous media as permitted in *a.* above, then the static pressure test mentioned in *b.* above need not be carried out.

2. *Vibration (fatigue) test.* In order to establish the capability of the mechanical joint assembly to withstand fatigue, which is likely to occur due to vibrations under service conditions, mechanical joints assembly is to be subject to the following vibration test.

Conclusions of the vibration tests should show no leakage or damage, which could subsequently lead to a failure.

a. Testing of compression couplings and pipe unions. Compression couplings, pipe unions or other similar joints intended for use in rigid connections of pipe are to be tested in accordance with this method described as follows. Rigid connections are joints, connecting pipe length without free angular or axial movement. Two lengths of pipe are to be connected by means of the joint to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibration rig. Such arrangement is shown in 4-6-2/Figure 3.

FIGURE 3
Arrangement for the Test Rig and the Joint Assembly Specimen Being Tested *(2007)*



Note: Dimensions are in millimeters.

The joint assembly is to be filled with test fluid, de-aerated and pressurized to the design pressure of the joint. Pressure during the test is to be monitored. In the event of drop in the pressure and visual signs of leakage the test is to be repeated as described in 4-6-2/5.9.2(e)iv). Visual examination of the joint assembly is to be carried out for signs of damage which may eventually lead to joint leakage. Re-tightening may be accepted once during the first 1000 cycles. Vibration amplitude is to be within 5% of the value calculated from the following formula:

$$A = (2SL^2)/(3ED)$$

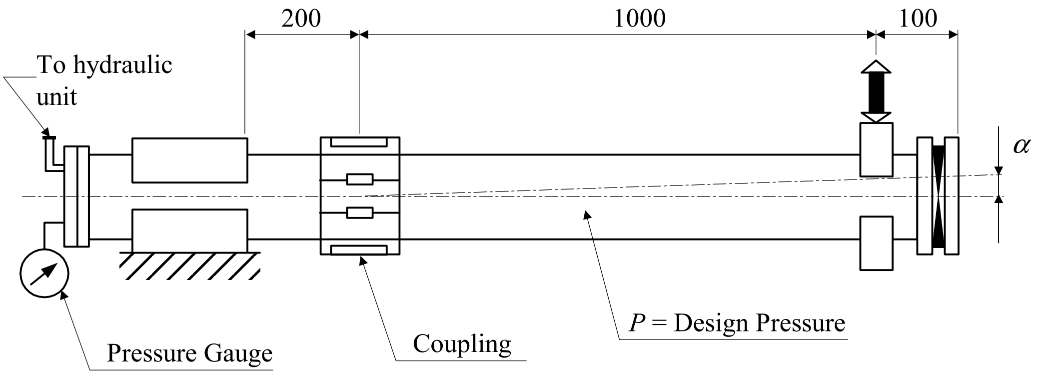
where

A	=	single amplitude, mm (cm, in)
L	=	length of the pipe, mm (cm, in)
S	=	allowable bending stress, in N/mm^2 (kgf/cm^2, psi) based on 0.25 of the yield stress
E	=	modulus of elasticity of tube material (for mild steel, E = 210 kN/mm^2, 214 × 10^4 kgf/cm^2, 30 × 10^6 psi)
D	=	outside diameter of tube, mm (cm, in)

Test specimen is to withstand not less than 10^7 cycles with frequency 20-50 Hz without leakage or damage.

b. *Grip type and Machine grooved type joints.* Grip type joints and other similar joints containing elastic elements are to be tested in accordance with the following method. A test rig of cantilever type used for testing fatigue strength of components may be used. Such arrangement is shown in 4-6-2/Figure 4.

FIGURE 4
Arrangement for the Test Specimen Being Tested in the Test Rig *(2007)*



Note: Dimensions are in millimeters.

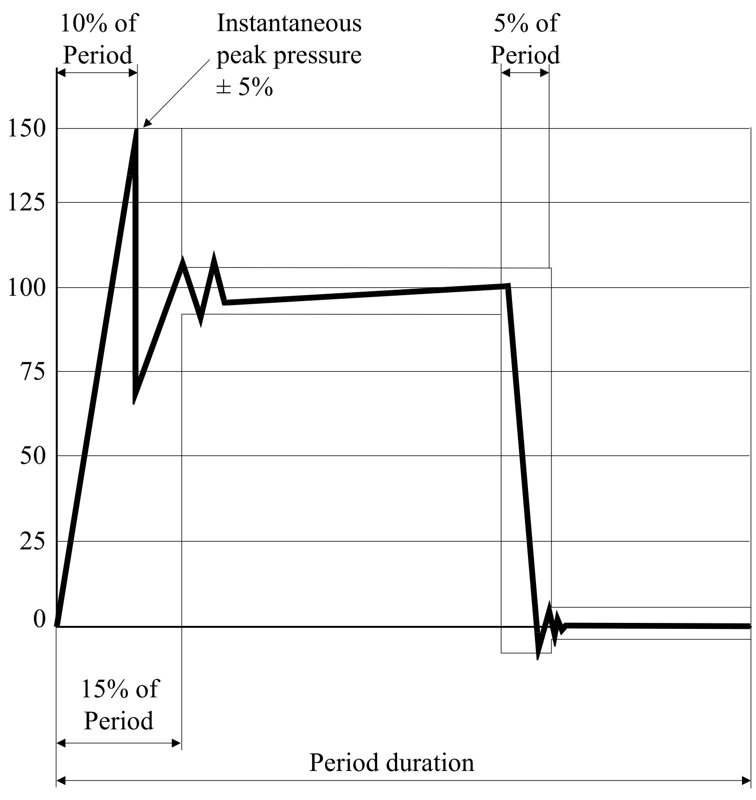
Two lengths of pipes are to be connected by means of joint assembly specimen to be tested. One end of the pipe is to be rigidly fixed while the other end is to be fitted to the vibrating element on the rig. The length of pipe connected to the fixed end should be kept as short as possible and in no case exceeds 200 mm (20 cm, 7.9 inch). Mechanical joint assemblies are not to be longitudinally restrained. The assembly is to be filled with test fluid, de-aerated and pressurized to the design pressure of the joint. Preliminary angle of deflection of pipe axis is to be equal to the maximum angle of deflection, recommended by the manufacturer. The amplitude is to be measured at 1m (3.3 ft) distance from the centerline of the joint assembly at free pipe end connected to the rotating element of the rig. (See 4-6-2/Figure 4) Parameters of testing are to be as indicated below and to be carried out on the same assembly:

Number of Cycles	*Amplitude, mm*	*Frequency Hz*
3×10^6	± 0.06	100
3×10^6	± 0.5	45
3×10^6	± 1.5	10

Pressure during the test is to be monitored. In the event of a drop in the pressure and visual signs of leakage the test is to be repeated as described in 4-6-2/5.9.2(e)iv). Visual examination of the joint assembly is to be carried out for signs of damage which may eventually cause leakage.

3. *Pressure pulsation test.* In order to determine the capability of a mechanical joint assembly to withstand pressure pulsation likely to occur during working conditions, joint assemblies intended for use in rigid connections of pipe lengths, are to be tested in accordance with the following method. The mechanical joint test specimen for carrying out this test may be the same as that used in the test in 4-6-2/5.9.2(e)v)1(a) provided it passed that test. The vibration test in 4-6-2/5.9.2(e)v2 and the pressure pulsation test are to be carried out simultaneously for compression couplings and pipe unions. The mechanical joint test specimen is to be connected to a pressure source capable of generating pressure pulses of magnitude as shown in 4-6-2/Figure 5.

FIGURE 5
Distribution of the Pressure Pulses Magnitude % Design Pressure vs. Period Duration *(2007)*



Impulse pressure is to be raised from 0 to 1.5 times the design pressure of the joint with a frequency equal to 30-100 cycles per minute. The number of cycles is not to be less than 5×10^5 cycles. The mechanical joint is to be examined visually for sign of leakage or damage during the test.

4. *Burst pressure test.* In order to determine the capability of the mechanical joint assembly to withstand a pressure as stated by 4-6-2/5.9.1(e), the following burst test is to be carried out. Mechanical joint test specimen is to be connected to the pipe or tubing in accordance with the requirements of 4-6-2/5.9.2(e)iii), filled with test fluid, de-aerated and pressurized to test pressure with an increasing rate of 10% per minute of test pressure. The mechanical joint assembly intended for use in rigid connections of pipe lengths is not to be longitudinally restrained. Duration of this test is not to be less than 5 minutes at the maximum pressure. This pressure value will be annotated. Where consider convenient, the mechanical joint test specimen used in tightness test in 4-6-2/5.9.2(e)v)1, same specimen may be used for the burst test provided it passed the tightness test. The specimen may have small deformation whilst under test pressure, but no leakage or visible cracks are permitted.

5. *Pull-out test.* In order to determine ability of a mechanical joint assembly to withstand axial load likely to be encountered in service without the connecting pipe from becoming detached, following pull-out test is to be carried out. Pipe length of suitable size is to be fitted to each end of the mechanical joints assembly test specimen. The test specimen is to be pressurized to design pressure such that the axial loads imposed are of a value calculated by the following formula:

   $$L = (\pi D^2/4)p$$

   where

   D = pipe outside diameter, mm (in.)

   p = design pressure, N/mm^2 (kgf/mm^2, psi)

   L = applied axial load, N (kgf, lbf)

   This axial load is to be maintained for a period of 5 minutes. During the test, pressure is to be monitored and relative movement between the joint assembly and the pipe measured. The mechanical joint assembly is to be visually examined for drop in pressure and signs of leakage or damage. There are to be no movement between the mechanical joint assembly and the connecting pipes.

6. *Fire endurance test (1 July 2007).* In order to establish the capability of the mechanical joints to withstand the effects of fire which may be encountered in service, mechanical joints are to be subjected to a fire endurance test. The fire endurance test is to be conducted on the selected test specimens as per the following international standards.

   - ISO 19921:2005(E) Ship and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods.
   - ISO 19922:2005(E) Ship and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.

   Clarification to the standard requirements:

   - If the fire test is conducted with circulating water at a pressure different from the design pressure of the joint [however of at least 5 bar (5.1 kgf/cm^2, 72.5 psi)] the subsequent pressure test is to be carried out to twice the design pressure.
   - A selection of representative nominal bores may be tested in order to evaluate the fire resistance of a series or range of mechanical joints of the same design. When a mechanical joint of a given nominal bore (D_n) is so tested, then other mechanical joints falling in the range D_n to $2 \times D_n$ (both inclusive) are considered accepted.

7. *Vacuum test.* In order to establish capability of mechanical joint assembly to withstand internal pressures below atmosphere, similar to the conditions likely to be encountered under service conditions, following vacuum test is to be carried out. Mechanical joint assembly is to be connected to a vacuum pump and subjected to a pressure 170 mbar (173 mkgf/cm^2, 2.47 psi) absolute. Once this pressure is stabilized the mechanical joint assembly test specimen under test are to be isolated from the vacuum pump and this pressure is to be retained for a period of 5 minutes. Pressure is to be monitored during the test. No internal pressure rise is permitted.

8. *Repeated assembly test.* Mechanical joint test specimen are to be dismantled and reassembled 10 times in accordance with manufacturers instructions and then subjected to a tightness test as defined in 4-6-2/5.9.2(e)i).

5.11 Valves

5.11.1 Standard

In general, valves are to comply with a recognized national standard and are to be permanently marked in accordance with the requirements of the standard (see 4-6-1/7.1.4). For valves not complying with a recognized national standard, see 4-6-2/5.15.

5.11.2 Design Pressure

The design pressure of valves intended for use onboard a vessel is to be at least the maximum pressure to which they will be subjected but at least 3.5 bar (3.6 kgf/cm^2, 50 lb/in^2). Valves used in open-ended systems, except those attached to side shell (see 4-6-2/9.13), may be designed for pressure below 3.5 bar. Such valves may include those in vent and drain lines, and those mounted on atmospheric tanks which are not part of the pump suction or discharge piping (e.g., level gauges, drain cocks, and valves in inert gas and vapor emission control system).

5.11.3 Construction Details

5.11.3(a) Handwheel. All valves are to close with a right hand (clockwise) motion of the handwheel when facing the end of the stem. Valves are to be either of the rising stem type or fitted with an indicator to show whether the valve is open or closed.

5.11.3(b) Bonnet. All valves of Classes I and II piping systems having nominal diameters exceeding 50 mm (2 in.) are to have bolted, pressure seal or breech lock bonnets. All valves for Classes I and II piping systems and valves intended for use in steam or oil services are to be constructed so that the stem is positively restrained from being screwed out of the body.

All cast iron valves are to have bolted bonnets or are to be of the union bonnet type. For cast iron valves of the union bonnet type, the bonnet ring is to be of steel, bronze or malleable iron.

5.11.3(c) Valve trim. Stems, discs or disc faces, seats and other wearing parts of valves are to be of corrosion resistant materials suitable for intended service. Resilient materials, where used, are subject to service limitations as specified by the manufacturers. Use of resilient materials in valves intended for fire mains (see 4-7-3/1.11.1) is to be specifically approved based on submittal of certified fire endurance tests conforming to a recognized standard.

5.11.3(d) Valve ends. All valves of Classes I and II piping systems having nominal diameters exceeding 50 mm (2 in.) are to have flanged or welded ends. Welded ends are to be butt welding type, except that socket welding ends may be used for valves having nominal diameters of 80 mm (3 in.) or less (see 4-6-2/5.5.2).

5.11.4 Manufacturer's Guarantee

The manufacturer of a valve is to guarantee that the valve is constructed to the standard and conforming to the identifications to which it is marked. The manufacturer is to guarantee also that the valve has been tested before shipment to the pressure required by the pressure rating of the valve. The certificate of test is to be submitted upon request.

5.13 Safety Relief Valves

Safety relief valves are to be treated as valves for the purposes of these Rules and are to be constructed of materials permitted for the piping system classes and services in which they are installed. In general, they are also to comply with a recognized standard for relieving capacity.

5.15 Nonstandard Components

Components not manufactured to a recognized national standard are preferably to be Type Approved (see 1-1-A3/5). They may be considered for acceptance based on manufacturers' specified pressure and temperature ratings and on presenting evidence, such as design calculations or type test data, that they are suitable for the intended purpose. For Classes I and II piping applications, drawings showing details of construction, materials, welding procedures, etc., as applicable, are to be submitted for such components, along with the basis for the pressure and temperature ratings.

5.17 Type Approval Program

The Type Approval Program (as described in Appendix 1-1-A3) may be applied to design evaluation and approval of piping components in 4-6-2/5.5 through 4-6-2/5.15. Each product approved under this program need not be subjected to further design review or a prototype test, or both, each time the product is proposed for use. The list of approved products will be posted on the ABS website, http://www.eagle.org/typeapproval.

7 Fabrication and Tests

7.1 Welded Fabrication

Requirements for welding of pipes and fittings, heat treatment and nondestructive testing are given in Section 2-4-4. For the purpose of radiography, see 2-4-4/11.3.1.

7.3 Hydrostatic Tests *(2002)*

7.3.1 Hydrostatic Test of Pipes Before Installation Onboard

All Classes I and II pipes and integral fittings after completion of shop fabrication, but before insulation and coating, are to be hydrostatically tested in the presence of a Surveyor, preferably before installation, at the following pressure.

$$P_H = 1.5P$$

where P_H = test pressure, and P = design pressure.

Class III steam, boiler feed, compressed air and fuel oil pipes and their integral fittings, where the design pressure is greater than 3.5 bar (3.6 kgf/cm^2, 50 psi), are to be hydrostatically tested to the test pressure p_H, as defined above.

Small bore pipes and tubes of less than 15 mm outside diameter may be exempted from the required hydrostatic test, depending on the intended application.

For steel pipes and integral fittings where the design temperature is above 300°C (572°F), the test pressure is to be determined by the following formula, but need not exceed 2P. The test pressure may be reduced, however, to avoid excessive stress in way of bends to 1.5P. In no case is the membrane stress to exceed 90% of the yield stress at the test temperature.

$$P_H = 1.5P\frac{S_{100}}{S_T}$$

where S_{100} = permissible stress at 100°C (212°F), and S_T = permissible stress at design temperature.

Where it is not possible to carry out the required hydrostatic tests for all segments of pipes and integral fittings before installation, the remaining segments, including the closing seams, may be so tested after installation. Or, where it is intended to carry out all of the required hydrostatic tests after installation, such tests may be conducted in conjunction with those required in 4-6-2/7.3.3. In both of these cases, testing procedures are to be submitted to the Surveyor for acceptance.

7.3.2 Hydrostatic Tests of Shell Valves

All valves intended for installation on the side shell at or below the deepest load waterline, including those at the sea chests, are to be hydrostatically tested in the presence of the Surveyor, before installation, to a pressure of at least 5 bar (5.1 kgf/cm^2, 72.5 psi).

7.3.3 Tests After Installation

7.3.3(a) General. All piping systems are to be tested in the presence of the Surveyor under working conditions after installation and checked for leakage. Where necessary, other techniques of tightness test in lieu of a working pressure test may be considered.

7.3.3(b) Specific Systems. The following piping systems are to be hydrostatically tested in the presence of the Surveyor after installation to 1.5P, but not less than 4 bar (4.1 kgf/cm^2, 58 psi).

- Gas and liquid fuel systems
- Heating coils in tanks

For cargo oil, liquefied gas, and chemical cargo and associated piping, see 5C-1-7/3.3.5, 5C-8-5/5.2 and 5C-9-5/4.2 respectively.

7.3.4 Pneumatic Tests in Lieu of Hydrostatic Tests

In general, pneumatic tests in lieu of hydrostatic test are not permitted. Where it is impracticable to carry out the required hydrostatic tests, pneumatic tests may be considered. In such cases, the procedure for carrying out the pneumatic test, having regard to safety of personnel, is to be submitted to the Surveyor for review.

7.5 Resistance Testing

Piping required by 4-6-2/9.15 to be electrically earthed (grounded) to the hull are to be checked in the presence of the Surveyor to ensure that the resistance from any point along the piping to the hull does not exceed 1 MΩ. Where bonding straps are used, they are to be located in visible locations.

9 Installation Details

9.1 Protection from Mechanical Damage

All piping located in a position where it is liable to mechanical damage is to be protected. The protective arrangements are to be capable of being removed to enable inspection.

9.3 Protection of Electrical Equipment

The routing of pipes in the vicinity of switchboards and other electrical equipment is to be avoided as far as possible. When such a routing is necessary, care is to be taken to ensure that no flanges or joints are installed over or near the equipment unless provisions are made to prevent any leakage from damaging the equipment or creating a hazard for personnel.

9.5 Provisions for Expansion and Contraction of Piping *(2004)*

Provisions are to be made to take care of expansion and contraction of piping due to temperature and pressure variations as well as working of the hull. Suitable provisions include, but are not limited to, piping bends, elbows, offsets and changes in direction of the pipe routing or expansion joints.

Where expansion joints are used, the following requirements apply:

i) *Pipe support*. Adjoining pipes are to be suitably supported so that the expansion joints do not carry any significant pipe weight.

ii) *Alignment.* Expansion joints are not to be used to make up for piping misalignment errors. Misalignment of an expansion joint reduces the rated movements and can induce severe stresses into the joint material, thus causing reduced service life. Alignment is to be within tolerances specified by the expansion joint manufacturer.

iii) *Anchoring.* Expansion joints are to be installed as close as possible to an anchor point. Where an anchoring system is not used, control rods may be installed on the expansion joint to prevent excessive movements from occurring due to pressure thrust of the line.

iv) *Mechanical damage.* Where necessary, expansion joints are to be protected against mechanical damage.

v) *Accessible location.* Expansion joints are to be installed in accessible locations to permit regular inspection and/or periodic servicing.

vi) *Mating flange.* Mating flanges are to be clean and usually of the flat faced type. When attaching beaded end flange expansion joints to raised face flanges, the use of a ring gasket is permitted. Rubber expansion joints with beaded end flange are not to be installed next to wafer type check or butterfly valves. Serious damage to the rubber flange bead can result due to lack of flange surface and/or bolt connection.

9.6 Mechanical Joints *(2005)*

The installation of mechanical pipe joints, as covered by 4-6-2/5.5.5 and 4-6-2/5.9, 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 specified and supplied as necessary by the manufacturer. These special tools are to be kept onboard.

9.7 Piping Penetrations Through Bulkheads, Decks and Tank Tops

9.7.1 Watertight Integrity

Where it is necessary for pipes to penetrate watertight bulkheads, decks or tank tops, the penetrations are to be made by methods which will maintain the watertight integrity. For this purpose, bolted connections are to have bolts threaded into the plating from one side; through bolts are not to be used. Welded connections are either to be welded on both sides or to have full penetration welds from one side.

9.7.2 Fire Tight Integrity

Where pipes penetrate bulkheads, decks or tank-tops which are required to be fire tight or smoke tight, the penetrations are to be made by approved methods which will maintain the same degree of fire tight or smoke tight integrity.

9.7.3 Collision Bulkhead Penetrations

Piping penetrating collision bulkheads is to comply with the following requirements:

i) Pipes which penetrate a collision bulkhead are to be fitted with valves complying with the following:

- The valves are to be secured directly to the collision bulkhead inside the forepeak. Alternatively, the valves may be located outside of the forepeak tank provided they are secured to the after side of the collision bulkhead and the valves are readily accessible at all times. These valves are not to be located in a cargo space.
- The valves are to be operable (open and close) from a position above the bulkhead deck and are to have open/closed indicators locally and above the bulkhead deck, see 4-6-2/5.11.3(a).
- Gray cast iron valves are not acceptable. The use of nodular iron valve is acceptable, see 4-6-2/3.1.4.

ii) No valves or cocks for sluicing (draining) are to be fitted on a collision bulkhead.

9.7.4 Valve in Watertight Bulkhead for Sluicing Purposes

Where valves are fitted directly onto watertight bulkheads without piping on either side for sluicing, drainage or liquid transfer, the valves are to be readily accessible at all times and are to be operable (open and close) from a position above the bulkhead deck. Indicators are to be provided to show whether the valves are open or closed.

9.9 Protection from Overpressure

9.9.1 General

Each piping system or part of a system which may be exposed to a pressure greater than that for which it is designed is to be protected from overpressurization by a relief valve. Other protective devices, such as bursting discs, may be considered for some systems.

9.9.2 System Pressurized by Centrifugal Pumps

Where systems are served only by centrifugal pumps such that the pressure delivered by the pump cannot exceed the design pressure of the piping, relief valves are not necessary.

9.9.3 Relief Valve Discharges

For systems conveying flammable liquids or gases, relief valves are to be arranged to discharge back to the suction side of the pump or to a tank. The relief valve of a CO_2 system is to discharge outside of the CO_2 container storage compartment. In all cases, when discharging directly to the atmosphere, the discharge is not to impinge on other piping or equipment and is to be directed away from areas used by personnel.

9.9.4 Setting

Relief valves are to be set at pressures not exceeding the piping design pressure. For hydraulic systems, see 4-6-7/3.7.2; for steering gear hydraulic piping systems, see 4-3-4/9.1.6.

9.9.5 Pressure Vessels Associated with Piping System

A pressure vessel, which can be isolated from piping system relief valves, is to have another relief valve fitted either directly on the pressure vessel or between the pressure vessel and the isolation valve.

9.11 Temperature and Pressure Sensing Devices

9.11.1 Temperature

Where thermometers or other temperature sensing devices are fitted in piping systems, thermometer wells are to be used so that the devices can be removed without impairing the integrity of the pressurized system.

9.11.2 Pressure

Where pressure gauges or other pressure sensing devices are fitted in piping systems, valves are to be provided so that the devices can be isolated and removed without impairing the integrity of the pressurized system.

9.11.3 Tanks

Pressure, temperature and level sensing devices installed on tanks at locations where they are subjected to a static head of liquid are to be fitted with valves or arranged such that they may be removed without emptying the tank.

9.13 Shell Connections

9.13.1 General

Positive closing valves are to be fitted at the shell at inlets (including sea chests) and discharges. Discharges from scuppers and drains are to be fitted with valves as required by 4-6-4/3.3. Where it is impractical to install the valve directly at the shell, a distance piece can be provided. Materials readily rendered ineffective by heat are not to be used for connection to the shell where the failure of the material in the event of a fire would give rise to danger of flooding. Discharges at the shell are to be so located as to prevent any discharge from falling onto a lowered lifeboat.

9.13.2 Valves

Shell valves are to comply with the following requirements:

i) Gray cast iron valves are not to be used as shell valves. Nodular iron valves are acceptable, see 4-6-2/3.1.4.

ii) Shell valves are to be installed such that the inboard piping can be removed and the valve can remain in place without impairing the watertight integrity. Wafer-type butterfly valves are not acceptable. Butterfly valves with lugs, however, may be accepted.

iii) Controls for positive closing valves are to be readily accessible and controllable from the floors or gratings. Open or closed indicators are to be provided, see 4-6-2/5.11.3(a).

iv) Power-operated valves are to be arranged for manual operation in the event of a failure of the power supply.

v) For hydrostatic tests, see 4-6-2/7.3.2.

9.13.3 Connection Details *(2006)*

Where the valve is connected directly to the shell, studs can be used if a reinforcing ring of substantial thickness (a heavy pad) is welded to the inside of the shell. In this case, the studs are to be threaded into the reinforcing ring and are not to penetrate the shell.

Where a distance piece is fitted between the shell and the shell valves, the pipe is to be of steel and of wall thickness not less than that specified below:

Nominal Size, d	*Min. Wall Thickness*
$d \leq 65$ mm (2.5 in.)	7 mm (0.276 in.)
$d = 150$ mm (6 in.)	10 mm (0.394 in.)
$d \geq 200$ mm (8 in.)	12.5 mm (0.492 in.)

For intermediate nominal pipe sizes, the wall thicknesses are to be obtained by linear interpolation as follows:

For $65 < d < 150$: $7 + 0.035(d - 65)$ mm or $0.28 + 0.034(d - 2.5)$ in.

For $150 < d < 200$: $10 + 0.05(d - 150)$ mm or $0.39 + 0.05(d - 6.0)$ in.

In general, the pipe is to be as short as possible. The pipe is to extend through the shell plating and is to be welded on both sides or with full strength welds from one side. Consideration is to be given to supporting the pipe to the surrounding structure.

Where an inlet or discharge is to pass through a wing tank or a cargo hold, the valve may be installed on the inner bulkhead or similar location provided that the pipe between the valve and the shell is of wall thickness not less than as specified above, with all joints welded and with built-in provision for flexibility. Such pipes, where located in a cargo hold, are to have protection from mechanical damage.

Threaded connections are not considered an acceptable method of connection outboard of the shell valves.

9.13.4 Boiler Blow-off

Boiler and evaporator blow-off overboard discharges are to have doubling plates or heavy inserts fitted. The pipe is to extend through the doubling and the shell.

9.13.5 Sea Chests

Sea chests are to comply with the following requirements:

i) Located in positions where the possibility of blanking off the suction is minimized;

ii) Fitted with strainer plates through which the clear area is to be at least 1.5 times the area of the inlet valves;

iii) Means are provided for clearing the strainer plates, such as by using compressed air or low pressure steam;

iv) Additional requirements for sea chests on ice strengthened vessels in 6-1-1/47.15, 6-1-1/47.17 and 6-1-2/31.3 are to be complied with, where applicable.

9.15 Control of Static Electricity

In order to prevent dangerous build-up of static charges resulting from the flow of fluid in piping, the following items are to be earthed (grounded) to the hull such that the resistance between any point on the piping and the hull (across joints, pipe to hull) does not exceed 1 MΩ:

- Piping and independent tanks containing fluids having flash point of 60°C (140°F) or less.
- Piping that is routed through hazardous areas.

This can be achieved if the items are directly, or via their supports, either welded or bolted to the hull. Bonding straps are required for items not permanently connected to the hull, for example:

- Independent cargo tanks
- Piping which is electrically insulated from the hull
- Piping which has spool pieces arranged for removal

Bonding straps are to be:

- Installed in visible locations
- Protected from mechanical damage
- Made of corrosion-resistant material

This requirement does not apply to tank containers.

9.17 Accessibility of Valves *(2007)*

Where the valves are required by the Rules to be readily accessible, their controls, during normal operating conditions, are to be:

i) Located in a space normally entered without using tools;

ii) Clear of or protected from obstructions, moving equipment and hot surfaces that prevent operation or servicing; and

iii) Within operator's reach.

For propulsion machinery spaces intended for centralized or unattended operations (**ACC**/**ACCU** notation), the location of the controls of any valve serving a sea inlet, a discharge below the waterline or an emergency bilge system [see also 4-6-4/5.5.5(c)] is to be such as to allow adequate time for operation in case of influx of water to the space, having regard to the time likely to be required in order to reach and operate such controls. If the level to which the space could become flooded with the ship in the fully loaded condition so requires, arrangements are to be made to operate the controls from a position above such level.

9.19 Common Overboard Discharge

In general, various types of systems which discharge overboard are not to be interconnected without special approval; that is, closed pumping systems, deck scuppers, solid lines or sanitary drains are not to have a common overboard discharge.

TABLE 1
Allowable Stress Values *S* for Steel Pipes; N/mm^2 (kgf/mm^2, psi) (see 4-6-2/5.1.2)

Material	Tensile	*Service Temperature*									
ABS Gr. ASTM Gr. Nominal Composition	Strength N/mm^2 kgf/mm^2 psi	–29°C (0°F) to 344°C (650°F)	372°C 700°F	399°C 750°F	427°C 800°F	455°C 850°F	483°C 900°F	510°C 950°F	538°C 1000°F	566°C 1050°F	593°C 1100°F
M		0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.4	1.4	1.4
Gr.1 A53-FBW	310 31.5 45000	46.9 4.78 6800	46.6 4.75 6500								
Gr. 2 A53-A, ERW C, Mn	330 33.7 48000	70.3 7.17 10200	68.3 6.96 9900	62.8 6.40 9100	53.1 5.41 7700						
Gr.2 A53-A, SML C, Mn	330 33.7 48000	82.8 8.44 12000	80.6 8.22 11700	73.7 7.52 10700	62.1 6.33 9000						
Gr.3 A53-B, ERW C, Mn	415 42 60000)	88.3 9.0 12800	84.1 8.58 12200	75.8 7.73 11000	63.4 6.47 9200						
Gr.3 A53-B, SML C, Mn	415 42 60000	103.5 10.55 15000	99.2 10.12 14400	89.6 9.14 13000	74.4 7.59 10800						
Gr.4 A106-A C, Mn, Si	330 33.7 48000	82.8 8.44 12000	80.7 8.23 11700	73.7 7.52 10700	62.1 6.33 9000						
Gr.5 A106-B C, Mn, Si	415 42 60000	103.5 10.55 15000	99.2 10.12 14400	89.6 9.14 13000	74.4 7.59 10800						
Gr.6 A355-P1 1/2 Mo	380 39 55000	95.1 9.70 13800	95.1 9.70 13800	95.1 9.70 13800	93.1 9.49 13500	90.3 9.21 13100					
Gr. 7 A335-P2 1/2 Cr 1/2 Mo	380 39 55000	95.1 9.70 13800	95.1 9.70 13800	95.1 9.70 13800	93.1 9.49 13500	90.3 9.21 13100	88.3 9.0 12800	63.4 6.47 9200	40.7 4.15 5900		
Gr. 8 A135-A	330 33.7 48000	70.3 7.17 10200	68.3 6.96 9900	62.8 6.40 9100	53.1 5.41 7700						
Gr. 9 A135-B	415 42 60000	88.3 9.0 12800	84.1 8.58 12200	75.8 7.73 11000	63.4 6.47 9200						
Gr.11 A335-P11 1-1/4 Cr 1/2 Mo	415 42 60000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	99.2 10.12 14400	90.3 9.21 13100	75.8 7.73 11000	45.4 4.64 6600	28.2 2.88 4100	20.7 2.11 3000
Gr. 12 A335-P12 1 Cr 1/2 Mo	415 42 60000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	101.7 10.37 14750	91.9 9.98 14200	90.3 9.21 13100	75.8 7.73 11000	45.5 4.64 6600	28.2 2.88 4100	19.3 1.97 2800
Gr. 13 A335-P22 2-1/4 Cr 1 Mo	415 42 60000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	99.2 10.12 14400	90.3 9.21 13100	75.8 7.73 11000	53.7 5.48 7800	35.9 3.66 5200	28.9 2.95 4200

Notes

1. Intermediate values of *S* and *M* may be determined by interpolation.
2. For grades of pipe other than those given in this Table, *S* values may be obtained from ANSI/ASME B31.1 *Code for Pressure Piping*.
3. Consideration to be given to the possibility of graphite formation in the following steels: Carbon steel above 425°C (800°F); carbon-molybdenum steel above 468°C (875°F); chrome-molybdenum steel (with chromium under 0.60%) above 524°C (975°F).

TABLE 2
Allowable Stress *S* for Copper and Copper Alloy Pipes (see 4-6-2/5.1.1)

Material	*Minimum Tensile Strength*	*Allowable Stress S, N/mm², kgf/mm², psi*										
	N/mm² kgf/mm² psi	50°C 122°F	75°C 167°F	100°C 212°F	125°C 257°F	150°C 302°F	175°C 347°F	200°C 392°F	225°C 437°F	250°C 482°F	275°C 527°F	300°C 572°F
Copper	215 22 31200	41 4.2 5950	41 4.2 5950	40 4.1 5800	40 4.1 5800	34 3.5 4930	27.5 2.8 3990	18.5 1.9 2680				
Brass	325 33 47100	78 8.0 11310	78 8.0 11310	78 8.0 11310	78 8.0 11310	78 8.0 11310	51 5.2 7395	24.5 2.5 3550				
Copper nickel (with less than 10% nickel)	275 28 39900	68 6.9 9860	68 6.9 9860	67 6.8 9715	65.5 6.7 9500	64 6.5 9280	62 6.3 8990	59 6.0 8555	56 5.7 8120	52 5.3 7540	48 4.9 6960	44 4.5 6380
Copper nickel (with 10% or more nickel)	365 37.2 52900	81 8.3 11745	79 8.1 11455	77 7.8 11165	75 7.6 10875	73 7.4 10585	71 7.2 10295	69 7.0 10005	67 6.8 9715	65.5 6.7 9500	64 6.5 9280	62 6.3 8990

Notes

1 Intermediate values are to be determined by interpolation

2 Materials not listed in this table can be used upon approval of the permissible stress

TABLE 3
Corrosion Allowance *c* for Steel Pipes (see 4-6-2/5.1.1) *(2007)*

Piping Service	*Corrosion Allowance, c*	
	mm	*in.*
Superheated steam	0.3	0.012
Saturated steam	0.8	0.032
Steam heating coils in cargo tanks	2.0	0.079
Feed water for boilers in open circuits	1.5	0.059
Feed water for boilers in closed circuits	0.5	0.02
Blowdown for boilers	1.5	0.059
Compressed air	1.0	0.039
Hydraulic oil	0.3	0.012
Lubricating oil	0.3	0.012
Fuel oil	1.0	0.039
Cargo oil	2.0	0.079
Refrigerant	0.3	0.012
Fresh water	0.8	0.032
Sea water	3.0	0.118

Notes

1 *(2007)* The corrosion allowance may be reduced by 50% where pipes and any integral joints are protected against corrosion by means of coating, lining, etc.

2 For pipes passing through tanks, the proper additional corrosion allowance is to be taken into account for the external medium.

3 For special alloy steels which are considered to be corrosion resistant, the corrosion allowance can be reduced to zero.

TABLE 4
Minimum Wall Thickness for Steel Pipes (See 4-6-2/5.1.3)

Nom. Size mm	*Outside Dia. mm*	*Wall Thickness, mm*				
		A	*B*	*C*	*D*	*E*
6	10.2	1.6				
8	13.5	1.8				
10	17.2	1.8				
15	21.3	2.0	2.8			
20	26.9	2.0	2.8			
25	33.7	2.0	3.2	4.2	6.3	6.3
32	42.4	2.3	3.5	4.2	6.3	6.3
40	48.3	2.3	3.5	4.2	6.3	6.3
50	60.3	2.3	3.8	4.2	6.3	6.3
65	76.1	2.6	4.2	4.2	6.3	7.0
80	88.9	2.9	4.2	4.2	7.1	7.6
90	101.6	2.9	4.5	4.5	7.1	8.1
100	114.3	3.2	4.5	4.5	8.0	8.6
125	139.7	3.6	4.5	4.5	8.0	9.5
150	168.3	4.0	4.5	4.5	8.8	11.0
200	219.1	4.5	5.8	5.8	8.8	12.5
250	273.0	5.0	6.3	6.3	8.8	12.5
300	323.9	5.6	6.3	6.3	8.8	12.5
350	355.6	5.6	6.3	6.3	8.8	12.5
400	406.4	6.3	6.3	6.3	8.8	12.5
450	457.0	6.3	6.3	6.3	8.8	12.5

Nom. Size in.	*Outside Dia. in.*	*Wall Thickness, in.*				
		A	*B*	*C*	*D*	*E*
1/8	0.405	0.063				
1/4	0.540	0.071				
3/8	0.675	0.071				
1/2	0.840	0.079	0.110			
3/4	1.050	0.079	0.110			
1	1.315	0.079	0.126	0.165	0.248	0.248
1 1/4	1.660	0.091	0.138	0.165	0.248	0.248
1 1/2	1.900	0.091	0.138	0.165	0.248	0.248
2	2.375	0.091	0.150	0.165	0.248	0.248
2 1/2	2.875	0.102	0.165	0.165	0.248	0.276
3	3.500	0.114	0.165	0.165	0.280	0.300
3 1/2	4.000	0.114	0.177	0.177	0.315	0.318
4	4.500	0.126	0.177	0.177	0.315	0.337
5	5.563	0.142	0.177	0.177	0.346	0.375
6	6.625	0.157	0.177	0.177	0.346	0.432
8	8.625	0.177	0.228	0.228	0.346	0.5
10	10.750	0.197	0.248	0.248	0.346	0.5
12	12.750	0.220	0.248	0.248	0.346	0.5
14	14.000	0.220	0.248	0.248	0.346	0.5
16	16.000	0.248	0.248	0.248	0.346	0.5
18	18.000	0.248	0.248	0.248	0.346	0.5

Columns:

A *(2003)* Pipes in general, except where Columns B, C, D or E are applicable

B Bilge, ballast and sea water pipes except those covered by column D.

C *(2003)* Vent, overflow and sounding pipes for integral tanks except those covered by column D (see Notes 6 and 7) and fuel oil pipes passing through fuel oil tanks.

D Bilge, ballast, vent, overflow and sounding pipes passing through fuel tanks (see Notes 6, 7 and 8).
Bilge, vent, overflow, sounding and fuel pipes passing through ballast tanks (see Notes 6, 7 and 8).

E Ballast pipes passing through cargo oil tanks (see Note 9).
Cargo pipes passing through ballast tanks (see Note 9).

Notes:

1 *(2002)* The minimum thicknesses are the smallest thicknesses selected from those thicknesses specified in ISO 4200 Series 1, JIS, or ASTM Standards. Notwithstanding the requirements of this Table, diameters and thicknesses specified in other recognized standards will also be acceptable.

2 For threaded pipes, where approved, the thickness is to be measured to the bottom of the thread.

3 For pipes protected against corrosion, a reduction of thickness not exceeding 1 mm (0.039 in.) may be considered.

4 For minimum wall thicknesses of copper, copper alloy and austenitic stainless steel pipes, see 4-6-2/Table 5A and 4-6-2/Table 5B.

5 This table is not applicable to exhaust gas pipes.

6 For that part of a vent pipe exposed to weather, pipe wall is to be as specified in 4-6-4/9.3.2(a).

7 The thickness indicated for sounding pipes is for the portions outside the tanks to which the pipe is opened. Within bilge well, to which the pipe is not opened, the thickness is to be extra-heavy; see 4-6-4/11.3.3iv).

8 For bilge pipes, column D thickness applies only where required by 4-6-4/5.5.4(c).

9 Where permitted by 5C-1-7/3.3.3 and 5C-1-7/5.3.2.

10 *(2002)* For nominal sizes larger than 450 mm (18 in.), the minimum wall thickness specified for 450 mm (18 in.) nominal size pipe is applicable.

TABLE 5A
Minimum Wall Thickness for Copper and Copper Alloy Pipes (see 4-6-2/5.1.3)

Outside Diameter		*Minimum Wall Thickness*			
		Copper		*Copper Alloy*	
mm	*in.*	*mm*	*in.*	*mm*	*in.*
8 – 10	0.30 – 0.40	1.0	0.039	0.8	0.031
12 – 20	0.475 – 0.80	1.2	0.047	1.0	0.039
25 – 44.5	1.00 – 1.75	1.5	0.059	1.2	0.047
50 – 76.1	2.00 – 3.00	2.0	0.079	1.5	0.059
88.9 – 108	3.50 – 4.25	2.5	0.098	2.0	0.079
133 – 159	5.25 – 6.25	3.0	0.118	2.5	0.098
193.7 – 267	7.625 – 10.50	3.5	0.138	3.0	0.118
273 – 457.2	10.75 – 18.00	4.0	0.157	3.5	0.138
470	18.50	4.0	0.157	3.5	0.138
508	20.00	4.5	0.177	4.0	0.157

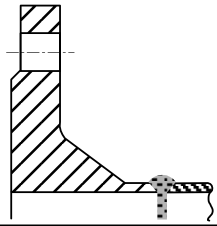
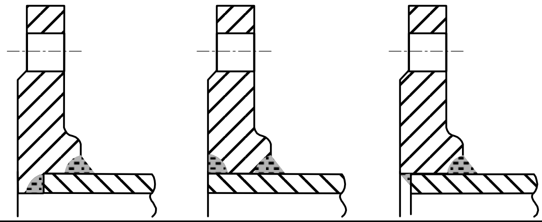
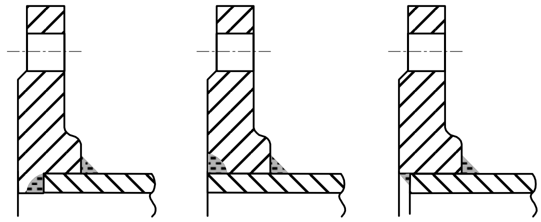
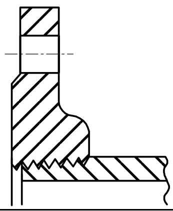
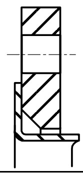
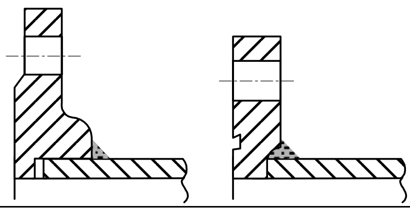
Note: The above minimum thicknesses are taken from those thicknesses available in ISO Standards. Diameter and thickness according to other recognized standards will be accepted.

TABLE 5B
Minimum Wall Thickness for Austenitic Stainless Steel Pipes, (see 4-6-2/5.1.3) *(2007)*

External Diameter		*Minimum Wall Thickness*	
mm	*in.*	*mm*	*in.*
10.2 – 17.2	0.40 – 0.68	1.0	0.039
21.3 – 48.3	0.84 – 1.90	1.6	0.063
60.3 – 88.9	2.37 – 3.50	2.0	0.079
114.3 – 168.3	4.50 – 6.63	2.3	0.091
219.1	8.63	2.6	0.102
273.0	10.75	2.9	0.114
323.9 – 406.4	12.75 – 16.00	3.6	0.142
Over 406.4	Over 16.00	4.0	0.157

Note: *(2007)* Diameters and thicknesses according to national or international standards may be accepted.

TABLE 6
Typical Flange Types (see 4-6-2/5.5.4) *(2002)*

Flange Type	*Typical Configuration*
Type A Weld neck flange, raised face or flat face with ring type gasket.	
Type B Slip-on welded hub (or without hub) flange; attached to pipe with at least a groove weld deposited from the back of the flange and a fillet weld or equivalent on the other side; raised face or flat face with ring type gasket.	
Type C Slip-on welded hub (or without hub) flange; attached to pipe with double fillet welds or equivalent; raised face or flat face with ring type gasket.	 (Must be with hub)
Type D Threaded hub flange; attached to pipe by tapered threads; some designs require the pipe be expanded, or the threaded ends be seal-welded; raised face or flat face with ring type gasket.	
Type E Unattached flange; no attachment to pipe.	
Type G Socket-welded flange; attached to pipe by single fillet weld, with or without groove weld, deposited from one side of the flange only; raised face (with gasket) or flat face (with o-ring).	

Notes:

1 "Integral" flanges are designs where the flange is cast or forged integrally with the pipe wall, or otherwise welded in such a manner that the flange and the pipe wall are considered to be the equivalent of an integral structure.

2 "Loose" flanges are designs where the method of attachment of the flange to the pipe is not considered to give the mechanical strength equivalent of an integral flange, or in which the flange has no direct connection to the pipe wall. Slip-on welded flange attached to pipe with fillet welds only is generally considered a loose flange.

TABLE 7
Limitation of Use for Typical Flange Types (see 4-6-2/5.5.4) *(2005)*

Flange Type	*Class of Piping*	*Limitations*
A	I, II, III	None
B	I, II, III	Pressure/temperature rating ≤ ASME B16.5 Class 300 or equivalent recognized national standard. For steam piping additionally limited to pipe sizes *d* ≤ NPS 100 mm (4 in.) Slip-on flanges for higher ratings, which comply with ASME or other recognized standards, will be subject to special consideration. [Ref. 2-4-2/9.5.3, 2-4-4/5.7 and 2-4-4/17.5]
C	I, II, III	Same as for type B above.
D	II, III	Not for toxic fluid, corrosive fluid, volatile flammable liquid [1], liquefied gas, fuel oil, lubricating oil, thermal oil and flammable hydraulic oil. For other services as per limitations for type B above.
E	II, III	Not for toxic fluid, corrosive fluid, volatile flammable liquid [1], liquefied gas, fuel oil, lubricating oil, thermal oil, flammable hydraulic oil and steam systems. For water and open-ended lines. For other services, see 4-6-2/5.15.
G	I, II, III	Pressure/temperature rating ≤ ASME B16.5 Class 600 and NPS ≤ 80 mm (3 in.), or equivalent recognized national standard. Pressure/temperature rating ≤ ASME B16.5 Class 1500 and NPS ≤ 65 mm (2.5 in.), or equivalent recognized national standard Not to be used in steering gear and controllable pitch propeller systems. [Ref. 2-4-4/5.7 and 2-4-4/17.5]

Note:

1 Volatile flammable liquid is a flammable liquid heated to above its flash point, or a flammable liquid having a flash point at or below 60°C (140°F) other than cargo oil.

TABLE 8
Commercial Pipe Sizes and Wall Thicknesses

Nominal Pipe Size	*Outside Diameter (in., mm)*	*Nominal Wall Thickness (in., mm)*					
		Standard	*Sch.40*	*Extra Strong*	*Sch.80*	*Sch.160*	*Double Extra Strong*
1/8 in. 6 mm	0.405 10.287	0.068 1.727	0.068 1.727	0.095 2.413	0.095 2.413	--	--
1/4 in. 8 mm	0.540 13.716	0.088 2.235	0.088 2.235	0.119 3.023	0.119 3.023	--	--
3/8 in. 10 mm	0.675 17.145	0.091 2.311	0.091 2.311	0.126 3.200	0.126 3.200	--	--
1/2 in. 15 mm	0.840 21.336	0.109 2.769	0.109 2.769	0.147 3.734	0.147 3.734	0.188 4.775	0.294 7.468
3/4 in. 20 mm	1.050 26.670	0.113 2.870	0.113 2.870	0.154 3.912	0.154 3.912	0.219 5.563	0.308 7.823
1 in. 25 mm	1.315 33.401	0.133 3.378	0.133 3.378	0.179 4.547	0.179 4.547	0.250 6.350	0.358 9.903
1 1/4 in. 32 mm	1.660 42.164	0.140 3.556	0.140 3.556	0.191 4.851	0.191 4.851	0.250 6.350	0.382 9.703
1 1/2 in. 40 mm	1.900 48.260	0.145 3.683	0.145 3.683	0.200 5.080	0.200 5.080	0.281 7.137	0.400 10.160
2 in. 50 mm	2.375 60.325	0.154 3.912	0.154 3.912	0.218 5.537	0.218 5.537	0.344 8.738	0.436 11.074
2 1/2 in. 65 mm	2.875 73.025	0.203 5.156	0.203 5.156	0.276 7.010	0.276 7.010	0.375 9.525	0.552 14.021
3 in. 80 mm	3.500 88.900	0.216 5.486	0.216 5.486	0.300 7.620	0.300 7.620	0.438 11.125	0.600 15.240
3 1/2 in. 90 mm	4.000 101.600	0.226 5.740	0.226 5.740	0.318 8.077	0.318 8.077	--	--
4 in. 100 mm	4.500 114.300	0.237 6.020	0.237 6.020	0.337 8.560	0.337 8.560	0.531 13.487	0.674 17.120
5 in. 125 mm	5.5.63 141.300	0.258 6.553	0.258 6.553	0.375 9.525	0.375 9.525	0.625 15.875	0.750 19.050
6 in. 150 mm	6.625 168.275	0.280 7.112	0.280 7.112	0.432 10.973	0.432 10.973	0.719 18.263	0.864 21.946
8 in. 200 mm	8.625 219.075	0.322 8.179	0.322 8.179	0.500 12.700	0.500 12.700	0.906 23.012	0.875 22.225
10 in. 250 mm	10.750 273.050	0.365 9.271	0.365 9.271	0.500 12.700	0.594 15.088	1.125 28.575	1.000 25.400
12 in. 300 mm	12.750 323.850	0.375 9.525	0.406 10.312	0.500 12.700	0.688 17.475	1.312 33.325	1.000 25.400
14 in. 350 mm	14.000 355.600	0.375 9.525	0.438 11.125	0.500 12.700	0.750 19.050	1.406 35.712	--
16 in. 400 mm	16.000 406.400	0.375 9.525	0.500 12.700	0.500 12.700	0.844 21.438	1.594 40.488	--
18 in. 450 mm	18.000 457.200	0.375 9.525	0.562 14.275	0.500 12.700	0.938 23.825	1.781 45.231	--
20 in. 500 mm	20.000 508.000	0.375 9.525	0.594 15.088	0.500 12.700	1.031 26.187	1.969 50.013	--
22 in. 550 mm	22.000 558.800	0.375 9.525	--	0.500 12.700	1.125 28.575	2.125 53.975	--
24 in. 600 mm	24.000 609.600	0.375 9.525	0.688 17.475	0.500 12.700	1.219 30.963	2.344 59.538	--

These pipe sizes and wall thicknesses are according to ANSI B36.10.

TABLE 9
Examples of Mechanical Joints *(2006)*

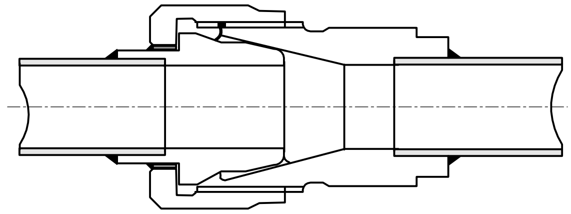
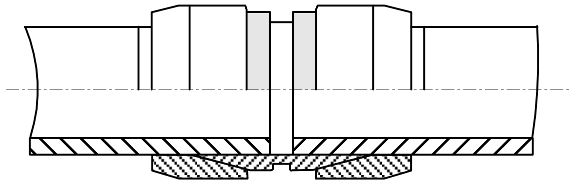
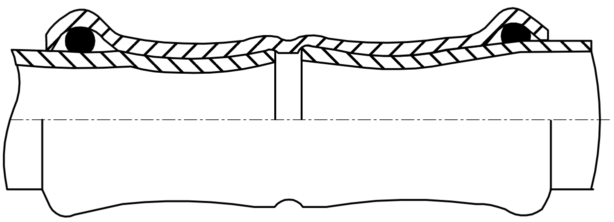
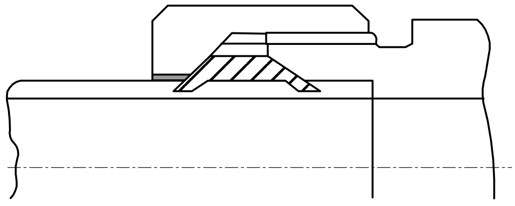
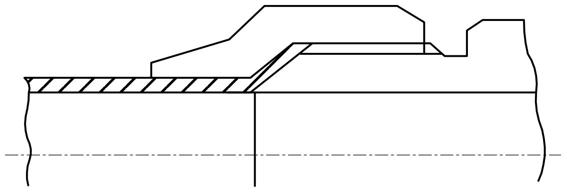
Pipe Unions	
Welded and Brazed Types	
Compression Couplings	
Swage Type	
Press Type	
Bite Type	
Flared Type	

TABLE 9 (continued)
Examples of Mechanical Joints *(2006)*

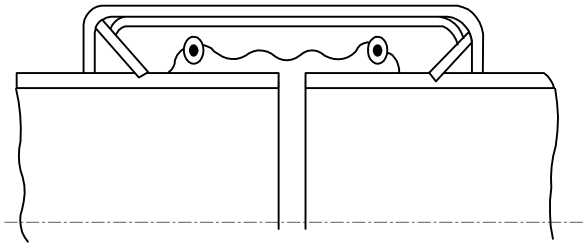
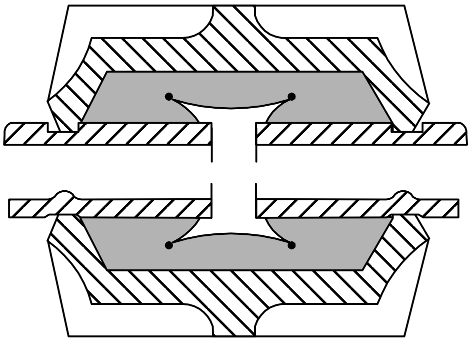
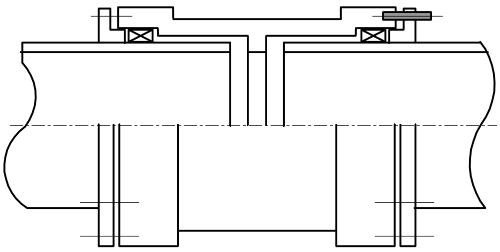
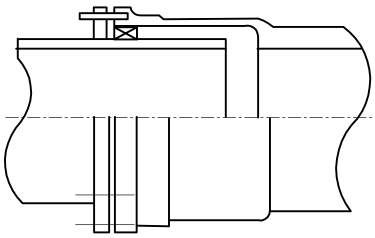
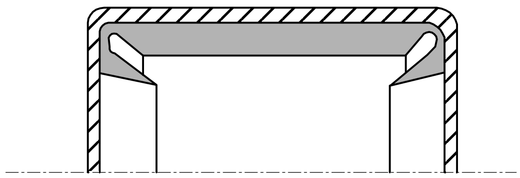
Slip-on Joints	
Grip Type	
Machine Grooved Type	
Slip Type	  

TABLE 10
Application of Mechanical Joints *(2006)*

The following table indicates systems where the various kinds of joints may be accepted. However, in all cases, acceptance of the joint type is to be subject to approval for the intended application, and subject to conditions of the approval and applicable Rules.

Systems		*Kind of Connections*		
		Pipe Unions	*Compression Couplings* (6)	*Slip-on Joints*
		Flammable Fluids (Flash Point ≤ 60°)		
1	Cargo oil lines	Y	Y	Y (5, 11)
2	Crude oil washing lines	Y	Y	Y (5)
3	Vent lines	Y	Y	Y (3, 13)
		Inert gas		
4	Water seal effluent lines	Y	Y	Y (16)
5	Scrubber effluent lines	Y	Y	Y
6	Main lines	Y	Y	Y (2, 5)
7	Distributions lines	Y	Y	Y (5)
		Flammable Fluids (Flash Point > 60°)		
8	Cargo oil lines	Y	Y	Y (5, 11)
9	Fuel oil lines	Y	Y	Y (2, 3)
10	Lubricating oil lines	Y	Y	Y (2, 3)
11	Hydraulic oil	Y	Y	Y (2, 3, 12)
12	Thermal oil	Y	Y	Y (2, 3)
		Sea Water		
13	Bilge lines	Y	Y	Y (1, 8)
14	Fire main and water spray	Y	Y	Y (3, 7)
15	Foam system	Y	Y	Y (3, 7)
16	Sprinkler system	Y	Y	Y (3, 7)
17	Ballast system	Y	Y	Y (1, 9, 10)
18	Cooling water system	Y	Y	Y (1)
19	Tank cleaning services	Y	Y	Y
20	Non-essential systems	Y	Y	Y
		Fresh Water		
21	Cooling water system	Y	Y	Y (1, 8)
22	Condensate return	Y	Y	Y (1, 8)
23	Non-essential system	Y	Y	Y
		Sanitary/Drains/Scuppers		
24	Deck drains (internal)	Y	Y	Y (4)
25	Sanitary drains	Y	Y	Y
26	Scuppers and discharge (overboard)	Y	Y	N (14)
		Sounding/Vent		
27	Water tanks/Dry spaces	Y	Y	Y
28	Oil tanks (f.p.> 60°C)	Y	Y	Y (2, 3)
		Miscellaneous		
29	Starting/Control air (1)	Y	Y	N
30	Service air (non-essential)	Y	Y	Y
31	Brine	Y	Y	Y
32	CO_2 system (1)	Y	Y	N
33	Steam	Y	Y	Y (15)

TABLE 10 (continued) Application of Mechanical Joints *(2006)*

Abbreviations

Y – Application is allowed

N – Application is not allowed

Footnotes:

1 Inside machinery spaces of category A – only approved fire resistant types.

2 Not inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.

3 Approved fire resistant types.

4 Above freeboard deck only.

5 In pump rooms and open decks – only approved fire resistant types.

6 If Compression Couplings include any components which readily deteriorate in case of fire, they are to be of approved fire resistant type as required for Slip-on joints.

7 In accessible locations at all times under normal condition.

8 In accessible locations in machinery spaces, container holds carrying non-dangerous goods, shaft tunnels, pipe tunnels, etc.

9 In accessible locations in machinery spaces, shaft tunnels, pipe tunnels, etc. In pipelines located within other ballast tanks. For tankers, in clean or dirty ballast lines provided lines terminate in cargo pump room [see 5C-1-7/5.3.2(a) of the Rules for prohibitions].

10 Inside pump room – only with approved fire resistant types.

11 Within cargo tanks.

12 Not permitted in steering gear hydraulic systems, otherwise Class III systems only.

13 On vent risers on decks only.

14 Accessible location inboard of required shell valve(s) may be permitted. Slip-on joints are not permitted where there are no shell valve(s), for example, when outboard end >450 mm below free board deck or outboard end < 600 mm above summer waterline. For such instances, the overboard piping is required to be of substantial thickness per definition in 4-6-2/9.13.3.

15 Permitted in Class III piping in machinery spaces of Category A, other machinery spaces, accommodation spaces and open deck. Additionally, on open decks restrained slip type joints only are permitted for pressures up to 10 bar (10.2 kgf/cm^2, 145 psi).

16 On the open deck only.

TABLE 11
Application of Mechanical Joints Depending Upon the Class of Piping *(2006)*

Types of Joints	*Classes of Piping Systems*		
	Class I	*Class II*	*Class III*
Pipe Unions			
Welded and brazed type	Y (OD ≤ 60.3 mm)	Y(OD ≤ 60.3 mm)	Y
Compression Couplings			
Swage type	Y	Y	Y
Bite type	Y (OD ≤ 60.3 mm)	Y (OD ≤ 60.3 mm)	Y
Flared type	Y (OD ≤ 60.3 mm)	Y (OD ≤ 60.3 mm)	Y
Press type	N	N	Y
Slip-on joints			
Machine grooved type	Y	Y	Y
Grip type	N	Y	Y
Slip type	N	Y	Y

Abbreviations:

Y – Application is allowed

N – Application is not allowed

TABLE 12
Testing Requirements for Mechanical Joints *(2007)*

	Tests	*Types of Mechanical Joints*			*Notes and References*
		Compression Couplings and Pipe Unions	*Slip-on Joints*		
			Grip Type & Machine Grooved Type	*Slip Type*	
1	Tightness test	Y	Y	Y	4-6-2/5.9.2(e)v)1
2	Vibration (fatigue) test	Y	Y	N	4-6-2/5.9.2(e)v)2
3	Pressure pulsation test [1]	Y	Y	N	4-6-2/5.9.2(e)v)3
4	Burst pressure test	Y	Y	Y	4-6-2/5.9.2(e)v)4
5	Pull-out test	Y	Y	N	4-6-2/5.9.2(e)v)5
6	Fire endurance test	Y	Y	Y	4-6-2/5.9.2(e)v)6 If required by 4-6-2/5.9.1(f)
7	Vacuum test	Y [2]	Y	Y	4-6-2/5.9.2(e)v)7 for suctions lines only
8	Repeated assembly test	Y [3]	Y	N	4-6-2/5.9.2(e)v)8

Abbreviations:

Y - Test is required

N - Test is not required

Notes:

1. For use in those systems where pressure pulsation other than water hammer is expected (e.g., systems using positive displacement pumps).
2. Except joints with metal-to-metal tightening surfaces.
3. Except press type.

PART
4

CHAPTER **6 Piping Systems**

SECTION **3 Plastic Piping**

1 General

Pipes and piping components made of thermoplastic or thermosetting plastic materials, with or without reinforcement, may be used in piping systems referred to in 4-6-3/Table 1 subject to compliance with the following requirements. For the purpose of these Rules "plastic" means both thermoplastic and thermosetting plastic materials, with or without reinforcement, such as polyvinyl chloride (PVC) and fiber reinforced plastics (FRP).

3 Plans and Data to be Submitted *(2007)*

Rigid plastic piping is to be in accordance with a recognized national or international standard acceptable to the Bureau. Specifications for the plastic piping, including thermal and mechanical properties and chemical resistance, are to be submitted for review together with the spacing of the pipe supports.

The following information for the plastic pipes, fittings and joints is to be also submitted for approval.

3.1 General Information

i) Pipe and fitting dimensions

ii) Maximum internal and external working pressure

iii) Working temperature range

iv) Intended services and installation locations

v) Level of fire endurance

vi) Electrical conductivity

vii) Intended fluids

viii) Limits on flow rates

ix) Serviceable life

x) Installation instructions

xi) Details of marking

3.3 Drawings and Supporting Documentation

i) Certificates and reports for relevant tests previously carried out. See 4-6-3/9

ii) Details of relevant standards. See 4-6-3/Table 2 and 4-6-3/Table 3

iii) All relevant design drawings, catalogues, data sheets, calculations and functional descriptions

iv) Fully detailed sectional assembly drawings showing pipe, fittings and pipe connections

v) Documentation verifying the certification of the manufacturer's quality system and that the system addresses the testing requirements in 4-6-3/5.1 through 4-6-3/5.15. See 4-6-3/9.

3.5 Materials

i) Resin type

ii) Catalyst and accelerator types and concentration employed in the case of reinforced polyester resin pipes or hardeners where epoxide resins are employed

iii) A statement detailing all reinforcements employed where the reference number does not identify the mass per unit area or the strand count (Tex System or Yardage System) of a roving used in a filament winding process

iv) Full information regarding the type of gel-coat or thermoplastic liner employed during construction, as appropriate

v) Cure/post-cure conditions. The cure and post-cure temperatures and times employed for given resin/reinforcement ratio

vi) Winding angle and orientation.

vii) Joint bonding procedures and qualification tests results. See 4-6-3/11

5 Design

5.1 Internal Pressure

A pipe is to be designed for an internal pressure not less than the design pressure of the system in which it will be used. The maximum internal pressure, P_{int}, for a pipe is to be the lesser of the following:

$$P_{int} = \frac{P_{sth}}{4} \quad \text{or} \quad P_{int} = \frac{P_{lth}}{2.5}$$

where

P_{sth} = short-term hydrostatic test failure pressure

P_{lth} = long-term hydrostatic test failure pressure (> 100,000 hours)

The hydrostatic tests are to be carried out under the following standard conditions:

Atmospheric pressure = 1 bar (1 kgf/cm^2, 14.5 psi)

Relative humidity = 30%

Fluid temperature = 25°C (77°F)

The hydrostatic test failure pressure may be verified experimentally or determined by a combination of testing and calculation methods which are to be submitted to the Bureau for approval.

5.3 External Pressure

External pressure is to be considered for any installation which may be subject to vacuum conditions inside the pipe or a head of liquid on the outside of the pipe. A pipe is to be designed for an external pressure not less than the sum of the pressure imposed by the maximum potential head of liquid outside the pipe plus full vacuum, 1 bar (1 kgf/cm^2, 14.5 psi), inside the pipe. The maximum external pressure for a pipe is to be determined by dividing the collapse test pressure by a safety factor of 3.

The collapse test pressure may be verified experimentally or determined by a combination of testing and calculation methods which are to be submitted to the Bureau for approval.

5.5 Axial Strength

The sum of the longitudinal stresses due to pressure, weight and other dynamic and sustained loads is not to exceed the allowable stress in the longitudinal direction. Forces due to thermal expansion, contraction and external loads, where applicable, are to be considered when determining longitudinal stresses in the system.

In the case of fiber reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed one-half of the nominal circumferential stress derived from the maximum internal pressure determined according to 4-6-3/5.1. The allowable longitudinal stress may alternatively be verified experimentally or by a combination of testing and calculation methods.

5.7 Temperature *(2007)*

The maximum allowable working temperature of a pipe is to be in accordance with the manufacturer's recommendations. In each case, it is to be at least 20°C (36°F) lower than the minimum heat distortion temperature of the pipe material determined according to ISO 75 method A or equivalent. The minimum heat distortion temperature is not to be less than 80°C (176°F). This minimum heat distortion temperature requirement is not applicable to pipes and pipe components made of thermoplastic materials, such as polyethylene (PE), polypropylene (PP), polybutylene (PB) and intended for non-essential services.

Where low temperature services are considered, special attention is to be given with respect to material properties.

5.9 Impact Resistance

Plastic pipes and joints are to have a minimum resistance to impact in accordance with a recognized national or international standard such as ASTM D2444 or equivalent. After the impact resistance is tested, the specimen is to be subjected to hydrostatic pressure equal to 2.5 times the design pressure for at least one hour.

5.11 Fire Endurance

4-6-3/Table 1 specifies fire endurance requirements for pipes based upon system and location. Pipes and their associated fittings whose functions or integrity are essential to the safety of the vessel are to meet the indicated fire endurance requirements which are described below.

5.11.1 Level 1

Level 1 will ensure the integrity of a system during a full-scale hydrocarbon fire and is particularly applicable to systems where the loss of integrity may result in outflow of flammable liquids and worsen the fire situation. Piping having passed the fire endurance test specified in 4-6-3/13 hereunder for a duration of a minimum of one hour without loss of integrity in the dry condition is considered to meet the Level 1 fire endurance standard (L1).

5.11.2 Level 2

Level 2 intends to ensure the availability of systems essential to the safe operation of the vessel after a fire of short duration, allowing the system to be restored after the fire has been extinguished. Piping having passed the fire endurance test specified in 4-6-3/13 hereunder for a duration of a minimum of 30 minutes without loss of integrity in the dry condition is considered to meet the Level 2 fire endurance standard (L2).

5.11.3 Level 3

Level 3 is considered to provide the fire endurance necessary for a water-filled piping system to survive a local fire of short duration. The system's functions are capable of being restored after the fire has been extinguished. Piping having passed the fire endurance test specified in 4-6-3/15 hereunder for a duration of a minimum of 30 minutes without loss of integrity in the wet condition is considered to meet the Level 3 fire endurance standard (L3).

5.11.4 Fire Endurance Coating *(2007)*

Where a fire protective coating of pipes and fittings is necessary to achieve the fire endurance standard required, the following requirements apply:

i) Pipes are generally to be delivered from the manufacturer with the protective coating applied, with on-site application limited to that necessary for installation purposes (i.e., joints). See 4-6-3/7.13 regarding the application of the fire protection coating on joints.

ii) The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come in contact with the piping.

iii) In considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations and elasticity are to be taken into account.

iv) The fire protection coatings are to have sufficient resistance to impact to retain their integrity.

v) Random samples of pipe are to be tested to determine the adhesion qualities of the coating to the pipe.

5.13 Flame Spread

5.13.1 Plastic PIpes

All pipes, except those fitted on open decks and within tanks, cofferdams, void spaces, pipe tunnels and ducts are to have low flame spread characteristics. The test procedures in IMO Resolution A.653(16) *Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling, and Deck Finish Materials*, modified for pipes as indicated in 4-6-3/17 hereunder, are to be used for determining the flame spread characteristics. Piping materials giving average values for all of the surface flammability criteria not exceeding the values listed in Resolution A.653(16) are considered to meet the requirements for low flame spread.

Alternatively, flame spread testing in accordance with ASTM D635 may be used in lieu of the IMO flame spread test provided such testing is acceptable to the appropriate administration of the vessel's registry.

5.13.2 Multi-core Metallic Tubes Sheathed by Plastic Materials *(2005)*

The multi-core tubes in "bundles" made of stainless steel or copper tubes covered by an outer sheath of plastic material are to comply with the flammability test criteria of IEC 60332, Part 3, Category A/F or A/F/R. Alternatively, the tube bundles complying with at least the flammability test criteria of IEC 60332, Part 1 or a test procedure equivalent thereto are acceptable, provided they are installed in compliance with approved fire stop arrangements.

5.15 Electrical Conductivity

5.15.1 Pipe Conductivity

Piping conveying fluids with a conductivity of less than 1000 pico-siemens per meter is to be electrically conductive.

5.15.2 Hazardous Areas

Regardless of the fluid being conveyed, plastic piping is to be electrically conductive if the piping passes through a hazardous area.

5.15.3 Electrical Resistance

Where electrically conductive piping is required, the resistance per unit length of the pipes and fittings is not to exceed 1×10^5 Ω/m (3×10^4 Ω/ft). See also 4-6-3/7.7.

5.15.4 Non-homogeneous Conductivity

Pipes and fittings with layers having different conductivity are to be protected against the possibility of spark damage to the pipe wall.

5.17 Marking *(2007)*

Plastic pipes and other components are to be permanently marked with identification in accordance with a recognized standard. Identification is to include pressure ratings, the design standard that the pipe or fitting is manufactured in accordance with, the material with which the pipe or fitting is made, and the date of fabrication.

7 Installation of Plastic Pipes

7.1 Supports

7.1.1 Spacing

Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing is not to be greater than the pipe manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account pipe dimensions, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer and vibrations to which the system may be subjected. Combinations of these loads are to be checked.

7.1.2 Bearing

Each support is to evenly distribute the load of the pipe and its contents over the full width of the support. Measures are to be taken to minimize wear of the pipes where they contact the supports.

7.1.3 Heavy Components

Heavy components in the piping system such as valves and expansion joints are to be independently supported.

7.1.4 Working of the Hull

The supports are to allow for relative movement between the pipes and the vessel's structure, having due regard to the difference in the coefficients of thermal expansion and deformations of the vessel's hull and its structure.

7.1.5 Thermal Expansion

When calculating the thermal expansion, the system working temperature and the temperature at which assembling is performed are to be taken into account.

7.3 External Loads

When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowances are to include at least the force exerted by a load (person) of 980 N (100 kgf, 220 lbf) at mid-span on any pipe more than 100 mm (4 in.) nominal diameter.

Pipes are to be protected from mechanical damage, where necessary.

7.5 Plastic Pipe Connections

7.5.1 General Requirements

The following general principles are applicable to all pipe connections:

i) The strength of fittings and joints is not to be less than that of the piping they connect.

ii) Pipes may be joined using adhesive-bonded, welded, flanged or other joints.

iii) Tightening of flanged or mechanically coupled joints is to be performed in accordance with manufacturer's instructions.

iv) Adhesives, when used for joint assembly, are to be suitable for providing a permanent seal between the pipes and fittings throughout the temperature and pressure range of the intended application.

7.5.2 Procedure and Personal Qualifications

Joining techniques are to be in accordance with manufacturer's installation guidelines. Personnel performing these tasks are to be qualified to the satisfaction of the Bureau, and each bonding procedure is to be qualified before shipboard piping installation commences. Requirements for joint bonding procedures are in 4-6-3/11.

7.7 Electrical Conductivity

Where electrically conductive pipe is required by 4-6-3/5.15, installation of the pipe is to be in accordance with the following provisions.

7.7.1 Resistance Measurement

The resistance to earth (ground) from any point in the system is not to exceed 1 MΩ. The resistance is to be checked in the presence of the Surveyor.

7.7.2 Earthing Wire

Where used, earthing wires or bonding straps are to be accessible for inspection. The Surveyor is to verify that they are in visible locations.

7.9 Shell Connections

Where plastic pipes are permitted in systems connected to the shell of the vessel, the valves installed on the shell and the pipe connection to the shell are to be metallic. The side shell valves are to be arranged for remote control from outside the space in which the valves are located. For further details of the shell valve installation, their connections and material, refer to 4-6-2/9.13.

7.11 Bulkhead and Deck Penetrations

Where it is intended to pass plastic pipes through bulkheads or decks, the following general principles are to be complied with:

i) The integrity of watertight bulkheads and decks is to be maintained where plastic pipes pass through them.

ii) Where plastic pipes pass through "A" or "B" class divisions, arrangements are to be made to ensure that the fire endurance is not impaired. These arrangements are to be tested in accordance with IMO Resolution. A.754(18), *Recommendation on Fire Resistance Tests for "A", "B" and "F" Class Divisions*, as amended.

iii) If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause inflow of liquid from a tank, then a metallic shut-off valve operable from above the bulkhead deck is to be fitted at the bulkhead or deck.

7.13 Application of Fire Protection Coatings

Fire protection coatings are to be applied on the joints, where necessary for meeting the required fire endurance criteria in 4-6-3/5.11, after performing hydrostatic pressure tests of the piping system (see 4-6-3/19). The fire protection coatings are to be applied in accordance with the manufacturer's recommendations, using a procedure approved in each particular case.

9 Manufacturing of Plastic Pipes *(1 July 2009)*

The manufacturer is to have a quality system and be certified in accordance with 1-1-A3/5.3, 1-1-A3/5.5 or ISO 9001 (or equivalent). The quality system is to consist of elements necessary to ensure that pipes and components are produced with consistent and uniform mechanical and physical properties in accordance with recognized standards, including testing to demonstrate the compliance of plastic pipes, fittings and joints with 4-6-3/5.1 through 4-6-3/5.15 and 4-6-3/19, as applicable.

Where the manufacturer does not have a certified quality system in accordance with 1-1-A3/5.3, 1-1-A3/5.5 or ISO 9001 (or equivalent), the tests in 4-6-3/5.1 through 4-6-3/5.15 and 4-6-3/19, as applicable, will be required using samples from each batch of pipes being supplied for use aboard the vessel and are to be carried out in the presence of the Surveyor.

Each length of pipe and each fitting is to be tested at the manufacturer's production facility to a hydrostatic pressure not less than 1.5 times the maximum allowable internal pressure of the pipe in 4-6-3/5.1. Alternatively, for pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognized national or international standard to which the pipe or fittings are manufactured, provided that there is an effective quality system in place.

Depending upon the intended application, the Bureau reserves the right to require the hydrostatic pressure testing of each pipe and/or fitting.

If the facility does not have a certified quality system in accordance with 1-1-A3/5.3, 1-1-A3/5.5 or ISO 9001 (or equivalent), then the production testing is to be witnessed by the Surveyor.

The manufacturer is to provide documentation certifying that all piping and piping components supplied are in compliance with the requirements of Section 4-6-3.

11 Plastic Pipe Bonding Procedure Qualification

11.1 Procedure Qualification Requirements

11.1.1 Joint Bonding Parameters

To qualify joint bonding procedures, the tests and examinations specified herein are to be successfully completed. The procedure for making bonds is to include the following:

- Materials used
- Tools and fixtures
- Environmental requirements
- Joint preparation requirements
- Cure temperature
- Dimensional requirements and tolerances
- Test acceptance criteria for the completed assembly

11.1.2 Requalification

Any change in the bonding procedure which will affect the physical and mechanical properties of the joint will require the procedure to be requalified.

11.3 Procedure Qualification Testing

11.3.1 Test Assembly

A test assembly is to be fabricated in accordance with the procedure to be qualified, and it is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint. When the test assembly has been cured, it is to be subjected to a hydrostatic test pressure at a safety factor of 2.5 times the design pressure of the test assembly for not less than one hour. No leakage or separation of joints is to be allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential direction.

11.3.2 Pipe Size

Selection of the pipes used for test assembly is to be in accordance with the following:

i) When the largest size to be joined is 200 mm (8 in.) nominal outside diameter or smaller, the test assembly is to be the largest pipe size to be joined.

ii) When the largest size to be joined is greater than 200 mm (8 in.) nominal outside diameter, the size of the test assembly is to be either 200 mm (8 in.) or 25% of the largest piping size to be joined, whichever is greater.

11.3.3 Bonding Operator Qualification

When conducting performance qualifications, each bonder and each bonding operator are to make up test assemblies, the size and number of which are to be as required above.

13 Tests by the Manufacturer – Fire Endurance Testing of Plastic Piping in the Dry Condition (for Level 1 and Level 2)

13.1 Test Method

13.1.1 Furnace Test Temperature

The specimen is to be subjected to a furnace test with fast temperature increase similar to that likely to occur in a fully developed liquid hydrocarbon fire. The time/temperature is to be as follows:

At the end of 5 minutes	945°C	(1733°F)
At the end of 10 minutes	1033°C	(1891°F)
At the end of 15 minutes	1071°C	(1960°F)
At the end of 30 minutes	1098°C	(2008°F)
At the end of 60 minutes	1100°C	(2012°F)

13.1.2 Furnace Temperature Control

The accuracy of the furnace control is to be as follows:

i) During the first 10 minutes of the test, variation in the area under the curve of mean furnace temperature is to be within ±15% of the area under the standard curve.

ii) During the first 30 minutes of the test, variation in the area under the curve of mean furnace temperature is to be within ±10% of the area under the standard curve.

iii) For any period after the first 30 minutes of the test, variation in the area under the curve of mean furnace temperature is to be within ±5% of the area under the standard curve.

iv) At any time after the first 10 minutes of the test, the difference in the mean furnace temperature from the standard curve is to be within ±100°C (±180°F).

13.1.3 Furnace Temperature Measurement

The locations where the temperatures are measured, the number of temperature measurements and the measurement techniques are to be approved by the Bureau.

13.3 Test Specimen

13.3.1 Pipe Joints and Fittings

The test specimen is to be prepared with the joints and fittings intended for use in the proposed application.

13.3.2 Number of Specimens

The number of specimens is to be sufficient to test typical joints and fittings including joints between non-metal and metal pipes and metal fittings to be used.

13.3.3 End Closure

The ends of the specimen are to be closed. One of the ends is to allow pressurized nitrogen to be connected. The pipe ends and closures may be outside the furnace.

13.3.4 Orientation

The general orientation of the specimen is to be horizontal and it is to be supported by one fixed support with the remaining supports allowing free movement. The free length between supports is not to be less than 8 times the pipe diameter.

13.3.5 Insulation

Most materials will require a thermal insulation to pass this test. The test procedure is to include the insulation and its covering.

13.3.6 Moisture Condition of Insulation

If the insulation contains or is liable to absorb moisture, the specimen is not to be tested until the insulation has reached an air dry-condition, defined as equilibrium with an ambient atmosphere of 50% relative humidity at 20 ± 5°C (68 ± 9°F). Accelerated conditioning is permissible provided the method does not alter the properties of the component material. Special samples are to be used for moisture content determination and conditioned with the test specimen. These samples are to be so constructed as to represent the loss of water vapor from the specimen having similar thickness and exposed faces.

13.5 Test Condition

A nitrogen pressure inside the test specimen is to be automatically maintained at 0.7 ± 0.1 bar (0.7 ± 0.1 kgf/cm^2, 10 ± 1.5 psi) during the test. Means are to be provided to record the pressure inside the pipe and the nitrogen flow into and out of the specimen in order to indicate leakage.

13.7 Acceptance Criteria

13.7.1 During the Test

During the test, no nitrogen leakage from the sample is to occur.

13.7.2 After the Test

After termination of the furnace test, the test specimen together with fire protective coating, if any, is to be allowed to cool in still air to ambient temperature and then tested to the maximum allowable pressure of the pipes, as defined in 4-6-3/5.1 and 4-6-3/5.3. The pressure is to be held for a minimum of 15 minutes without leakage. Where practicable, the hydrostatic test is to be conducted on bare pipe (i.e., coverings and insulation removed) so that any leakage will be visible.

13.7.3 Alternative Tests

Alternative test methods and/or test procedures considered to be at least equivalent, including open pit testing method, may be accepted in cases where the pipes are too large for the test furnace.

15 Test by Manufacturer – Fire Endurance Testing of Water-filled Plastic Piping (for Level 3)

15.1 Test Method

15.1.1 Burner

A propane multiple burner test with a fast temperature increase is to be used.

15.1.2 Pipes up to 152 mm (6 in.) OD

For piping up to and including 152 mm (6 in.) OD, the fire source is to consist of two rows of five burners, as shown in 4-6-3/Figure 1. A constant heat flux averaging 113.6 kW/m^2 (36,000 BTU/h-ft^2) ± 10% is to be maintained at the 12.5 ± 1 cm (5 ± 0.4 in.) height above the centerline of the burner array. This flux corresponds to a pre-mix flame of propane with a fuel flow rate of 5 kg/h (11 lb/h) for a total heat release of 65 kW (3700 BTU/min.). The gas consumption is to be measured with an accuracy of at least ±3% in order to maintain a constant heat flux. Propane with a minimum purity of 95% is to be used.

15.1.3 Pipes More than 152 mm (6 in.) OD

For piping greater than 152 mm (6 in.) OD, one additional row of burners is to be included for each 50 mm (2 in.) increase in pipe diameter. A constant heat flux averaging 113.6 kW/m^2 (36,000 BTU/h-ft^2) ± 10% is still to be maintained at the 12.5 ± 1 cm (5 ± 0.4 in.) height above the centerline of the burner array. The fuel flow is to be increased as required to maintain the designated heat flux.

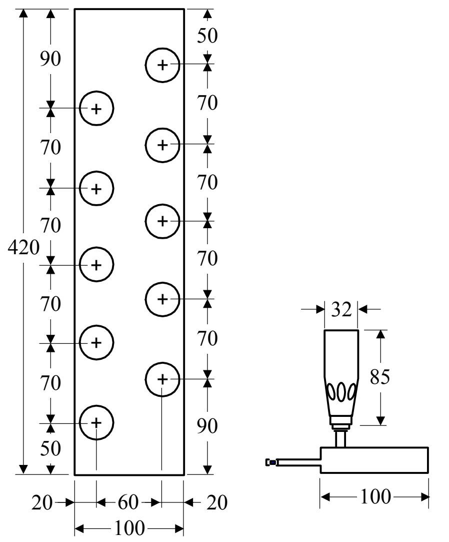
15.1.4 Burner Type and Arrangement

The burners are to be type "Sievert No. 2942" or equivalent which produces an air mixed flame. The inner diameter of the burner heads is to be 29 mm (1.14 in.). See 4-6-3/Figure 1. The burner heads are to be mounted in the same plane and supplied with gas from a manifold. If necessary, each burner is to be equipped with a valve in order to adjust the flame height.

15.1.5 Burner Position

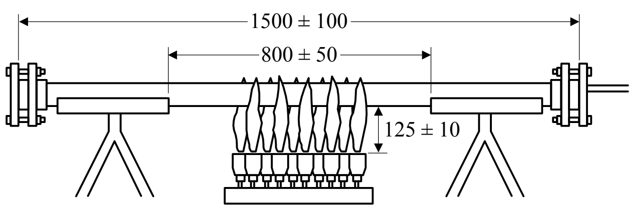
The height of the burner stand is also to be adjustable. It is to be mounted centrally below the test pipe with the rows of burners parallel to the pipe's axis. The distance between the burner heads and the pipe is to be maintained at 12.5 ± 1 cm (5 ± 0.4 in.) during the test. The free length of the pipe between its supports is to be 0.8 ± 0.05 m (31.5 ± 2 in.). See 4-6-3/Figure 2.

FIGURE 1
Fire Endurance Test Burner Assembly



a) Top View   b) Side View of one Burner

FIGURE 2
Fire Endurance Test Stand with Mounted Sample



15.3 Test Specimen

15.3.1 Pipe Length

Each pipe is to have a length of approximately 1.5 m (5 ft).

15.3.2 Pipe Joints and Fittings

The test pipe is to be prepared with the permanent joints and fittings intended to be used. Only valves and straight joints versus elbows and bends are to be tested as the adhesive in the joint is the primary point of failure.

15.3.3 Number of Specimens

The number of pipe specimens is to be sufficient to test all typical joints and fittings.

15.3.4 End Closure

The ends of each pipe specimen are to be closed, except to allow pressurized water and air vent to be connected.

15.3.5 Moisture of Insulation

If the insulation contains or is liable to absorb moisture, the specimen is not to be tested until the insulation has reached an air dry-condition, defined as equilibrium with an ambient atmosphere of 50% relative humidity at 20 ± 5°C (68 ± 9°F). Accelerated conditioning is permissible provided the method does not alter the properties of the component material. Special samples are to be used for moisture content determination and conditioned with the test specimen. These samples are to be so constructed as to represent the loss of water vapor from the specimen having similar thickness and exposed faces.

15.3.6 Orientation

The pipe samples are to rest freely in a horizontal position on two V-shaped supports. The friction between pipe and supports is to be minimized. The supports may consist of two stands, as shown in 4-6-3/Figure 2.

15.3.7 Relief Valve

A relief valve is to be connected to one of the end closures of each specimen

15.5 Test Conditions

15.5.1 Sheltered Test Site

The test is to be carried out in a sheltered test site in order to prevent any draft influencing the test.

15.5.2 Water-filled

Each pipe specimen is to be completely filled with deaerated water to exclude air bubbles.

15.5.3 Water Temperature

The water temperature is not to be less than 15°C (59°F) at the start and is to be measured continuously during the test. The water is to be stagnant and the pressure maintained at 3 ± 0.5 bar (3.1 ± 0.5 kgf/cm^2, 43.5 ± 7.25 psi) during the test.

15.7 Acceptance Criteria

15.7.1 During the Test

During the test, no leakage from the sample(s) is to occur except that slight weeping through the pipe wall may be accepted.

15.7.2 After the Test

After termination of the burner test, the test specimen together with fire protective coating, if any, is to be allowed to cool to ambient temperature and then tested to the maximum allowable pressure of the pipes, as defined in 4-6-3/5.1 and 4-6-3/5.3. The pressure is to be held for a minimum of 15 minutes without significant leakage [i.e., not exceeding 0.2 l/min. (0.05 gpm)]. Where practicable, the hydrostatic test is to be conducted on bare pipe (i.e., coverings and insulation removed) so that any leakage will be visible.

17 Tests by Manufacturer – Flame Spread

17.1 Test Method

Flame spread of plastic piping is to be determined by IMO Resolution A.653(16) *Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling, and Deck Finish Materials* with the following modifications.

i) Tests are to be made for each pipe material and size.

ii) The test sample is to be fabricated by cutting pipes lengthwise into individual sections and then assembling the sections into a test sample as representative as possible of a flat surface. A test sample is to consist of at least two sections. The test sample is to be at least 800 ± 5 mm (31.5 ± 0.2 in.) long. All cuts are to be made normal to the pipe wall.

iii) The number of sections that must be assembled together to form a test sample is to be that which corresponds to the nearest integral number of sections which makes up a test sample with an equivalent linearized surface width between 155 mm (6 in.) and 180 mm (7 in.). The surface width is defined as the measured sum of the outer circumference of the assembled pipe sections that are exposed to the flux from the radiant panel.

iv) The assembled test sample is to have no gaps between individual sections.

v) The assembled test sample is to be constructed in such a way that the edges of two adjacent sections coincide with the centerline of the test holder.

vi) The individual test sections are to be attached to the backing calcium silicate board using wire (No. 18 recommended) inserted at 50 mm (2 in.) intervals through the board and tightened by twisting at the back.

vii) The individual pipe sections are to be mounted so that the highest point of the exposed surface is in the same plane as the exposed flat surface of a normal surface.

viii) The space between the concave unexposed surface of the test sample and the surface of the calcium silicate backing board is to be left void.

ix) The void space between the top of the exposed test surface and the bottom edge of the sample holder frame is to be filled with a high temperature insulating wool if the width of the pipe segments extend under the side edges of the sample holding frame.

19 Testing by Manufacturer – General *(2007)*

Testing is to demonstrate the compliance with 4-6-3/5.1 through 4-6-3/5.15, as applicable, for plastic pipes, fittings and joints for which approval in accordance with Section 4-6-3 is requested. These tests are to be in compliance with the requirements of relevant standards as per 4-6-3/Table 2 and 4-6-3/Table 3. Other recognized standards may be considered.

21 Testing Onboard After Installation

Piping systems are to be subjected to a hydrostatic test pressure of not less than 1.5 times the design pressure to the satisfaction of the Surveyor.

For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be conducted to the satisfaction of the Surveyor.

TABLE 1
Fire Endurance Requirement Matrix

	PIPING SYSTEMS	*LOCATION* A	B	C	D	E	F	G	H	I	J	K
CARGO (Flammable cargoes with flash point ≤ 60°C (140°F))												
1	Cargo lines	NA	NA	L1	NA	NA	0	NA	0(10)	0	NA	L1(2)
2	Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0(10)	0	NA	L1(2)
3	Vent lines	NA	NA	NA	NA	NA	0	NA	0(10)	0	NA	X
INERT GAS												
4	Water seal effluent line	NA	NA	0(1)	NA	NA	0(1)	0(1)	0(1)	0(1)	NA	0
5	Scrubber effluent line	0(1)	0(1)	NA	NA	NA	NA	NA	0(1)	0(1)	NA	0
6	Main line	0	0	L1	NA	NA	NA	NA	NA	0	NA	L1(6)
7	Distribution lines	NA	NA	L1	NA	NA	0	NA	NA	0	NA	L1(2)
FLAMMABLE LIQUIDS [flash point > 60°C (140°F)]												
8	Cargo lines	X	X	L1	X	X	NA(3)	0	0(10)	0	NA	L1
9	Fuel oil	X	X	L1	X	X	NA(3)	0	0	0	L1	L1
10	Lubricating oil	X	X	L1	X	X	NA	NA	NA	0	L1	L1
11	Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
SEA WATER (See Note 1)												
12	Bilge main and branches	L1(7)	L1(7)	L1	X	X	NA	0	0	0	NA	L1
13	Fire main and water spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
14	Foam system	L1	L1	L1	NA	NA	NA	NA	NA	0	L1	L1
15	Sprinkler system	L1	L1	L3	X	NA	NA	NA	0	0	L3	L3
16	Ballast	L3	L3	L3	L3	X	0(10)	0	0	0	L2	L2
17	Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	0	0	NA	L2
18	Tank cleaning services, fixed machines	NA	NA	L3	NA	NA	0	NA	0	0	NA	L3(2)
19	Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
FRESH WATER												
20	Cooling water, essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
21	Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
22	Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
SANITARY/DRAINS/SCUPPERS												
23	Deck drains (internal)	L1(4)	L1(4)	NA	L1(4)	0	NA	0	0	0	0	0
24	Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
25	Scuppers and discharges (overboard)	0(1,8)	0(1,8)	0(1,8)	0(1,8)	0(1,8)	0	0	0	0	0(1,8)	0
VENTS/SOUNDING												
26	Water tanks/dry spaces	0	0	0	0	0	0(10)	0	0	0	0	0
27	Oil tanks [flashpoint > 60°C (140°F)]	X	X	X	X	X	X(3)	0	0(10)	0	X	X
MISCELLANEOUS												
28	Control air	L1(5)	L1(5)	L1(5)	L1(5)	L1(5)	NA	0	0	0	L1(5)	L1(5)
29	Service air (non-essential)	0	0	0	0	0	NA	0	0	0	0	0
30	Brine	0	0	NA	0	0	NA	NA	NA	0	0	0
31	Auxiliary low pressure steam [Pressure ≤ 7 bar (7 kgf/cm^2, 100 psi)]	L2	L2	0(9)	0(9)	0(9)	0	0	0	0	0(9)	0(9)

TABLE 1 (continued)
Fire Endurance Requirement Matrix

Locations

A	Category A machinery spaces
B	Other machinery spaces
C	Cargo pump rooms
D	Ro-ro cargo holds
E	Other dry cargo holds
F	Cargo tanks
G	Fuel oil tanks
H	Ballast water tanks
I	Cofferdams, void spaces, pipe tunnels and ducts
J	Accommodation, service and control spaces
K	Open decks

Abbreviations

L1	Fire endurance test in dry conditions, 60 minutes, in accordance with 4-6-3/13
L2	Fire endurance test in dry conditions, 30 minutes, in accordance with 4-6-3/13
L3	Fire endurance test in wet conditions, 30 minutes, in accordance with 4-6-3/15
0	No fire endurance test required
NA	Not applicable
X	Metallic materials having a melting point greater than 925°C (1700°F).

Notes:

1 Where non-metallic piping is used, remotely controlled valves are to be provided at the vessel's side. These valves are to be controlled from outside the space.

2 Remote closing valves are to be provided at the cargo tanks.

3 When cargo tanks contain flammable liquids with a flash point greater than 60°C (140°F), "0" may replace "NA" or "X".

4 For drains serving only the space concerned, "0" may replace "L1".

5 When controlling functions are not required by statutory requirements, "0" may replace "L1".

6 For pipe between machinery space and deck water seal, "0" may replace "L1".

7 For passenger vessels, "X" is to replace "L1".

8 Scuppers serving open decks in positions 1 and 2, as defined in Regulation 13 of the International Convention on Load Lines, 1966, are to be "X" throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent downflooding.

9 For essential services, such as fuel oil tank heating and ship's whistle, "X" is to replace "0".

10 For tankers where compliance with paragraph 3(f) of Regulation 13F of Annex I of MARPOL 73/78 is required, "NA" is to replace "0".

TABLE 2
Standards for Plastic Pipes – Typical Requirements for All Systems *(2007)*

	Test	*Typical Standard*	*Notes*
1	Internal pressure (1)	4-6-3/5.1 ASTM D 1599, ASTM D 2992 ISO 15493 or equivalent	Top, Middle, Bottom (of each pressure range) Tests are to be carried out on pipe spools made of different pipe sizes, fittings and pipe connections.
2	External pressure (1)	4-6-3/5.3 ISO 15493 or equivalent	As above, for straight pipes only.
3	Axial strength (1)	4-6-3/5.5	As above.
4	Load deformation	ASTM D 2412 or equivalent	Top, Middle, Bottom (of each pressure range)
5	Temperature limitations (1)	4-6-3/5.7 ISO 75 Method A GRP piping system: HDT test on each type of resin acc. to ISO 75 method A. Thermoplastic piping systems: ISO 75 Method AISO 306 Plastics - Thermoplastic materials - Determination of Vicat softening temperature (VST) VICAT test according to ISO 2507 Polyesters with an HDT below 80°C should not be used.	Each type of resin
6	Impact resistance (1)	4-6-3/5.9 ISO 9854: 1994, ISO 9653: 1991 ISO 15493 ASTM D 2444, or equivalent	Representative sample of each type of construction
7	Ageing	Manufacturer's standard ISO 9142:1990	Each type of construction
8	Fatigue	Manufacturer’s standard or service experience.	Each type of construction
9	Fluid absorption	ISO 8361:1991	
10	Material compatibility (2)	ASTM C581 Manufacturer’s standard	

Notes:

1 Where the manufacturer does not have a certified quality system, test to be witnessed by the Surveyor. See 4-6-3/9.

2 If applicable.

TABLE 3
Standards for Plastic Pipes – Additional Requirements Depending on Service and/or Location of Piping *(2007)*

	Test	*Typical Standard*	*Notes*
1	Fire endurance [1,2]	4-6-3/5.11	Representative samples of each type of construction and type of pipe connection.
2	Flame spread [1,2]	(4-6-3/5.13)	Representative samples of each type of construction.
3	Smoke generation [2]	IMO Fire Test Procedures Code	Representative samples of each type of construction.
4	Toxicity [2]	IMO Fire Test Procedures Code	Representative samples of each type of construction.
5	Electrical conductivity [1,2]	4-6-3/5.15 ASTM F1173-95 or ASTM D 257, NS 6126/ 11.2 or equivalent	Representative samples of each type of construction

Notes:

1 Where the manufacturer does not have a certified quality system, test to be witnessed by the Surveyor. See 4-6-3/9.

2 If applicable.

Note: Test items 1, 2 and 5 in 4-6-3/Table 3 are optional. However, if not carried out, the range of approved applications for the pipes will be limited accordingly (see 4-6-3/Table 1).

PART
4

CHAPTER 6 Piping Systems

SECTION 4 Ship Piping Systems and Tanks

1 General

1.1 Scope

The provisions of Part 4, Chapter 6, Section 4 (referred to as 4-6-4) apply to piping systems – other than liquid cargo systems – serving tanks and normally dry spaces. Piping systems for normally dry spaces include gravity drain and bilge systems. Systems for tanks include ballast systems, fuel oil and lubricating oil storage and transfer systems, and vent, overflow and sounding systems. Additional requirements for fuel oil and lubricating oil systems relating to operation of internal combustion engines, steam turbines and boilers are provided in Section 4-6-5 and Section 4-6-6.

Additional requirements for liquid cargo piping, vent and overflow, sounding, bilge and ballast systems for specialized vessels, including passenger vessels, are provided in Part 5C.

1.3 Effective Drainage

All vessels are to be provided with effective means of pumping out or draining tanks. They are also to have means of draining or pumping bilge water from normally dry compartments and void tanks.

1.5 Damage Stability Consideration

Piping serving tanks and dry spaces, where installed within zones of assumed damage under damage stability conditions, is also to be considered damaged. Damage to such piping is not to lead to progressive flooding of spaces not assumed damaged. If it is not practicable to route piping outside the zone of assumed damage, then means are to be provided to prevent progressive flooding. Such means, for example, may be the provision of a remotely operated valve in the affected piping. Alternatively, intact spaces that can be so flooded are to be assumed flooded in the damage stability conditions.

3 Gravity Drain Systems

3.1 General

3.1.1 Application

These requirements apply to gravity drain systems from watertight and non-watertight spaces located either above or below the freeboard deck.

3.1.2 Definitions *(2007)*

3.1.2(a) Gravity drain system. A gravity drain system is a piping system in which flow is accomplished solely by the difference between the height of the inlet end and the outlet end. For the purposes of the Rules, gravity drain systems include those which discharge both inside and outside the vessel.

3.1.2(b) Gravity discharge. A gravity discharge is an overboard drain from a watertight space such as spaces below freeboard deck or within enclosed superstructures or deckhouses. Back-flooding through a gravity discharge would affect the reserve buoyancy of the vessel.

3.1.2(c) Inboard end (2005). The inboard end of an overboard gravity discharge pipe is that part of the pipe at which the discharge originates. The inboard end to be considered for these requirements is the lowest inboard end where water would enter the vessel if back-flooding would occur. See also 4-6-4/9.5.3 for exception to this definition.

3.1.2(d) Scupper. A scupper is an overboard drain from a non-watertight space or deck area. Back-flooding through a scupper would not affect the reserve buoyancy of the vessel**.**

3.1.3 Basic Principles *(2007)*

Enclosed watertight spaces (spaces below freeboard deck or within enclosed superstructures or deckhouses) are to be provided with means of draining. This may be achieved by connection to the bilge system or by gravity drain. In general, a gravity drain is permitted wherever the position of the space allows liquid to be discharged by gravity through an appropriate opening in the boundary of the space. Unless specifically stated (see 4-6-4/3.5.2 or the following paragraph), the discharge can be directed overboard or inboard. Where directed overboard, means are to be provided to prevent entry of sea water through the opening in accordance with 4-6-4/3.3. Where directed inboard, suitable arrangements are to be provided to collect and dispose of the drainage.

Non-watertight spaces (open superstructures or deckhouses) and open decks, where liquid can accumulate, are also to be provided with means of draining. In general, a gravity drain is permitted for all non-watertight spaces. All such drains are to be directed overboard.

Gravity drains are to be capable of draining the space when the vessel is on even keel and either upright or listed 5 degrees on either side.

In addition to the requirements identified below, for gas carriers see 5C-8-2/3, for chemical carriers see 5C-9-2/3 and for passenger vessels see 5/11.3.2 of the ABS *Guide for Building and Classing Passenger Vessels*.

3.3 Protection from Sea Water Entry *(2005)*

3.3.1 Overboard Gravity Discharges – Normally Open

Gravity discharge pipes led overboard from any watertight space are to be fitted with an effective and accessible means, as described below, to prevent backflow of water from the sea into that space. The requirements for non-return valves in this subparagraph are applicable only to those discharges which remain open during the normal operation of the vessel.

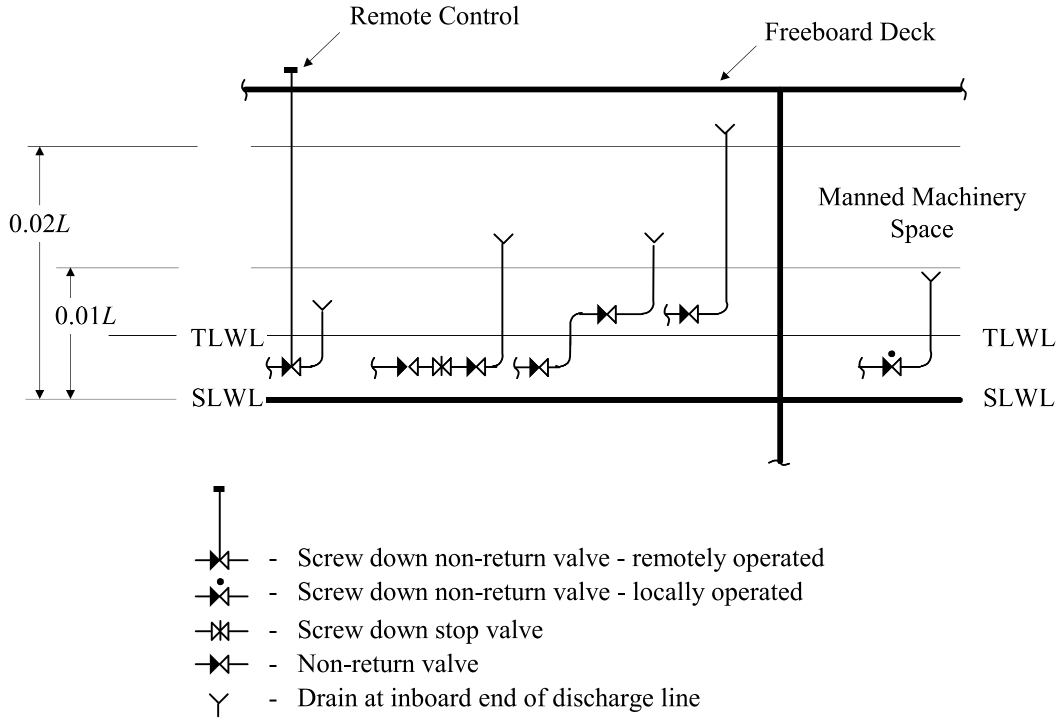
Normally, each separate discharge is to have one non-return valve with a positive means of closing it from a position above the freeboard deck. The means for operating the positive closing valve is to be readily accessible and provided with an indicator showing whether the valve is open or closed. Alternatively, one non-return valve and one positive closing valve controlled from above the freeboard deck may be accepted.

Where, however, the vertical distance from the summer load waterline (or, where assigned, timber summer load waterline) to the inboard end of the discharge pipe exceeds $0.01L_f$ (where L_f is the freeboard length of the vessel, as defined in 3-1-1/3.3), the discharge may have two non-return valves without positive means of closing, provided that the inboard non-return valve is always accessible for examination under all service conditions, that is, above the tropical load waterline (or, where assigned, timber tropical load waterline.) If this is impracticable, a locally operated positive closing valve may be provided between the two non-return valves, in which case, the inboard non-return valve need not be located above the specified tropical load waterline.

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds $0.02L_f$, a single non-return valve without positive means of closing is acceptable, provided it is located above the tropical load waterline (or, where assigned, timber tropical load waterline.) If this is impracticable, a locally operated positive closing valve may be provided below the single non-return valve, in which case, the non-return valve need not be located above the specified tropical load waterline.

Where sanitary discharges and scuppers lead overboard through the shell in way of machinery spaces, the fitting to the shell of a locally operated positive closing valve, together with a non-return valve inboard, will be acceptable.

FIGURE 1
Overboard Discharges – Valve Requirements *(2005)*



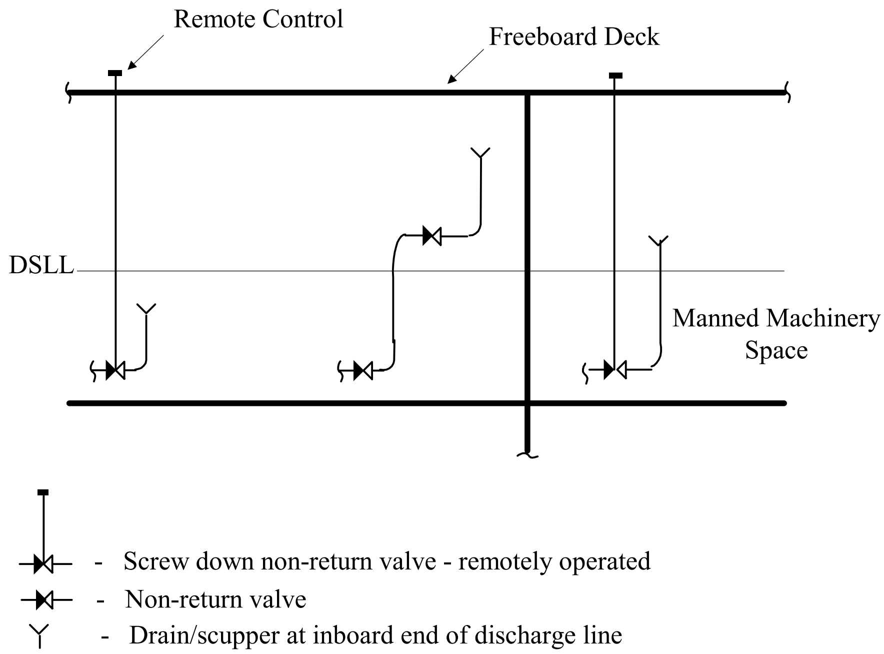
3.3.2 Overboard Gravity Discharges – Normally Closed

For overboard discharges which are closed at sea, such as gravity drains from topside ballast tanks, a single screw down valve operated from above the freeboard deck is acceptable.

3.3.3 Overboard Gravity Discharges from Spaces below the Freeboard Deck on Vessels Subject to SOLAS Requirements *(2007)*

For vessels subject to SOLAS requirements, instead of the requirements identified in 4-6-4/3.3.1 above, each separate gravity discharge led through the shell plating from spaces below the freeboard deck is to be provided with either one automatic non–return valve fitted with a positive means of closing it from above the freeboard deck or with two automatic non–return valves without positive means of closing, provided that the inboard valve is situated above the deepest subdivision load line (DSLL) and is always accessible for examination under service conditions. Where a valve with positive means of closing is fitted, the operating position above the freeboard deck shall always be readily accessible and means shall be provided for indicating whether the valve is open or closed.

FIGURE 2
SOLAS Vessels – Overboard Discharges from Spaces below Freeboard Deck – Valve Requirements *(2007)*



3.3.4 Scuppers and Discharges below the Freeboard Deck – Shell Penetration *(2007)*

Scuppers and discharge pipes originating at any level and penetrating the shell either more than 450 mm (17.5 in.) below the freeboard deck or less than 600 mm (23.5 in.) above the summer load waterline are to be provided with a non-return valve at the shell. This valve, unless required above may be omitted if the length of piping from the shell to freeboard deck has a wall thickness in accordance with 4-6-2/9.13.3.

3.5 Gravity Drains of Cargo Spaces on or Above Freeboard Deck

3.5.1 Overboard Drains

Enclosed cargo spaces of a vessel, whose summer freeboard is such that the deck edge of the cargo spaces being drained is not immersed when the vessel heels 5 degrees, may be drained by means of a sufficient number of suitably sized gravity drains discharging directly overboard. These drains are to be fitted with protection complying with 4-6-4/3.3.

3.5.2 Inboard Drains

Where the summer freeboard is such that the deck edge of the cargo space being drained is immersed when the vessel heels 5 degrees, the drains from these enclosed cargo spaces are to be led to a suitable space, or spaces, of adequate capacity, having a high water level alarm and provided with fixed pumping arrangement for discharge overboard. In addition, the system is to be designed such that:

i) The number, size and disposition of the drain pipes are to prevent unreasonable accumulation of free water;

ii) The pumping arrangements are to take into account the requirements for any fixed pressure water-spraying fire-extinguishing system;

iii) Water contaminated with substances having flash point of 60°C (140°F) or below is not to be drained to machinery spaces or other spaces where sources of ignition may be present; and *iv)* Where the enclosed cargo space is protected by a fixed gas fire-extinguishing system, the drain pipes are to be fitted with means to prevent the escape of the smothering gas. The U-tube water seal arrangement should not be used due to possible evaporation of water and the difficulty in assuring its effectiveness.

3.5.3 Cargo Spaces Fitted with Fixed Water-spray System

Where the cargo space is fitted with a fixed water-spray fire extinguishing system, the drainage arrangements are to be such as to prevent the build-up of free surfaces. If this is not possible, the adverse effects upon stability of the added weight and free surface of water are to be taken into account for the approval of the stability information. See 4-7-2/7.3.1 and 4-7-2/7.3.9.

3.7 Gravity Drains of Spaces Other than Cargo Spaces

3.7.1 Gravity Drains Terminating in Machinery Space

Watertight spaces such as a steering gear compartment, accommodations, voids, etc. may be drained to the main machinery space; all such drains are to be fitted with a valve operable from above the freeboard deck or a quick-acting, self closing valve. The valve is to be located in an accessible and visible location and preferably in the main machinery spaces.

3.7.2 Gravity Drains Terminating in Cargo Holds

When gravity drains from other spaces are terminated in cargo holds, the cargo hold bilge well is to be fitted with high level alarm.

3.7.3 Gravity Drains Terminating in a Drain Tank

Where several watertight compartments are drained into the same drain tank, each drain pipe is to be provided with a stop-check valve.

3.7.4 Escape of Fire Extinguishing Medium

Gravity drains which terminate in spaces protected by fixed gas extinguishing systems are to be fitted with means to prevent the escape of the extinguishing medium. See also 4-6-4/3.5.2.

3.9 Gravity Drains of Non-watertight Spaces

3.9.1 General *(2007)*

Scuppers leading from open deck and non-watertight superstructures or deckhouses are to be led overboard. The requirements of 4-6-4/3.3.4 also apply.

3.9.2 Helicopter Decks

Drainage piping of helicopter decks is to be constructed of steel. The piping is to be independent of any other piping system and is to be led directly overboard close to the waterline. The drain is not to discharge onto any part of the vessel.

3.11 Vessels Subject to Damage Stability

Gravity drain piping where affected by damage stability considerations is to meet 4-6-4/5.5.12.

3.13 Vessels Receiving Subdivision Loadlines *(2008)*

For vessel receiving subdivision loadlines, the bulkhead deck is to apply to provisions given in 4-6-4/3.3 when it is higher than the freeboard deck.

5 Bilge System

5.1 General

5.1.1 Application

The provisions of 4-6-4/5 apply to bilge systems serving propulsion and other machinery spaces, dry cargo spaces and spaces where accumulation of water is normally expected. Additional requirements for bilge systems of specialized vessels such as oil carriers, passenger vessels, etc. are provided in Part 5C.

5.1.2 Basic Principles

5.1.2(a) Function. A bilge system is intended to dispose of water which may accumulate in spaces within the vessel due to condensation, leakage, washing, fire fighting, etc. It is to be capable of controlling flooding in the propulsion machinery space as a result of limited damage to piping systems.

5.1.2(b) Cross-flooding prevention. The system is to be designed to avoid the possibility of cross-flooding between spaces and between the vessel and the sea.

5.1.2(c) System availability. To enhance system availability, bilge pump integrity is to be assured through testing and certification; at least two bilge pumps are to be provided, and bilge suction control valves are to be accessible for maintenance at all times.

5.1.2(d) Oil pollution prevention. Provision is to be made to process oily bilge water prior to discharging overboard.

5.3 Bilge System Sizing

5.3.1 Size of Bilge Suctions

The minimum internal diameter of the bilge suction pipes is to be determined by the following equations, to the nearest 6 mm (0.25 in.) of the available commercial sizes.

5.3.1(a) Bilge main. The diameter of the main bilge line suction is to be determined by the following equations:

$$d = 25 + 1.68\sqrt{L(B + D)} \text{ mm} \qquad d = 1 + \sqrt{\frac{L(B + D)}{2500}} \text{ in.}$$

where

d	=	internal diameter of the bilge main pipe; mm (in.)
L	=	scantling length of vessel, as defined in 3-1-1/3.1; m (ft); see also 4-6-4/5.3.1(b)
B	=	breadth of vessel, as defined in 3-1-1/5; m (ft)
D	=	depth to bulkhead or freeboard deck, as defined in 3-1-1/7.1; m (ft); see also 4-6-4/5.3.1(e).

However, no bilge main suction pipe is to be less than 63 mm (2.5 in.) internal diameter.

5.3.1(b) Bilge system serving only engine room. Where the engine room bilge pumps are fitted primarily for serving the engine room and they do not serve cargo space bilges, L may be reduced by the combined length of the cargo tanks or cargo holds. In such cases, the cross sectional area of the main bilge line is not to be less than twice the required cross sectional area of the engine room branch bilge lines.

5.3.1(c) Direct bilge suction. The diameter of the direct bilge suction [see 4-6-4/5.5.5(a)] is to be not less than that determined by the equation in 4-6-4/5.3.1(a).

5.3.1(d) Bilge branch. The diameter of the bilge branch suction for a compartment is to be determined by the following equation. If the compartment is served by more than one branch suction, the combined area of all branch suction pipes is not to be less than the area corresponding to the diameter determined by the following equations:

$$d_B = 25 + 2.16\sqrt{c(B+D)} \text{ mm} \qquad d_B = 1 + \sqrt{\frac{c(B+D)}{1500}} \text{ in.}$$

where

d_B = internal diameter of the bilge branch pipe; mm (in.)

c = length of the compartment; m (ft)

However, no branch suction pipe needs to be more than 100 mm (4 in.) internal diameter, nor is to be less than 50 mm (2 in.) internal diameter, except that for pumping out small pockets or spaces, 38 mm (1.5 in.) internal diameter pipe may be used.

5.3.1(e) Enclosed cargo space on bulkhead deck. For calculating the bilge main diameter of vessels having enclosed cargo spaces on the bulkhead deck or the freeboard deck, which is drained inboard by gravity in accordance with 4-6-4/3.5.2 and which extends for the full length of the vessel, D is to be measured to the next deck above the bulkhead or freeboard deck. Where the enclosed cargo space covers a lesser length, D is to be taken as a molded depth to the freeboard deck plus $\ell h/L$, where ℓ and h are aggregate length and height, respectively, of the enclosed cargo space.

5.3.1(f) Bilge common-main (2005). The diameter of each common-main bilge line may be determined by the equation for bilge branches given in 4-6-4/5.3.1(d) using the combined compartment length upstream of the point where the diameter is being determined. In case of double hull construction with full depth wing tanks served by a ballast system, where the beam of the vessel is not representative of the breadth of the compartment, B, may be appropriately modified to the breath of the compartment. However, no common-main bilge pipe needs to be more than the diameter for the bilge main given in 4-6-4/5.3.1(a).

5.3.2 Bilge Pump Capacity

When only two bilge pumps are fitted, each is to be capable of giving a speed of water through the bilge main required by 4-6-4/5.3.1(a) of not less than 2 m (6.6 ft) per second. The minimum capacity Q of the required bilge pump may be determined from the following equation:

$$Q = \frac{5.66\text{d}^2}{10^3} \text{ m}^3\text{/hr} \qquad Q = 16.1d^2 \text{ gpm}$$

where

d = the required internal diameter, mm (in.), of the bilge main as defined in 4-6-4/5.3.1(a).

When more than two pumps are connected to the bilge system, their arrangement and aggregate capacity are not to be less effective.

5.5 Bilge System Design

5.5.1 General

All vessels are to be fitted with an efficient bilge pumping system. The system is to meet the basic principles of 4-6-4/5.1.2, and be capable of pumping from and draining any watertight compartment other than spaces permanently used for carriage of liquids and for which other efficient means of pumping are provided. Non-watertight compartments liable to accumulate water, such as chain lockers, non-watertight cargo holds, etc., are also to be provided with an efficient bilge pumping system.

A gravity drain system, in lieu of a bilge pumping system, may be accepted subject to the provisions of 4-6-4/3 above.

Bilge pumping systems are to be capable of draining the spaces when the vessel is on even keel and either upright or listed 5 degrees on either side.

5.5.2 Bilge Pumps

5.5.2(a) Number of pumps. At least two power driven bilge pumps are to be provided, one of which may be driven by the propulsion unit. Bilge pump capacity is to be in accordance with 4-6-4/5.3.2.

5.5.2(b) Permissible use of other pumps. Sanitary, ballast and general service pumps may be accepted as independent power bilge pumps, provided they are of required capacity, not normally used for pumping oil, and are appropriately connected to the bilge system.

5.5.2(c) Priming. Where centrifugal pumps are installed, they are to be of the self-priming type or connected to a priming system. However, pumps used for emergency bilge suction [see 4-6-4/5.5.5(b)] need not be of the self-priming type.

5.5.2(d) Test and certification. Bilge pumps are to be certified in accordance with 4-6-1/7.3.

5.5.3 Strainers *(2005)*

Bilge lines in machinery spaces other than emergency suctions are to be fitted with strainers, easily accessible from the floor plates, and are to have straight tail pipes to the bilges. The ends of the bilge lines in other compartments are to be fitted with suitable strainers having an open area of not less than three times the area of the suction pipe.

5.5.4 Bilge Piping System – General

5.5.4(a) Bilge manifolds and valves. Bilge manifolds and valves in connection with bilge pumping are to be located in positions which are accessible at all times for maintenance under ordinary operating conditions. All valves at the manifold controlling bilge suctions from the various compartments are to be of the stop-check type. In lieu of a stop-check valve, a stop valve and a non-return valve may be accepted.

5.5.4(b) Main control valves. Where a bilge pump is connected for bilge, ballast and other sea water services, the bilge suction main, the ballast suction main, etc. are each to be provided with a stop valve, so that when the pump is used for one service, the other services can be isolated.

5.5.4(c) Bilge piping passing through tanks. Where passing through deep tanks, unless being led through a pipe tunnel, bilge suction lines are to be of steel having a thickness at least as required by column D of 4-6-2/Table 4. Pipes of other materials having dimensions properly accounting for corrosion and mechanical strength may be accepted. The number of joints in these lines is to be kept to a minimum. Pipe joints are to be welded or heavy flanged (e.g., one pressure rating higher). The line within the tank is to be installed with expansion bends. Slip joints are not permitted. A non-return valve is to be fitted at the open end of the bilge line. These requirements are intended to protect the space served by the bilge line from being flooded by liquid from the deep tank in the event of a leak in the bilge line.

5.5.4(d) Arrangement of suction pipes. For drainage when the vessel is listed (see 4-6-4/5.5.1), wing suctions will often be necessary, except in narrow compartments at the ends of the vessel. Arrangements are to be made whereby water in the compartment will drain to the suction pipe.

5.5.5 Requirements for Propulsion Machinery Space

5.5.5(a) Direct bilge suction. One of the required independently driven bilge pumps is to be fitted with a suction led directly from the propulsion machinery space bilge to the suction main of the pump, so arranged that it can be operated independently of the bilge system. The size of this line is not to be less than that determined by 4-6-4/5.3.1(c). The direct bilge suction is to be controlled by a stop-check valve.

If watertight bulkheads separate the propulsion machinery space into compartments, a direct bilge suction is to be fitted from each compartment, unless the pumps available for bilge service are distributed throughout these compartments. In such a case, at least one pump with a direct suction is to be fitted in each compartment.

5.5.5(b) Emergency bilge suction. In addition to the direct bilge suction required by 4-6-4/5.5.5(a), an emergency bilge suction is to be fitted for the propulsion machinery space. The emergency bilge suction is to be directly connected to the largest independently driven pump in the propulsion machinery space, other than the required bilge pumps. Where this pump is not suitable, the second largest suitable pump in the propulsion machinery space may be used for this service, provided that the selected pump is not one of the required bilge pumps and its capacity is not less than that of the required bilge pump.

The emergency bilge line is to be provided with a suction stop-check valve, which is to be so located as to enable rapid operation, and a suitable overboard discharge line.

In addition, the following arrangements are also to be complied with, as applicable:

i) For internal-combustion-engine propulsion machinery spaces, the area of the emergency bilge suction pipe is to be equal to the full suction inlet of the pump selected.

ii) For steam propulsion machinery spaces, the main cooling water circulating pump is to be the first choice for the emergency bilge suction, in which case, the diameter of the emergency bilge suction is to be at least two-thirds the diameter of the cooling water pump suction.

5.5.5(c) Centralized or unattended operation. Where the propulsion machinery space is intended for centralized or unattended operation (**ACC/ACCU** notation), a high bilge water level alarm system is to be fitted, see 4-9-3/15.3. As a minimum, bilge valve controls are to be located above the floor grating, having regard to the time likely to be required in order to reach and operate the valves.

5.5.6 Requirements for Small Compartments *(2005)*

Small compartments, such as chain lockers, echo sounder spaces and decks over peak tanks, etc., may be drained by ejectors or hand pumps. Where ejectors are used for this purpose, the overboard discharge arrangements are to comply with 4-6-4/3.3.

5.5.7 Common-main Bilge Systems *(2005)*

A common-main bilge system normally consists of one or more main lines installed along the length of the vessel fitted with branch bilge suction connections to various compartments. Where only one fore-aft bilge main is installed, the bilge main is to be located inboard of 20% of the molded beam of the vessel, measured inboard from the side of the ship, perpendicular to the centerline at the level of the summer load line. If there is at least one bilge main on each side of the vessel, then these bilge mains may be installed within 20% of the molded beam measured inboard from the side of the ship, perpendicular to the centerline at the level of the summer load line. In such cases, piping arrangements are to be such that it is possible to effectively pump out all compartments using the main on either side of the vessel.

For single common-main bilge systems, the control valves required in the branches from the bilge main are to be accessible at all times for maintenance. This accessibility is not required for multiple common-main bilge systems arranged such that any single control valve failure will not disable the bilge pumping capability from any one space. In all cases, control valves are to be of the stop-check type with remote operators. Remote operators may be controlled from a manned machinery space, or from an accessible position above the freeboard deck, or from under deck walkways. Remote operators may be of hydraulic, pneumatic, electric or reach rod type.

5.5.8 Cargo Spaces of Combination Carriers

For combination carriers, such as oil-or-bulk carriers, arrangements are to be made for blanking off the oil and ballast lines and removing the blanks in the bilge lines when dry or bulk cargo is to be carried. Conversely, the bilge lines are to be blanked-off when oil or ballast is to be carried.

5.5.9 Cargo Spaces Intended to Carry Dangerous Goods

The following requirements apply to cargo spaces intended to carry dangerous goods as defined in 4-7-1/11.23.

5.5.9(a) Independent bilge system. A bilge system, independent of the bilge system of the machinery space and located outside the machinery space, is to be provided for cargo spaces intended to carry flammable liquids with a flash point of less than 23°C or toxic liquids. The independent bilge system is to comply with the provisions of 4-6-4/5, including the provision of at least two bilge pumps. The space containing the independent bilge pumps is to be independently ventilated, giving at least six air changes per hour. This, however, does not apply to eductors located in cargo space.

5.5.9(b) Combined bilge system. As an alternative to 4-6-4/5.5.9(a) above, the cargo spaces may be served by the bilge system of the machinery space and an alternative bilge system. The alternative bilge system is to be independent of or capable of being segregated from the machinery space bilge system. The capacity of the alternative bilge system is to be at least 10 m^3/h per cargo space served, but need not exceed 25 m^3/h. This alternative bilge system need not be provided with redundant pumps. Whenever flammable liquids with flash point of less than 23°C or toxic liquids are carried in the cargo spaces, the bilge lines leading into the machinery space are to be blanked off or closed off by lockable valves. In addition, a warning notice to this effect is to be displayed at the location.

5.5.9(c) Gravity drain system. If the cargo spaces are drained by gravity, the drainage is to be led directly overboard or into a closed drain tank located outside machinery spaces. The drain tank is to be vented to a safe location on the open deck. Drainage from a cargo space to the bilge well of a lower cargo space is permitted only if both spaces satisfy the same requirements.

5.5.10 Cargo Spaces Fitted with Fixed Water-spray System

Where the cargo space is fitted with a fixed water-spray fire extinguishing system, the drainage arrangements are to be such as to prevent the build-up of free surfaces. If this is not possible, the adverse effect upon stability of the added weight and free surface of water are to be taken into account for the approval of the stability information. See 4-7-2/7.3.1 and 4-7-2/7.3.9.

5.5.11 Bilge Suctions for Normally Unmanned Spaces

Normally, unmanned spaces located below the waterline, such as bow thruster compartment, emergency fire pump room, etc., for which bilge pumping is required, are to be arranged such that bilge pumping can be effected from outside the space, or alternatively, a bilge alarm is to be provided.

5.5.12 Vessels Subject to Damage Stability

Bilge pipes installed within the regions of assumed damage under damage stability conditions are to be considered damaged. Bilge piping will affect damage stability considerations if:

- It is installed within the extent of assumed damage in damage stability consideration, and
- The damage to such bilge piping will lead to progressive flooding of intact spaces through open ends in the bilge piping system.

Affected bilge piping is to be fitted with non-return valves in the lines in the intact spaces to prevent the progressive flooding of these spaces. The valves will not be required if it can be shown that, even with the progressively flooded spaces taken into consideration, the vessel still complies with the applicable damage stability criteria.

5.7 Oil Pollution Prevention Measures

5.7.1 General

Means are to be provided to process oil contaminated water from machinery space bilges prior to discharging it overboard. In general, the discharge criteria of MARPOL ANNEX 1, Regulation 15 are to be complied with.

5.7.2 Oily Water Filtering or Separating Equipment

Oily water filtering equipment capable of processing oily mixtures to produce an effluent with oil content not exceeding 15 parts per millions (PPM) and complying with IMO Resolution MEPC.107(49) is to be provided to allow oily water from the bilges to be processed prior to discharging overboard. For vessels of 10,000 tons gross tonnage and above, the equipment is to be fitted with an alarm and an arrangement to automatically stop the discharge when 15 PPM cannot be maintained.

5.7.3 Sludge Tank

A tank or tanks of adequate capacity is to be provided to receive oily residues such as those resulting from the oily water filtering or separating equipment and from the purification of fuel and lubricating oils. The minimum sludge tank capacity V_1 is to be calculated by the following formula:

$$V_1 = K_1 CD \qquad \text{m}^3\ (\text{ft}^3)$$

where

K_1 = 0.015 for vessels where heavy fuel oil is purified for main engine use or

= 0.005 for vessels using diesel oil or heavy fuel oil which does not require purification before use

C = daily fuel oil consumption, m^3 (ft^3)

D = maximum period of voyage between ports where sludge can be discharged ashore (days). In the absence of precise data, a figure of 30 days is to be used.

For vessels fitted with incinerators or similar equipment for onboard disposal of sludge, the minimum sludge tank capacity may be reduced to 50% of V_1 or 2 m^3 (72 ft^3) [1 m^3 (36 ft^3) for vessels below 4,000 gross tonnage], whichever is greater.

The sludge tank is to be so designed as to facilitate cleaning. Where heavy fuel oil residue is expected to be received by the sludge tank, heating arrangements are to be provided to facilitate the discharge of the sludge tank.

5.7.4 Sludge Piping System

5.7.4(a) Sludge pump. The sludge tank is to be provided with a designated pump of a suitable type, capacity and discharge head for the discharge of the tank content to shore reception facilities.

5.7.4(b) Standard discharge connection. To enable the discharge of sludge to shore reception facilities, the sludge piping is to be provided with a standard discharge connection, in accordance with 4-6-4/Table 1.

TABLE 1
Dimensions and Details of Standard Discharge Connection Flange

	Dimension
Outside diameter	215 mm
Inner diameter	According to pipe outside diameter
Bolt circle diameter	183 mm
Slots in flange	6 holes 22 mm in diameter equidistantly placed on a bolt circle of the above diameter, slotted to the flange periphery. The slot width to be 22 mm
Flange thickness	20 mm
Bolts and nuts:	6 sets, each of 20 mm in diameter and of suitable length
The flange is designed to accept pipes up to a maximum internal diameter of 125 mm and is to be of steel or other equivalent material having a flat face. This flange, together with a gasket of oil-proof material, is to be suitable for a service pressure of 6 kg/cm^2	

5.7.4(c) Sludge piping. There is to be no interconnection between the sludge tank discharge piping and bilge piping other than the possible common piping, with appropriate valves, leading to the standard discharge connection. Piping to and from sludge tanks is to have no direct connection overboard other than the standard discharge connection referred to in 4-6-4/5.7.4(b).

5.9 Testing and Trials

The bilge system is to be tested under working conditions, see 4-6-2/7.3.3. See also 3-7-2/3 for bilge system trials.

7 Ballast Systems

7.1 General

7.1.1 Application

These requirements apply to ballast systems for all vessels. For additional ballast system requirements for oil carriers, see Part 5C.

7.1.2 Basic Principles

These requirements are intended to provide a reliable means of pumping and draining ballast tanks through the provision of redundancy and certification of ballast pumps, and the provision of suitable remote control, where fitted.

7.3 Ballast Pumps

At least two power driven ballast pumps are to be provided, one of which may be driven by the propulsion unit. Sanitary, bilge and general service pumps may be accepted as independent power ballast pumps. Alternative means of deballasting, such as an eductor or a suitable liquid cargo pump with an appropriate temporary connection to the ballast system [see 5C-1-7/5.3.1(c)], may be accepted in lieu of a second ballast pump.

Ballast pumps are to be certified in accordance with 4-6-1/7.3.

7.5 Ballast Piping and Valves

7.5.1 Ballast Tank Valves

Valves controlling flow to ballast tanks are to be arranged so that they will remain closed at all times except when ballasting. Where butterfly valves are used, they are to be of a type with positive holding arrangements, or equivalent, that will prevent movement of the valve position due to vibration or flow of fluids.

7.5.2 Remote Control Valves

Remote control valves, where fitted, are to be arranged so that they will close and remain closed in the event of loss of control power. Alternatively, the remote control valves may remain in the last ordered position upon loss of power, provided that there is a readily accessible manual means to close the valves upon loss of power.

Remote control valves are to be clearly identified as to the tanks they serve and are to be provided with position indicators at the ballast control station.

7.5.3 Vessels Subject to Damage Stability

Ballast pipes installed in the regions of assumed damage under damage stability consideration are to be considered damaged. Ballast piping will affect damage stability considerations if:

- It is installed within the extent of assumed damage in damage stability consideration, and
- The damage to the ballast pipe will lead to progressive flooding of intact ballast tanks through open ends in the ballast piping system.

Affected ballast piping is to be fitted with valves in the pipes in the intact tanks to prevent progressive flooding of these tanks. The valves are to be of a positive closing type and operable from above the freeboard deck or from a manned machinery space. Where the valves are electrically, hydraulically or pneumatically actuated, the cables or piping for this purpose are not to be installed within the extent of assumed damage, or, alternatively, the valves are to be arranged to fail in the closed position upon loss of control power.

The valves will not be required if it can be shown that, even with the progressively flooded spaces taken into consideration, the vessel still complies with the applicable damage stability criteria.

7.5.4 Ballast Pipes Passing Through Fuel Oil Tanks

To minimize cross-contamination, where passing through fuel oil tanks, unless being led through pipe tunnel, ballast lines are to be of steel or equivalent [see 4-6-4/5.5.4(c)] having a thickness at least as required by column D of 4-6-2/Table 4. The number of joints in these lines is to be kept to a minimum. Pipe joints are to be welded or heavy flanged (e.g., one pressure rating higher). The line within the tank is to be installed with expansion bends. Slip joints are not permitted.

9 Tank Vents and Overflows

9.1 General

9.1.1 Application

These requirements apply to vents and overflows of liquid and void tanks. Tanks containing flammable liquids, such as fuel oil and lubricating oil, are subject to additional requirements, which are provided in this subsection. For hydraulic oil, see also 4-6-7/3.3.2. Vents and overflows, and inerting systems, as applicable, for liquid cargo tanks are provided in Part 5C of the Rules.

Ventilators installed for ventilation of normally dry compartments, such as steering gear compartment, cargo hold, etc., are to comply with the provisions of 3-2-17/9.1.

9.1.2 Basic Requirements

9.1.2(a) Purposes of vents. All tanks served by pumps are to be provided with vents. Primarily, vents allow air or vapor from within the tank to escape when the tank is being filled, and take in air when the tank is being discharged. Vents are also needed for tanks in the storage mode to allow them to 'breathe'. In general, vents are to be fitted at the highest point of the tanks so that venting can be achieved effectively.

9.1.2(b) Purposes of overflows. Tanks filled by a pumping system may, in addition to vents, be fitted with overflows. Overflows prevent overpressurization of a tank if it is overfilled and also provide for safe discharge or disposal of the overflowing liquid. Overflows may also be fitted to limit the level at which a tank may be filled. Overflows are to be sized based on the capacity of the pump and the size of the filling line. Considerations are to be given to receiving the overflow.

9.1.2(c) Combining vents and overflows. Vents may also act as overflows provided all the requirements applicable to both vents and overflows are complied with.

9.1.2(d) Termination of the outlet ends of vents and overflows. Generally, vents emanating from tanks containing liquids likely to evolve flammable or hazardous vapor are to have their outlets located in the open weather. Depending on the liquid contained in the tank, overflow outlets are to be located such that they either discharge overboard or into designated overflow tanks so as to avoid inadvertent flooding of internal spaces. Outlet ends of vents and overflows, where exposed to the weather, are to be provided with means to prevent sea water from entering the tanks through these openings.

9.1.2(e) Small spaces. Small voids which are not fitted with a permanent means of pumping out bilges, or through which no pressurized piping passes, may be exempted from being fitted with vents.

9.1.3 Vessels Subject to Damage Stability Requirements

Vents and overflows of vessels subject to damage stability requirements are to be terminated above the equilibrium water line in the damaged conditions. Automatic means of closure are to be fitted to the outlets of vents whose intersection with the deck is below the equilibrium water line. Such means are also required for those vents whose outlets will be submerged in the range of residual stability beyond the equilibrium where such range is required by the applicable damage stability criteria.

9.3 Tank Vents

9.3.1 General Requirements

Generally, each tank served by a pumping system, as indicated in 4-6-4/9.1.2, is to be fitted with at least two vents. Tanks with surface area less than $B^2/16$ (where B is the breath of the vessel as defined in 3-1-1/5) may, however, be fitted with one vent. The vents are to be located as far apart as possible.

As far as practicable, the vent pipe is to be located at the highest point of the tank. This is to permit air, vapor and gas from all parts of the tank to have access to the vent pipe with the vessel at an upright position or at varying angles of heel and trim. Vent pipes are to be arranged to provide adequate drainage. No shutoff valve is to be installed in vent piping.

9.3.2 Vent Pipe Height and Wall Thickness

9.3.2(a) Exposed to weather (2010). Vent pipes on decks exposed to the weather are to have the following heights:

760 mm (30 in.) for those on the freeboard deck; and

450 mm (17.5 in.) for those on the superstructure deck.

The height is to be measured from the deck to the point where water may have access below. Where these heights may interfere with the working of the vessel, a lower height may be accepted, provided the Bureau is satisfied that the closing arrangements and other circumstances justify a lower height.

The wall thicknesses of vent pipes where exposed to the weather are to be not less than that specified below. For vent pipes located on the fore deck, as defined in 3-2-17/9.7.1, the strength and wall thickness requirements are to also comply with 3-2-17/9.7.2 and 3-2-17/9.7.3:

Nominal Size, d	*Min. Wall Thickness*
$d \leq 65$ mm (2.5 in.)	6.0 mm (0.24 in.)
65 mm (2.5 in.) < d < 150 mm (6 in.)	by interpolation (1)
$d \geq 150$ mm (6 in.)	8.5 mm (0.33 in.)

Note:

1 $6 + 0.029(d - 65)$ mm or $0.24 + 0.026(d - 2.5)$ in.

9.3.2(b) Not exposed to weather. Vent pipes not exposed to the weather need not comply with the height and wall thickness required by 4-6-4/9.3.2(a). However, vent pipes passing through fuel oil or ballast tanks are to have wall thicknessess not less than that indicated in column D of 4-6-2/Table 4. Other vent pipes are to meet thickness requirements of column C of the same table.

9.3.3 Vent Pipe Size

9.3.3(a) Minimum size. The minimum nominal bore of vent pipes is to be as follows:

Tank	*Minimum Internal Diameter, mm (in.)*
Water tanks	50 (2) *
Oil tanks	65 (2.5)

* *Note:* Minimum diameter of vent pipes on fore deck not to be less than 65 mm. See 3-2-17/9.7.3(b).

where water tanks refer to freshwater and sea water tanks; oil tanks refer to fuel oil, lubricating oil, hydraulic oil and other oil tanks. Small water or oil tanks of less than 1 m^3 (36 ft^3) may have vent pipe of 38 mm (1.5 in.) minimum internal diameter.

9.3.3(b) Vent sizing. Where a separate overflow is not fitted, the aggregate area of the vent pipe(s) provided for the tank is to be at least 125% of the effective area of the filling line.

Where overflow pipe(s) are fitted, and the aggregate area of the overflow pipes is at least 125% of the effective area of the filling line, in such cases, vent pipes need not exceed the minimum sizes in 4-6-4/9.3.3(a).

Where high capacity or high head pumps are used, calculations demonstrating the adequacy of the vent and overflow to prevent over- or underpressurization of the ballast tanks are to be submitted. See also 4-6-4/9.5.2.

9.3.4 Termination of Vent Pipe Outlets

9.3.4(a) Termination on weather deck (2005). Outlets of vents from the following tanks are to be led to the weather:

- Ballast tanks
- Fuel-oil tanks, except fuel-oil drain tanks with a volume less than 2 m^3 (70.6 ft^3) and which cannot be filled by a pump – see 4-6-4/13.3.4
- Thermal oil tanks
- Tanks containing liquids having flash point of 60°C (140°F) or below
- Void tanks adjacent to tanks containing liquids having a flash point of 60°C or below

Where it is impracticable to terminate vents on a weather deck as required, such as the case of open car deck of a ro-ro vessel, vents may be led overboard from a deck below the weather deck. In such a case, non-return valves of an approved type are fitted at the outlets to prevent ingress of water. See also 4-6-4/9.5.3.

9.3.4(b) Termination on or above freeboard deck. Vent outlets from double bottom and other structural tanks, including void tanks, whose boundaries extend to the shell of the vessel at or below the deepest load waterline, are to be led above the freeboard deck. This is so that in the event of shell damage in way of these tanks the vent pipes will not act as a possible source of progressive flooding to otherwise intact spaces below the freeboard deck.

9.3.4(c) Termination in machinery space. Vents from tanks other than those stated in 4-6-4/9.3.4(a) and 4-6-4/9.3.4(b) may terminate within the machinery space, provided that their outlets are so located that overflow therefrom will not impinge on electrical equipment, cause a hazardous consequence such as fire, or endanger personnel.

9.3.5 Protection of Vent Outlets

9.3.5(a) Protection from weather and sea water ingress (2010). All vents terminating in the weather are to be fitted with return bends (gooseneck), or equivalent, and the vent outlet is to be provided with an automatic means of closure i.e., close automatically upon submergence (e.g., ball float or equivalent) complying with 4-6-4/9.3.7.

9.3.5(b) Protection for fuel oil tanks. In addition to 4-6-4/9.3.5(a), vents from fuel oil tanks are to comply with the following:

i) *(2007)* Vent outlets are to be fitted with corrosion resistant flame-screens. Either a single screen of corrosion-resistant wire of at least 12 by 12 mesh per linear cm (30 by 30 mesh per linear inch), or two screens of at least 8 by 8 mesh per linear cm (20 by 20 mesh per linear inch) spaced not less than 13 mm (0.5 inch) nor more than 38 mm (1.5 inch) apart are acceptable. The clear area through the mesh of the flame-screen is to be not less than the required area of the vent pipe specified in 4-6-4/9.3.3.

Note: Mesh count is defined as a number of openings in a linear cm (inch) counted from the center of any wire to the center of a parallel wire.

ii) Vent outlets are to be situated where possibility of ignition of the gases issuing therefrom is remote.

iii) Vents for fuel oil service and settling tanks directly serving the propulsion and generator engines are to be so located and arranged that in the event of a broken vent pipe, this will not directly lead to the risk of ingress of sea water splashes or rain water into the fuel oil tanks.

9.3.5(c) Protection for lubricating oil tanks. Vents for lubricating oil tanks directly serving propulsion and generator engines, where terminated on the weather deck are to be so located and arranged that in the event of a broken vent pipe, this will not directly lead to the risk of ingress of sea water splashes or rain water.

9.3.6 Oil Pollution Prevention

Vents from fuel oil and other oil tanks, which, in the event of an inadvertent overflow, may result in oil pollution of the marine environment, are to be fitted with overflow arrangements (see 4-6-4/9.5.5) or means of containment, such as a coaming, in way of vent outlets.

9.3.7 Vent Outlet Closing Devices *(2003)*

9.3.7(a) General. Where vent outlets are required by 4-6-4/9.3.5(a) to be fitted with automatic closing devices, they are to comply with the following:

9.3.7(b) Design.

i) Vent outlet automatic closing devices are to be so designed that they will withstand both ambient and working conditions, and be suitable for use at inclinations up to and including ±40°.

ii) Vent outlet automatic closing devices are to be constructed to allow inspection of the closure and the inside of the casing, as well as changing the seals.

iii) *(2005)* Efficient ball or float seating arrangements are to be provided for the closures. Bars, cage or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state and made in such a way that the ball or float is not damaged when subjected to water impact due to a tank being overfilled.

iv) Vent outlet automatic closing devices are to be self-draining.

v) The clear area through a vent outlet closing device in the open position is to be at least equal to the area of the inlet.

vi) An automatic closing device is to:

- Prevent the free entry of water into the tanks,
- Allow the passage of air or liquid to prevent excessive pressure or vacuum developing in the tank.

vii) In the case of vent outlet closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim.

viii) The maximum allowable tolerances for wall thickness of floats should not exceed ±10% of thickness.

ix) *(2005)* The inner and outer chambers of an automatic air pipe head is to be of a minimum thickness of 6 mm (0.24 inch).

9.3.7(c) Materials

i) Casings of vent outlet closing devices are to be of approved metallic materials adequately protected against corrosion.

ii) *(2005)* For galvanized steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 micrometers (2.756 to 3.937 mil).

iii) *(2005)* For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more to either side) an additional harder coating should be applied. This is to be an aluminum bearing epoxy, or other equivalent coating, applied over the zinc.

iv) Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and to seawater, and suitable for operating at ambient temperatures between -25°C and 85°C (-13°F and 185°F).

9.3.7(d) Type Testing

i) *Testing of Vent Outlet Automatic Closing Devices.* Each type and size of vent outlet automatic closing device is to be surveyed and type tested at the manufacturer's works or other acceptable location.

The minimum test requirements for a vent outlet automatic closing device are to include the determination of the flow characteristics of the vent outlet closing device, the measurement of the pressure drop versus the rate of volume flow using water and with any intended flame or insect screens in place and also tightness tests during immersion/ emerging in water, whereby the automatic closing device is to be subjected to a series of tightness tests involving not less than two (2) immersion cycles under each of the following conditions:

- The automatic closing device is to be submerged slightly below the water surface at a velocity of approximately 4 m/min (13.12 ft/min) and then returned to the original position immediately. The quantity of leakage is to be recorded.
- The automatic closing device is to be submerged to a point slightly below the surface of the water. The submerging velocity is to be approximately 8 m/min and the air pipe vent head is to remain submerged for not less than 5 minutes. The quantity of leakage is to be recorded.
- Each of the above tightness tests are to be carried out in the normal position as well as at an inclination of 40 degrees.

The maximum allowable leakage per cycle is not to exceed 2 ml/mm (1.312×10^{-2} gal/inch) of nominal diameter of inlet pipe during any individual test.

ii) *Testing of Nonmetallic Floats.* Impact and compression loading tests are to be carried out on the floats before and after pre-conditioning as follows:

Test temperature °C (°F):	*-25°C (-13°F)*	*20°C (68°F)*	*85°C (185°F)*
Test conditions			
Dry	Yes	Yes	Yes
After immersing in water	Yes	Yes	Yes
After immersing in fuel oil	NA	Yes	NA

Immersing in water and fuel oil is to be for at least 48 hours.

Impact Test. The test may be conducted on a pendulum type testing machine. The floats are to be subjected to 5 impacts of 2.5 N-m (1.844 lbf-ft) each and are not to suffer permanent deformation, cracking or surface deterioration at this impact loading.

Subsequently, the floats are to be subjected to 5 impacts of 25 N-m (18.44 lbf-ft) each. At this impact energy level some localized surface damage at the impact point may occur. No permanent deformation or cracking of the floats is to appear.

Compression Loading Test. Compression tests are to be conducted with the floats mounted on a supporting ring of a diameter and bearing area corresponding to those of the float seating with which it is intended that the float shall be used. For a ball type float, loads are to be applied through a concave cap of the same internal radius as the test float and bearing on an area of the same diameter as the seating. For a disc type float, loads are to be applied through a disc of equal diameter as the float.

A load of 3430 N (350 kgf, 770 lbf) is to be applied over one minute and maintained for 60 minutes. The deflection is to be measured at intervals of 10 minutes after attachment of the full load.

The record of deflection against time is to show no continuing increase in deflection and, after release of the load, there is to be no permanent deflection.

iii) *Testing of Metallic Floats.* The above described impact tests are to be carried out at room temperature and in the dry condition.

9.5 Tank Overflows

9.5.1 General Requirements

Generally, all tanks capable of being filled by a pumping system, as indicated in 4-6-4/9.1.2, are to be provided with a means of overflow. This may be achieved by overflowing through dedicated overflow pipes or through the tank vents, provided the size of the vents meet 4-6-4/9.3.3(b). Overflows are to discharge outboard, i.e., on the weather deck or overboard, or into designated overflow tanks. Overflow lines are to be self-draining.

9.5.2 Overflow Pipe Size

In general, the aggregate area of the overflow pipes is not to be less than 125% of the effective area of the filling line. Where high capacity or high head pumps are used, calculations demonstrating the adequacy of the overflow as well as the vent to prevent over- or underpressurization of the ballast tanks are to be submitted. See also 4-6-4/9.3.3(b). Where overflows complying with this requirement are fitted, tank vents need only meet the minimum size complying with 4-6-4/9.3.3(a). Where, however, tank vents complying with 4-6-4/9.3.3(b) are fitted, separate overflows will not be required.

9.5.3 Overflows Discharging Overboard

In general, overflow pipes discharging through the vessel’s sides are to be led above the freeboard deck and are to be fitted with a non-return valve (not to be of cast iron, see 4-6-2/9.13.2) at the shell.

Where the overflow discharging overboard cannot be led above the freeboard deck, the opening at the shell is to be protected against sea water ingress in accordance with the same provisions as that for overboard gravity drain from watertight spaces described in 4-6-4/3.3. In this connection, the vertical distance of the ‘inboard end’ from the summer load water line may be taken as the height from the summer load water line to the level that the sea water has to rise to find its way inboard through the overboard pipe.

Where, in accordance with the provisions of 4-6-4/3.3, a non-return valve with a positive means of closing is required, means is to be provided to prevent unauthorized operation of this valve. This may be a notice posted at the valve operator warning that it may be shut by authorized personnel only.

9.5.4 Overflow Common Header

Where overflows from tanks in more than one watertight subdivision are connected to a common header below the freeboard or bulkhead deck, the arrangement is to be such as to prevent fore-and-aft flooding from one watertight subdivision to another in the event of damage.

9.5.5 Fuel Oil Tank Overflows

Fuel oil tanks are not to be fitted with overflows discharging overboard. Fuel oil tank overflows are to be led to an overflow tank or to a storage tank with sufficient excess capacity (normally 10 minutes at transfer pump capacity) to accommodate the overflow. The overflow tank is to be provided with a high level alarm, see 4-6-4/13.5.4.

9.5.6 Overflow Pipe Wall Thickness

In general, overflow pipes exposed to the weather are to have wall thicknesses not less than standard thickness, see 4-6-4/9.3.2(a). Overflow pipes not exposed to the weather are to meet the thickness requirements of vents in 4-6-4/9.3.2(b). However, that portion of the overflow pipe subject to the provisions of 4-6-4/3.3, as indicated in 4-6-4/9.5.3, are to be in accordance with the pipe wall thicknesses in 4-6-4/3.3.

11 Means of Sounding

11.1 General

11.1.1 Application

These requirements apply to the provision of a means of sounding for liquid and void tanks and for normally dry but not easily accessible compartments. The requirements in this subsection, however, do not apply to sounding arrangements of liquid cargoes, such as crude oil, liquefied gases, chemicals, etc., for which specific requirements of provided in Part 5C.

The means of sounding covered in this subsection include sounding pipes and gauge glasses. For level-indicating devices fitted to tanks containing flammable liquid, such as fuel oil, see 4-6-4/13.5.6(b). Remote tank level indicating systems are to be submitted for consideration in each case.

11.1.2 Basic Requirements

All tanks, cofferdams, void spaces and all normally dry compartments, such as cargo holds, which are not easily accessible, and which have the possibility of water accumulation (e.g., adjacent to sea, pipe passing through), are to be provided with a means of the sounding level of liquid present. In general, this means is to be a sounding pipe. A gauge glass, level indicating device, remote-gauging system, etc. may also be accepted as a means of sounding.

11.3 Sounding Pipes

11.3.1 General Installation Requirements

Sounding pipes are to be led as straight as possible from the lowest part of tanks or spaces and are to be terminated in positions which are always accessible under all operational conditions of the vessel. Sounding pipes installed in compartments, such as the cargo holds, where they may be exposed to mechanical damage, are to be adequately protected.

11.3.2 Sounding Pipe Size

The internal diameter of the sounding pipe is not to be less than 32 mm (1.26 in.).

11.3.3 Sounding Pipe Wall Thickness

Steel sounding pipes are to have wall thickness not less than that given in the appropriate column (A, C or D) of 4-6-2/Table 4 and in accordance with their locations of installation as follows:

i) Within the tank to which the sounding pipe serves: column A.

ii) Exposed to weather and outside the tank to which the sounding pipe serves: column C.

iii) Passing through fuel oil or ballast tanks and outside the tank to which the sounding pipe serves: column D.

iv) Passing through the bilge well and outside the tank to which the sounding pipe serves: extra heavy thickness (see 4-6-1/3.9).

11.3.4 Materials of Sounding Pipes

The material of sounding pipes for tanks containing flammable liquids is to be steel or equivalent. Plastic pipes may be used in such tanks and all other tanks subject to compliance with the following:

- The plastic pipe is confined to within the tank which the sounding pipe serves.
- The penetration of the tank boundary is of steel.
- The plastic pipes used are in compliance with Section 4-6-3.

11.3.5 Protection of Tank Bottom Plating

Provision is to be made to protect the tank bottom plating from repeated striking by the sounding device. Such provision may be a doubler plate fitted at the tank bottom in way of the sounding pipe, or equivalent.

11.3.6 Deck of Termination and Closing Device

Sounding pipes are to be terminated on decks on which they are always accessible under normal operating conditions so as to enable sounding of the tanks. In general, the exposed end of each sounding pipe is to be provided with a watertight closing device, permanently attached, such as a screw cap attached to the pipe with a chain.

Sounding pipes of double bottom tanks and tanks whose boundaries extend to the shell at or below the deepest load water line are, in addition, to terminate on or above the freeboard deck. This is so that in the event of a shell damage in way of the tank, the opening of the sounding pipe will not cause inadvertent flooding of internal spaces. Termination below the freeboard deck is permitted, however, if the closing device fitted at the open end is a gate valve, or screw cap. For oil tanks, the closing device is to be of the quick acting valve, see also 4-6-4/11.3.7.

11.3.7 Sounding Pipes of Fuel Oil and Lubricating Oil Tanks

Sounding pipes from fuel oil tanks are not to terminate in any spaces where a risk of ignition of spillage exists. In particular, they are not to terminate in passenger or crew spaces, in machinery spaces or in close proximity to internal combustion engines, generators, major electric equipment or surfaces with temperature in excess of 220°C (428°F). Where this is not practicable, the following are to be complied with.

11.3.7(a) Fuel oil tanks. Sounding pipes from fuel oil tanks may terminate in machinery spaces provided that the following are met:

i) The sounding pipes are to terminate in locations remote from the ignition hazards, or effective precautions, such as shielding, are taken to prevent fuel oil spillage from coming into contact with a source of ignition.

ii) The termination of sounding pipes is fitted with a quick-acting self-closing valve and with a small diameter self-closing test cock or equivalent located below the self-closing valve for the purpose of ascertaining that fuel oil is not present before the valve is opened. Provisions are to be made to prevent spillage of fuel oil through the test cock from creating an ignition hazard.

iii) *(2005)* A fuel oil level gauge complying with 4-6-4/13.5.6(b) is fitted. However, short sounding pipes may be used for tanks other than double bottom tanks without the additional closed level gauge, provided an overflow system is fitted. See 4-6-4/13.5.4.

11.3.7(b) Lubricating oil tanks. Sounding pipes from lubricating oil tanks may terminate in machinery spaces provided that the following are met:

i) The sounding pipes are to terminate in locations remote from the ignition hazards, or effective precautions, such as shielding, are taken to prevent oil spillage from coming into contact with a source of ignition.

ii) *(2005)* The termination of sounding pipes is fitted with a quick-acting self-closing gate valve. Alternatively, for lubricating oil tanks that cannot be filled by a pump, the sounding pipes may be fitted with an appropriate means of closure, such as a shut-off valve or a screw cap attached by chain to the pipe.

11.5 Gauge Glasses

11.5.1 Flat Glass Type

Where gauge glasses are installed as means of level indication, flat glass type gauge glasses are required for the following tanks:

- Tanks whose boundaries extend to the vessel's shell at or below the deepest load waterline.
- Tanks containing flammable liquid (except as indicated in 4-6-4/11.5.2 for hydraulic oil and for small tanks).

Flat glass type gauge glasses are to be fitted with a self-closing valve at each end and are to be adequately protected from mechanical damage.

11.5.2 Tubular Glass Type

11.5.2(a) General. Tubular glass gauge glasses may be fitted to tanks other than those mentioned in 4-6-4/11.5.1. A self-closing valve is to be fitted at each end of the gauge glass.

11.5.2(b) Hydraulic oil tanks. Tubular glass gauge glasses with a self-closing valve at each end may be fitted to hydraulic oil tanks provided:

- The tanks are located outside machinery spaces of category A,
- The space does not contain ignition sources such as diesel engines, major electrical equipment, hot surfaces having a temperature of 220°C (428°F) or more, and
- The tank boundaries do not extend to the shell at or below the deepest load water line.

11.5.2(c) Small tanks. Small tanks, including those containing hydraulic oil or lubricating oil located in a machinery space of category A, may be fitted with tubular glass gauge glasses without a valve at the upper end, subject to the following:

- The tank capacity does not exceed 100 liters (26.5 gallons).
- A self-closing valve is fitted at the lower end.
- The upper connection is as close to the tank top as possible and is to be above the maximum liquid level in the tank.
- The gauge glass is so located or protected that any leakage therefrom will be contained.

11.5.2(d) Fresh water tanks. Structural tanks whose boundaries do not extend to the vessel's shell, and independent tanks for fresh water may all be fitted with tubular gauge glasses with a valve at each end or a valve at the bottom end of the glass.

11.7 Level Indicating Device *(2005)*

Where a level-indicating device is provided for determining the level in a tank containing flammable liquid, the failure of the device is not to result in the release of the contents of the tank through the device. Level switches, which penetrate below the tank top, may be used, provided they are contained in a steel enclosure or other enclosures not being capable of being destroyed by fire.

11.9 Remote Level Indicating Systems

Where fitted, plans showing the arrangements and details of the system, along with particulars of the sensing and transmitting devices, are to be submitted for review in each case.

13 Fuel Oil Storage and Transfer Systems

13.1 General

13.1.1 Application

The provisions of 4-6-4/13 apply to fuel oil storage, transfer and processing systems, in general. They are to be applied, as appropriate, together with fuel oil system requirements specific to each type of propulsion or auxiliary plant provided in 4-6-5/3 (for internal combustion engines) and 4-6-6/7 (for boilers).

13.1.2 Fuel Oil Flash Point

The provisions of this subsection apply to fuel oils having a flash point (closed cup test) above 60°C (140°F).

Fuel oil with a flash point of 60°C or below, but not less than 43°C (110°F), may only be used for vessels classed for services in specified geographical areas. The climatic conditions of such areas are to preclude the ambient temperature of spaces where such fuel oil is stored from rising to within 10°C (18°F) below its flash point.

Not withstanding this restriction, prime movers of emergency generators may use fuel oil with a flash point of not less than 43°C.

13.1.3 Basic Requirement

The intent of the requirements of 4-6-4/13 for fuel oil systems is to minimize the possibility of fire due to fuel oil primarily by identifying and separating likely fuel leakages from ignition sources, collection and drainage of fuel leakages and proper design of fuel containment systems.

13.3 Installation Requirements

13.3.1 Access, Ventilation and Maintenance

All spaces where fuel oil installations, settling tanks or service tanks are located are to be easily accessible. Such spaces are to be sufficiently ventilated to prevent accumulation of oil vapor. As far as practicable, materials of either combustible or oil-absorbing properties are not to be used in such spaces.

13.3.2 Hot Surfaces

To prevent the ignition of fuel oil, all hot surfaces, e.g., steam and exhaust piping, turbochargers, exhaust gas boilers, etc. likely to reach a temperature above 220°C (428°F) during service are to be insulated with non-combustible, and preferably non-oil-absorbent, materials. Such insulation materials, if not impervious to oil, are to be encased in oil-tight steel sheathing or equivalent. The insulation assembly is to be well installed and supported having regard to its possible deterioration due to vibration.

13.3.3 Arrangement of Fuel Oil Equipment and Piping *(2005)*

As far as practicable, fuel oil tanks, pipes, filters, heaters, etc. are to be located far from sources of ignition, such as hot surfaces and electrical equipment. In particular, they are not to be located immediately above nor near such ignition sources. The number of pipe joints is to be kept to a minimum. Spray shields are to be fitted around flanged joints, flanged bonnets and any other flanged or threaded connections in fuel oil piping systems under pressure exceeding 1.8 bar (1.84 kgf/cm^2, 26 psi) which are located above or near units of high temperature, including boilers, steam pipes, exhaust manifolds, silencers or other equipment required to be insulated in accordance with 4-6-4/13.3.2, and also to avoid oil spray or oil leakage into machinery air intakes or other sources of ignition.

13.3.4 Leakage Containment and Drainage System

13.3.4(a) Leakage containment. Fuel oil system components, such as pumps, strainers, purifiers, etc., and fuel oil heaters, which require occasional dismantling for examination, and where leakage may normally be expected, are to have drip pans fitted underneath to contain the leakage.

In way of valves fitted near the bottom of fuel oil tanks located above the double bottom and in way of other tank fittings, where leakage may be expected, drip pans are also to be provided.

Freestanding fuel oil tanks are to be provided with oil tight spill trays, as required in 4-6-4/13.5.2.

13.3.4(b) Drainage (2005). Drip pans, spill trays and other leakage containment facilities are to be provided with a means of drainage. Where they are led to a drain tank, protection against back flows and venting through the drain lines is to be provided as follows:

i) The drain tank is not to form part of the fuel oil overflow system.

ii) The drain tank is to be fitted with a high level alarm for propulsion machinery spaces intended for centralized operation (**ACC** notation) or unattended operation (**ACCU** notation). See 4-9-3/15.1.2 and 4-9-4/17.

iii) Where drain lines entering the tank are not fitted with non-return valves, they are to be led to the bottom of the tank to minimize venting of the tank through the drain lines. This is not applicable to fuel oil drain tanks with a volume less than 2 m^3 (70.6 ft^3) and which cannot be filled up by a pump. Regarding termination of air vents, see 4-6-4/9.3.4(a).

iv) Where the drain tank is a double bottom tank, all drain lines entering the tank are to be fitted with non-return valves at the tank so as to protect the engine room from flooding in case of bottom damage to the tank.

v) The drain tank is to be fitted with a pumping arrangement to enable transfer of its content to the shore facility or to other waste oil tanks

13.3.5 Valve Operation

Valves related to fuel oil systems are to be installed in readily operable and accessible positions.

13.5 Fuel Oil Tanks

13.5.1 Arrangements of Structural Tanks

13.5.1(a) Machinery space of category A. As far as practicable, fuel oil tanks are to be part of the vessel's structure and located away from the machinery spaces of category A. However, where it is found necessary to locate the fuel oil tanks adjacent to or inside the machinery spaces of category A, the arrangements are to reduce the area of the tank boundary common with the machinery space of category A to a minimum, and to comply with the following:

i) Fuel tanks having boundaries common with machinery spaces of category A are not to contain fuel oils having flash point of 60°C (140°F) or less.

ii) At least one of their vertical sides is to be contiguous to the machinery space boundary.

iii) *(2002)* The bottom of the fuel oil tank is not to be so exposed that it will be in direct contact with flame should there be a fire in a Category A machinery space. The fuel tank is to extend to the double bottom. Alternatively, the bottom of the fuel oil tank is to be fitted with a cofferdam. The cofferdam is to be fitted with suitable drainage arrangements to prevent accumulation of oil in the event of oil leakage from the tank.

iv) Fuel oil tanks are to be located such that no spillage or leakage therefrom can constitute a hazard by falling on heated surfaces or electrical equipment. If this is not practicable, the latter are to be protected from such spillage or leakage by shields, coamings or trays as appropriate.

13.5.1(b) Drainage of water. Means are to be provided for draining water from the bottom of the settling tanks. Where there are no settling tanks installed similar arrangements for draining the water is to be fitted to the fuel oil storage or the daily service tank.

Where the drainage of water from these tanks is through open drains, valves or cocks of a self-closing type, arrangements such as gutterways or other similar means are to be provided for collecting the drains. Means are to be provided to collect the oily discharge.

13.5.1(c) Location. Tanks forward of the collision bulkhead are not to be arranged for the carriage of fuel oil. See also 3-2-10/1.3.

13.5.1(d) Service tanks (2004). At least two fuel oil service tanks for each type of fuel used onboard necessary for propulsion and vital systems, or equivalent arrangements, are to be provided. Each service tank is to have a capacity of at least eight (8) hours at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

A service tank is a fuel tank which contains only fuel of a quality ready for use, that is, fuel of a grade and quality that meets the specification required by the equipment manufacturer. A service tank is to be declared as such and is not to be used for any other purpose.

Use of a settling tank with or without purifiers or use of purifiers alone is not acceptable as an equivalent arrangement to providing a service tank. 4-6-4/Table 2 shows examples of acceptable arrangements.

TABLE 2
Alternative Arrangements for Fuel Oil Service Tanks

<table>
<tr><th></th><th>Consumption</th><th>Number of Service Tanks Required</th><th>Acceptable Alternative Service Tanks</th><th>Comments</th></tr>
<tr><td>Mono-fuel vessels (HFO)</td><td>HFO: PE+GE+AB</td><td>2×8 hr HFO</td><td>1×8 hr HFO (PE+GE+AB), and
1×8 hr MDO (PE+GE+AB)</td><td>Duplication of tank for MDO for initial cold start of engines/boilers is not required. However, if AB is fitted with pilot burner, another 8 hr MDO tank for this purpose is required.
AB need not be accounted if exhaust gas boiler is normally used for heating HFO.</td></tr>
<tr><td rowspan="2">Dual-fuel vessels (HFO + MDO) (1)</td><td>HFO: PE+AB</td><td>2×8 hr HFO</td><td rowspan="2">1×8 hr HFO (PE +AB) and the greater of:
2×4 hr MDO (PE + GE+AB); or
2×8 hr MDO (GE +AB)</td><td rowspan="2"></td></tr>
<tr><td>MDO: GE</td><td>2×8 hr MDO</td></tr>
</table>

Legend: PE = propulsion engine(s) GE = generator engine(s) HFO = heavy fuel oil
AB = auxiliary boiler(s) MDO = marine diesel oil

Note:

1 This arrangement applies, provided the propulsion and essential systems support rapid fuel changeover and are capable of operating in all normal operating conditions at sea with both types of fuels (MDO and HFO).

13.5.2 Arrangements of Free-standing Tanks

The use of free standing fuel oil tanks in the machinery spaces of category A is to be avoided as far as possible, see the general intent in 4-6-4/13.5.1(a). Where this is unavoidable, free-standing fuel oil tanks in machinery spaces of category A are to be kept to a minimum and their installation is to be as follows:

- The fuel oil tanks are to be placed in an oil tight spill tray of ample size (e.g., large enough to cover leakage points such as manhole, drain valves, gauge glass, etc.) with a drainage facility to a suitable drain tank.
- The fuel oil tanks are not to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces. In particular they are not to be located over boilers.

13.5.3 Valves on Fuel Oil Tanks

13.5.3(a) Required valves (2003). Every fuel oil pipe emanating from any fuel oil tank, which, if damaged, would allow fuel oil to escape from the tank, is to be provided with a positive closing valve directly on the tank. The valve is not to be of cast iron, although the use of nodular cast iron is permissible, see 4-6-2/3.1.4. The positive closing valve is to be provided with means of closure both locally and from a readily accessible and safe position outside of the space. In the event that the capacity of the tank is less than 500 liters (132 US gallons), this remote means of closure may be omitted.

If the required valve is situated in a shaft tunnel or pipe tunnel or similar spaces, the arrangement for remote closing may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar spaces. If such an additional valve is fitted in a machinery space, it is to be provided with a means of closure both locally and from a readily accessible position outside of this space.

When considering two adjacent fuel oil tanks, the fuel oil suction pipe from the tank on the far side may pass through the adjacent tank, and the required positive closing valve may be located at the boundary of the adjacent tank. In such instances, the thickness of the fuel oil suction pipe passing through the adjacent fuel oil tank is to be in accordance with Column C in 4-6-2/Table 4 and of all welded construction.

13.5.3(b) Remote means of closure. The remote closure of the valves may be by reach rods or by electric, hydraulic or pneumatic means. The source of power to operate these valves is to be from outside of the space in which these valves are situated. For a pneumatically operated system, the air supply may be from a source located within the same space as the valves provided that an air receiver complying with the following is located outside the space:

- Sufficient capacity to close all connected valves twice.
- Fitted with low air pressure alarm.
- Fitted with a non-return valve adjacent to the air receiver in the air supply line.

This remote means of closure is to override all other means of valve control. The use of an electric, hydraulic or pneumatic system to keep the valve in the open position is not acceptable.

Materials readily rendered ineffective by heat are not to be used in the construction of the valves or the closure mechanism unless protected adequately to ensure effective closure facility in the event of fire. Electric cables, where used, are to be fire-resistant, meeting the requirements of IEC Publication 60331.

The controls for the remote means of closure of the valves of the emergency generator fuel tank and the emergency fire pump fuel tank, as applicable, are to be grouped separately from those for other fuel oil tanks.

13.5.4 Filling and Overflow

In general, filling lines are to enter at or near the top of the tank; but if this is impracticable, they are to be fitted with a non-return valve at the tank. Alternatively, the filling line is to be fitted with a remotely operable valve as required by 4-6-4/13.5.3(a). Overflows from fuel oil tanks are to be led to an overflow tank with sufficient volume to accommodate the overflows (normally 10-minutes at transfer pump capacity). A high level alarm is to be provided for the overflow tank. Overflow lines are to be self-draining.

13.5.5 Vents

Vents are to be fitted to fuel oil tanks and are to meet the requirements of 4-6-4/9.

13.5.6 Level Measurement

13.5.6(a) Sounding pipes. Sounding pipes are to meet the general requirements of 4-6-4/11.

13.5.6(b) Level gauges. Level gauges may be fitted in lieu of sounding pipes, provided that the failure of, or the damage to, the level gauge will not result in the release of fuel oil. Where the gauge is located such that it is subjected to a head of oil, a valve is to be fitted to allow for its removal, see 4-6-2/9.11.3. The level gauge is to be capable of withstanding the hydrostatic pressure at the location of installation, including that due to overfilling. For passenger vessels, no level gauge is to be installed below the top of the tank.

13.5.6(c) Gauge glasses. Gauge glasses complying with the intent of 4-6-4/13.5.6(b) may be fitted in lieu of sounding pipes, provided they are of flat glass type with a self-closing valve at each end and are adequately protected from mechanical damage. See also 4-6-4/11.5.1.

13.5.6(d) Level switches. Where fitted, they are to be encased in steel, or equivalent, such that no release of fuel oil is possible in the event of their damage due to fire. Where the device is located, such that it is subjected to a head of oil, a valve is to be fitted to allow for its removal, see 4-6-2/9.11.3.

13.5.6(e) High level alarm. To prevent spillage, an alarm is to be fitted to warn of the level reaching a predetermined high level. For tanks fitted with overflow arrangements, the high level alarm may be omitted, provided a flow sight glass is fitted in the overflow pipes. Such flow sight glass is to be fitted only on the vertical section of overflow pipe and in readily visible position.

13.5.6(f) Additional level alarms. For propulsion machinery spaces intended for centralized or unattended operation (**ACC** or **ACCU** notation), low level conditions of fuel oil settling and service tanks are to be alarmed at the centralized control station. Where tanks are automatically filled, high level alarms are also to be provided. For **ACCU** notation, these tanks are to be sized for at least 24-hour operation without refilling, except that for automatically filled tanks, 8-hour operation will suffice.

13.5.7 Heating Arrangements in Tanks *(2003)*

13.5.7(a) Flash point (2001). Fuel oil in storage tanks is not to be heated within 10°C (18°F) below its flash point. Where fuel oil in service tanks, settling tanks and any other tanks in the supply system is heated, the arrangements are to comply with the following:

i) The length of the vent pipes from the tanks and/or cooling device is to be sufficient for cooling the vapors to below 60°C, or the outlet of the vent pipes is located at least 3 m (10 ft) away from a source of ignition.

ii) There are no openings from the vapor space of the fuel tanks leading into machinery spaces, except for bolted manholes.

iii) Enclosed spaces, such as workshops, accommodation spaces, etc., are not to be located directly over the fuel tanks, except for vented cofferdams.

iv) Electrical equipment is not to be fitted in the vapor space of the tanks, unless it is certified to be intrinsically safe.

13.5.7(b) Fuel oil temperature control. All heated fuel oil tanks located within machinery spaces are to be fitted with a temperature indicator. Means of temperature control are to be provided to prevent overheating of fuel oil, in accordance with 4-6-4/13.5.7(a).

13.5.7(c) Temperature of heating media. Where heating is by means of a fluid heating medium (steam, thermal oil, etc.), a high temperature alarm is to be fitted to warn of any high medium temperature. This alarm may be omitted if the maximum temperature of the heating medium can, in no case, exceed 220°C (428°F).

13.5.7(d) Steam heating. To guard against possible contamination of boiler feed water, where fuel oil tanks are heated by steam heating coils, steam condensate returns are to be led to an observation tank, or other approved means, to enable detection of oil leaking into the steam system.

13.5.7(e) Electric heating. Where electric heating is installed, the heating elements are to be arranged to be submerged at all times during operation, and are to be fitted with an automatic means of preventing the surface temperature of the heating element from exceeding 220°C (428°F). This automatic feature is to be independent of the fuel oil temperature control and is to be provided with manual reset.

13.5.7(f) ***ACC*** *or* ***ACCU*** *notation.* For vessels whose propulsion machinery spaces are intended for centralized or unattended operation (**ACC** or **ACCU** notation), see 4-9-3/15.1.3.

13.7 Fuel Oil System Components *(2003)*

13.7.1 Pipes and Fittings

13.7.1(a) Pipes. Pipes are to meet the general requirements of certification in 4-6-1/7.1; materials in 4-6-2/3; and design in 4-6-2/5.1, subject to the following:

i) Pipes passing through fuel oil tanks are to be of steel except that other materials may be considered where it is demonstrated that the material is suitable for the intended service.

ii) Limited use of plastic pipes will be permitted, subject to compliance with the requirements of Section 4-6-3.

iii) *(2003)* For pipes, the design pressure is to be taken in accordance with 4-6-4/Table 3.

TABLE 3
Design Pressure for Fuel Oil Pipes *(2003)*

*Maximum Allowable Working Pressure (P)**	*Maximum Working Temperature (T)*	
	T ≤ 60°C (140°F)	*T > 60°C (140°F)*
P ≤ 7 bar (7.15 kgf/cm^2, 101.5 psi)	3 bar (3.1 kgf/cm^2, 43 psi) or *P**, whichever is greater	3 bar (3.1 kgf/cm^2, 43 psi) or *P**, whichever is greater
P > 7 bar (7.15 kgf/cm^2, 101.5 psi)	*P**	14 bar (14.3 kgf/cm^2, 203 psi) or *P**, whichever is greater

* *P* = maximum allowable working pressure of the system, as defined in 4-6-1/3.19, in bar (kgf/cm^2, psi)

13.7.1(b) Pipe fittings and joints (2003). Pipe fittings and joints are to meet the general requirements of certification in 4-6-1/7.1; materials in 4-6-2/3; and design in 4-6-2/5.5 and 4-6-2/5.15 subject to limitations in 4-6-4/Table 4. Fittings and joints in piping systems are also to be compatible with the pipes to which they are attached in respect of their strength (see 4-6-4/13.7.1(a)iii) for design pressure) and are to be suitable for effective operation at the maximum allowable working pressure they will experience in service. For flanges, their pressure-temperature rating is subject to the limitations in 4-6-2/5.5.4.

13.7.1(c) Hoses. Hoses, where installed, are to comply with 4-6-2/5.7. Hose clamps are not permitted.

TABLE 4
Pipe Joint Limitations for Fuel Oil Piping *(2006)*

Types of joint	*Class I*	*Class II*	*Class III*
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint (1)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint (2)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint	Types A & B only.	Types A, B & C only.	Types A, B & C only.
Taper-thread joint	≤ 80 mm (3 in.) Permissible pressure/size: see 4-6-2/5.5.5(a)	≤ 80 mm (3 in.) Permissible pressure/size: see 4-6-2/5.5.5(a)	No limitation.
Compression couplings (3)	≤ 60 mm (2.4 in.) OD.	≤ 60 mm (2.4 in.) OD.	No size limitation.
Molded non-metallic expansion joint	Not permitted	Not permitted	Not permitted
Molded expansion joint of composite construction	Subject to compliance with 4-6-2/5.8.1(b)	Subject to compliance with 4-6-2/5.8.1(b)	Subject to compliance with 4-6-2/5.8.1(b)
Metallic bellow type expansion joint	No limitation	No limitation	No limitation
Slip-on joints	See Note 3	See Note 3	See Note 3
Hoses	Subject to fire resistance test: 4-6-2/5.7.3(c).	Subject to fire resistance test: 4-6-2/5.7.3(c).	Subject to fire resistance test: 4-6-2/5.7.3(c).

Notes:

1 See 4-6-2/5.5.2 for further operational limitations.

2 See 4-6-2/5.5.3 for further operational limitations.

3 See 4-6-2/5.9 for further limitations.

Pipe sizes are nominal bore, except where indicated otherwise.

13.7.2 Valves *(2003)*

Valves are to meet the general requirements of certification in 4-6-1/7.1; materials in 4-6-2/3; and design in 4-6-2/5.11 and 4-6-2/5.13. Cast iron valves are not to be used as shut-off valves for fuel oil tanks, as indicated in 4-6-4/13.5.3(a).

Valves in piping systems are also to be compatible with the pipes to which they are attached in respect to their strength, (see 4-6-4/13.7.1(a)iii) for design pressure) and are to be suitable for effective operation at the maximum allowable working pressure they will experience in service. Their pressure rating is subject to the limitations in 4-6-2/5.11.2.

13.7.3 Pumps

Fuel oil pumps are to be fitted with stop valves at the suction and discharge sides. A relief valve is to be fitted on the discharge side, unless the pump is of the centrifugal type having a shut-off head no greater than the design pressure of the piping system. Where fitted, the relief valve is to discharge to the suction side of the pump or into the tank.

Fuel oil pumps requiring certification are specified in 4-6-1/7.3. See also 4-6-5/3 and 4-6-6/7.

13.7.4 Heaters

13.7.4(a) Heater housing. All fuel oil heaters having any of the following design parameters are to be certified by the Bureau (for pressure vessels, see Section 4-4-1):

- Design pressure > 6.9 bar (7 kgf/cm^2, 100 psi) on either side;
- Design pressure > 1 bar (1 kgf/cm^2, 15 psi), internal volume > 0.14 m^3 (5 ft^3), and design temperature > 66°C (150°F) on the oil side or > 149°C (300°F) on the heating medium side;
- All fired heaters with design pressure > 1 bar (1 kgf/cm^2, 15 psi).

Electric oil heaters not required to be certified by the above are to have their housing design submitted for review.

13.7.4(b) Fuel oil temperature control (2003). All heaters are to be fitted with a fuel oil temperature indicator and a means of temperature control.

13.7.4(c) Heating media and electric heating (2003). The provisions of 4-6-4/13.5.7(c), (d) and (e) are also applicable to fuel oil heaters.

13.7.4(d) Relief valves (2006). Relief valves are to be fitted on the fuel oil side of the heaters. The discharge from the relief valve is to be arranged to discharge back to the storage tank or other suitable tank of adequate capacity.

13.7.4(e) ***ACC*** *or* ***ACCU*** *notation (2003).* For vessels whose propulsion machinery spaces are intended for centralized or unattended operation (**ACC** or **ACCU** notation), see 4-9-3/15.1.3.

13.7.5 Filters and Strainers

Filters and strainers are to be designed to withstand the maximum working pressure of the system in which they are installed.

Where filters and strainers are fitted in parallel to enable cleaning without disrupting the oil supply, means are to be provided to minimize the possibility of a filter or strainer being opened inadvertently.

Where they are required to be opened for cleaning during operation, they are to be fitted with means of depressurizing before being opened and venting before being put into operation. For this purpose, valves and cocks for drainage and venting are to be provided. Drain pipes and vent pipes are to be led to a safe location. For leakage containment and drainage, see 4-6-4/13.3.4.

13.7.6 Sight Flow Glasses

A sight flow glass may be fitted only in the vertical sections of fuel oil overflow pipes, and provided that it is in a readily visible position.

13.9 Fuel Oil Transfer, Filling and Purification Systems

13.9.1 Fuel Oil Transfer Pumps

There are to be at least two fuel oil transfer pumps. At least one of the pumps is to be independent of the main engine. Fuel oil transfer pumps are to be fitted with remote means of controls situated outside the space in which they are located so that they may be stopped in the event of fire in that space.

For filling and overflow, see 4-6-4/13.5.4. For automatic filling in propulsion machinery spaces intended for centralized or unattended operation (**ACC** or **ACCU** notation), see 4-6-4/13.5.6(f).

13.9.2 Segregation of Purifiers for Heated Fuel Oil *(1 July 2002)*

Fuel oil purifiers for heated oil are to be placed in a separate room or rooms, enclosed by steel bulkheads extending from deck to deck and provided with self-closing doors. In addition, the room is to be provided with the following:

i) Independent mechanical ventilation or ventilation arrangement that can be isolated from the machinery space ventilation, of the suction type.

ii) Fire detection system.

iii) Fixed fire-extinguishing system capable of activation from outside the room. The extinguishing system is to be dedicated to the room but may be a part of the fixed fire extinguishing system for the machinery space.

However, for the protection of purifiers on cargo vessels of 2000 gross tonnage and above located within a machinery space of category A above 500 m^3 (17,657 ft^3) in volume, the above referenced fixed dedicated system is to be a fixed water-based or equivalent, local application fire-extinguishing system complying with the provisions of 4-7-2/1.11.2. The system is to be capable of activation from outside the purifier room. In addition, protection is to be provided by the fixed fire-extinguishing system covering the Category A machinery space in which the purifier room is located, see 4-7-2/1.1.1.

iv) Means of closing ventilation openings and stopping the ventilation fans, purifiers, purifier-feed pumps, etc. from a position close to where the fire extinguishing system is activated.

If it is impracticable to locate the fuel oil purifiers in a separate room, special consideration will be given with regard to location, containment of possible leakage, shielding and ventilation. In such cases, a local fixed water-based fire-extinguishing system complying with the provisions of 4-7-2/1.11.2 is to be provided. Where, due to the limited size of the category A machinery space (less than 500 m^3 (17,657 ft^3) in volume), a local fixed water-based fire-extinguishing system is not required to be provided, then an alternative type of local dedicated fixed fire-extinguishing system is to be provided for the protection of the purifiers. In either case, the local fire extinguishing system is to activate automatically or manually from the centralized control station or other suitable location. If automatic release is provided, additional manual release is also to be arranged.

13.11 Waste Oil Systems for Incinerators *(2005)*

The requirements for fuel oil storage, transfer and heating, as provided in 4-6-4/13, are applicable to waste oil service tanks and associated piping systems for incinerators.

15 Lubricating Oil Storage and Transfer Systems

15.1 General and Installation Requirements

15.1.1 Application

The provisions of 4-6-4/15 apply to storage and transfer and processing of lubricating oil. They are to be applied, as appropriate, together with requirements for lubricating oil systems specific to each type of propulsion or auxiliary machinery specified in 4-6-5/5 (for internal combustion engines) and 4-6-6/9 (for steam turbines). In addition, the requirements of 4-6-4/13.5.7(b) through (f) and 4-6-4/13.7.4 are applicable.

15.1.2 Basic Requirement

The requirements for the lubricating oil storage and transfer system are intended to minimize the fire risks of lubricating oil.

15.1.3 Dedicated Piping

The lubricating oil piping, including vent and overflow piping, is to be entirely separated from other piping systems.

15.1.4 Hot Surfaces

To prevent the ignition of lubricating oil, all hot surfaces, e.g., steam and exhaust piping, turbochargers, exhaust gas boilers, etc. likely to reach a temperature above 220°C (428°F) during service are to be insulated with non-combustible, and preferably non-oil-absorbent, materials. Such insulation materials, if not impervious to oil, are to be encased in oil-tight steel sheathing or equivalent. The insulation assembly is to be well installed and supported having regard to its possible deterioration due to vibration.

15.1.5 Arrangement of Lubricating Oil Equipment and Piping *(2005)*

As far as practicable, lubricating oil tanks, pipes, filters, heaters, etc. are to be located far from sources of ignition, such as hot surfaces and electrical equipment. In particular, they are not to be located immediately above nor near such ignition sources. The number of pipe joints is to be kept to a minimum. Spray shields are to be fitted around flanged joints, flanged bonnets and any other flanged or threaded connections in lubricating oil piping systems under pressure exceeding 1.8 bar (1.84 kgf/cm^2, 26 psi) which are located above or near units of high temperature, including boilers, steam pipes, exhaust manifolds, silencers or other equipment required to be insulated in accordance with 4-6-4/15.1.4, and also to avoid oil spray or oil leakage into machinery air intakes or other sources of ignition.

15.1.6 Leakage Containment

Lubricating oil system components, such as pumps, strainers, purifiers, etc., which require occasional dismantling for examination, and where leakage may normally be expected, are to be provided with leakage containment and drainage arrangements, as required in 4-6-4/13.3.4.

15.3 Lubricating Oil Tanks

15.3.1 Location

Tanks forward of the collision bulkhead are not to be arranged for the carriage of lubricating oil. See also 3-2-10/1.3. They are not to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces or electrical equipment.

15.3.2 Valves on Lubricating Oil Tanks

Normally opened valves on lubricating oil tanks are to comply with the same requirements as those for fuel oil tanks given in 4-6-4/13.5.3. To protect propulsion and essential auxiliary machinery not fitted with automatic shutdown upon loss of lubricating oil, the remote means of closing the lubricating oil tank valve may be omitted if its inadvertent activation from the remote location could result in damage to such machinery.

15.3.3 Vents

Vents are to meet the applicable requirements in 4-6-4/9. Lubricating oil tank vents may terminate within the machinery space provided that the open ends are situated to prevent the possibility of overflowing on electric equipment, engines or heated surfaces.

15.3.4 Level Measurement

15.3.4(a) Sounding pipes. Sounding pipes are to meet the applicable requirements in 4-6-4/11.

15.3.4(b) Level gauges. Level gauges may be fitted in lieu of sounding pipes, provided that the failure of, or the damage to, the level gauge will not result in the release of lubricating oil. Where the device is located such that it is subjected to a head of oil, a valve is to be fitted to allow for its removal, see 4-6-2/9.11.3. The level gauge is to be capable of withstanding the hydrostatic pressure at the location of installation, including that due to overfilling. For passenger vessels, no level gauge is to be installed below the top of the tank.

15.3.4(c) Gauge glasses. Gauge glasses complying with the intent of 4-6-4/15.3.4(b) may be fitted in lieu of sounding pipes, provided they are of flat glass type with a self-closing valve at each end and are adequately protected from mechanical damage.

15.3.4(d) Level switches. Where fitted, they are to be encased in steel, or equivalent, such that no release of lubricating oil is possible in the event of their damage due to fire. Where the device is located such that it is subjected to a head of oil, a valve is to be fitted to allow for its removal, see 4-6-2/9.11.3.

15.3.4(e) Level alarms. For propulsion machinery spaces intended for centralized or unattended operation (**ACC** or **ACCU** notation), lubricating oil tank low-level alarms are to be provided for:

- Slow-speed propulsion diesel engines (see 4-9-4/Table 3A);
- Gas turbines and reduction gears (see 4-9-4/Table 5);
- Steam turbines and gears (see 4-9-4/Table 4).

15.5 Lubricating Oil System Components

15.5.1 Pipes, Fittings and Valves

Pipes, fittings and valves are to comply with the same requirements as those for fuel oil systems in 4-6-4/13.7.1 and 4-6-4/13.7.2.

15.5.2 Pumps

Lubricating oil pumps requiring certification are specified in 4-6-1/7.3. See also 4-6-5/5 and 4-6-6/9.

15.5.3 Filters and Strainers

Filters and strainers are to comply with the same requirements as for those for fuel oil systems in 4-6-4/13.7.5.

15.5.4 Coolers

Lubricating oil coolers having either of the following design parameters are to be certified by the Bureau:

- Design pressure > 6.9 bar (7 kgf/cm^2, 100 psi) on either side;
- Design pressure > 1 bar (1 kgf/cm^2, 15 psi), internal volume > 0.14 m^3 (5 ft^3), and design temperature > 90°C (200°F) on the lubricating oil side.

15.5.5 Sight-flow Glasses *(2006)*

A sight flow glass may be fitted only in the vertical sections of lubricating oil overflow pipes, provided that it is in a readily visible position.

17 Additional Measures for Oil Pollution Prevention *(1 July 2003)*

17.1 General *(1 August 2007)*

17.1.1 Application

The provisions of 4-6-4/17 provide the arrangement of fuel oil tanks for compliance with MARPOL 73/78, as amended. They are to be applied in addition to the requirements of 4-6-4/13 and are applicable to all types of vessels classed with the Bureau.

17.1.2 Submission of Plans

Plans showing compliance with the applicable requirements in 4-6-4/17.3 are to be submitted for review.

17.3 Tank Protection Requirements *(1 August 2007)*

17.3.1 General *(2009)*

The requirements in this section apply to vessels having an aggregate fuel oil capacity of 600 m^3 (21,190 ft^3) and above. However, the requirements need not be applied to individual fuel oil tanks with a capacity not greater than 30 m^3 (1060 ft^3), provided that the aggregate capacity of such excluded tanks is not greater than 600 m^3 (21,190 ft^3). Further, individual fuel oil tanks are not to have capacity greater than 2,500 m^3 (88,290 ft^3).

Fuel oil tanks of any volume are not to be used for ballast water.

17.3.2 Protective Location of Tanks

The protective locations for the tanks specified in 4-6-4/17.3.1 above are to be as follows:

17.3.2(a) Deterministic Approach (2009). All applicable tanks are to be located away from the vessel's bottom or side shell plating for a distance as specified in *i), ii)* or *iii)*. Small suction wells may extend below fuel oil tanks bottoms, if they are as small as possible and the distance between the vessel's bottom plate and the suction well bottom is not reduced by more than half of the distance required by *i)*.

i) For vessels having an aggregate oil fuel capacity of 600 m^3 (21,190 ft^3) and above, all tanks are to be arranged above vessel's molded line of bottom shell plating at least of the distance h as specified below:

$h = B/20$ m or

$h = 2.0$ m (6.6 ft), whichever is smaller

where B is the breadth of the vessel, as defined in 3-1-1/5, in m (ft).

h is in no case to be less than 0.76 m (2.5 ft).

ii) For vessels having an aggregate oil fuel capacity greater than or equal to 600 m^3 (21190 ft^3) but less than 5000 m^3 (176570 ft^3), tanks are to be arranged inboard of the molded line of side plating not less than the distance *w* as specified below:

$w = 0.4 + 2.4C/20000$ m $\qquad$ $w = 1.31 + 7.87C/706290$ ft

where

C = vessel's total volume of oil fuel in m^3 (ft^3) at 98% tank filling;

w = at least 1.0 m (3.3 ft)

for individual tanks smaller than 500 m^3 (17,657 ft^3) *w* is to be at least 0.76 m (2.5 ft)

iii) For vessels having an aggregate oil fuel capacity of 5000 m^3 (176570 ft^3) and above, tanks are to be arranged inboard of the molded line of side plating not less than the distance *w* as specified below:

$w = 0.5 + C/20000$ m $\qquad$ $w = 1.64 + C/706290$ ft or

$w = 2.0$ m $\qquad$ $w = 6.6$ ft, whichever is smaller

where C is the vessel's total volume of oil fuel in m^3 (ft^3) at 98% tank filling.

The minimum value of $w = 1.0$ m (3.3 ft).

17.3.2(b) Probabilistic Approach (2009). As an alterative to the deterministic approach of 4-6-4/17.3.2(a), arrangements complying with the accidental oil fuel outflow performance standard of Regulation 12A, Annex I, MARPOL 73/78, as amended, would be acceptable.

17.5 Class Notation – POT *(2009)*

In addition to the requirements for fuel oil tank protection as specified in 4-6-4/17.3.1 utilizing the deterministic approach of 4-6-4/17.3.2(a), where lubricating oil tanks are also arranged in the same manner as required by the deterministic approach [4-6-4/17.3.2(a)] for fuel oil tanks, vessels are to be eligible for the optional Class notation, **POT** – Protection of Fuel and Lubricating Oil Tanks. Further, the following exemptions are applicable to lubrication oil tanks:

i) In application of equation in 4-6-4/17.3.2(a)ii) or iii), total volume of lubricating oil tanks need not be accounted for C (vessel's total volume of oil fuel in m^3 (ft^3) at 98% tank filling).

ii) Tanks used as main engine lubricating oil drain tanks need not be located in a protected location away from the vessel's side or bottom plates.

PART
4

CHAPTER **6 Piping Systems**

SECTION **5 Piping Systems for Internal Combustion Engines**

1 Applications

The provisions of this section are applicable to systems essential for operation of internal combustion engines (diesel engines and gas turbines) and associated reduction gears intended for propulsion and electric power generation. These systems include fuel oil, lubricating oil, cooling, starting air, exhaust gas and crankcase ventilation. Reference should be made to Section 4-2-1 and Section 4-2-3 for engine appurtenances of diesel engines and gas turbines, respectively.

These provisions contain requirements for system design, system components and specific installation details. Requirements for plans to be submitted, pipe materials, pipe and pipe fitting designs, fabrication, testing, general installation details and component certification are given in Section 4-6-1 and Section 4-6-2. For plastic piping, see Section 4-6-3.

3 Fuel Oil Systems

3.1 General

3.1.1 Application

The provisions of 4-6-5/3 apply to systems supplying fuel oil to internal combustion engines intended for propulsion and power generation. Requirements for shipboard fuel oil storage, transfer, heating and purification, as provided in 4-6-4/13, are to be complied with. System component requirements in 4-6-4/13.7 are applicable here also.

3.1.2 Fuel Oil Flash Point

The provisions of 4-6-5/3 are intended for internal combustion engines burning fuel oils having a flash point (closed cup test) above 60°C (140°F). Engines burning fuel oil of a lesser flash point are subject to special consideration. In general, fuel oil with a flash point of 60°C (140°F) or below, but not less than 43°C (110°F), may only be used for vessels classed for services in specific geographical areas. The climatic conditions in these areas are to preclude the ambient temperature of spaces where such fuel oil is stored from rising to within 10°C (18°F) below its flash point.

Engines driving emergency generators may use fuel oil with a flash point of 60°C (140°F) or below, but not less than 43°C (110°F).

3.1.3 Basic Requirement

The intent of the provisions of 4-6-5/3 along with those of 4-6-4/13 is:

- To provide for a reliable source of fuel oil supply to the prime movers for propulsion and power generation, primarily by means of certification of critical components and providing redundancy in the system, so that propulsion and maneuvering of the vessel may still be possible in the event of single failure in the system;
- To minimize the possibility of fire due to fuel oil, primarily by identifying and segregating likely fuel leakages from ignition sources, collection and drainage of fuel leakages and proper design of fuel containment systems.

3.3 Fuel Oil Service System for Propulsion Diesel Engines

3.3.1 Service and Booster Pumps

3.3.1(a) Standby pump. An independently driven standby pump is to be provided for each service pump, booster pump and other pumps serving the same purpose.

3.3.1(b) Multiple engine installation. For vessels fitted with two or more propulsion engines, the provision of a common standby pump (for each service pump, booster pump, etc.) capable of serving all engines will suffice rather than providing individual standby pumps for each engine.

3.3.1(c) Attached pumps. Engines having service, booster or similar pumps attached to and driven by the engine may, in lieu of the standby pump, be provided with a complete pump carried on board as a spare. The spare pump, upon being installed, is to allow the operation of the engine at rated power. This alternative, however, is only permitted for multiple-engine installations where one of the engines may be inoperable (while its pump is being changed) without completely disrupting the propulsion capability of the vessel.

3.3.1(d) Emergency shutdown. Independently driven fuel oil service pumps, booster pumps and other pumps serving the same purpose are to be fitted with remote means of controls situated outside the space in which they are located so that they may be stopped in the event of fire arising in that space.

3.3.1(e) Certification of pumps. Fuel oil transfer pumps, and fuel oil service and booster pumps associated with propulsion gas turbine and propulsion diesel engines with bores greater than 300 mm (11.8 in.) are to be certified in accordance with 4-6-1/7.3.

3.3.2 Fuel-injector Cooling Pumps

Where pumps are provided for fuel injector cooling, a standby pump is to be fitted as per 4-6-5/3.3.1

3.3.3 Heaters

When fuel oil heaters are required for propulsion engine operation, at least two heaters of approximately equal size are to be installed. The combined capacity of the heaters is not to be less than that required by the engine(s) at rated power. See 4-6-4/13.7.4 for heater design requirements.

3.3.4 Filters or Strainers

Filters or strainers are to be provided in the fuel oil injection-pump suction lines and are to be arranged such that they can be cleaned without interrupting the fuel supply. This may be achieved by installing two such filters or strainers in parallel or installing the duplex type with a changeover facility that will enable cleaning without interrupting the fuel supply. An auto-backwash filter satisfying the same intent may also be accepted. See 4-6-4/13.7.5 for depressurization and venting requirements.

Filters and strainers are to be arranged and located so that, in the event of leakage, oil will not spray onto surfaces with temperature in excess of 220°C (428°F).

3.3.5 Purifiers

Where heavy fuel oil is used, the number and capacity of purifiers are to be such that with any unit not in operation, the remaining unit(s) is to have a capacity not less than that required by the engines at rated power.

3.3.6 Piping Between Booster Pump and Injection Pumps *(2005)*

In addition to complying with 4-6-4/13.7.1, pipes from booster pump to injection pump are to be seamless steel pipe of at least standard wall thickness. Pipe fittings and joints are to be in accordance with 4-6-4/Table 3, subject to further limitations as follows:

- Connections to valves and equipment may be of taper-thread joints up to 50 mm (2 in.) nominal diameter; and
- Pipe joints using taper-thread fittings and screw unions are not to be in sizes of 25 mm (1 in.) nominal diameter and over.

Spray shields are to be fitted around flanged joints, flanged bonnets and any other flanged or threaded connections in fuel oil piping systems under pressure exceeding 0.18 N/mm^2 (1.84 kgf/cm^2, 26 psi) which are located above or near units of high temperature, including boilers, steam pipes, exhaust manifolds, silencers or other equipment required to be insulated by 4-6-4/13.3.2, and to avoid, as far as practicable, oil spray or oil leakage into machinery air intakes or other sources of ignition. The number of joints in such piping systems is to be kept to a minimum.

3.3.7 Piping Between Injection Pump and Injectors

3.3.7(a) Injection piping (2001). All external high-pressure fuel delivery lines between the high-pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high-pressure line failure. A jacketed pipe incorporates an outer pipe into which the high-pressure fuel pipe is placed, forming a permanent assembly. Metallic hose of approved design may be accepted as the outer pipe, where outer piping flexibility is required for the manufacturing process of the permanent assembly. The jacketed piping system is to include means for collection of leakages, and arrangements are to be provided for an alarm to be given of a fuel line failure.

3.3.7(b) Fuel oil returns piping. When the peak-to-peak pressure pulsation in the fuel oil return piping from the injectors exceeds 20 bar (20.5 kgf/cm^2, 285 lb/in^2), jacketing of the return pipes is also required.

3.3.8 Isolating Valves in Fuel Supply and Spill Piping *(1 July 2002)*

In multi-engine installations which are supplied from the same fuel source, a means of isolating the fuel supply and spill (return) piping to individual engines is to be provided. The means of isolation is not to affect the operation of the other engines and is to be operable from a position not rendered inaccessible by a fire on any of the engines.

3.5 Fuel Oil Service System for Auxiliary Diesel Engines

3.5.1 Service Pumps

Where generator engines are provided with a common fuel oil service pump or similar, a standby pump capable of serving all engines is to be installed. Engines having individual service pumps, or having service pumps attached to and driven by the engines need not be provided with a standby service pump.

3.5.2 Fuel Injector Cooling Pumps

Where pumps are provided for fuel injector cooling, the provision for a standby pump is to be in accordance with 4-6-5/3.5.1.

3.5.3 Heaters

When fuel oil heaters are required for generator engine operation, at least two heaters of approximately equal size are to be installed. The capacity of the heaters, with one heater out of operation, is not to be less than that required by the engine(s) at a power output for the normal sea load specified in 4-8-2/3.1.1. For generator engines arranged for alternately burning heavy fuel oil and diesel oil, consideration may be given to providing one heater only.

3.5.4 Filters or Strainers

Where common filters or strainers are provided to serve the fuel oil injection-pump suction lines of all of the generator engines, they are to be arranged such that they can be cleaned without interrupting the power supply specified in 4-8-2/3.1.1. In the case where each of the generator engines is fitted with its own strainer or filter, this arrangement alone will suffice.

3.5.5 Piping

Applicable requirements of 4-6-5/3.3.6 and 4-6-5/3.3.7 are to be complied with.

3.5.6 Isolating Valves in Fuel Supply and Spill Piping *(1 July 2002)*

For multi-engine installations, the requirements of 4-6-5/3.3.8 are to be complied with.

3.7 Fuel Oil Service System for Gas Turbines

3.7.1 General

The fuel oil service system is to be in accordance with 4-6-5/3.3 for propulsion gas turbines and 4-6-5/3.5 for generator gas turbines, as applicable, and the provisions in 4-6-5/3.7.

3.7.2 Shielding of Fuel Oil Service Piping *(2001)*

Piping between the service pump and the combustors is to be effectively jacketed or shielded as in 4-6-5/3.3.6 or 4-6-5/3.3.7, respectively.

3.7.3 Fuel Oil Shutoff

3.7.3(a) Automatic shutoff. Each gas turbine is to be fitted with a quick closing device which will automatically shut off the fuel supply upon sensing malfunction in its operation, see 4-2-3/7.7.2 for a complete list of automatic shutdowns.

3.7.3(b) Hand trip gear. Hand trip gear for shutting off the fuel supply in an emergency is also to be fitted, see 4-2-3/7.9.

3.9 System Monitoring and Shutdown

4-6-5/Table 1 summarizes the basic alarms and shutdown required for fuel oil systems, as required by 4-6-4/13 and 4-6-5/3.

Propulsion machinery spaces intended for centralized or unattended operation are to be fitted with additional alarms and automatic safety system functions. See, e.g., 4-9-4/Table 3A, 4-9-4/Table 3B, and 4-9-4/Table 5 for propulsion engines and 4-9-4/Table 8 for auxiliary engines.

TABLE 1
Fuel Oil System Alarms and Shutdown

Equipment	*Requirement*	*Reference*
Overflow tank	High-level alarm	4-6-4/13.5.4
Fuel oil tank	High-level alarm, unless overflow is fitted	4-6-4/13.5.6(e)
Fuel oil heaters	High-temperature alarm unless heating medium precludes overheating.	4-6-4/13.5.7(b) and 4-6-4/13.7.4(b)
Fuel oil pumps	Remote manual shutdown	4-6-5/3.3.1(d)
Fuel oil supply to gas turbines	Automatic shutdown and alarms for specified conditions	4-6-5/3.7.3(a)
Fuel delivery pipes	Leak alarm	4-6-5/3.3.7(a), 4-6-5/3.5.5 and 4-6-5/3.7.2

3.11 Testing and Trials

Hydrostatic tests are to be in accordance with 4-6-2/7.3.1 and 4-6-2/7.3.3. The system is to be tried under working condition in the presence of a Surveyor.

5 Lubricating Oil Systems

5.1 General

5.1.1 Application

The provisions of 4-6-5/5 apply to lubricating oil systems of internal combustion engines and their associated reduction gears intended for propulsion and power generation. Requirements for lubricating oil storage and transfer systems as provided in 4-6-4/15 are to be complied with. System component requirements in 4-6-4/15.5 are applicable here also.

5.1.2 Basic Requirement

The intent of the provisions of 4-6-5/5 and 4-6-4/15 is to:

- Provide for continuity of supply of lubricating oil or provide reasonable redundancy in lubricating oil supply to the propulsion and auxiliary machinery;
- Provide warning of failure of lubricating oil system and other measures to prevent rapid deterioration of propulsion and auxiliary machinery;
- Minimize the fire risks of lubricating oil.

5.1.3 Vessel Inclination

The lubricating oil systems and the associated equipment are to have the capability of satisfactory operation when the vessel is inclined at the angles indicated in 4-1-1/7.9.

5.1.4 Dedicated Piping

The lubricating oil piping, including vents and overflows, is to be entirely separated from other piping systems.

5.3 Lubricating Oil Systems for Propulsion Engines

5.3.1 Lubricating Oil Pumps

5.3.1(a) Standby pump. Each pressurized lubricating oil system essential for operation of the propulsion engine, turbine or gear is to be provided with at least two lubricating oil pumps, at least one of which is to be independently driven. The capacity of the pumps, with any one pump out of service, is to be sufficient for continuous operation at rated power. For multiple propulsion unit installations, one or more independently driven standby pumps may be provided such that all units can be operated at rated power in the event of any one lubricating oil pump for normal service being out of service.

5.3.1(b) Attached pump. Where the lubricating oil pump is attached to and driven by the engine, the turbine or the gear, and where lubrication before starting is not necessary, the independently driven standby pump required in 4-6-5/5.3.1(a) is not required if a complete duplicate of the attached pump is carried onboard as a spare. This alternative, however, is only permitted for multiple propulsion unit installations, where one of the units may be inoperable, while its pump is being changed without completely disrupting the propulsion capability of the vessel.

5.3.1(c) Certification of pumps. Lubricating oil pumps for propulsion gas turbine, propulsion diesel engines with bores greater than 300 mm (11.8 in.) and reduction gears associated with these propulsion engines and turbines are to be certified in accordance with 4-6-1/7.3.

5.3.2 Lubricating Oil Failure Alarms

Audible and visual alarms are to be fitted for each lubricating oil system of engine, turbine or gear to warn of the failure of the lubricating oil system.

5.3.3 Gas Turbines and Associated Reduction Gears

Propulsion gas turbines are to be fitted with an automatic quick acting device to shut off the fuel supply upon failure of the lubricating oil supply to the gas turbine or the associated gear.

5.3.4 Diesel Engines and Associated Reduction Gears

Where reduction gears are driven by multiple (two or more) diesel engines, an automatic means is to be fitted to stop the engines in the event of failure of the lubricating oil supply to the reduction gear.

5.3.5 Lubricating Oil Coolers

For all types of propulsion plants, oil coolers with means for controlling the lubricating oil temperature are to be provided. Lubricating oil coolers are to be provided with means to determine the oil temperature at the outlet. See also 4-6-5/7.7.3 for cooling water requirements.

5.3.6 Filters and Strainers

5.3.6(a) Safety requirements. Strainers and filters are also to be arranged and located so that, in the event of leakage, oil will not spray onto surfaces with temperature in excess of 220°C (428°F). See 4-6-4/13.7.5 for depressurization and venting requirements.

5.3.6(b) Gas turbines. A magnetic strainer and a fine mesh filter are to be fitted in the lubricating oil piping to the turbines. Each filter and strainer is to be of the duplex type or otherwise arranged so that it may be cleaned without interrupting the flow of oil.

5.3.6(c) Diesel engines. An oil filter of the duplex type is to be provided or otherwise arranged so that it may be cleaned without interrupting the flow of oil. In the case of main propulsion engines which are equipped with full-flow-type filters, the arrangement is to be such that the filters may be cleaned without interrupting the oil supply.

5.3.6(d) Reduction gears. A magnetic strainer and a fine mesh filter are to be fitted. Each filter and strainer is to be of the duplex type or otherwise arranged so that they may be cleaned without interrupting the flow of oil.

5.3.7 Purifiers

For main propulsion gas turbines, a purifier of the mechanical type is to be provided for separation of dirt and water from the lubricating oil in systems containing more than 4.0 m^3 (4000 liters, 1057 gallons) of lubricating oil.

5.3.8 Drain Pipes

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

5.5 Lubricating Oil Systems for Auxiliary Engines

Lubricating oil systems for auxiliary engines driving generators are to meet applicable requirements of 4-6-5/5.3, except as provided below.

5.5.1 Lubricating Oil Pumps

A standby lubricating oil pump is not required for generator diesel engines and gas turbines. For generators driven by the propulsion system, the lubrication of the drive system, if independent of that of the propulsion system, is to be fitted with a standby means of lubrication. This requirement need not apply to drive systems that can be disengaged from the propulsion system.

5.5.2 Strainers and Filters

In multiple-generator installations, each diesel engine or gas turbine may be fitted with a simplex strainer and/or filter provided the arrangements are such that the cleaning can be readily performed by changeover to a standby unit without the loss of propulsion capability.

5.7 System Monitoring and Safety Shutdown

4-6-5/Table 2 summarizes the basic alarms of the lubricating oil system and the safety shutdowns as required by 4-6-5/5.

TABLE 2
Lubrication Oil System Basic Alarms and Safety Shutdown

Equipment	*Requirement*	*Reference*
Lub. oil system for engines, turbines and gears – propulsion and auxiliary	Failure alarm	4-6-5/5.3.2
Propulsion gas turbines and gears, auxiliary gas turbines	Shutdown in case of – turbine of gear lub. oil system failure	4-6-5/5.3.3
Common reduction gears of multiple propulsion diesel engines	Engines shutdown in case of gear lub. oil system failure	4-6-5/5.3.4

Propulsion machinery spaces intended for centralized or unattended operation are to be fitted with additional alarms and automatic safety system functions. See e.g., 4-9-4/Table 3A, 4-9-4/Table 3B, and 4-9-4/Table 5 for propulsion engines and 4-9-4/Table 8 for generator engines.

5.9 Testing and Trials

Hydrostatic tests are to be in accordance with 4-6-2/7.3.1 and 4-6-2/7.3.3. The system is to be tried under working condition, including simulated functioning of alarms and automatic shutdowns, in the presence of a Surveyor.

7 Cooling System

7.1 General

7.1.1 Application

The provisions of 4-6-5/7 apply to cooling systems of diesel engines and gas turbines and their associated reduction gears, as applicable, intended for propulsion and electric power generation.

7.1.2 Basic Requirements

The requirements for cooling systems are intended to provide for continuity of supply of cooling medium through providing redundancy in the system to the propulsion and auxiliary machinery.

7.3 Cooling System Components

7.3.1 Pumps

Cooling water pumps of propulsion gas turbine and associated reduction gear and cooling water pumps of propulsion diesel engines with bores greater than 300 mm and associated reduction gears are to be certified in accordance with 4-6-1/7.3. Pumps supplying cooling media other than water are to be subjected to the same requirements.

7.3.2 Coolers

7.3.2(a) General. Water and air coolers having either of the following design parameters are to be certified by the Bureau:

- Design pressure > 6.9 bar (7 kgf/cm^2, 100 lb/in^2) on either side
- Design pressure > 1 bar (1 kgf/cm^2, 15 lb/in^2), internal volume > 0.14 m^3 (5 ft^3), and design temperature > 149°C (300°F) on either side.

7.3.2(b) Charge air coolers. Charge air coolers are not subject to 4-6-5/7.3.2(a). They are to be hydrostatically tested on the water side to 4 bar (4.1 kgf/cm^2, 57 psi), but not less than 1.5 times the design pressure on the water side, either in the manufacturer's plant or in the presence of the Surveyor, after installation onboard the vessel. See also 4-2-1/13.3 for acceptance of manufacturer's certificate.

7.3.3 Pipe Fittings and Joints

Pipe fittings and joints are to meet the requirements for certification in 4-6-1/7.1; materials in 4-6-2/3; and design in 4-6-2/5.5 and 4-6-2/5.15 subject to limitations in 4-6-5/Table 3. Molded non-metallic expansion joints, where used, are to be of an approved type; see 4-6-2/5.8.1.

TABLE 3
Pipe Joint Limitations for Cooling Water Systems *(2006)*

Pipe joints	*Class I*	*Class II*	*Class III*
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint [(1)]	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint [(2)]	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint	Types A & B	Types A, B, C & D	Types A, B, C & D
Taper-thread joint	≤ 80 mm (3 in.) Permissible pressure/size, see 4-6-2/5.5.5(a).	≤ 80 mm (3 in.) Permissible pressure/size, see 4-6-2/5.5.5(a).	No limitation
Compression couplings	≤ 60 mm (2.4 in.) OD	≤ 60 mm (2.4 in.) OD	No limitation
Slip-on joints	See Note 3	See Note 3	See Note 3

Notes:

1 See 4-6-2/5.5.2 for further operational limitations.

2 See 4-6-2/5.5.3 for further operational limitations.

3 See 4-6-2/5.9 for further limitations.

Pipe sizes indicated are nominal diameter, except where specified otherwise.

7.5 Sea Chests

At least two sea chests, located below the lightest waterline, as far apart as practicable and preferably on opposite sides of the vessel, are to be provided. Each of the sea chests is to be capable of supporting the cooling of propulsion and auxiliary machinery and other services drawing sea water from the same sea chest.

For shell valve and sea chest requirements, see 4-6-2/9.13.2 and 4-6-2/9.13.5.

7.7 Cooling Systems for Propulsion and Auxiliary Engines

7.7.1 Cooling Water Pumps

7.7.1(a) Standby pump. There are to be at least two means to supply cooling water or other medium to propulsion and auxiliary engines, air compressors, coolers, reduction gears, etc. The capacity of each means is to be sufficient for continuous operation of the propulsion unit and its essential auxiliary services at rated power. One of these means is to be independently driven and may consists of a connection from a suitable pump of adequate size normally used for other purposes, such as a general service pump, or in the case of fresh water cooling, one of the vessel's fresh water pumps.

7.7.1(b) Attached pumps. Where the cooling pump is attached to and driven by the engine, and the connection to an independently driven pump is impracticable, the standby pump will not be required if a complete duplicate of the attached pump is carried onboard as a spare. This alternative, however, is only permitted for multiple-engine installations where one of the engines may be inoperable while its pump is being changed without completely disrupting the propulsion capability of the vessel.

7.7.1(c) Multiple auxiliary engines. Multiple auxiliary engine installations having individual cooling systems need not be provided with standby pumps.

7.7.2 Strainers

Where sea water is used for direct cooling of the engines, suitable strainers are to be fitted between the sea valve and the pump suction. The strainers are to be either of the duplex type or arranged such that they can be cleaned without interrupting the cooling water supply.

This applies also to engines fitted with indirect cooling where direct sea water cooling is used as an emergency means of cooling.

7.7.3 Cooling Medium Circulation

In general means are to be provided to indicate proper circulation of cooling medium. This may be accomplished by means of pressure or flow and temperature indicators. For diesel engines, the primary cooling medium is to be provided with a pressure indicator at the inlet and with a temperature indicator at the outlet.

All lubricating oil coolers are to be provided with temperature indicators at the cooling medium inlet and at the lubricating oil outlet. Means to determine the cooling medium and lubricating oil pressures are also to be provided.

7.7.4 Overpressure Protection

The cooling water system and all jackets are to be protected against overpressurization, in accordance with 4-6-2/9.9.

7.7.5 System Monitoring and Safety Functions

For propulsion machinery spaces intended for centralized or unattended operations (**ACC/ACCU** notation), alarms for abnormal conditions (pressure and temperature) of the cooling media and automatic safety system functions are to be provided. See e.g., 4-9-4/Table 3A, 4-9-4/Table 3B and 4-9-4/Table 5 for propulsion engines and 4-9-4/Table 8 for generator engines.

7.9 Cooler Installations External to the Hull *(2006)*

7.9.1 General

The inlet and discharge connections of external cooler installations are to be in accordance with 4-6-2/9.13.1 through 4-6-2/9.13.3 and 4-6-2/9.17, except that wafer type valves are acceptable.

7.9.2 Integral Keel Cooler Installations

The positive closing valves required by 4-6-5/7.9.1 above need not be provided if the keel (skin) cooler installation is integral with the hull. To be considered integral with the hull, the installation is to be constructed such that channels are welded to the hull with the hull structure forming part of the channel, the channel material is to be at least the same thickness and quality as that required for the hull and the forward end of the cooler is to be faired to the hull with a slope of not greater than 4 to 1.

If positive closing valves are not required at the shell, all flexible hoses or joints are to be positioned above the deepest load waterline or be provided with an isolation valve.

7.9.3 Non-integral Keel Cooler Installations

Where non-integral keel coolers are used, if the shell penetrations are not fully welded, the penetration is to be encased in a watertight enclosure.

Non-integral keel coolers are to be suitably protected against damage from debris and grounding by recessing the unit into the hull or by the placement of protective guards.

7.11 Testing and Trials

Hydrostatic tests are to be in accordance with 4-6-2/7.3.1 and 4-6-2/7.3.3. The system is to be tried under working condition in the presence of a Surveyor.

9 Starting Air System

9.1 General

9.1.1 Application

The provisions of 4-6-5/9 apply to the starting air systems for propulsion diesel engines and gas turbines.

9.1.2 Basic Requirements

The intent of the requirements in 4-6-5/9 for starting air system is:

- To provide propulsion engines with ready and adequate supply, as well as an adequate reserve, of starting air; and
- To provide for proper design and protection of the compressed air system.

9.1.3 Overpressure Protection

Means are to be provided to prevent overpressure in any part of the compressed air system. This is to include parts of air compressors not normally subjected to air pressure, as indicated in 4-6-5/9.3.2.

9.1.4 Oil and Water Contamination

Provisions are to be made to minimize the entry of oil or water into the compressed air system. Suitable separation and drainage arrangements are to be provided before the air enters the reservoirs.

9.3 Air Compressors

9.3.1 Number and Capacity of Air Compressors

There are to be two or more air compressors, at least one of which is to be driven independently of the propulsion engines, and the total capacity of the air compressors driven independently of the propulsion engines is to be not less than 50% of the total required.

The total capacity of air compressors is to be sufficient to supply, within one hour, the quantity of air needed to satisfy 4-6-5/9.5.1 by charging the reservoirs from atmospheric pressure.

The total capacity, V, required by 4-6-5/9.5.1 is to be approximately equally divided between the number of compressors fitted, n, excluding the emergency air compressor, where fitted. However, one of the air compressors can have a capacity larger than the approximate equal share V/n, provided the capacity of each remaining air compressor is approximately V/n.

9.3.2 Overpressure Protection

Water jackets or casing of air compressors and coolers which may be subjected to dangerous overpressure due to leakage into them from air pressure parts are to be provided with suitable pressure relief arrangements.

9.3.3 Air Compressor Acceptance Test

Air compressors need not be certified by the Bureau. They may be accepted based on satisfactory performance and verification of capacity stated in 4-6-5/9.3.1 after installation onboard.

9.5 Air Reservoirs

9.5.1 Number and Capacity of Air Reservoirs *(2006)*

Vessels having internal combustion engines arranged for air starting are to be provided with at least two starting air reservoirs of approximately equal size. The total capacity of the starting air reservoirs is to be sufficient to provide, without recharging the reservoirs, at least the number of consecutive starts stated in 4-6-5/9.5.1(a) or 4-6-5/9.5.1(b) plus the requirement in 4-6-5/9.5.1(c). For vessels whose propulsion machinery spaces are intended for centralized or unattended operation (**ACC** or **ACCU** notation), all starts are to be demonstrated from the engine control room or from the engine control panel on the navigation bridge, whichever location is more demanding on air consumption.

9.5.1(a) Diesel or turbine propulsion. The minimum number of consecutive starts (total) required to be provided from the starting air reservoirs is to be based upon the arrangement of the engines and shafting systems, as indicated in 4-6-5/Table 4.

TABLE 4
Required Number of Starts for Propulsion Engines

	Single propeller vessels		*Multiple propeller vessels*	
Engine type	*One engine coupled to shaft directly or through reduction gear*	*Two or more engines coupled to shaft through clutch and reduction gear*	*One engine coupled to each shaft directly or through reduction gear*	*Two or more engines coupled to each shaft through clutch and reduction gear*
Reversible	12	16	16	16
Non-reversible	6	8	8	8

9.5.1(b) Diesel-electric or turbine-electric propulsion (2006). The minimum number of consecutive starts (total) required to be provided from the starting air reservoirs is to be determined from the following equation:

$$S = 6 + G(G - 1)$$

where

S = total number of consecutive starts

G = number of engines necessary to maintain sufficient electrical load to permit vessel transit at full seagoing power and maneuvering. The value of G need not exceed 3.

9.5.1(c) Other compressed air systems. If other compressed air consuming systems, such as control air, are supplied from the starting air reservoirs, the aggregate capacity of the reservoirs is to be sufficient for continued operation of these systems after the air necessary for the required number of starts has been used.

9.5.2 Certification of Starting Air Reservoirs

Starting air reservoirs having a design pressure greater than 6.9 bar (7 kgf/cm^2, 100 psi) or with a design pressure greater than 1.0 bar (1.0 kgf/cm^2, 15 psi) and design temperature greater than 149°C (300°F) are to be certified by the Bureau, see 4-4-1/1.1.

9.5.3 Air Reservoir Fixtures

Air reservoirs are to be installed with drain connections effective under extreme conditions of trim. Where they can be isolated from the system relief valve, they are to be provided with their own relief valves or equivalent devices.

9.5.4 Automatic Charging

Arrangements are to be made to automatically maintain air reservoir pressure at a predetermined level.

9.7 Starting Air Piping

9.7.1 Pipe Fittings and Joints

Pipe fittings and joints are to meet the requirements for certification in 4-6-1/7.1; materials in 4-6-2/3; and design in 4-6-2/5.5 and 4-6-2/5.15, subject to limitations in 4-6-5/Table 5.

TABLE 5
Pipe Joint Limitations for Starting Air Systems *(2006)*

Pipe joints	*Class I*	*Class II*	*Class III*
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint [(1)]	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint [(2)]	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint	Types A & B	Types A, B, C & D	Types A, B, C & D
Taper-thread joint	≤ 80 mm (3 in.) Permissible pressure/size, see 4-6-2/5.5.5(a)	≤ 80 mm (3 in.) Permissible pressure/size, see 4-6-2/5.5.5(a)	No limitation
Compression couplings	≤ 60 mm (2.4 in.) OD	≤ 60 mm (2.4 in.) OD	No limitation

Notes:

1 See 4-6-2/5.5.2 for further operational limitations.

2 See 4-6-2/5.5.3 for further operational limitations.

Pipe sizes indicated are nominal diameter, except where specified otherwise.

9.7.2 Piping from Compressor to Reservoir

All discharge pipes from starting air compressors are to be led directly to the starting air reservoirs, and all starting air pipes from the air reservoirs to propulsion or auxiliary engines are to be entirely separated from the compressor discharge piping system.

9.7.3 Starting Air Mains

Where engine starting is by direct injection of air into engine cylinders, and in order to protect starting air mains against explosions arising from improper functioning of starting valves, an isolation non-return valve or equivalent is to be installed at the starting air supply connection of each engine. Where engine bore exceeds 230 mm ($9^{1}/_{16}$ in.), a bursting disc or flame arrester is to be fitted in way of the starting valve of each cylinder for direct reversing engines having a main starting manifold or at the supply inlet to the starting air manifold for non-reversing engines.

9.9 System Alarms

Where a propulsion engine can be started from a remote propulsion control station, low starting air pressure is to be alarmed at that station. Propulsion machinery spaces intended for centralized or unattended operations (**ACC/ACCU** notation) are also to be provided with alarms for low starting air pressures in the centralized control station.

9.11 Testing and Trials

Hydrostatic tests are to be in accordance with 4-6-2/7.3.1 and 4-6-2/7.3.3. The system is to be tried under working condition in the presence of a Surveyor.

11 Exhaust Gas Piping

11.1 Application

These requirements apply to internal combustion engine exhaust gas piping led to the atmosphere through the funnel.

11.3 Insulation

Exhaust pipes are to be water-jacketed or effectively insulated with non-combustible material. In places where oil spray or leakage can occur, the insulation material is not to be of the oil-absorbing type unless encased in metal sheets or equivalent.

11.5 Interconnections

Exhaust pipes of several engines are not to be connected together, but are to be run separately to the atmosphere unless arranged to prevent the return of gases to an idle engine. Boiler uptakes and engine exhaust lines are not to be interconnected except when specially approved as in cases where the boilers are arranged to utilize the waste heat from the engines.

11.7 Installation

Exhaust pipes are to be adequately supported and fitted with means to take account of the expansion and contraction to prevent excessive strain on the pipes. Expansion joints or equivalent may be used.

Precautions are to be taken in the installation of equipment and piping handling fuel oil, lubricating oil and hydraulic oil, such that any oil that may escape under pressure will not come in contact with exhaust gas piping.

11.9 Diesel Engine Exhaust

11.9.1 Temperature Display

Propulsion diesel engines with bore exceeding 200 mm (7.87 in.) are to be fitted with a means to display the exhaust gas temperature at the outlet of each cylinder.

11.9.2 Alarms

Propulsion machinery spaces intended for centralized or unattended operations (**ACC/ACCU** notation) are to be provided with alarms for high exhaust gas temperature in the centralized control station.

11.11 Gas Turbines Exhaust

The exhaust gas system of gas turbines is to be installed in accordance with the turbine manufacturer's recommendations. In addition, reference is made to 4-2-3/7.13 for the installation of silencers, and to 4-9-4/Table 5 for exhaust gas temperature indication, alarm and automatic shutdown for propulsion machinery spaces intended for centralized or unattended operation.

13 Crankcase Ventilation and Drainage

13.1 General *(2006)*

Crankcase ventilation is to be provided in accordance with engine manufacturer's recommendations. Ventilation of the crankcase or any arrangement which could produce a flow of external air into the crankcase is, in general, to be avoided, except for dual fuel engines where crankcase ventilation is to be provided in accordance with 6.5.3 of the ABS *Guide for Propulsion Systems for LNG Carriers*. Vent pipes, where provided, are to be as small as practicable to minimize the inrush of air after a crankcase explosion. If a forced extraction of the oil mist atmosphere in the crankcase is provided (for oil mist detection purposes, for example), the vacuum in the crankcase is not to exceed 2.5 mbar (2.55 mkgf/cm^2, 36.26 mpsi).

13.3 Crankcase Vent Piping Arrangement

13.3.1 General Arrangements *(2003)*

Crankcase ventilation piping is not to be directly connected with any other piping system. The crankcase ventilation pipe from each engine is normally to be led independently to the weather. However, manifold arrangements in accordance with 4-6-5/13.3.2 may also be accepted.

13.3.2 Manifold Arrangements

Where a manifold is employed, its arrangements are to be as follows:

i) The vent pipe from each engine is to:

- Run independently to the manifold, and
- Be fitted with a corrosion resistant flame screen within the manifold.

ii) The manifold is to be located as high as practicable so as to allow a substantial length of piping separating the crankcases. It is not to be located lower than one deck above the main deck.

iii) The manifold is to be accessible for inspection and maintenance of the flame screens.

iv) *(2003)* The manifold is to be vented to the weather, such that the clear open area of the vent outlet is not less than the aggregate area of the individual crankcase vent pipes entering the manifold.

v) The manifold is to be provided with drainage arrangements.

13.5 Crankcase Drainage

No interconnections are allowed between drain pipes from crankcases. Each drain pipe is to be led separately to the drain tank and is to be submerged at its outlet, see 4-6-5/5.3.8.