Excerpt from ABS Rules Developed for Boilers and Pressure

Booklet developed on 1 January, 2026

Excerpt from ABS Rules Developed
for Boilers and Pressure

American Bureau of Shipping

Incorporated by Act of legislature

of the State of New York 1862.

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While every effort has been made to ensure the accuracy and completeness of the Vendor Rule Book, where there are discrepancies between the Vendor Rule Book content and the pdf versions of the Rules and Guides on American Bureau of Shipping (ABS) Eagle.org, the pdf versions from the web site are to be considered the official version.

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Foreword

Purpose

This booklet is an excerpt from the ABS Rules. It has been created to support equipment manufacturers in identifying the appropriate ABS Rules for their products.

Application

Equipment manufacturers seeking to have their products approved for marine and offshore applications under ABS classification or certification will find this booklet a practical reference for determining which sections of the ABS Rules are applicable to their specific equipment types.

This excerpt does not replace or supersede the complete ABS Rules. Users are responsible for consulting the full text of the applicable Rules and ensuring compliance with the most current edition, including any published corrigenda and notices.

Additional Information

For questions regarding the applicability of specific Rules to your equipment. Please contact your local ABS office.

The ABS Rules are available in their complete form at American Bureau of Shipping (ABS) Eagle.org.

1 General

1.1 Application (1 July 2024)

Regardless of the system in which they form a part, boilers, fired and unfired heaters, pressure vessels and heat exchangers of the following categories are to be subjected to the requirements 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 and for containment of gas as fuel defined in Section .
iv. Welded accumulators, regardless of their diameters, see .
v. Accumulators of extruded seamless construction are to be designed, manufactured and tested in accordance with a recognized standard for this type of pressure vessel, see .
vi. Other pressure vessels and heat exchangers specified in , having design pressure, temperature and volume as defined in . Group II pressure vessels and heat exchangers under 150 mm (6 in.) in diameter are not required to comply with the requirements of this section. Acceptance of them are 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.
vii. Boilers and fired heaters not included above, fired inert gas generators and incinerators are subject to the requirements of only.
viii. Oil-fired air-heating furnaces - used on the Great Lakes vessels during winter lay-up (see 4-4-1/18).

TABLE 1
Pressure Vessels Covered in Part 4, Chapter 4

		Pressure				Temperature			Volume		ABS Type Approval Tier	Rule Reference
		bar	kgf/cm^2	psi		°C	°F		m^3	ft^3		
a)	Pressure vessels and heat exchangers for toxic andcorrosive substances (see 4-1-1/1.9.5)	>1.0	>1.0	>15	-	all	all	-	all	all	5	4-4-1/1.9
b)	Pressure vessels, heat exchangers and heatersother than a)	>6.9	>7	>100	-	all	all	-	all	all	4/5 Tier	4-4-1/1.9
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	4/5	4-4-1/1.11.3 4-4-1/1.5

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.

1.2 Objective **(2024)**

1.2.1 Goals

Boilers, pressure vessels and fired equipment addressed in this section are to be designed, constructed, operated, and maintained to:

Goal No.	Goal
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 5.1	facilitate safe access, ease of inspection, survey, and maintenance of the vessel, machinery and electrical systems.
AUTO 1	perform its functions as intended and in a safe manner.
AUTO 2	indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
AUTO 3	have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
AUTO 4	provide the equivalent degree of safety and operability from a remote location as those provided by local controls.
AUTO 5	be provided with a safety system that automatically leads the machinery being controlled to a fail-safe state in response to a fault which may endanger the safety of persons on board, machinery/equipment or environment.
FIR 4	detect, *contain, control and suppress or swiftly extinguish a fire in the compartment of origin.*

Materials are to be suitable for the intended application in accordance with the following goals in support of the Tier 1 goals as listed above.

Goal No.	Goals
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
MAT 2	The manufacturing process is to be capable of producing products to meet the specified quality and property requirements.
MAT 3	The fabrication and welding process is to be capable of producing products that meet the specified quality and property requirements.

The goals covered in the cross-referenced Rules are also to be met.

1.2.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the boilers, pressure vessels and fired equipment are to be in accordance with the following functional requirements:

Functional Requirement No.	Functional Requirement
Safety Management (MGMT)	
MGMT-FR1	Provide means or arrangements to facilitate operations, cleaning, inspection, and maintenance.
MGMT-FR2	Provide means for monitoring thermal oil samples onboard.
MGMT-FR3	Information containing guidance for the safe operation of the equipment and system is to be provided.
Safety of Personnel (SAFE)	
SAFE-FR1	Pressure-containing parts are to withstand the design pressures and temperatures of the gas or liquid.
SAFE-FR2	Prevent fatigue failure during the anticipated design life.
SAFE-FR3	Provide adequate corrosion allowance for the anticipated design life.
SAFE-FR4	Provide adequate support for the anticipated environmental conditions, vessel movements, temperature effects, shock and vibrations.
SAFE-FR5	Provide protective devices if the equipment can be subjected to a pressure more than its design pressure and adequately sized to prevent excessive pressure build-up upstream.
SAFE-FR6	Prevent equipment from overheating.
SAFE-FR7	Minimize risk of leakage due to failure of joints.
SAFE-FR8	Provide means to isolate the boilers from steam and feedwater pressure.
SAFE-FR9	Provide means to stop back flow where back flow is possible.
SAFE-FR10	Provide means to reduce the effects of metal temperature differentials.
SAFE-FR11	Prevent heat from equipment causing fire hazards or adverse thermal effects on equipment, structures or cargo.
SAFE-FR12	Minimize or prevent hot surfaces contact with the crew during operation.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Provide means to effectively operate and safely shutdown the equipment and its associated auxiliaries during normal operation and emergency condition/failure of component.
AUTO-FR2	Provide means to shutdown the system remotely and manually in the event of fire in the space.
AUTO-FR3	Provide operational status of equipment and its associated auxiliaries during normal operations and upon occurrence of fault/faults in the system.
Fire Safety (FIR)	
FIR-FR1	*Detect a fire in the space of origin and to provide for alarm to notify crew for safe evacuation and fire-fighting activity. (SOLAS II-2)*
FIR-FR2	Effective containment and extinction of any fire within space of origin with due regard to the type of fire and fire growth potential of the protected space.
Materials (MAT)	
MAT-FR1	Impact Toughness to be considered for low temperature performance.
MAT-FR2	Weldability (Carbon content, Carbon Equivalent) to be considered when the items/components are welded.
MAT-FR3	For elevated design temperatures, calculations are to consider the effects of temperature on tensile properties. In case of steels, for temperatures above 121 °C (250 °F).
MAT-FR4	Formability to be considered for ease of manufacturing and potential loss of ductility and toughness.
MAT-FR5	Heat treatment is to be capable of producing the specified material properties and a homogeneous microstructure.

The functional requirements covered in the cross-referenced Rules are also to be met.

1.2.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 Definitions

1.3.1 Design Pressure (**1 July 2024**)

Design Pressure is the 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, including static head, 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 (**2024**)

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 for that pressure. It is the least of the values for MAWP determined for any pressure-containing parts, including environmental loads and static head between the part considered and the top of the boiler or pressure vessel.

1.3.3 Design Temperature (**1 July 2024**)

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 recognized standard.

Commentary:

Definitions are based on American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC).

End of Commentary

1.5 Recognized Codes or Standards **(2024)**

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 4-4-1-A1 of this section. Alternatively, they are to comply with a recognized code or standard. The following are some recognized standards and codes that are considered recognized for the purpose of this section:

Boilers:

- ASME Boiler and Pressure Vessel Code Section I
- British Standard (BS) European Norm (EN) BS EN 12952 Water-tube boilers and auxiliary installations
- BS EN 12953 Shell Boilers

Pressure vessels and heat exchangers:

- ASME Boiler and Pressure Vessel Code Section VIII Div. 1; or Section VIII Div. 2
- Tubular Exchanger Manufacturers Association (TEMA) Standards
- BS EN 13445 Unfired pressure vessels
- British Standard institution Specification PD 5500 for unfired pressure vessels
- Japanese Industrial Standard (JIS) B8265 *et al* for Pressure vessels

Other international and national standards or codes will be considered, if they are no less effective.

1.7 Grouping of Boilers and Pressure Vessels **(2024)**

Boilers and pressure vessels are categorized as in 4-4-1/1.9 TABLE 2to specify the degree of inspection and testing during certification.

1.9 Certification **(2024)**

All boilers and pressure vessels within the scope of 4-4-1/1.1 are to be certified by ABS.

The manufacturers of welded boilers and Group **I** and **II** pressure vessels are to be approved by ABS. ABS Manufacturer Approval is valid for 3 years subject to annual verification by the attending Surveyor. Manufacturers holding a valid accreditation under ASME Boiler and Pressure Vessel Certification Program or equivalent program of Pressure Equipment Directive (PED), are acceptable in lieu of ABS Manufacturer Approval. Quality processes established by the manufacturer are to be followed regardless of the pressure vessel's certification by ASME or PED.

4-4-1/1.9 TABLE 3 provides important elements of the certification process for each group of boilers and pressure vessels. Columns 1, 2, 3 and 5 in the table are to be complied with for all Groups **I** and **II** boilers and pressure vessels regardless of the applicable standard or code. Fabrication and inspection details in column 4 (see Section 2-4-3 of the ABS *Rules for Materials and Welding (Part 2)* are to be complied with unless alternative requirements based on applicable standard or code are submitted to the Surveyor for acceptance. Mass-produced pressure vessels, including seamless extruded cylinders and fluid power cylinders, can be certified by alternative means as described in 4-4-1/1.11.

Commentary:

Refer to 4-4-1/1.9 TABLE 2 Note 7; design pressure of a pressure vessel is typically higher than system working pressure. Therefore, ABS accepts the system working pressure as design pressure of the pressure vessel if a pressure relief device is provided and is set at system working pressure.

End of Commentary

TABLE 2
Grouping of Boilers and Pressure Vessels (2024)

		bar	kgf/cm^2	psi		°C	°F		m^3	ft^3		mm	in.		
Grp	*Type*	*Design Pressure*				*Design Temperature*			*Volume*			*Thickness*		*ABS Type App-roval Tier*	*Rule Reference*
I	a) Boilers and steam generators	>3.5	>3.6	>50	-	all	all	-	all	all	-	all	all	5	4-4-1/7
	b) Pressure vessels and heat exchangers other than d) and e)	>41.4	>42.2	>600	*or*	>371[1] >204[2]	>700[1] >400[2]	*and*	all	all	*or*	>38	>1.5	5	4-4-1/7
	c) Fired heaters for oil	>41.4	>42.2	>600	-	all	all	-	all	all	-	all	all	5	4-4-1/7

		bar	kgf/cm^2	psi		°C	°F		m^3	ft^3		mm	in.		
	d) Liquefied gas pressure vessel cargo tanks and fuel tanks	≥2.1	≥2.1	≥30	-	all	all	-	all	all	-	all	all	5	4-4-1/7, 5C-8-4, 5C-13-6
	e) Pressure vessels and heat exchangers for toxic or corrosive substances	>1.0	>1.0	>15	-	all	all	-	all	all	-	all	all	5	4-4-1/7
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	4/5	4-4-1/1.11 4-4-1/7
	b) Pressure vessels & 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	4/5	4-4-1/1.11 4-4-1/7
	c) Pressure vessels & 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	4/5	4-4-1/1.11 4-4-1/7

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.

7 If the equipment is protected by a pressure relief device, the design pressure of the pressure vessel is to be based on the relief setting.

TABLE 3
Certification Details (1 July 2020)

	1	2	3	4				5	ABS Type Approval Tier	Rule Reference
	Design approval	Survey during fabrication	Material test witnessed by Surveyor	Full radiography	Post-weld heat treatment	Production test plate	Charpy V-notch test	Hydrostatic test		
Group I	x	x	x	x	x	x	as required	x	5	4-4-1/7
Group II	x	x	-	as required	-	-	as required	x	4/5	4-4-1/1.11 4-4-1/7

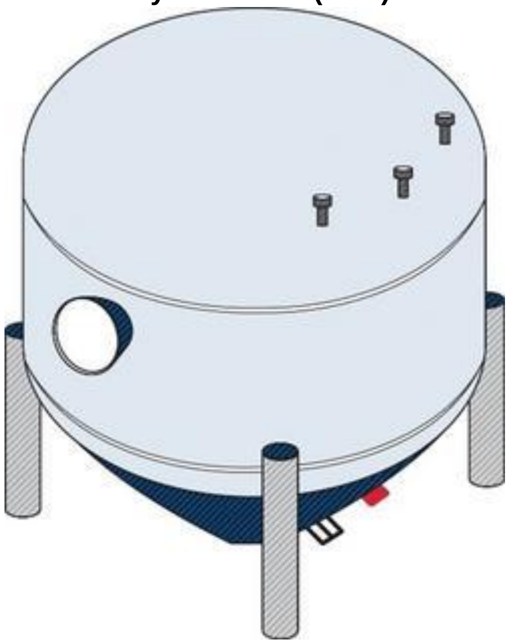
1.11 Special Cases

1.11.1 Independent Cargo Pressure Vessels (2024)

Pressure vessels independent of the ship's hull and intended for the carriage of liquefied gases as cargo are, in addition to the requirements of this section, to comply with 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 requirements of this section if the operating pressure and volume of the vessels exceed that indicated in 4-4-1/1.1 TABLE 1 item c. See 4-4-1/Figure 1.

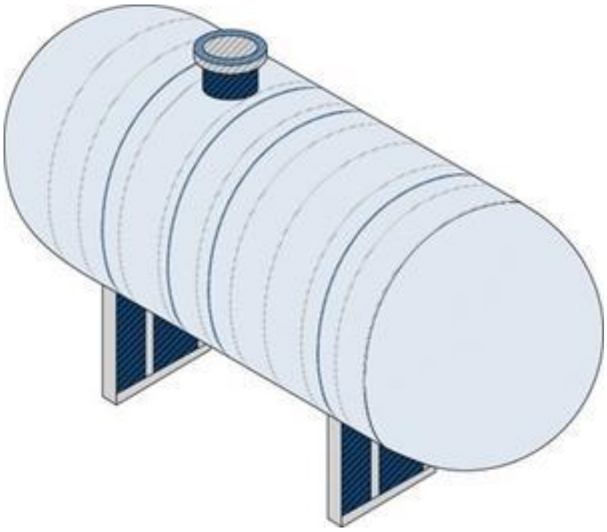
FIGURE 1
Dry Bulk Tank (2024)



1.11.2 Independent Fuel Pressure Vessels (2024)

Pressure vessels independent of the ship's hull and intended for the containment of liquefied gases as fuel are, in addition to the requirements of this section, to comply with Section 5C-13-6. See 4-4-1/Figure 2.

FIGURE 2
Independent Fuel Tank (2024)



1.11.3 Mass-produced Boilers and Pressure Vessels (**2024**)

Mass-produced boilers, pressure vessels and heat exchangers can also be certified on the basis of the ABS Type Approval Program (see 1A-1-4/7.7 of the ABS *Rules for Conditions of Classification (Part 1A)*, 4-1-1/9 TABLE 5 and 1A-1-A3/5 of the ABS *Rules for Conditions of Classification (Part 1A)*). See 4-4-1/Figures 3 through 6 for various types of pressure vessels and boilers.

FIGURE 3
Air Receiver (2024)

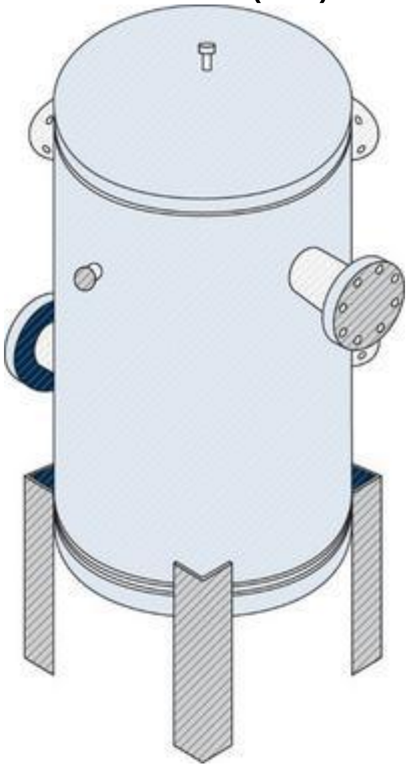


FIGURE 4
U-Tube Heat Exchanger (2024)

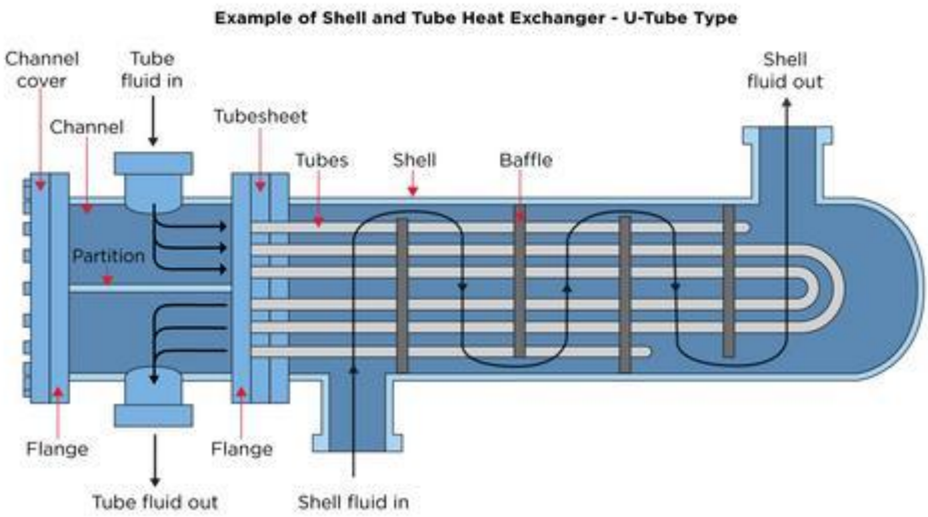


FIGURE 5
Plate Heat Exchanger (2024)

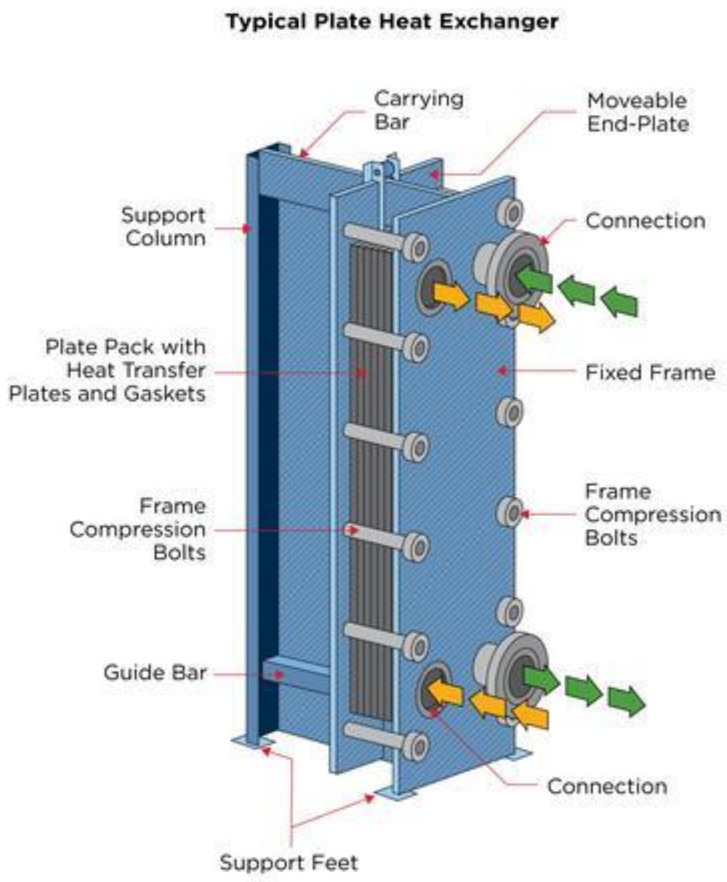


FIGURE 6A
Firetube Boiler (2024)

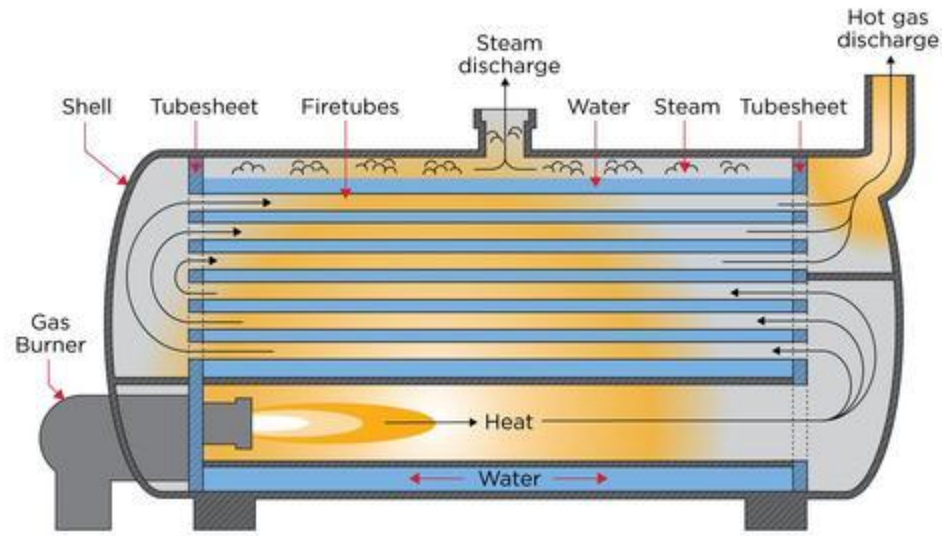
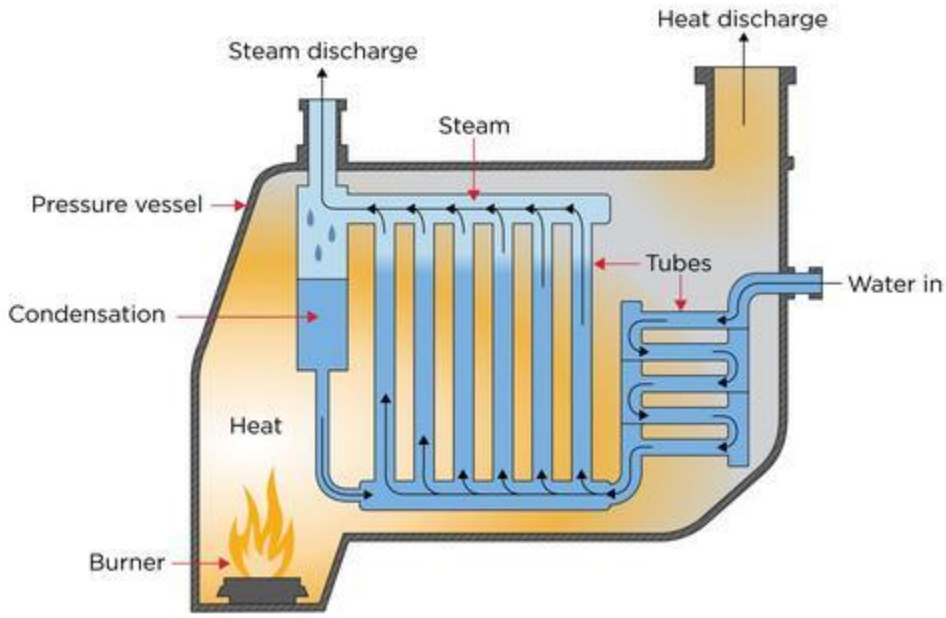


FIGURE 6B
Watertube Boiler (2024)



Commentary:

Boilers, pressure vessels and heat exchangers may be considered as mass-produced if they meet the following criteria:

- The boiler, pressure vessel or heat exchanger is produced in quantity to a standardized design.
- The materials and components used for the construction are manufactured in accordance with approved quality control procedures specified by the manufacturer.
- The machinery used for manufacturing of the boiler, pressure vessel and heat exchanger components is specially calibrated and subject to regular inspection to meet the manufacturer’s specifications and quality requirements and allow for assembly or interchangeability of components without any re-machining.
- Welding fabrication, dimensional tolerances and nondestructive examinations and applicable documentation is carried out in accordance with quality control procedures specified by the manufacturer.
- Each assembled boiler, pressure vessel and heat exchanger undergoes final testing in accordance with specified procedures and in accordance with the applicable standard or code.

End of Commentary

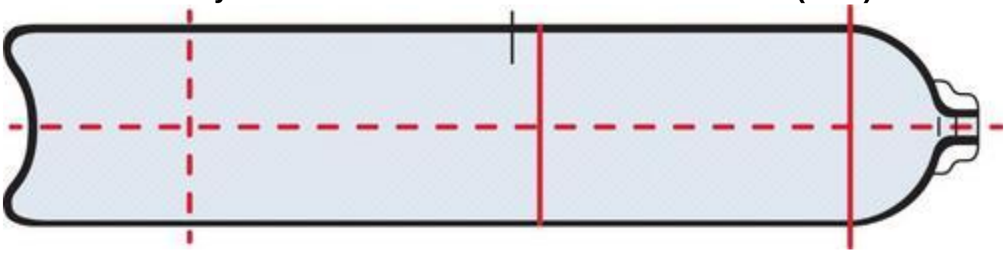
1.11.4 Pressure Vessels Included in Self-contained Equipment

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.

1.11.5 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 are based on their compliance with the standard as verified by either ABS 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.

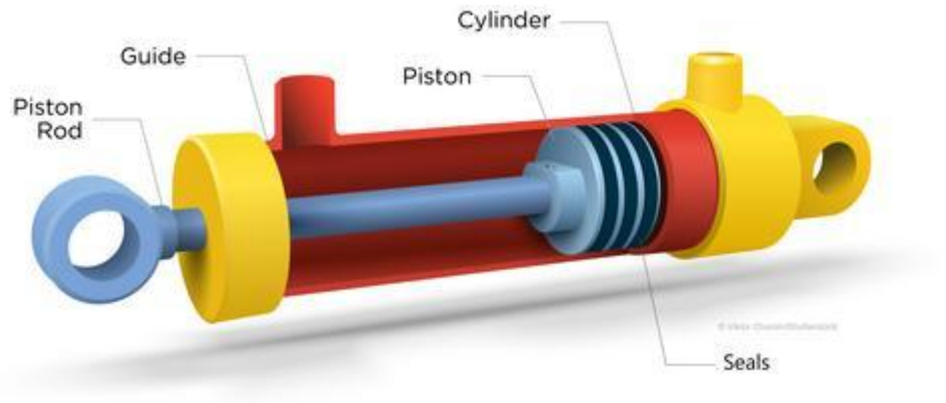
FIGURE 7
Gas Cylinder of Extruded Seamless Construction (2024)



1.11.6 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.

FIGURE 8
Fluid Power Cylinder (2024)



1.13 Plans and Data to be Submitted **(2024)**

R: Documents to be reviewed

I: Documentation for information and verification for consistency with related review.

OB: Documentation which needs to be kept onboard.

1.13.1 Boilers (**2024**)

General arrangement **(R)**

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. **(I)**

Materials of all pressurized parts and their welded attachments **(I)**

Sectional assembly **(R)**

Seating arrangements **(R)**

Steam and water drums, and header details **(R)**

Waterwall details **(R)**

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

Economizer arrangement, header details, and element details **(R)**

Casing arrangement **(R)**

Typical weld joint designs **(R)**

Post-weld heat treatment and nondestructive examination **(R)**

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

Integral piping **(R)**

Reheat section (when fitted) **(R)**

Burner unit assembly and details **(R)**

Fuel oil burning arrangements including burners and registers **(R)**

Forced draft system **(R)**

Boiler instrumentation, monitoring and control systems **(R)**

1.13.2 Pressure Vessels and Heat Exchangers (**2024**)

General arrangements **(R)**

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 **(I)**

Material specifications including heat treatment and mechanical properties **(R)**

Shell and head details, and shell to head joint details **(R)**

Nozzles, openings, manways, etc., and their attachment details; flanges and covers, as applicable **(R)**

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

Support structures, seating, etc. **(R)**

For Brazed Plate Heat Exchangers, results of the burst tests carried out in accordance with UG-101(m) of ASME Section VIII Div 1 together with the appropriate joint efficiency factor as defined per UB-14 are to be submitted for determining the MAWP. **(R)**

1.13.3 Thermal Oil Heaters (**2024**)

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. **(I)**

Thermal oil plant design parameters: thermal oil circulation rate; circulating pump head/capacity; designed maximum oil film temperature. **(I)**

Arrangement and details of appurtenances; relief valve capacities. **(R)**

Schematic of thermal oil piping system. **(R)**

Fire extinguishing fixtures for the furnace space. **(R)**

Instrumentation, monitoring and control systems **(R)**

1.13.4 Calculations (**2024**)

Calculations in accordance with a recognized standard or code. **(I)**

1.13.5 Fabrication (**2024**)

Where applicable, the following information is to be included in the design package submitted for engineering review by ABS Materials Department for Group I and Group II Pressure Vessels and Boilers. For other equipment (excluding Group I and Group II Pressure Vessels and Boilers) the following information is to be submitted to the Surveyor.

i. Welding procedure specifications (WPS) and procedure qualification records (PQR)
ii. Post-weld heat treatment procedure
iii. Nondestructive examination (NDE) plan and associated NDE procedures
iv. Hot and cold forming procedures
v. Fabrication procedures

Welder qualification records, for all equipment, are to be submitted to the Surveyor. **(R)**

3 Materials

3.1 Permissible Materials

3.1.1 General

Pressure-containing parts of boilers and pressure vessels are to be constructed of materials conforming to specifications permitted by the applicable standard or code. Boiler and pressure vessel material specifications provided in Section 2-3-1 of the ABS *Rules for Materials and Welding (Part 2)* may be used in connection with the requirements of Appendix 4-4-1-A1. Materials for non-pressure-containing 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-containing parts.

3.1.2 Materials for High Temperature Service

Materials of pressure-containing 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; alternatively, the application of the materials is to be limited by allowable stresses at elevated temperatures as specified in the applicable standard or code. The use of materials specified in Section 2-3-1 of the ABS *Rules for Materials and Welding (Part 2)* is to be in accordance with the allowable stresses specified in Appendix 4-4-1-A1.

3.1.3 Materials for Low Temperature Service

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

3.3 Permissible Welding Consumables

Welding consumables are to conform to recognized standards or codes. Welding consumables tested, certified and listed by ABS in its publication *Approved Welding Consumables* for meeting a standard may be used in all cases. See Section 2-4-3 of the ABS *Rules for Materials and Welding (Part 2)*.

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, used in 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 4-4-1/1.9 TABLE 3, main pressure-containing 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 compliance with corresponding material specifications. Welding consumables, in these instances, are to have their mechanical strength verified by 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 4-4-1-A1. Alternatively, they are to comply with a recognized code or standard (see 4-4-1/1.5). 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 **(2023)**

Welding of pressure-containing parts and of non-pressure-containing parts to pressure-containing parts are 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 of the ABS *Rules for Materials and Welding (Part 2)* or the applicable standard or code. Welding procedure specifications and their qualification records are to be submitted for engineering review to the ABS Materials Department as indicated in 4-4-1/1.13.5. The Surveyor is to have the option to witness 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 standard or code and is to be to the satisfaction of the Surveyor.

7.5 Dimensional Tolerances **(2024)**

The manufacturer is to check that the parts to be welded are aligned within the tolerances specified in Section 2-4-2 of the ABS *Rules for Materials and Welding (Part 2)* or the applicable standard or code. The fitting of the main seams, 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 to the satisfaction of the Surveyor. Local thin areas (LTAs) in cylindrical shells or spherical segments of shells (such as spherical vessel, hemispherical heads and the spherical portion of torispherical and ellipsoidal heads) under internal pressure are to comply with applicable standard or code such as ASME Sec VIII Div 1 Mandatory Appendix 32 Local Thin Areas in Cylindrical Shells and in Spherical Segments of Shells.

7.7 Nondestructive Examination

Radiographic examinations are to be in accordance with Section 2-4-2/23 of the ABS *Rules for Materials and Welding (Part 2)* 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 non-destructive examination, such as ultra-sonic, dye penetrant, or magnetic particle, are to be in accordance with the applicable 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 of the ABS *Rules for Materials and Welding (Part 2)* 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 code or standard. Postweld heat treatment procedure is to be submitted to the Surveyor for review prior to the heat treatment.

7.11 Hydrostatic Tests

7.11.1 Boilers **(2024)**

The Surveyor is to witness hydrostatic tests on all boilers. See 4-4-1/1.9. The test pressure is not to be less than 1.5 times the MAWP or at pressures as specified by the applicable standard or code.

7.11.2 Pressure Vessels **(2024)**

The Surveyor is to witness hydrostatic tests on all pressure vessels. See 4-4-1/1.9. The test pressure is not to be less than 1.3 times the MAWP or at such pressures as specified by the applicable standard or code. Where hydrostatic tests are impracticable, alternative methods of pressure testing, such as pneumatic test, are to be proposed and such test procedures submitted to the Surveyor for consideration in each case.

Commentary:

Refer to ASME BVPC Section VIII Div. 1 UG-100 Pneumatic Test for considerations to use pneumatic test.

End of Commentary

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 .* 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 is not to be less than 19 mm ($^3/_4$ in.) nor more than 102 mm (4 in.). **(2024)**

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). **(2024)**

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. **(2024)**

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. **(2024)**

Minimum mass of steam per hour per heating surface area of oil-fired boilers, kg/h/m^2 (lb/h/ft^2)		
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. **(2024)**

9.1.2(c) *Exhaust gas boiler*. Minimum required relieving capacity of 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. **(2024)**

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 MAWP. See 4-4-1/9.1.8. **(2024)**

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 MAWP. If more than one safety valve is installed, the highest setting among the safety valves is not to exceed the MAWP 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. **(2024)**

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. **(2024)**

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 is to be positively lifted from its seat. This mechanism is to be so arranged that the valves is to 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 main or auxiliary steam outlet. This does not apply to superheater safety valves, which may be mounted on the fitting for 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 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 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 MAWP 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 can 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 MAWP 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 MAWP 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 is to be in accordance with 2-3-10/1 of the ABS *Rules for Materials and Welding (Part 2)*.

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

9.3.3 Valve Design **(2024)**

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

9.5 Steam and Feed Valves

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 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

One steam stop valve is to be fitted to each steam outlet from a propulsion or auxiliary boiler. Where a superheater is fitted, the steam stop valve is to be located at the superheater to allow 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.

Where two or more boilers are connected, the steam stop valve is to be of the non-return type. In addition, the steam outlet connecting pipe from each boiler is to be provided with an additional shut off valve located in series and downstream of the required steam stop valve.

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. **(2024)**

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*. **(2024)**

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. Feed stop valve may be installed near an operating platform instead of attaching directly on the economizer 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 to 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 interposed between the stop check valve is acceptable if a by-pass is also fitted. **(2024)**

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. **(2024)**

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. **(2024)**

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. **(2024)**

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. **(2024)**

- Watertube boilers: the lowest permissible water level is to be just above (usually 25 mm or 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. **(2024)**

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 as one of the required means for determining the water level where the boiler is an auxiliary installation with a MAWP 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 watertube 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 **(2024)**

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. Inspection openings designed in accordance with alternative requirements in recognized standards or codes are to be submitted for acceptance in each case.

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 Spare Parts **(2024)**

While spare parts are not required for purpose of classification, maintenance of spare parts aboard each vessel is the responsibility of the owner.

ABS offers spare parts certification through the optional Preventative Maintenance Program's Reliability Based Maintenance (RBM) and Reliability Centered Maintenance (RCM) risk-based maintenance development processes. Refer to 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)* and the ABS *Guide for Surveys Based on Machinery Reliability and Maintenance Techniques*.

9.17 Additional Requirements for Shell Type Exhaust Gas Economizers

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. **(2020)**

9.17.3(b) *Discharge Pipe .* To avoid the accumulation of condensate on the outlet side of safety valves, the discharge pipes and/or 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 a threat to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements. **(2020)**

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 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. **(2020)**

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. **(2020)**

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. **(2020)**

11.5.1(d) *Boiler control power*. Loss of boiler control power is to automatically shut off the fuel supply to the burners. **(2020)**

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. **(2020)**

11.5.2 Alarms

11.5.2(a) *Fuel oil shutoff.* Actuation of any of the fuel shutoffs 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. **(2020)**

11.5.2(b) *Air supply and flue* . Means are to be fitted to detect and alarm at an early stage a fire in the boiler air supply and the exhaust duct. In the absence of an air casing for small boilers, heat (temperature) detector fitted in the windbox would meet this requirement. Further, for auxiliary boilers, without an air casing, the required means to detect and alarm of a fire in the boiler air supply duct may be omitted provided the burner system is a pressure jet type and the windbox forms part of the combustion fan housing. **(2020)**

4-4-1/11.5.2 TABLE 4 provides a summary of the required alarms and shutdowns.

TABLE 4
List of Alarms and Shutdowns - Fired Boilers

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)

Monitored Parameter		Alarm	Automatic Shutdown with Alarm	Notes
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. **(2020)**

11.5.3(b) *Trail-for-ignition period*. Means provided to by-pass the flame-scanner control system temporarily 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. **(2020)**

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. **(2020)**

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. **(2020)**

11.5.3(e) *Atomizing medium*. Off-limit condition of burner primary-air pressure or atomizing-steam pressure is to be alarmed. **(2020)**

11.7 Control for Waste Heat Boilers **(2024)**

Control of waste heat boilers is to meet the requirements in 4-4-1/11.5 for fired boilers, as applicable. The following specific requirements are also applicable:

11.7.1 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 and alarming are not applicable to waste heat boilers designed for dry condition operations.

11.7.2 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. 4-4-1/11.7.2 TABLE 5 provides a summary of the required alarms.

TABLE 5
List of Alarms - Waste Heat Boilers

Monitored Parameter		Alarm	Notes
Smoke tube type			
A1	Boiler drum water level -low	x	4-4-1/11.7.1
B1	Exhaust gas automatic diversion	x	4-4-1/11.7.1
C1	Exhaust gas temperature at outlet -high	x	4-4-1/11.5.1
Water tube type			
D1	Water flow in the tubes -low	x	4-4-1/11.7.2
E1	Exhaust gas temperature at outlet -high	x	4-4-1/11.5.2

11.7.3 Soot Cleaning

Waste heat boiler 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

Control of fired water heaters is to be as for fired boilers, as applicable.

4-4-1/11.9 TABLE 6 provides a summary of the required alarms and shutdowns.

TABLE 6
List of Alarms and Shutdowns - Fired Water Heaters

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			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 on board 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

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

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 shutoff is to be fitted for the conditions as indicated in 4-4-1/13.3.3 TABLE 7:

TABLE 7
List of Alarms and Shutdowns - Fired Thermal Oil Heaters

	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

Monitored Parameter		Automatic Shutdown with Alarm	Notes
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 the heater is located.

13.5 Exhaust-gas Thermal Oil Heaters

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 are to 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.

4-4-1/13.5 TABLE 8 provides a summary of the required alarms and shutdown.

TABLE 8
List of Alarms and Shutdowns - Exhaust-gas Thermal Oil Heaters

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 circulationsystem -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 requirements 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 applicable for incinerator also. In addition, automatic fuel shutoff 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 MAWP 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 MAWP. Installation of pressure relief valve in the piping system connected to the pressure vessel is acceptable, provided that this relief valve is of the required capacity and that it cannot be isolated from the pressure vessel by any intervening valve. Attention is also to be directed to the requirements of safety relief valve in the applicable code or standard.

17.3 Inspection Openings **(2020)**

All pressure vessels and heat exchangers are to be provided with suitable manhole, handhole, or other inspection openings for examination and cleaning and maintenance.

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 to be less than 381 mm (15 in.) inside diameter and a handholes 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 inside 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 inside 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 inside 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

Alternatively, flanged and/or threaded connections from which piping instruments or similar attachments can be removed may be acceptable provided that the connections are at least equal to the size of the required openings and the connections are sized and located to allow at least an equal view of the interior as the required openings.

17.3.6 Corrosion (2024)

Inspection openings may be omitted, provided a sufficient corrosion allowance to meet the expected design life is applied or documentation is specified by the manufacturer that internal corrosion will not occur.

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 is to be used extending inward from any location to the lowest point.

18 Oil-Fired Air-Heating Furnaces - Great Lakes (1 July 2024)

Following requirements are to be applied to all new oil fired furnace installations as well as those already installed on existing Great Lakes vessels.

18.1 General

The furnace is to meet an industry standard.
Commentary:

As these furnaces are only used during the winter lay-up on the Great Lakes and are not used during vessel operation, the industry standards refer to non-maritime standards that these furnaces would meet for land-based use.

End of Commentary

18.3 Fuel Oil Piping and Storage

Fuel oil piping and storage that supply the furnace are to comply with 4-6-4/13 of the Rules, as applicable.

18.5 Alarms and Shutdowns

Alarms and shutdowns are to be fitted in accordance with 4-4-1/15 as applicable to the furnace installation under consideration.

18.7 Alarm Repeater at Vessel Keeper and/or Watch Keeper's Station.

An alarm repeater, separate from the vessel's main monitoring and alarm system, is to be provided at the vessel keeper and/or watch keeper's station.

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 3-2-4/1.2 and 3-2-4/9.9.

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 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 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 75 mm (3 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 4-7-2/1.2.

19.5 Installation of Thermal Oil Heaters and Incinerators

The installation of thermal oil heaters, incinerators and other fired equipment is to be in accordance with 4-4-1/19.3. Consideration is to 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 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 ulation 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.

1 General

1.1 Application

These requirements apply to the design and fabrication of boilers and pressure vessels. They are based on ASME BPVC 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 (2024)

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

1.5 Deformation Testing (2024)

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 MAWP determined from a hydrostatic deformation test made on a full-sized sample.

Commentary:

Experimental stress and fatigue analysis should be in accordance with recognized Codes and Standards such as ASME Section VIII Division 1, Annex 5-F. Submission should include test procedures, reports and justifications on MAWP and empirical equations obtained.

End of Commentary

1.7 Plate and Pipe Thickness Undertolerance (2024)

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 (2024)

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

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

$$W = fSE\log_e\left(\frac{R+T}{R}\right) \; (2)$$

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

where

f	=	factor for units of measure = 10 (100, 1) for SI (MKS, US) units respectively
W	=	internal design 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 TABLE 2 (SI units) andTABLE 2 (MKS units); 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 3.3.4, 3.3.5 and 3.5.4. Note: When circumferential joint efficiency is less than one-half the longitudinal joint efficiency, longitudinal stress (in circumferential joints) may govern the minimum required thickness. Refer to ASME BPVC UG-27(c)(2). **End of Commentary**
T	=	minimum required 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 3.3.6 and 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 MAWP 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 pressure 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 thickness 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 FIGURE 1, E is to be given by the equation: **(1 July 2019)**

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

When the pitch of the tube holes on any one row is unequal, as in FIGURE 2 and FIGURE 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

3.3.5(b) *Diagonal ligament efficiency*. Where the tube holes are as shown in FIGURE 4, the efficiency of such ligaments is to be determined from FIGURE 5. When the diagonal efficiency is less than the efficiency determined from 3.3.5(a), it is to be used in calculating the minimum shell thickness. **(1 July 2019)**

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

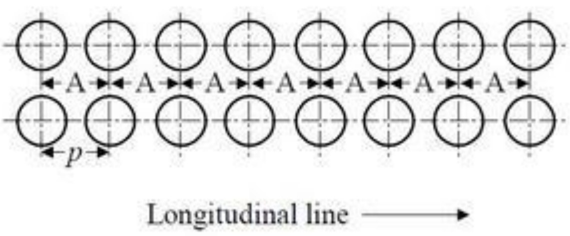


FIGURE 2
Example of Tube Spacing with Pitch of Holes Unequal in Every Second Row

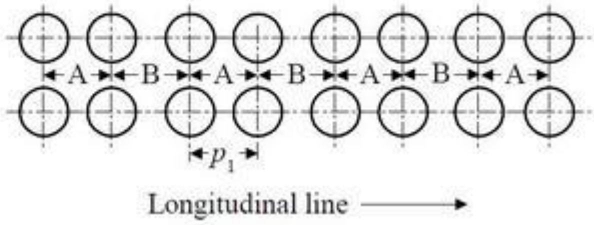


FIGURE 3
Example of Tube Spacing with Pitch of Holes Varying in Every Second Row

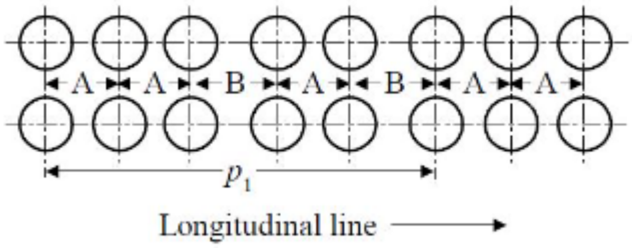


FIGURE 4
Example of Tube Spacing with Tube Holes on Diagonal Lines

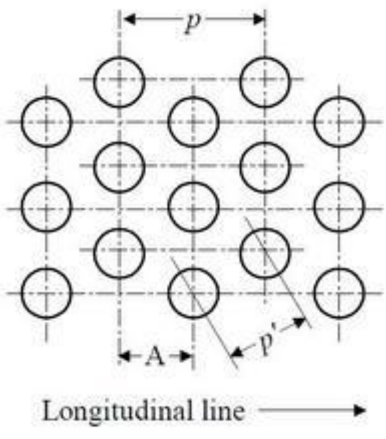
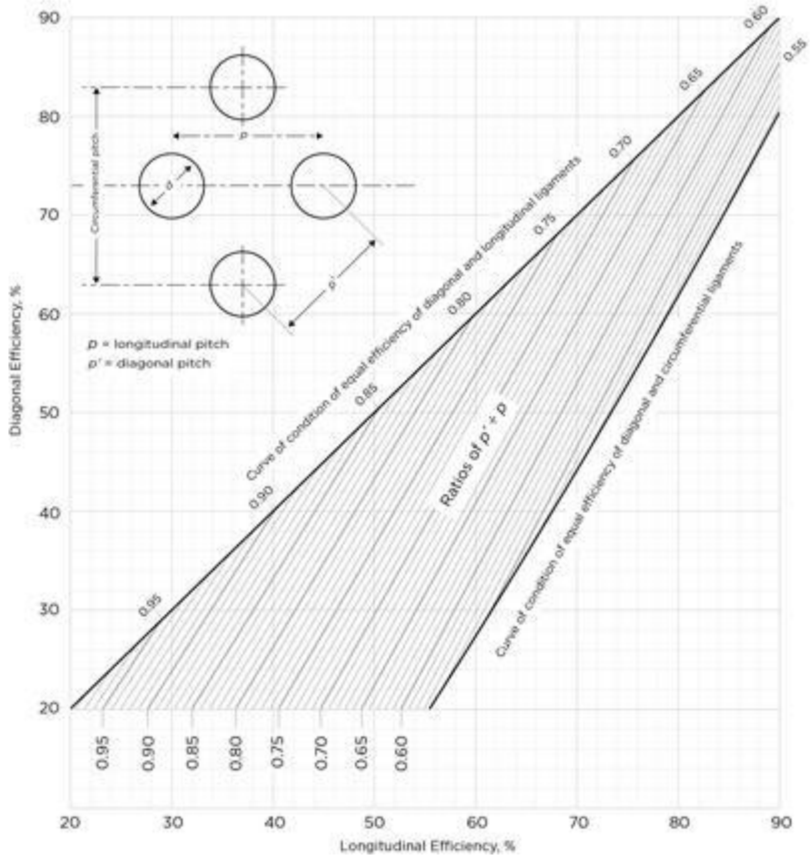


FIGURE 5
Diagram for Determination of Diagonal Efficiency (2024)

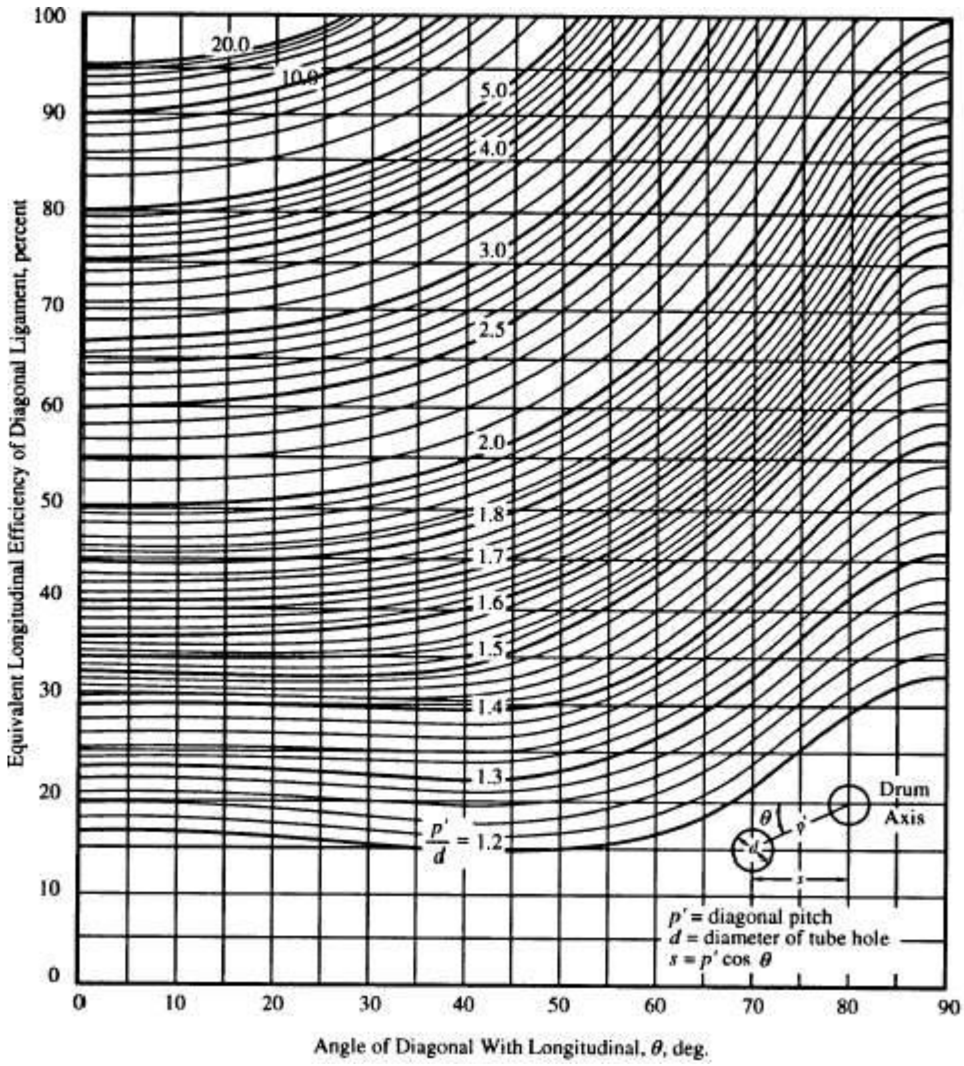


3.3.5(c) *Unsymmetrical ligament efficiency*. When tubes or holes are unsymmetrically spaced, the average ligament efficiency is to be not less than that given by the following requirements, which apply to ligaments between tube holes and not to single openings. This procedure may give lower efficiencies in some cases than those for symmetrical groups which extend a distance greater than the inside diameter of the shell as covered under 3.3.5(a) and 3.3.5(b). When this occurs, the efficiencies computed under 3.3.5(a) and 3.3.5(b) are to be used. **(2024)**

i. For a length equal to the inside diameter of the shell for the position which gives the minimum efficiency, the efficiency is to be not less than that on which the MAWP is based. When the inside diameter of the shell 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 shell for the position which gives the minimum efficiency, the efficiency is to be not less than 80% of that on which the MAWP is based. When the inside radius of the shell 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 shell but which are not in a straight line, the above Rules for calculating efficiency are to hold, except that the equivalent longitudinal efficiency of a diagonal ligament is to be used. To obtain the equivalent efficiency in , the angle of diagonal with longitudinal of the two holes and ratio of diagonal pitch to diameter of tube hole are used as given.

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 3.3.5(a) and is to be equal to at least one-half the efficiency of the latter. **(1 July 2019)**

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 MAWP 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 **(2024)**

A corrosion allowance, C, of not less than one-sixth of the required 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 TABLE 2 (SI units) and TABLE 2 (MKS units) 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. Corrosion allowance may be omitted for the following cases:

- When 0.8 of the S values taken from and are used in the design or,
- When values of E in column (c) of 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 excluding corrosion allowance.

3.5.4 Weld Joint Efficiency

Efficiencies for welded unfired pressure vessels are to be determined from 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 Heads (2024)

5.1 Torispherical and Hemispherical Heads (2024)

5.1.1 Minimum Thickness (2024)

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 FIGURE 7u and FIGURE 7v.

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

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

M = 1.00 for hemispherical heads

where

T	=	minimum thickness of the head; mm (in.)
W	=	internal design pressure; bar (kgf/cm^2, psi)
R	=	inside radius to which the head is dished, measured on the concave side, see 5.1.2; mm (in.)
r	=	inside knuckle radius of head, see 5.1.3; mm (in.)
S	=	maximum allowable working stress, see 5.1.4; N/mm^2 (kgf/mm^2, psi)
E	=	lowest efficiency of any joint in the head, see 5.1.5
C	=	corrosion allowance, see 5.1.6; mm (in.)
f	=	factor = 10 (100, 1) for SI (MKS, US) units respectively

5.1.2 Crown Radius (2024)

The inside crown radius to which a head is dished is to be not greater than the outside diameter of the skirt of the head.

5.1.3 Knuckle Radius (2024)

The inside knuckle radius of the torispherical head for its attachment to the shell plate is to be

- Not less than three (3) times the thickness of the head, and
- Not less than 6% of the outside diameter of the skirt of the head.

5.1.4 Maximum Allowable Working Stress (2024)

The maximum allowable working stress is to be taken from TABLE 2 (SI units) and TABLE 2 (MKS units).

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 TABLE 1.

Head to shell seams are to be considered circumferential seams of shell and are to be dealt with as in 3.3.4 for boiler and 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 3.3.6 for boilers and 3.5.2 for pressure vessels.

5.3 Ellipsoidal Heads (2024)

5.3.1 Heads with Pressure on the Concave Side

The minimum thickness of an ellipsoidal head 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 FIGURE 7t)
D	=	inside diameter of the head skirt; mm (in.) (see FIGURE 7t)

T , W , S , E , C and f are as defined in 5.1.

5.5 Heads with Access Openings (2024)

5.5.1 Manhole Flange Depth (2024)

A flued-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.

5.5.2 Reinforced Access Openings

When an access opening is reinforced in accordance with 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 requirements of 4-4-1-A1/5.7. These requirements apply to both circular and noncircular heads and covers. Some acceptable types of flat heads and covers are shown in FIGURE 7a to FIGURE 7s. In the figures, 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 (2024)

B	=	total bolt load, as further defined here-under; N (kgf, lbf)
C	=	corrosion allowance, see 3.3.6 for boilers and 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 FIGURE 7a through FIGURE 7v, 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 FIGURE 7j and FIGURE 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 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 FIGURE 7a, FIGURE 7c-1, FIGURE 7c-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 TABLE 2 (SI units) and TABLE 2 (MKS units); 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 FIGURE 7i; mm (in.)

t_f = actual thickness of the flange on a forged head, at the large end, as indicated in 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 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 FIGURE 7g; mm (in.)

W = internal design 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 5.7.3(c).

A_b = Cross-sectional area of the bolts [= 0.785 x (root diameter of the thread or least diameter of unthreaded position, if less)^2 x N]; mm^2 (in^2.)

A_m = total required cross-sectional area of bolts, taken as the greater of B_1/S_a and B_2/S_b ; mm^2 (in^2.)

B_1 = required bolt load for initial tightening conditions; N (kgf, lbf)

B_2 = required bolt load for design conditions; N (kgf, lbf)

b = effective gasket or joint-contact-surface seating width; mm (in.)

S_a = maximum allowable bolt stress value at room temperature; N/mm^2 (kgf/mm^2, psi)

S_b = maximum allowable bolt stress value at design temperature; N/mm^2 (kgf/mm^2, psi)

G = diameter at location of gasket load reaction; mm (in.)

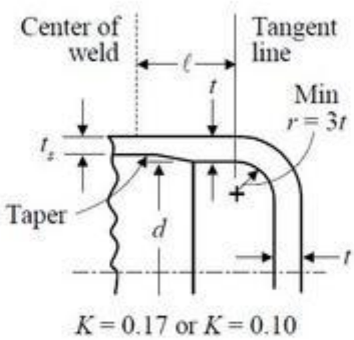
m_g = gasket factor

N = number of bolts

y = gasket or joint-contact-surface unit seating load (i.e. minimum design tightening pressure); N/mm^2 (kgf/mm^2, psi)

Values of b , G , m_g , y are to comply with recognized national or international standards as listed in 4-4-1/1.5.

FIGURE 7a
Some Acceptable Types of Unstayed Heads and Covers



a

FIGURE 7b-1
Some Acceptable Types of Unstayed Heads and Covers (2024)

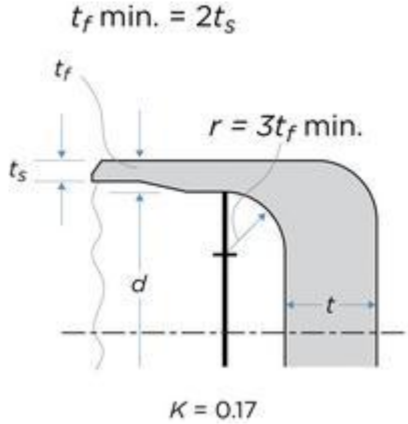


FIGURE 7b-2
Some Acceptable Types of Unstayed Heads and Covers

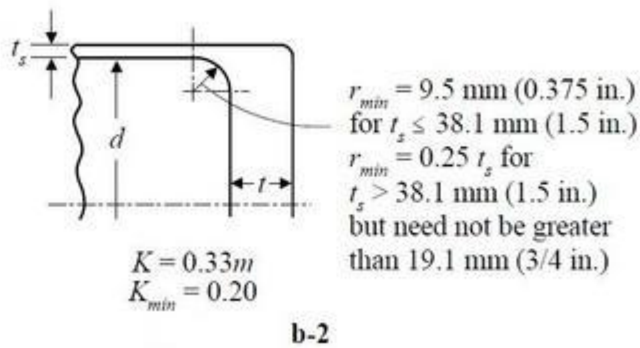


FIGURE 7c-1
Some Acceptable Types of Unstayed Heads and Covers

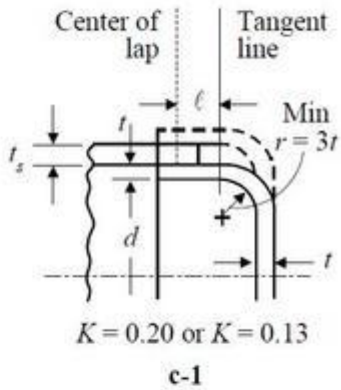
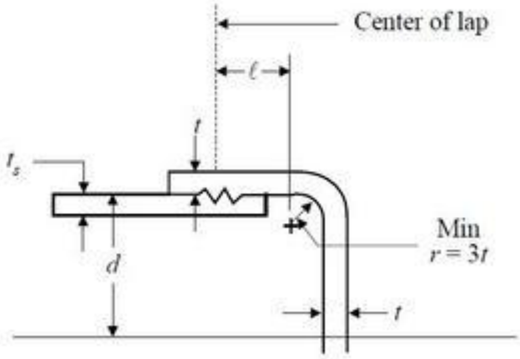


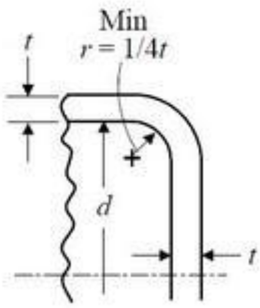
FIGURE 7c-2
Some Acceptable Types of Unstayed Heads and Covers



$K = 0.30$

c-2

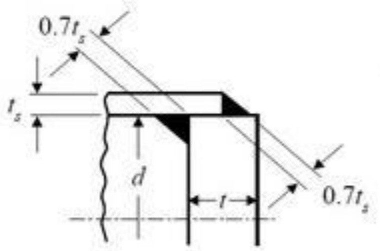
FIGURE 7d
Some Acceptable Types of Unstayed Heads and Covers



$K = 0.13$

d

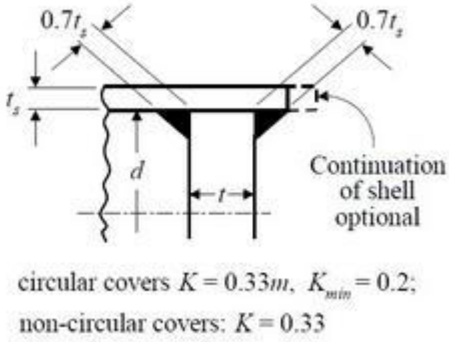
FIGURE 7e
Some Acceptable Types of Unstayed Heads and Covers



circular covers $K = 0.33m$, $K_{min} = 0.2$;
non-circular covers: $K = 0.33$

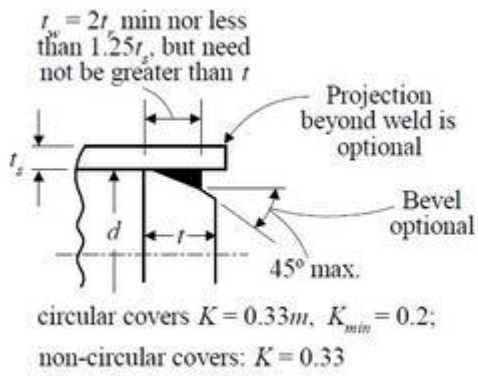
e

FIGURE 7f
Some Acceptable Types of Unstayed Heads and Covers



f

FIGURE 7g
Some Acceptable Types of Unstayed Heads and Covers



g

FIGURE 7i
Some Acceptable Types of Unstayed Heads and Covers (2024)

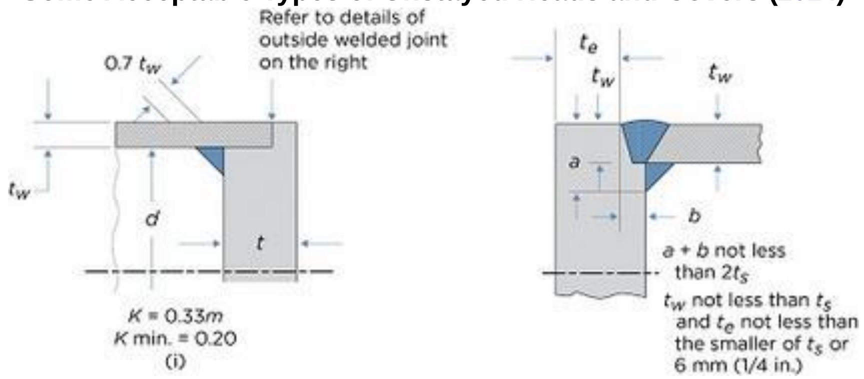


FIGURE 7j
Some Acceptable Types of Unstayed Heads and Covers

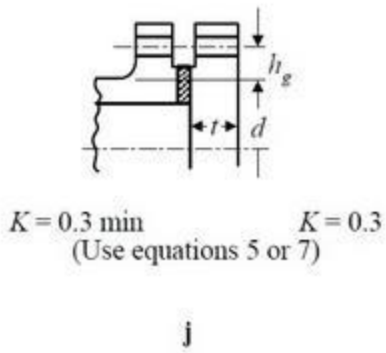


FIGURE 7k
Some Acceptable Types of Unstayed Heads and Covers

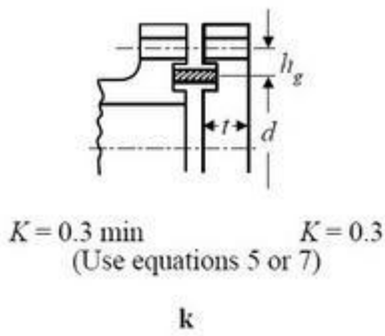


FIGURE 7m
Some Acceptable Types of Unstayed Heads and Covers

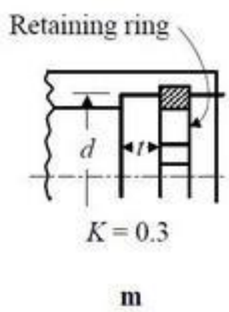


FIGURE 7n
Some Acceptable Types of Unstayed Heads and Covers

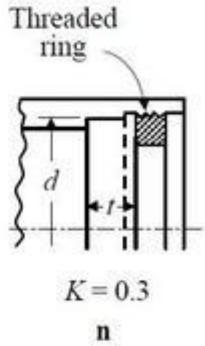


FIGURE 7o
Some Acceptable Types of Unstayed Heads and Covers

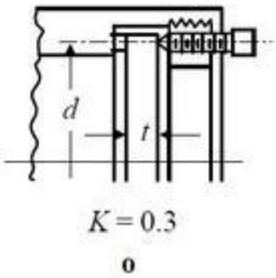


FIGURE 7p
Some Acceptable Types of Unstayed Heads and Covers

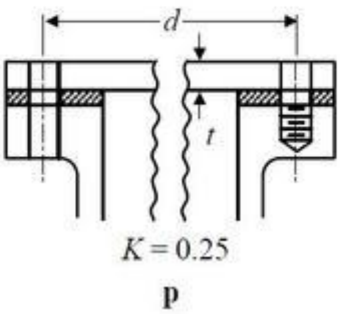


FIGURE 7q
Some Acceptable Types of Unstayed Heads and Covers

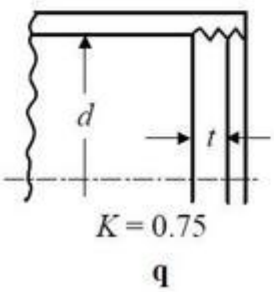


FIGURE 7r
Some Acceptable Types of Unstayed Heads and Covers (2024)

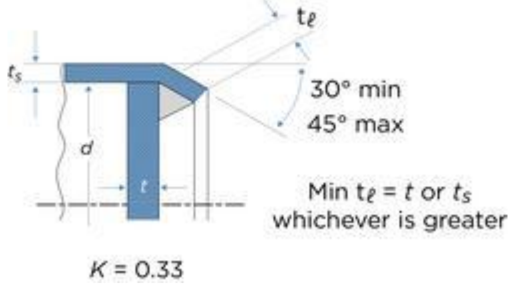


FIGURE 7s
Some Acceptable Types of Unstayed Heads and Covers

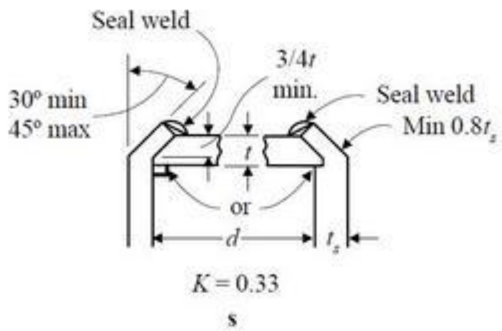


FIGURE 7t
Some Acceptable Types of Unstayed Heads and Covers

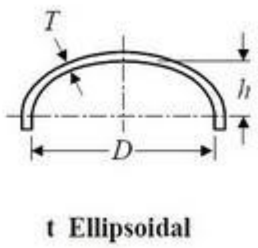
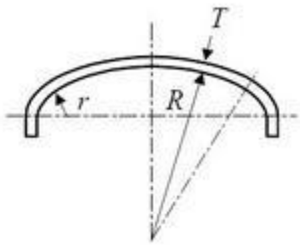
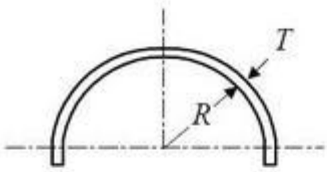


FIGURE 7u
Some Acceptable Types of Unstayed Heads and Covers



u Spherically dished (torispherical)

FIGURE 7v
Some Acceptable Types of Unstayed Heads and Covers



v Hemispherical

5.7.3 Equations for Minimum Thickness (**2024**)

The following requirements are used to evaluate the minimum required thickness for flat unstayed heads, covers, and blind flanges.

The equations in 5.7.3(b) through 5.7.3(d) consider stresses from pressure and bolt loading only. Greater thickness is necessary if deflection causes leakage at threaded or gasketed joints. In addition, equations (4) to (7) do not consider joint efficiency of welds. If welds are used to join different sections of the flat head, the allowable stress value S is to be reduced by multiplying the joint efficiency of welds E from TABLE 1.

5.7.3(a) *Standard blind flanges* (**2024**)

Circular blind flanges of ferrous materials conforming to ASME B16.5 are acceptable for the pressure-temperature ratings specified in the standard. These flanges are shown in FIGURE 7j and FIGURE 7k. Blind flanges complying with other compatible recognized national or international standards may be submitted for approval.

5.7.3(b) Circular heads (**1 July 2019**)

The minimum required thickness of flat unstayed circular heads, covers and blind flanges is to be calculated by the following equation:

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

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

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

Initial tightening conditions: $B = B_1 = (A_m + A_b) \times S_a/2$

Design conditions: $B = B_2 = 0.785G^2W + (2b \times 3.14Gm_gW)$

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 (W =0), the value for S at room temperature is to be used, and B (= B_1) 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 (= B_2) 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* (**2024**)

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:

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

$$Z = 3.4 - 2.4\,\frac{d}{D}$$

or Z = 2.5, whichever is less

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

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

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 FIGURE 7a to FIGURE 7s the values of K to be used in Equations 4, 5, 6, and 7 are to be as follows. (**2024**)

i. : $K = 0.17$ 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 specific requirement with regard to length of flange. Welding is to meet all the requirements for circumferential joints given in Section of the ABS *Rules for Materials and Welding (Part 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 at least 1:3:

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

K = 0.10 for circular heads, when the flange length ℓ is less than required in Equation 8 and the taper is at least 1:3, but the shell thickness is not less than that given in the following equation:

$t_s = 1.12 t_h \sqrt{(1.1 - Y/\sqrt{(dt_h)})}$, for a flange length of at least $2\sqrt{(dt_s)}$

ii. : $K = 0.17$ for circular and noncircular heads, forged integral with or butt-welded to the shell, pipe or header. The flange thickness is not less than two times the shell thickness, the corner radius on the inside is not less than three times the thickness of the flange and welding meets all the requirements for circumferential joints given in Section .

iii. : $K = 0.33m$ 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 $t_s \leq 38.1$ mm (1.5 in.)

$r_{\min} = 0.25 t_s$ 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 of the ABS *Rules for Materials and Welding (Part 2)*.

iv. : $K = 0.13$ for circular heads lapwelded or brazed to the shell with corner radius not less than $3t$ and ℓ not less than required by Equation 8 and where the welds meet the requirements of of the ABS *Rules for Materials and Welding (Part 2)*.

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

v. : $K = 0.30$ for circular flanged plates screwed over the end of the shell, pipe or header, with 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. : $K = 0.13$ 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 specific techniques of upsetting and spinning the end of the shell, pipe or header, such as employed in closing header ends.

vii. *through* :

$K = 0.33m$ 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 and is to be at least $0.7t_s$. The size of the weld t_w in 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 and is to be at least $0.7t_s$. The size of the weld t_w in 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. : $K = 0.33m$ 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 the details of outside welded joint are to be in accordance with the figure such that $a + b$ is not less than $2t_s$, t_w is not less than t_s, and t_e is to be at least equal to t_s but need not be more than 6.4 mm (0.25 in.). Radiographic examination is not required for any of the weld joints shown in the figure.

ix. *and* : $K = 0.3$ 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 , 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. *through* : $K = 0.3$ 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. : $K = 0.25$ for circular and noncircular covers bolted with a full-face gasket to shells, flanges or side plates.

: $K = 0.75$ 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 be subjected to ABS technical assessment and approval. Seal welding may be used, if desired.

Commentary:

Consider the note in . Minimum number of pipe threads for the threaded joint should be sufficient to withstand the expected loads. Refer to Table UG-43 of ASME BPVC Section VIII Division 1.

End of Commentary

xii. : $K = 0.33$ 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.

xiii. : $K = 0.33$ 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 (heads or portions thereof, wrapper sheets, furnace plates, side sheets, tube plates, combustion chamber plates, etc.) and curved plates with pressure on the convex side which are not self-supporting. No plates less than 8 mm (5/16 in.) in thickness is to be used in stayed surface construction.

5.9.2 Plates Supported by Stay Bars (2024)

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

$$T = p\sqrt{\frac{W}{fSK}}$$

where

T	=	minimum required thickness of the plate; mm (in.)
W	=	design pressure; bar (kgf/cm^2, psi)
p	=	maximum pitch measured between the centers of stays in adjacent 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 the plate is subjected and the method of construction, as given below:
	=	2.2 for plates under 11.1 mm (7/16 in.) with welded stays or stays screwed through the plates and ends riveted over
	=	2.1 for plates 11.1 mm (7/16 in.) and over, with welded stays or stays screwed through the plates and ends riveted over

Commentary:

For other arrangements and values of *K*, refer to ASME BPVC Section VIII Division 1 Subsection UG-47.

End of Commentary

5.9.3 Plates Supported by Stay Tubes **(2024)**

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

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

where

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

T, p, K, W, f and S are as defined in 5.9.2.

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 combustion chamber over tube plate and back sheet: mm (in.)
d	=	inside diameter of plain tube: mm (in.)

T, W, S and f are as defined in 5.9.2.

5.9.5 Stays **(2024)**

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

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

where

A_r	=	required cross sectional area of stay, mm^2 (in^2)
A	=	area supported by the stay, mm^2 (in^2)
W	=	design 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 (2024)

The following apply to all openings in shells, headers or heads except as otherwise provided in 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.).

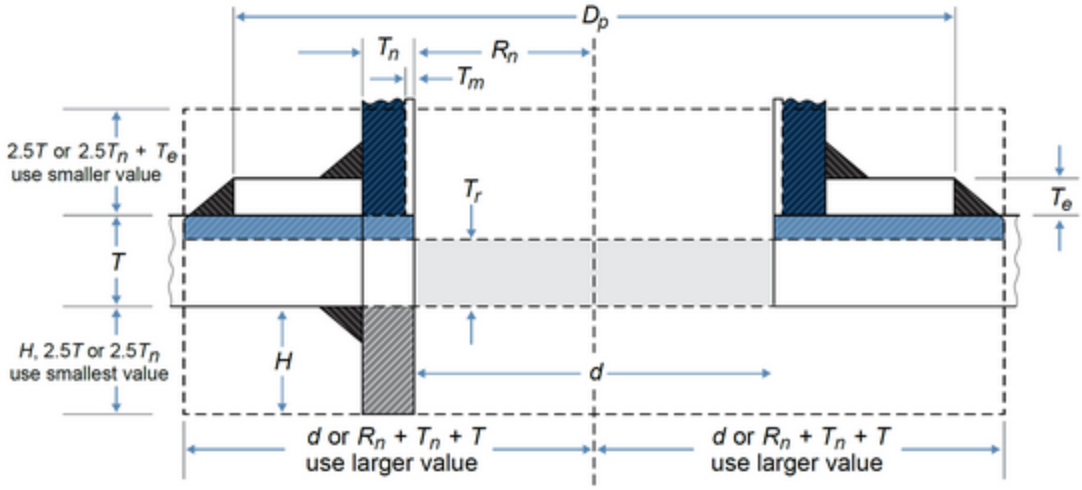
For FIGURE 8, allowable stress in nozzle is assumed to be equal or more than allowable stress in vessel. If not, area required *A* is to include sections of the shell removed and replaced by nozzle wall inserted through the shell.

Reinforcement of larger openings is to be submitted for ABS technical assessment and approval.
Commentary:

Reinforcement of larger openings in compliance with ASME BPVC Section VIII Division 1 Mandatory Appendix 1 Subsection 1-7 may be accepted subject to satisfactory review by ABS.

End of Commentary

FIGURE 8
Example of Reinforced Opening (2025)



Without Reinforcing Element

(light grey)	$= A$	$= d \times T_r \times F$	Area Required
(blue hatched)	$= A_1$	$= (ET - FT_r)(d - R_n)2 = (ET - FT_r)d$ or $= (ET - FT_r)(R_n + T_n + T - R_n)2 = (ET - FT_r)(T_n + T)2$	Area available in shell; use larger value
(dark blue hatched)	$= A_2$	$= (T_n - T_{rn})2.5T \times 2 = (T_n - T_{rn})5T$ or $= (T_n - T_{rn})2.5T_n \times 2 = (T_n - T_{rn})5T_n$	Area available in nozzle projecting outward; use smaller value
(grey hatched)	$= A_3$	$= (T_n)2H$ or $(T_n)2T_n$ or $(T_n)2T$	Area available in inward nozzle; use smallest value
(weld triangle)	$= A_4$	= Area of welds	Area available in welds

If $A_1 + A_2 + A_3 + A_4 \geq A$, opening is adequately reinforced.
If $A_1 + A_2 + A_3 + A_4 < A$, opening is not adequately reinforced so reinforcing element is to be added and/or thickness are to be increased.

With Reinforcing Element

A, A_1, A_3 same as without reinforcing element.
A_4 Area of welds considering the reinforcing element or doubler welds
$2.5T_n$ is measured from the top surface of the reinforcing element.
A_2 becomes the smaller of $(T_n - T_{rn})5T$ or $(T_n - T_{rn})(5T_{rn} + 2T_e)$.
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 Exempted from Reinforcement (**2024**)

Openings in vessels not subject to rapid fluctuations of pressure do not require reinforcement subject to the following:

i. Welded, brazed, and flued connections with a finished opening not larger than 89 mm (3.5 in.) in shells or heads with a required minimum thickness of 9.5 mm (3/8 in.) or less
ii. Welded, brazed, and flued connections with a finished opening not larger than 60 mm (2.375 in.) in shells or heads with a required minimum thickness of over 9.5 mm (3/8 in.)
iii. No two isolated unreinforced openings are to have their centers closer to each other than the sum of their diameters
iv. No two unreinforced openings, in a cluster of three or more unreinforced openings, is to have their centers closer to each other than the following:

for cylindrical shells $$(1 + 1.5\cos\theta)(d_1 + d_2)$$

for formed or flat heads		$2.5(d_1 + d_2)$

where

d_1, d_2	=	finished diameter of the two adjacent openings
θ	=	angle between the line connecting the center of the openings and the longitudinal axis of the shell

v. The centerline of an unreinforced opening is not to be closer than its finished diameter to any material used for reinforcement of an adjacent reinforced opening.

Commentary:

For exemptions of reinforcement for openings in boilers, the conditions are different. Refer to PG-32.1 of ASME BVPC Section I.

End of Commentary

See also 7.11.3 concerning reinforcement between tube holes.

7.1.3 Calculations **(2024)**

Calculations demonstrating compliance with 7.3 are to be made for all openings, except where these openings in the shell or heads comply with 7.1.2.

Tube holes arranged in a definite pattern are to comply with 7.3 when the tube holes do not comply with7.1.2.

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:

$$A = FdT_r$$

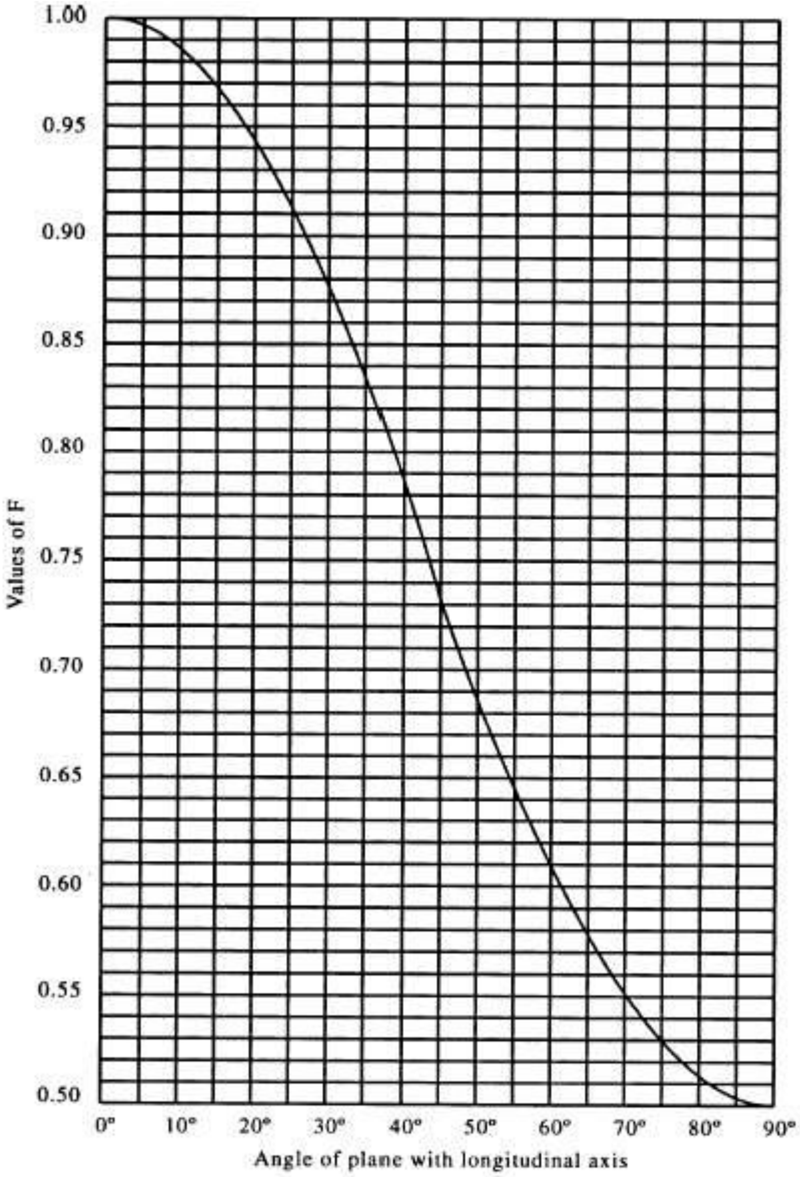
where

A	=	required reinforcement (see 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 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 3.1, 5.1, 5.3, or 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 using $M = 1$; and
- for elliptical heads as defined in 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 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 (**2024**)

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 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 5.7.3; however, the value of $2K$ to be used in the equations need not exceed 0.75 or for cases indicated in FIGURE 7b-1FIGURE 7b-2FIGURE 7e, FIGURE 7f, FIGURE 7g and FIGURE 7i, the value of 2*K* need not exceed 0.50. For the types of construction indicated in FIGURE 7j and FIGURE 7k the quantity under the square-root of Equations 5 and 7 given in 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 subject to ABS technical assessment and approval in accordance with ASME BPVC Section VIII Div. 1 UG-39(c).

7.5 Reinforcement Limits (2024)

Limits of reinforcement of a plane are the boundaries of the cross sectional area in the plane normal to the vessel wall and passing through the center of the opening within which metal are to be located to be considered as reinforcement. See FIGURE 8.

7.5.1 Limits Along Wall

The limits of reinforcement, measured along 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 (2024)

Metal within the reinforcement limits that are considered to have reinforcement value include the following.

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 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 (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 vessel wall, less corrosion allowance; mm (in.)
F	=	a factor, as defined in 7.3.1
T_r	=	the minimum required thickness of a seamless shell or head as defined in 7.3.1
T_n	=	thickness of nozzle wall, exclusive of corrosion allowance; mm (mm, in.)
d	=	diameter of the finished opening (or internal diameter of the nozzle) less corrosion allowance, in the plane under consideration; mm (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 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 (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 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

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 **(2024)**

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

$$V = dT_rS$$

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

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

where

V	=	the required strength (through load-carrying paths; see e.g. 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 TABLE 2 (SI units) andTABLE 2 (MKS units); N/mm^2 (kgf/mm^2, psi)

d, T_r, T are as defined in 7.7.1.

7.9.3 Calculating the Strength of Attachment Weld **(2024)**

Sufficient welding is to be deposited to develop the strength (through load-carrying paths, see 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 7.9.2. The weld shear areas to be used in the computation are to be in accordance with the following requirements:

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 3 (see), or the mean diameter of the weld when calculating path number 1 or 2 (see).

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 1 or 2, 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:

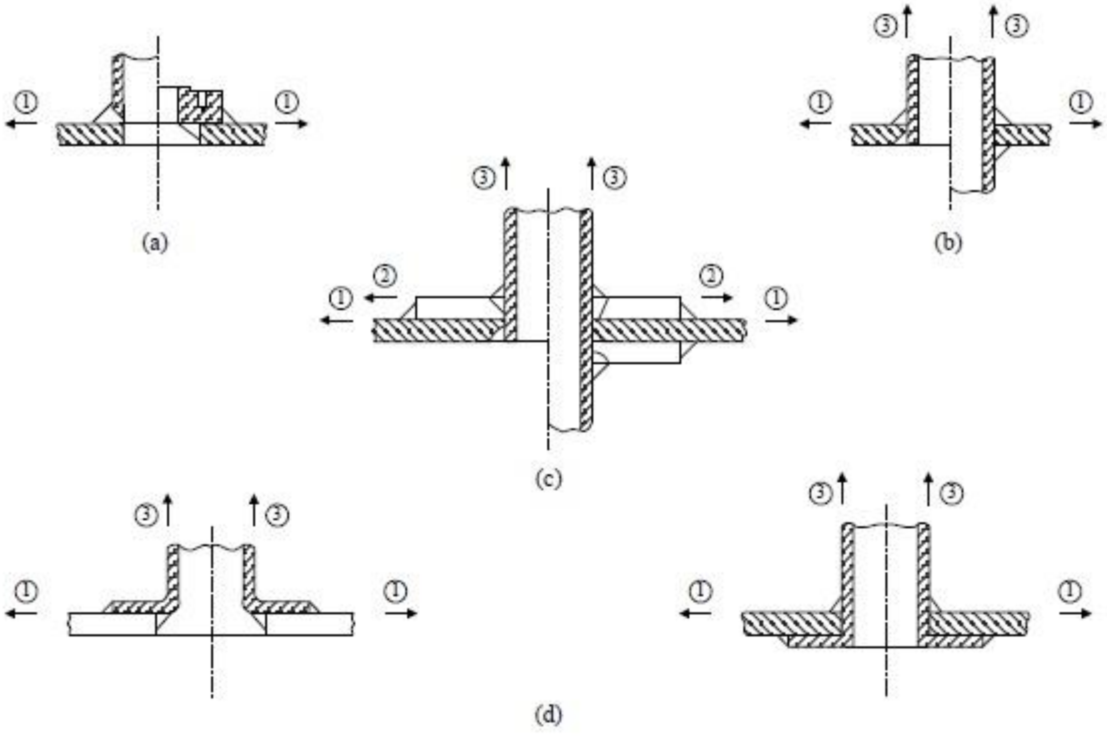
Nozzle wall shear	70%
Groove weld tension	74%
Groove weld shear	60%
Fillet weld shear	49%

Commentary:

Above is based on PW-15 of ASME BVPC Section I for Boilers. Refer to UW-15 of Section VIII Division 1 for more information on pressure vessels.

End of Commentary

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.

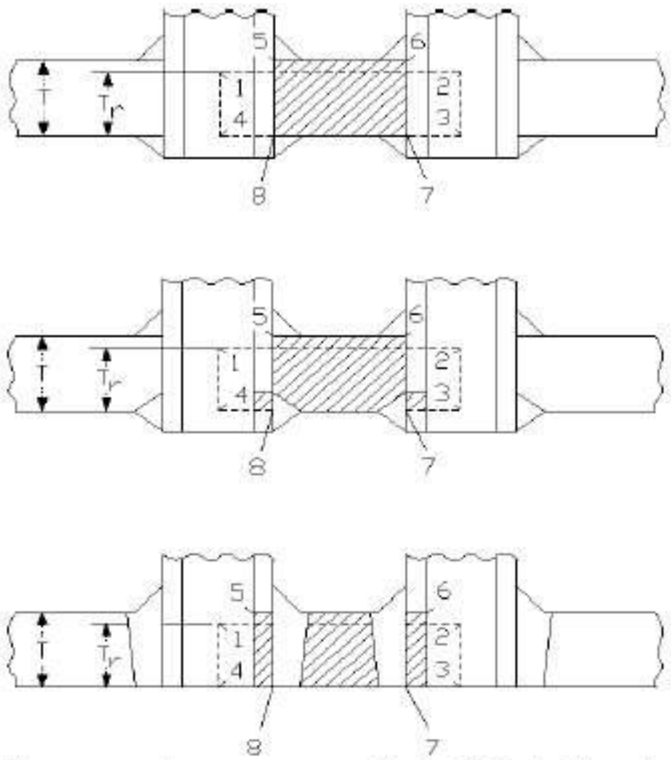
7.11.2 Reinforcement Overlapping (2024)

When adjacent openings are so spaced that their limits of reinforcement overlap, the opening is to be reinforced in accordance with 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. The available area of the head or shell between adjacent openings is to be proportioned between the two openings by the ratio of their diameters and the area of reinforcement between the two openings are to be at least equal to 50% of total required.

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 FIGURE 9 for the plane under consideration. See illustration of these requirements in 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 0.7F, in which F is a value from 4-4-1A1/Figure 9 and Tr 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 (2024)

The MAWP 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 allowable 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 TABLE 2 (SI units) and TABLE 2 (MKS units).
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 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 (2024)

The thickness of the ends of tubes strength-welded to headers or drums need not be made greater than the minimum thickness of tube wall as determined from 9.3. However, the thickness of tubes, where expanded into headers or drums, is to be not less than the minimum thickness required by 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 9.3 with e equal to zero, provided the thickness over a length of the seat plus 25 mm (1 in.) at the end of the tubes to be expanded is not less than:

- 2.40 mm (0.095 in.) for tubes 32 mm (1.25 in.) outside diameter.
- 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.
- 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.
- 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.
- 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 (2024)

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.) before flaring. 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 ABS-RL-MATL 2-4-2/7 and ABS-RL-MATL 2-4-2/9 of the ABS *Rules for Materials and Welding (Part 2)*.

13 Joint and Dimensional Tolerances

Joint and dimensional tolerances are to be in accordance with ABS-RL-MATL 2-4-2/5 of the ABS *Rules for Materials and Welding (Part 2)*.

15 Weld Tests

Welding procedure and welder/welding operator qualification tests are to be in accordance with Section ABS-RL-MATL 2-4-3 of the ABS *Rules for Materials and Welding (Part 2)*.

17 Radiography and Other Non-destructive Examination

Radiography of butt-welded seams is to be in accordance with ABS-RL-MATL 2-4-2/23 of the ABS *Rules for Materials and Welding (Part 2)*.

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 of the ABS *Rules for Materials and Welding (Part 2)*.

21 Hydrostatic Tests

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 MAWP (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 pressure or the MAWP, 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 MAWP (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 MAWP, and an inspection is to be made by the Surveyor of all joints and connections. 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.

TABLE 1
Joint Efficiencies for Welded Joints (2024)

Type of joint		Limitation	Degree of Radiography (4)		
			(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	0.70
(b)	Single welded butt joint with permanent backing strip other than those included above	None, except for circumferential butt joints having one plate offset as shown in ABS-RL-MATL 2-4-2/ FIGURE 1, thickness not to exceed 15.9 mm (0.625 in.).	0.90	0.80	0.65
(c)	Single-welded butt joint without use of permanent 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	i. Longitudinal joints not over 9.5 mm (0.375 in.) thick. ii. Circumferential joints not over 15.9 mm (0.625 in.) thick.			0.55
(e)	Single full-fillet lap joints with plug welds	i. 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). ii. Circumferential joints for attachment to shells of jackets not over 15.9 mm (0.625 in.) in thickness where distance from center of plug weld to the edge of plate is not less than 1.5 times diameter of hole for the plug			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 ABS-RL-MATL 2-4-2/23 of the ABS *Rules for Materials and Welding (Part 2)*.

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.

3 Joints attaching hemispherical heads to shells are excluded.

4 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 TABLE 2 (SI units) and TABLE 2 (MKS units). Where seamless vessel sections and heads with circumferential butt joints are not spot radiographed, they are to be designed for circumferential stress using E stress value not to exceed 0.85 . This 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 (2024)

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 BVPC Section II as applicable to Section VIII, Division 1.

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 ABS-RL-MATL 2-3-2 of the ABS *Rules for Materials and Welding (Part 2)*																				
MA	A285 Gr. A	C	310	1, 4	88.9	88.9	88.9	84.8	82	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-½Mo	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-½Mo	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-½Mo	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*				

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
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 ABS-RL-MATL 2-3-3 of the ABS *Rules for Materials and Welding (Part 2)*																				
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 ABS-RL-MATL 2-3-9 and ABS-RL-MATL 2-3-10 of the ABS *Rules for Materials and Welding (Part 2)*																				
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 ABS-RL-MATL 2-3-5 of the ABS *Rules for Materials and Welding (Part 2)*																				
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-½ 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-½ 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-½ 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	1¼Cr - ½ Mo-Si	414		117.9	115.8	111.7	108.2	106.2	104.1	102.0	99.3	96.5	*93.8*	*64.1*	*43.4*	*29.0*	*19.3*	*13.1*	*8.3*
O	A213 Gr. T12	1Cr - ½ Mo	414		113.8	113.8	113.8	112.4	110.3	108.9	106.9	105.5	102.7	*100.0*	*77.9*	*49.6*	*31.0*	*19.3*	*12.4*	*7.6*

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
P	A213 Gr. T22	2¼Cr - 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 prolonged exposure to temperatures above 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 BPVC, Section VIII, Division 1.

TABLE 2 (MKS units)
Maximum Allowable Stress Values for Ferrous Materials - kgf/mm^2 (2024)

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 BPVC Section II as applicable to Section VIII, Division 1.

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 ABS-RL-MATL 2-3-2 of the ABS *Rules for Materials and Welding (Part 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*				

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
H	A204 Gr. A	C-½Mo	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-½Mo	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-½Mo	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*	*2.77*				
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		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 ABS-RL-MATL 2-3-3 of the ABS *Rules for Materials and Welding (Part 2)*																				
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 – Section ABS-RL-MATL 2-3-9 and ABS-RL-MATL 2-3-10 of the ABS *Rules for Materials and Welding (Part 2)*																				
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 ABS-RL-MATL 2-3-5 of the ABS *Rules for Materials and Welding (Part 2)*																				
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*	*3.52*	*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-½ 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-½ 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	1¼Cr-½ Mo-Si	37.3	2	10.62	10.62	10.62	10.62	10.55	10.36	10.05	9.84	9.49	9.14	*5.77*	*3.37*				

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
N	A213 Gr. T11	1¼Cr - ½ Mo-Si	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	1Cr - ½ 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	2¼Cr - 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 prolonged exposure to temperatures above 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 BVPC, Section VIII, Division 1.

TABLE 2 (US units)
Maximum Allowable Stress Values for Ferrous Materials - ksi (2024)

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 BVPC Section II as applicable to Section VIII, Division 1.

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 ste els – Section ABS-RL-MATL 2-3-2 of the ABS *Rules for Materials and Welding (Part 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-Si	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-Si	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-Si	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*				

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
H	A204 Gr. A	C-½Mo	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-½Mo	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-½Mo	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-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*				
L*4.64*	A516 Gr. 60	C-Si	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-Si	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-Si	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 ABS-RL-MATL 2-3-3 of the ABS *Rules for Materials and Welding (Part 2)*																				
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 ABS-RL-MATL 2-3-9 and ABS-RL-MATL 2-3-10 of the ABS *Rules for Materials and Welding (Part 2)*																				
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 ABS-RL-MATL 2-3-5 of the ABS *Rules for Materials and Welding (Part 2)*																				
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-½Mo	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-½Mo	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-½Mo	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	1¼Cr - ½ Mo-Si	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	1Cr - ½Mo	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*	*1.9*	*1.1*
P	A213 Gr. T22	2¼Cr - 1Mo	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 prolonged exposure to temperatures above 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 BVPC, Section VIII, Division 1.

Chapter 6 Piping Systems

Section 7 Other Piping Systems

1 General (2024)

Part 4, Chapter 6, Section 7 (referred to as Section 4-6-7) covers requirements for piping systems not covered in Sections 4-6-4, 4-6-5 and 4-6-6. It includes hydraulic oil systems, pneumatic systems, helicopter refueling systems. and flammable gas systems, liquefied petroleum gases and ammonia refrigeration for air conditioning system. The provisions of Sections 4-6-1, 4-6-2 and 4-6-3 apply to piping systems in Section 4-6-7.

3 Hydraulic Oil Systems

3.1 Application (2024)

The requirements of 4-6-7/3 apply to all shipboard hydraulic oil systems. Hydraulic oil systems fitted in self-contained equipment not associated with propulsion and maneuvering of the vessel (e.g. a crane) and completely assembled by the equipment manufacturer need not comply with this subsection. Such hydraulic oil systems, however, are to comply with the accepted industry standards.

Hydraulic oil systems essential for the propulsion and maneuvering of the vessel are subject to further requirements. Controllable pitch propeller hydraulic system and steering gear hydraulic systems are also to comply with the requirements in Sections 4-3-3 and 4-3-4, respectively.

Hydraulic oil systems associated with remote propulsion control are to also comply with 4-9-2/5.5 for, among other requirements, duplication of hydraulic pumps. The same systems associated with propulsion machinery spaces intended for centralized or unattended operation (optional *ACC*/*ACCU*/*ABCU* notations) are also to meet the requirements of 4-9-9/9 for, among other requirements, flash point of hydraulic fluid.

3.2 Objective (2024)

3.2.1 Goals

The piping systems addressed in this section are to be designed, constructed, operated, and maintained to meet the following goals:

Goal No.	Goal
FIR 1	*prevent the occurrence of fire and explosion.*
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
PROP 1	provide sufficient thrust/power to move or maneuver the vessel when required.
POW 2	provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals as listed above.

Goal No.	Goal
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals covered in the cross-referenced Rules are also to be met.

3.2.2 Functional Requirements

In order to achieve the above-stated goals, the design, construction, and maintenance of the hydraulic oil system are to be in accordance with the following functional requirements:

Functional Requirement No.	Functional Requirements
Safety of Personnel (SAFE)	
SAFE-FR1	Be provided with means to determine level or amount of hydraulic oil in the storage tanks.
SAFE-FR2	Piping design is to mitigate hazards due to failure of joints.
SAFE-FR3	Piping and equipment are to safely contain the fluid media it conveys and able to withstand the most severe condition of coincident design pressures, temperatures, and loadings.
SAFE-FR4	Provide protective devices if the system/equipment can be subjected to a pressure more than its design pressure.
SAFE-FR5	Piping material is to be compatible with the fluid media it conveys.
Fire Safety (FIR)	
FIR-FR1	Provide means to prevent hydraulic oil from self-igniting or being ignited by flame/spark with due regard to leakages, spillage, hot surfaces and moving parts.
Materials (MAT)	
MAT-FR1	Fracture Toughness to be considered when required by design.
MAT-FR2	Tensile Properties to be considered for designing to a given load/force (tensile or compressive or shear or bending or torsion or bearing or hoop stress or buckling) a. Yield Strength b. Ultimate Tensile Strength c. Elongation d. Reduction of Area e. Modulus of Elasticity
Power Generation and Distribution (POW)	
POW-FR1 (PROP)	Be provided with sufficient sources or capacity for the starting of essential propulsion services without recharging for the starting of the main engines.

The functional requirements covered in the cross-referenced Rules are also to be met.

3.2.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3.3 Hydraulic Oil Storage Tanks

3.3.1 Location of Storage Tanks

Hydraulic oil tanks are not to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces in excess of 220°C (428°F).

3.3.2 Tank Vents (1 July 2024)

Hydraulic tank vents are to meet the requirements of 4-6-4/9. Vents from hydraulic oil tanks, other than double bottom or similar structural tanks, can be terminated in machinery and other enclosed spaces provided that their outlets are so located that overflow therefrom will not impinge on electrical equipment, heated surfaces, or other sources of ignition; see 4-6-4/9.3.4(c). Tank vents of hydraulic systems utilized for the actuation of valves located in cargo oil tanks are, however, to be terminated in the weather; see 5C-2-3/3.5.3.

3.3.3 Means of Sounding

A means of sounding is to be fitted for each hydraulic oil tank; such means is to meet the requirements of 4-6-4/11. If tubular gauge glasses are fitted to hydraulic oil tanks, they are subject to conditions indicated in 4-6-4/11.5.2(b) and 4-6-4/11.5.2(c).

3.5 Hydraulic System Components

3.5.1 Pipes and Fittings

Pipes, pipe fittings and joints are to meet the general requirements of certification in 4-6-1/7.1 (except that ABS certification is not required for all classes of hydraulic piping); materials in 4-6-2/3; and design in 4-6-2/5 subject to limitations in 4-6-7/3.5.1 TABLE 1.

TABLE 1
Pipe Joint Limitations for Hydraulic Piping (2024)

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 (3)	Types A, B & G only. For type B, ≤ 400°C (752°F) For type G, see 4-6-2/9.19 TABLE 7	Types A, B, C, D & G only. For types D, ≤ 250°C (482°F) For type G, see 4-6-2/9.19 TABLE 7	Types A, B, C, D & G only. For type G, see 4-6-2/9.19 TABLE 7
Taper-thread joint (4)	≤ 80 mm (3 in.), or ≤ 495°C (923°F), permissible pressure/size: see 4-6-2/5.5.5(a)	As for Class I	No limitation
Straight thread O-ring joint	Straight thread O-ring type fittings can be used for pipe connection to equipment such as pumps, valves, cylinders, accumulators, gauges and hoses, without size and pressure limitations. However, such fittings are not to be used for connecting sections of pipe.		
Compression couplings (5)	≤ 60 mm (2.4 in.) OD.	As for Class I	No size limitation.
Hoses	Subject to fire resistance test. See 4-6-2/5.7.3(c)	As for Class I	As for Class I
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	Subject to compliance with 4-6-2/5.8.1	Subject to compliance with 4-6-2/5.8.1
Slip-on Joints	Not permitted	Not permitted	See Note 5

Pipe sizes indicated are nominal pipe size unless specified otherwise.

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 Split flanges are not permitted in steering gear system, certified thruster systems, nor in systems which are vital to the propulsion or safety of the vessel.

Notes:

Split flanges within the thruster unit can be used in certified thruster systems subject to the following:

- The split-flanges are being used as internal components and integral part of the thruster design.
- The split flanges are designed in accordance with SAE J518 Standard and are to be used in conjunction with O-ring seals specified in SAE J120 and connecting bolts of SAE Grade 5 material or better as specified in SAE J429.
- The burst pressure of the split flanges is to be at least four (4) times the system pressure. The test report is to be submitted for review.
- The manufacturers are requested to submit their service experience to ABS for evaluation of their equipment. For example, the thruster manufacturer is to submit their service experience and declare that there have been no failures related to the internal spilt flanges used in their unit(s).

End of Commentary

4 Taper-thread joints up to 80 mm (3 in.) can be used without pressure limitation for pipe connection to equipment, such as pumps, valves, cylinders, accumulators, gauges and hoses. When such joints are used to connect sections of pipe, they are to be in accordance with limitations shown. However, hydraulic systems for the following services are to comply with the stated limitations in all respects [see 4-6-2/5.5.5(b) and 4-6-2/5.5.5(c)]:

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

5 See 4-6-2/5.9 for further limitations.

3.5.2 Hoses

Hoses are to comply with the requirements of 4-6-2/5.7 for flammable fluid service.

3.5.3 Valves

Valves are to meet the general requirements of certification in 4-6-2/7.1; materials in 4-6-2/3; and design in 4-6-2/5.11 and 4-6-2/5.13. Directional valves are to be treated as pipe fittings and are subject to pressure, temperature and fluid service restrictions specified by the manufacturers.

3.5.4 Hydraulic Accumulators

Welded hydraulic accumulators having operating pressures above 6.9 bar (7 kgf/cm^2, 100 psi) are to be certified in accordance with Section 4-4-1 as pressure vessels regardless of their diameters.

Accumulators 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 ABS 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.

Each accumulator which may be isolated from the system is to be protected by its own relief valve or equivalent. Where a gas charging system is used, a relief valve is to be provided on the gas side of the accumulator.

3.5.5 Hydraulic Power Cylinder

3.5.5(a) *General*. Hydraulic cylinders subject to Classes I and II fluid pressures and temperatures as defined in 4-6-1/5 TABLE 1 are to be designed, constructed and tested in accordance with a recognized standard for fluid power cylinders. Acceptance will be based on manufacturer's certification of compliance and on verification of permanent identification on each cylinder bearing the manufacturer's name or trademark, standard of compliance and maximum allowable working pressure and temperature. **(1 July 2025)**

3.5.5(b) *Non-compliance with a Recognized Standard*. As an Alternative to 4-6-7/3.5.5(a), hydraulic cylinders subject to Classes I and II fluid pressures and temperatures and which are not constructed to a recognized standard may be accepted based on the following: **(1 July 2025)**

i. Regardless of diameter, the design of the cylinder is to be shown to comply with one of the following:
   - A recognized pressure vessel code,
   - *Section of the Rules*. For instance, the cylinder is to have wall thickness not less than that given by equation 2 of ; and the cylinder ends are to meet the requirements of flat heads in , or
   - *Verification through burst tests*. Steel cylinders (other than cast steel) are to withstand not less than 4 times the maximum allowable working pressure, while cast steel, cast iron and nodular iron cylinders are to withstand not less than 5 times the maximum allowable working pressure.

   Documentation in this regard is to be submitted for review.
ii. Each individual unit is to be hydrostatic tested to 1.5 times the maximum allowable working pressure (2 times, for cast iron and nodular iron cylinders) by the manufacturer. Test certificate is to be submitted.
iii. Each cylinder is to be affixed with a permanent nameplate or marking bearing the manufacturer's name or trademark and the maximum allowable working pressure and temperature.

3.5.5(c) *Materials*. The materials of hydraulic power cylinders addressed in 4-6-7/3.5.5(a) and 4-6-7/3.5.5(b) above are to comply with the following: **(1 July 2025)**

i. The materials of a cylinder are to comply with the requirements of the standard or code to which the cylinder is designed and constructed. Where the design is verified though burst tests, the materials of the cylinder are to comply with or other acceptable standards.
ii. Ordinary cast iron having an elongation of less than 12% is not to be used for cylinders expected to be subjected to shock loading.
iii. Copies of certified mill test reports are to be made available to the Surveyor upon request.

3.5.5(d) *Rudder Actuators*. Rudder actuators are to comply with the material requirements of 4-3-4/3, be designed in accordance with 4-3-4/7 and to be certified by ABS in accordance with 4-3-4/19 **(1 July 2025)**

3.5.5(e) *Cylinders for Class III piping systems.* Cylinders subjected to Class III fluid pressures and temperatures can be used in accordance with the manufacturer's rating. **(1 July 2025)**

3.5.5(f) *Exemptions.* Fluid power cylinders that do not form part of the vessel's piping systems, machinery or equipment covered in Part 4 of these Rules are exempt from the requirements of 4-6-7/3.5.5. However, those fluid power cylinders which are integrated into piping systems associated with optional classification notations are to comply with the requirements of 4-6-7/3.5.5 and the applicable requirements specified in the applicable ABS Rules and Guides. **(1 July 2025)**

3.7 System Requirements

3.7.1 Fire Precautions

Hydraulic power units, including pumps and other pressurized components, with working pressure above 15 bar (225 psi) installed within machinery spaces are to be placed in separate room or rooms or shielded as necessary to prevent any oil or oil mist that may escape under pressure from coming into contact with surfaces with temperatures in excess of 220°C (428°F), electrical equipment, or other sources of ignition. Piping and other components are to have as few joints as practicable.

3.7.2 Relief Valves

Relief valves are to be fitted to protect the system from over-pressure. The relieving capacity is not to be less than full pump flow with a maximum pressure rise in the system of not more than 10% of the relief valve setting.

3.9 Hydraulic Starting

Hydraulic oil accumulators for starting the main propulsion engines are to have sufficient capacity without recharging for starting the main engines, as required in 4-6-5/9.5.1.

5 Pneumatic Systems

5.1 Application

The requirements of 4-6-7/5 apply to shipboard pneumatic systems for control and actuation services. The requirements for starting air system are in 4-6-5/9. Pneumatic systems fitted in self-contained equipment not associated with the propulsion and maneuvering of the vessel and completely assembled by the equipment manufacturer need not comply with this subsection. Such pneumatic systems, however, are to comply with the accepted practice of the industry.

5.2 Objectives **(2024)**

5.2.1 Goals

The pneumatic systems addressed in this section are to be designed, constructed, operated, and maintained to meet the following goals:

Goal No.	Goals
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
PROP 2	provide redundancy and/or reliability to maintain propulsion.
POW 2	provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.

The goals covered in the cross-referenced Rules are also to be met.

5.2.2 Functional Requirements

In order to achieve the above-stated goals, the design, construction, and maintenance of the pneumatic systems are to be in accordance with the following functional requirements:

Functional Requirement No.	Functional Requirements
Safety of Personnel (SAFE)	
SAFE-FR1	Piping and equipment are to safely contain the fluid media being conveyed and able to withstand the most severe condition of coincident design pressures, temperatures, and loadings.
SAFE-FR2	Provide protective devices if the system/equipment can be subjected to a pressure more than its design pressure.
SAFE-FR3	Provide means to remove contaminants or accumulated water from the system and in all normal vessel conditions to prevent equipment damage.
SAFE-FR4	Provide arrangements to preclude the entry of oil or other contaminants into the safety and control air systems.

Functional Requirement No.	Functional Requirements
SAFE-FR5	Reduce risk of failure of joints and to mitigate hazards upon failure.
Power Generation and Distribution (POW)	
POW-FR1 (PROP)	Be provided with sufficient sources or capacity for the starting of essential propulsion services without recharging for the starting of the main engines.
POW-FR2 (PROP)	Starting and pneumatic control systems are to be arranged and controlled to allow automatic availability and adequate independence.
Propulsion, Maneuvering and Station Keeping (PROP)	
PROP-FR1	Provide redundancy for rotating machinery in pneumatic control system to prevent loss of propulsion in case of malfunction.

The functional requirements covered in the cross-referenced Rules are also to be met.

5.2.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

5.3 Pneumatic System Components

5.3.1 Air Reservoir

Air reservoirs having a design pressure greater than 6.9 bar (7 kgf/cm^2, 100 lb/in^2) are to be certified by ABS (see 4-4-1/1.9, and for accumulators 4-6-7/3.5.4). Air reservoirs are to be fitted with drain connections effective under extreme conditions of trim. Where they can be isolated from the system safety valve, they are to be provided with their own safety valves or equivalent devices.

5.3.2 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 4-6-7/5.3.2 TABLE 2.

TABLE 2
Pipe Joint Limitations for Pneumatic Systems

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 & G For type G, see 4-6-2/9.19 TABLE 7	Types A, B, C, D & G For type G, see 4-6-2/9.19 TABLE 7	Types A, B, C, D & G For type G, see 4-6-2/9.19 TABLE 7
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.

5.3.3 Pneumatic Power Cylinders

The requirements of hydraulic cylinders in 4-6-7/3.5.5 apply also to pneumatic cylinders.

5.5 Pneumatic System Requirements

5.5.1 Pneumatic Air Source (1 July 2025)

The arrangements for the supply of compressed air to essential services are to be designed that sufficient compressed air is available to meet the total demand of the essential services at all times, including during normal operation, maintenance, and in the event of a failure of the compressed air system.

Where compressed air for general pneumatic control and actuation services or other essential services is drawn from engine starting air reservoirs, the aggregate capacity of the starting air reservoirs is to be sufficient for continued operation of these services after the air necessary for the required number of engine starts (as specified in 4-6-5/9.5.1) has been used.

For propulsion remote control purposes, pneumatic air is to be available from at least two air compressors. The starting air system, where consisting of two air compressors, can be used for this purpose. The required air pressure is to be automatically maintained. Pneumatic air supplies to safety and control systems may be derived from the same source but are to be by means of separate lines.

5.5.2 Air Quality

5.5.2(a) *General*. 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. **(2020)**

5.5.2(b) *Safety and Control Air Systems*. For requirements regarding the quality of the air supplied to safety and control air systems, see 4-9-2/5.7. **(2020)**

5.5.3 Overpressure Protection

Means are to be provided to prevent over-pressure in any part of the pneumatic system. This includes water jackets or casing of air compressors and coolers which may be subjected to dangerous over-pressure due to leakage into them from air pressure parts.