RULES FOR CLASSIFICATION

Ships

Edition July 2021

Part 4 Systems and components

Chapter 7 Pressure equipment

DNV AS

FOREWORD

DNV rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

Any comments may be sent by e-mail to *rules@dnv.com*

CHANGES – CURRENT

This document supersedes the July 2020 edition of DNVGL-RU-SHIP Pt.4 Ch.7.
The numbering and/or title of items containing changes is highlighted in red.

Changes July 2021, entering into force 1 January 2022

Topic	*Reference*	*Description*
Rebranding to DNV	All	This document has been revised due to the rebranding of DNV GL to DNV. The following have been updated: the company name, material and certificate designations, and references to other documents in the DNV portfolio. Some of the documents referred to may not yet have been rebranded. If so, please see the relevant DNV GL document. No technical content has been changed.

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.

Part 4 Chapter 7 Contents

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SECTION 1 GENERAL REQUIREMENTS

1 Classification

1.1 Application

1.1.1 Pressure equipment according to these rules are components subject to gaseous or liquid fluids with a design pressure above 0.5 bar. Pressure equipment may consist of more than one pressurized compartment.

1.1.2 The term pressure equipment in this section applies to the following components:

— pressure vessels necessary for performing the main functions listed in Pt.1 Ch.1 Sec.1 [1.2]
— other pressure vessels containing:

  — harmful fluids (toxic or corrosive)
  — fluids with flash point below 100°C
  — fluids with temperature above 220°C
  — fluids with pressure above 40 bar
  — compressed gases where

  $p_d \times V \geq 1500$ bar ltr

— boilers and hot water generators, including equipment, valves and fittings

— thermal-oil heaters, including equipment, valves and fittings

— oil or gas burners and oil or gas firing equipment.

p_d = design pressure
V = volume.

1.1.3 Pressure equipment according to [1.1.2] are subject to certification by the Society.

1.1.4 The control and monitoring systems shall be certified according to Ch.9 for the following:

— electrically heated pressure vessels
— boilers
— thermal-oil heaters
— hot and warm water generators
— oil or gas burners and oil or gas firing equipment.

1.2 Cross-references

1.2.1 Pressure equipment for liquefied gases shall meet the requirements in Pt.5 Ch.7 Sec.5.

Cargo process pressure vessels, as defined in Pt.5 Ch.7 Sec.1, shall be graded as class I pressure equipment. However, the selections of materials, qualification of welding procedures and production weld tests shall be according to the rules for classification of ships Pt.5 Ch.7 Sec.5 and Sec.6. Non-cargo process pressure vessels, as defined in the rules for classification of ships Pt.5 Ch.7 Sec.1, shall meet the requirements of Ch.7.

Boiler installations on liquefied gas carriers with gas operated machinery shall meet the requirements in the rules for classification of ships Pt.5 Ch.7 Sec.16

1.2.2 Pressure vessels for refrigerating plants shall, in addition to the requirements in this section, meet the requirements of the rules for classification of ships Pt.6 Ch.4 Sec.9 and Ch.6 Sec.6.

2 Definitions

2.1 Terms

2.1.1 A boiler is defined as a welded pressure equipment:

— In which steam is generated by the application of heat from oil or gas burners, coal, exhaust gases, etc., with a pressure above atmospheric pressure (steam generator) – the generated steam shall be used in a system outside of the steam generator.
— In which the temperature of water is raised to a temperature of >120°C at the discharge side (hot water generator) – the generated hot water shall be used in a system outside of the hot water generator.

Superheaters, economisers, re-heaters and other pressure parts including valves and fittings, connected directly to the boiler without intervening valves, shall be considered as parts of the boiler.

A steam drum shall be considered as an integral part of the boiler. It can either be connected directly to the heating surfaces or be arranged locally separated with or without intervening shut-off valves between heating surface and steam drum.

In an exhaust gas boiler the feed water or circulation water is heated up by exhaust gases to saturation temperature. The exhaust gas boiler may have an integral steam separation space/steam drum or can use the fired boiler or a steam drum arranged locally separated for separation of the steam and water. The heating surface of an exhaust gas boiler may consist of smoke tubes, plain, or finned water tubes.

Economisers are preheaters arranged in the flue gas duct of fired boilers used for preheating of feedwater without any steam produced in service. Economisers consist of plain or finned water tubes which can be disconnected from the water side of the boiler.

2.1.2 A thermal-oil heater is defined as an arrangement in which thermal oils (organic or inorganic fluids) are heated by oil or gas burners, exhaust gases or electricity to a temperature below the initial boiling point at atmospheric pressure and circulated for the purpose of heating fuel oil, or cargo, or for production of steam or hot water for auxiliary purposes.

2.1.3 A warm water generator is defined as an arrangement in which the temperature of the water is raised to a temperature of ≤120°C at the discharge side of the generator. Warm water generators are considered as pressure vessels.

2.1.4 A steam heated steam generator is a heat exchanger heated by steam with higher pressure/temperature for the production of steam at lower pressure/temperature. Steam heated steam generators are not endangered by overheating and are considered as pressure vessels.

2.1.5 Oil or gas burners and oil or gas firing equipment are used for burning liquid or gaseous fuels. They may be installed on propulsion boilers, auxiliary boilers, thermal-oil heaters, hot or warm water generators as well as inert gas generators.

2.1.6 Pressure is the pressure relative to atmospheric pressure, i.e. the gauge pressure. As a consequence, vacuum pressure is designated by a negative value.

2.1.7 The maximum allowable working pressure (MAWP) is the maximum pressure which may be safely held in normal operation of the pressure equipment.

2.1.8 The thermal oil temperature is the temperature of the thermal oil in the centre of the flow cross-section.

2.1.9 The film temperature is the wall temperature on the thermal oil side. In the case of heated surfaces, this may differ considerably from the temperature of the thermal oil.

2.1.10 The discharge temperature is the temperature of the fluid immediately at the heater outlet.

2.1.11 The return temperature is the temperature of the fluid immediately at the heater inlet,

2.2 Specifications

2.2.1 In once-through forced flow boilers, the design pressure is the pressure at the superheater outlet or, in the case of continuous flow boilers without a superheater, the steam pressure at the steam generator outlet.

2.2.2 The heating surface is that part of the boiler walls through which heat is supplied to the system, i.e.:

— the area [m^2] measured on the side exposed to fire or heating gas, or
— in the case of electrical heating, the equivalent heating surface:

$$H = \frac{P \times 860}{18,000}$$

where:

H = heating surface

P = electric power

2.2.3 The highest flue (HF) is the highest point on the side of the heating surface which is in contact with the water and which is exposed to flame radiation.

Additionally HF shall be defined by the boiler manufacturer in such a way that, after shut-down of the burner from full-load condition or reduction of the heat supply from the engine, the flue gas temperature or exhaust gas temperature respectively is reduced to a value below 400 °C at the level of the highest flue. This shall be achieved before, in case of interrupted feed water supply, the water level has dropped from the low low water level (LLWL) to a level 50 mm above HF.

The highest flue on water tube boilers with an upper steam drum is the top edge of the highest gravity tubes.

The requirements relating the highest flue do not apply to:

— water tube boiler risers up to 102 mm outer diameter
— once-through forced flow boilers
— superheaters
— flues and exhaust gas heated parts in which the temperature of the heating gases does not exceed 400°C at maximum continuous power.

The heat accumulated in furnaces and other heated boiler parts shall not lead to any inadmissible lowering of the water level due to subsequent evaporation when the burner is switched-off.

This requirement to an inadmissible lowering of the water level is met for example, if it has been demonstrated by calculation or trial that, after shut-down of the burner from full-load condition or reduction of the heat supply from the engine, the flue gas temperature or exhaust gas temperature respectively is reduced to a value below 400°C at the level of the highest flue, before, in case of interrupted feed water supply, the water level has dropped from the low low water level (LLWL) to a level 50 mm above the highest flue (HF).

The water level indicators shall be arranged in such a way that the distance measured are 50 mm above HF.

2.2.4 The sensor initiating a burner cut-off (BCO) shall be located at the low low water level (LLWL).LLWL shall be at least 150 mm above the highest flue (HF) also when the ship heels 4° to either side.

The highest flue (HF) shall remain wetted even when the ship is at list angles (athwartship, static) laid down in Ch.1.

The height of the water level is crucial to the response of the water level limiters.

The dropping time is the time taken by the water level under conditions of interrupted feed and allowable steam production, to drop from the low low water level (LLWL) to the level of the highest flue (HF).

$$T = \frac{60 \times V}{Ds \times v'}$$

where:

D_s = allowable steam output

T = dropping time

v’ = specific volume of water at saturation temperature

V = volume

The low low water level (LLWL) shall be set so that the dropping time is not less than 5 minutes.

2.3 Symbols

2.3.1 The symbols used are as given below in addition to those specifically stated in the relevant sections.

Table 1 Symbols

Symbol	*Description*	*Unit*
a	major dimension of elliptical or rectangular unsupported area	mm
a_p	diagonal pitch of holes projected on longitudinal axis	mm
a_o	diminution for calculation of out-of-roundness	mm
a_v	most probable largest combined vertical acceleration in 10^8 wave encounters(probability level $Q = 10^{-8}$)	-
A	area of reinforcement	mm²
A_c	compensating area for tube stubs	mm²
A_p	area supported by a stay	mm²
A_x	compensating area	mm²
A_σ	sectional area of a stay	mm²
A_1	sectional area of the stub projecting inside the shell	mm²
A_2	sectional area of fillet welds attaching the stub to the inside and outside of the shell	mm²
A_3	aggregate area of the orifice (safety valve – saturated steam)	mm²
A_4	aggregate area of the orifice (safety valve – superheated steam)	mm²
b	minor dimension of elliptical or rectangular unsupported area	mm
b_D	width of gasket	mm
b_p	diagonal pitch of holes projected circumferentially	mm
BCO	Burner cut-off	-
c	corrosion allowance	mm

Symbol	*Description*	*Unit*
c_1	design allowance	mm
C	factor depending on the method of supports	-
d	diameter of tube hole or opening	mm
d_a	mean inner diameter of the two openings	mm
d_c	calculation diameter of openings/tube holes	mm
d_e	diameter of the largest circle passing through points of support	mm
d_i	internal diameter of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical or non-circular openings	mm
d_k	root diameter of thread	mm
d_o	outer diameter of the branch or tube	mm
d_p	mean effective diameter of tube hole (efficiency of ligament)	mm
d_s	shank diameter of a necked-down bolt	mm
D	nominal diameter	mm
D_b	mean gasket diameter or bolt pitch circle diameter (in case of full face gasket)	mm
D_i	internal diameter	mm
D_m	mean diameter of plain furnace	mm
D_{max}	maximum mean diameter of the furnace	mm
D_{min}	minimum mean diameter of the furnace	mm
D_o	outside diameter	mm
D_s	allowable steam output	kg/h
D_C	internal diameter at the large end of the cone	mm
D_O	outside diameter of the conical section	mm
e	efficiency of ligament	-
e_g	distance between center lines of girders	mm
e_i	breadth of jointing surface (inspection openings)	mm
E	modulus of elasticity	N/mm²
f_G	coefficient for the calculation of gusset stays	-
F_g	load carried by one girder or gusset stay	N
F_B	force imposed on bolted connection by calculating pressure	N
F_D	force to close seal under service condition	N
F_{Do}	force to close seal in assembled condition	N
F'_{Do}	alternative force to close the seal in assembled condition, if $F_{Do} > F_S$	N
F_S	total load on bolted connection in service	N

Symbol	Description	Unit
F'_S	total load on bolted connection at test pressure	N
F_{So}	total load on bolted connection in assembled condition with no pressure exerted	N
F_Z	additional force due to connected piping under operating pressure	N
F'_Z	additional force due to connected piping under test pressure	
g_0	standard acceleration of gravity (9.81 m/s²)	m/s²
h	vertical distance from load point to top of pressure equipment	m
h_d	height of cylindrical portion of dished end	mm
h_D	height of gasket	mm
h_g	height of girder or gusset stay	mm
H	heating surface	m²
H_d	outside height of curvature of dished end	mm
HWL	high water level (alarm)	-
I_x	second moment of area	Nmm²
k	calculation factor for reinforced openings in spherical, cylindrical and conical shells	-
k_f	calculation factor for flat end plates	-
k_o	sealing factor for assembled condition	mm
k_1	sealing factor for service condition	mm
K	factor depending on the number of supports	-
K_C	factor taking into account the stress in the junction (conical shells)	-
K_D	sealing material deformation factor	N/mm²
K_S	factor for calculating the aggregate area of orifice for safety valves	-
l	free length between girder supports	mm
l_b	supporting length of the branch at openings	mm
l'_b	supporting length of the internal branch projection at openings	mm
l_s	supporting length of the shell at openings	mm
L	calculation length (conical section and furnace)	mm
L_b	calculation length at the branch (openings)	mm
L_s	calculation length at the shell (openings)	mm
LLWL	low low water level (lowest specified water level, burner cut-off (BCO))	-
LWL	low water level (alarm)	-
M	bending moment acting on girder at given load	Nmm
M_C	factor for calculating conical shells	-
n	number of bolts forming a connection	-

Symbol	*Description*	*Unit*
n_w	integral number of waves	-
NWL	normal water level	-
p	pressure	bar
p_c	calculating pressure	bar
p_d	design pressure	bar
p_t	test pressure	bar
P	electric power	kW
r	inside knuckle radius of tori-spherical ends	mm
r_i	inside radius of transition knuckle (conical shell)	mm
r_1	radius of the flanging at dished ends with openings	mm
R	inside radius of spherical part of tori-spherical ends	mm
R_{eH}	specified minimum upper yield stress at room temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied	N/mm^2
R_m	specified minimum tensile strength at room temperature	N/mm^2
R_{mt}	specified minimum tensile strength at calculating temperature	N/mm^2
R_{et}	specified minimum lower yield stress at calculating temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied	N/mm^2
$R_{m,100\,000}$	average stress to produce rupture in 100 000 hours at calculating temperature	N/mm^2
$R_{p0.2}$	0.2% proof stress	N/mm^2
$R_{p1.0}$	1.0% proof stress	N/mm^2
s	thickness	mm
s_a	actual thickness of the flat plate as built minus corrosion allowance	mm
s_b	thickness of the branch	mm
s_{ba}	thickness of the branch as built minus corrosion allowance	mm
s_g	thickness of girder	mm
s_m	minimum wall thickness of tube stub as calculated without corrosion allowance	mm
s_p	pitch of tubes	mm
s_{p1}	the shorter of any two adjacent pitches	mm
s_{p2}	the longer of any two adjacent pitches	mm
s_r	required thickness at the junction of the cone and the cylinder	mm
s_s	thickness of the shell as calculated	mm
s_{sa}	actual thickness of the shell as built minus corrosion allowance	mm
s_1	thickness of cylindrical shell as calculated	mm
s_2	thickness of end plate as calculated at the junction with the shell	mm

Symbol	Description	Unit
S	safety factor	-
S_K	safety factor against elastic instability	-
t_c	calculating temperature	°C
t_d	design temperature	°C
t_D	temperature difference between saturated and superheated steam	°C
T	dropping time	sec
u	percentage of out of roundness	%
v	joint efficiency	-
v′	specific volume of water at saturation temperature	m^3/kg
V	Volume (including its attachments up to the first detachable connection or up to the welding seam connecting the nozzle of the pressure equipment to the piping system)	m^3 or ltr
W	section modulus of one girder	mm^3
X	area requiring compensation at flat end plates (opening)	mm^2
X_1	coefficient considering shell and end plate thickness	-
y	factor depending on the ratio b/a	-
y_i	factor depending on the ratio b/a for calculating inspection openings	-
Y	area of reinforcement at flat end plates (openings)	mm^2
z	coefficient for section modulus	-
Z	number of teeth	-
α_C	half apex angle of the section (conical shells)	°
α_p	angle of centre line of cylinder to the centre line of diagonal holes	°
α	angle of gusset stay to longitudinal axis of the shell	°
β	shape factor for dished ends	-
φ	surface finish coefficient	-
ψ	difference between angle of slope of the adjoining parts	-
ρ	density of the fluid	t/m^3
σ_t	nominal design stress at calculating temperature	N/mm^2
ν	Poisson's ratio	-

2.4 Units

2.4.1 Unless otherwise specified the following units are used in this section:

— dimensions (lengths, diameters, thicknesses etc.): mm

— areas: mm^2 or m^2 for heating surface H
— pressures: bar
— temperatures: °C
— mechanical properties of materials (ultimate tensile strength, yield strength etc.): N/mm^2
— impact energy: J
— electric power: kW.

2.5 Pressure equipment classes

2.5.1 For rule purposes pressure equipment is graded in classes as shown in Table 2.

Table 2 Pressure equipment classes

Pressure equipment class	*I*	*II*	*III*
Steam boilers	$p_d > 3.5$	$p_d \leq 3.5$	-
Thermal oil heaters	$p_d > 10$ or $t_d > 300$	$p_d \leq 10$ and $t_d \leq 300$	-
Dust collectors, dust filters, bulk storage tanks		$p_d > 5$ or $D_o > 1000$	$p_d \leq 5$ and $D_o \leq 1000$
Fluids for pressure vessels			
Liquefied gases (propane, butane, etc.), flammable gases, flammable liquids (with flash point below 60°C), harmful fluids (toxic or corrosive)	all	–	–
Refrigerants (see Ch.6 Sec.6 [3.1])	Group 2	Group 1	–
Steam, compressed air, non-flammable gases (except refrigerants)	$p_d > 16$ or $t_d > 300$	$p_d \leq 16$ and $t_d \leq 300$	$p_d \leq 7$ and $t_d \leq 170$
Thermal oils	$p_d > 16$ or $t_d > 300$	$p_d \leq 16$ and $t_d \leq 300$	$p_d \leq 7$ and $t_d \leq 150$
Liquid fuels, lubricating oils, flammable hydraulic liquids, flammable liquids (flash point above 60°C)	$p_d > 16$ or $t_d > 150$	$p_d \leq 16$ and $t_d \leq 150$	$p_d \leq 7$ and $t_d \leq 60$
Water, non-flammable hydraulic liquids, other fluids	$p_d > 40$ or $t_d > 300$	$p_d \leq 40$ and $t_d \leq 300$	$p_d \leq 16$ and $t_d \leq 200$

Guidance note:

For pressure equipment with more than one chamber where the chambers have different pressure equipment classes, the boundaries between the chambers should fulfill the requirements of the higher class. The documentation of the pressure equipment should cover all chambers, even the chambers of pressure equipment class III.

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3 Documentation

3.1 Documentation requirements

3.1.1 Documentation shall be submitted as required by Table 3.

Table 3 Documentation requirements

Object	*Documentation type*	*Additional description*	*Info*
Pressure vessel	C010 – Design criteria	— design pressure — design temperature — volume — fluid — additional loads (if applicable) — heating surface of heat exchanger and warm water generator — heating power and discharge temperature of warm water generator — proposed set pressure of safety valve — pressure equipment class.	FI
	C020 – Assembly or arrangement drawing	Including valves and fittings.	FI
	C030 – Detailed drawing	Cross sectional and plan views. Attachments and supports.	AP
	C040 – Design analysis		FI
	M150 – Non-destructive testing (NDT) plan		FI
Propulsion boiler	C010 – Design criteria	— design pressure — design temperature — volume — heating surface — estimated evaporation — proposed set pressure of safety valves — blow-off capacity of safety valves — pressure equipment class.	FI
	C020 – Assembly or arrangement drawing	Including valves and fittings.	FI
	C030 – Detailed drawing	Including attachments and supports.	AP
	C040 – Design analysis		FI
	M150 – Non-destructive testing (NDT) plan		FI
	I200 – Control and monitoring system documentation		AP

	Z161—Operation manual		FI
Auxiliary boiler	C010 – Design criteria	— design pressure — design temperature — volume — heating surface — estimated evaporation — exhaust gas inlet and outlet temperature of exhaust gas boiler — heating power and discharge temperature of hot water generator — proposed set pressure of safety valves — blow-off capacity of safety valves — pressure equipment class	FI
	C020 – Assembly or arrangement drawing	Including valves and fittings.	FI
	C030 – Detailed drawing	Including attachments and supports.	AP
	C040 – Design analysis		FI
	M150 – Non-destructive testing (NDT) plan		FI
	I200 – Control and monitoring system documentation		AP
	Z161—Operation manual		FI
Thermal oil heater	C010 – Design criteria	— design pressure — design temperature — volume — heating surface — heating power — maximum discharge temperature — minimum flow rate — exhaust gas inlet and outlet temperature of exhaust gas heated thermal oil heater — data for the applicable thermal oil	FI
	C020 – Assembly or arrangement drawing	Including valves and fittings.	FI
	C020 – Assembly or arrangement drawing	Fire extinguishing in the heater furnace and at the exhaust gas heated thermal oil heater.	AP
	C030 – Detailed drawing	Cross sectional and plan views.	AP
	C040 – Design analysis	Calculations of maximum film temperature in the furnace tubes, in accordance with a recognized standard, e.g. DIN 4754.	FI, R
	M150 – Non-destructive testing (NDT) plan		FI
	I200 – Control and monitoring system documentation		AP

	Z161 – Operation manual		FI
	Z253 - Test procedure for quay and sea trial		AP, L
Burners	C010 – Design criteria	— heating power — fuels intended to be used.	FI
	C020 – Assembly or arrangement drawing	—	AP
	C030 – Detail drawing	— burner internal piping diagram — list of equipment	AP
	I200 – Control and monitoring system documentation	—	AP
	Z161 – Operation manual	— description of heat generation plant — start-up and shut-down sequence — specification of safety times during start-up and operation	FI
AP = For approval; FI = For information; R = On request			

3.1.2 For general requirements for documentation, see DNV-CG-0550 Sec.6.

3.1.3 For a full definition of the documentation types, see DNV-CG-0550 Sec.5.

3.1.4 For class III pressure equipment intended for water and non-flammable hydraulic fluids, documentation needs not to be submitted if the temperature of the fluid is less than 95°C. In such cases, certification shall be based on visual inspection, review of materials certificates and pressure testing witnessed by the surveyor.

Guidance note:

Even though the drawings for pressure equipment class III intended for water and non-flammable hydraulic fluids with a temperature of the fluid less than 95°C need not to be submitted for drawing approval, this pressure equipment class III has to fulfill the requirements of this chapter.

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3.1.5 Drawing approval of charge air coolers is not required. In respect to the requirements for inspection, testing and certification see Ch.3 Sec.1 Table 9.

3.2 Required compliance documentation

3.2.1 Requirements for manufacturers, materials, welding, testing and heat treatment for the different pressure equipment classes are indicated in Table 4.

Table 4 Requirements for pressure equipment classes

Class	*Approved pressure equipment manufacturer* Sec.7 [1.1.1]	*Approved material manufacturer*	*Material compliance documents*	*Welding procedure qualification* Sec.7 [1.1.2]	*Non-destructive testing* Sec.7 [4.1]	*Heat treatment*	*Visual and dimensional inspection* Sec.7 [4.5]	*Hydraulic test* Sec.7 [4.6]
I	Required	Required	See Table 5	Required	Depending on joint efficiency v	See Sec.7 [3]	Required	Required
II	Required	Required	See Table 6	Required	Depending on joint efficiency v	See Sec.7 [3]	Required	Required
III			See Table 7		Depending on joint efficiency v		Required	Required

3.2.2 Pressure equipment shall have compliance documents as required by Table 5 to Table 10. For definition of the different types of compliance documents see DNV-CG-0550 Sec.3.

Guidance note:

For materials of parts not covered by higher requirements for material compliance in Table 5 to Table 7 but directly welded to pressurised parts of the pressure equipment, e.g. doubling plates at support feet, lifting lugs, material test report (MTR) may be sufficient.

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Table 5 Compliance documents for pressure equipment class I

Component	*Compliance document type*	*Additional description*		*Issued by*	*Compliance standard*
		Condition	*Dimension*		
Pressure equipment class I	PC			Society	Rules
Plates, dished ends and heads	MC			Society	Rules
Pipes and tubes (for shells of pressure equipment and tubes of water tube boilers)	MC			Society	Rules
Stays, stay bolts and stay tubes	MC			Society	Rules
Smoke tubes (tubes subject to external pressure)	MD			Manufacturer	Rules
Tubes in heat exchanger and channel plates in plate heat exchangers	MD			Manufacturer	Rules

Flanges, nozzles and branches	MD			Manufacturer	Rules
Manhole, headhole and handhole closures	MD			Manufacturer	Rules
Reinforcement plates and discs	MD			Manufacturer	Rules
Bolts and tie rods	MD	Rm >500 N/mm²	≥M30	Manufacturer	Rules
	MD	Alloyed or heat treated	≥M16	Manufacturer	Rules
Nuts	MD	Rm >600 N/mm²	≥M30	Manufacturer	Rules
Forgings and castings	MD			Manufacturer	Rules

Table 6 Compliance documents for pressure equipment class II

Component	*Compliance document type*	*Additional description*		*Issued by*	*Compliance standard*
		Condition	*Dimension*		
Pressure equipment class II	PC			Society	Rules
Plates, dished ends and heads	MD			Manufacturer	Rules
Pipes and tubes (for shells of pressure equipment and tubes of water tube boilers)	MD			Manufacturer	Rules
Stays, stay bolts and stay tubes	MD			Manufacturer	Rules
Smoke tubes (tubes subject to external pressure)	MD			Manufacturer	Rules
Tubes in heat exchanger and channel plates in plate heat exchangers	MD			Manufacturer	Rules
Flanges, nozzles and branches	MD			Manufacturer	Rules
Manhole, headhole and handhole closures	MD			Manufacturer	Rules
Reinforcement plates and discs	MD			Manufacturer	Rules
Bolts and tie rods	MD	Rm >500 N/mm²	≥M30	Manufacturer	Rules
	MD	Alloyed or heat treated	≥M16	Manufacturer	Rules

Nuts	MD	Rm >600 N/mm²	≥M30	Manufacturer	Rules
Forgings and castings	MD			Manufacturer	Rules

Table 7 Compliance documents for pressure equipment class III

Component	*Compliance document type*	*Additional description*		*Issued by*	*Compliance standard*
		Condition	*Dimension*		
Pressure equipment class III	PC			Society	Rules
Plates, dished ends and heads	MTR			Manufacturer	Rules
Pipes and tubes (for shells of pressure equipment and tubes of water tube boilers)	MTR			Manufacturer	Rules
Stays, stay bolts and stay tubes	MTR			Manufacturer	Rules
Smoke tubes (tubes subject to external pressure)	MTR			Manufacturer	Rules
Tubes in heat exchanger and channel plates in plate heat exchangers	MTR			Manufacturer	Rules
Flanges, nozzles and branches	MTR			Manufacturer	Rules
Manhole, headhole and handhole closures	MTR			Manufacturer	Rules
Reinforcement plates and discs	MTR			Manufacturer	Rules
Bolts and tie rods	MTR	Rm >500 N/mm²	≥M30	Manufacturer	Rules
	MTR	Alloyed or heat treated	≥M16	Manufacturer	Rules
Nuts	MTR	Rm >600 N/mm²	≥M30	Manufacturer	Rules
Forgings and castings	MTR			Manufacturer	Rules

Table 8 Compliance documents for equipment, valves and fittings

Component	*Compliance document type*	*Additional description*		*Issued by*	*Compliance standard*
		Condition	*Dimension*		
Equipment, valves and fittings	PC	PN (pressure/ temperature rating)	DN >100 mm and PN >16 bar	Society	Ch.6 Sec.9 [3.2.1]

	PD	PN (pressure/ temperature rating)	DN ≤100 mm or PN ≤16 bar	Manufacturer	Ch.6 Sec.9 [3.2.1]
	PC	>120°C and designed for a specific pressure/ temperature combination	DN >100 mm and PN >16 bar	Society	Sec.7 [4.6.7]
	PD	>120°C and designed for a specific pressure/ temperature combination	DN ≤100 mm or PN ≤16 bar	Manufacturer	Sec.7 [4.6.7]
Boiler safety valves	PC			Society	
— PN: nominal pressure — DN: nominal diameter					

Table 9 Compliance documents for burners

Component	*Compliance document type*	*Additional description*		*Issued by*	*Compliance standard*
		Condition	*Dimension*		
Burner	PC			Society	Rules
Fuel oil pre-heater	PC			Society	Rules
Fuel oil cooler (MGO)	PC			Society	Rules
Pipes and tubes	MTR			Manufacturer	Rules
Fittings	MTR			Manufacturer	Rules
Equipment for alarm and safety action	PC			Society	Rules
Forced draft fans	PC	for propulsion boilers		Society	Rules

Table 10 Compliance documents for control, monitoring and safety systems

Component	*Compliance document type*	*Additional description*		*Issued by*	*Compliance standard**
		Condition	*Dimension*		
Boiler control, monitoring and safety system	PC			Society	
Thermal oil heater control, monitoring and safety system	PC			Society	

Fired water heater control, monitoring and safety system	PC			Society	
*Unless otherwise specified the certification standard is the Society's rules					

3.2.3 Gas cylinders for fixed fire extinguishing systems shall be delivered on board with a product certificate of the Society or with a certificate issued by a recognised certification authority according to national regulations based on the requirements of the design standard and marked accordingly π, UN or DOT.

3.2.4 For general requirements for certification, including definition of the certificate types, see DNV-CG-0550 Sec.4 and DNV-CG-0550 Sec.3.

4 Accumulators for hydraulic systems

4.1 Design

4.1.1 The accumulators shall be designed according to a recognised international code accepted by the Society, e.g. EN-14359, ISO 11120 or ISO 9809.

The information or documentation, as required by the standard, shall be submitted for approval.

4.1.2 Corrosion allowance shall not be less than 1 mm for accumulators made from carbon and low-ally steels.

4.2 Fabrication

4.2.1 The accumulators shall be made by a manufacturer approved by the Society for pressure equipment class I and II.

The accumulators shall be manufactured to the same standard which form basis of the design.

All materials, forming, heat treatment, prototype testing and product testing shall meet with the requirements of the same standard.

The certification of the materials shall be in accordance with Table 5, Table 6 or Table 7 *Certification requirements for pressure equipment*.

4.3 Certification

4.3.1 The accumulators shall be certified by the Society. The Society's product certificate will be issued after completion of the testing as specified in the standard.

5 Gas cylinders for fixed fire extinguishing systems

5.1 General

5.1.1 Gas cylinders under this section are defined to be mass produced seamless or welded transportable refillable pressure vessels used in fixed fire extinguishing systems.

5.1.2 Mass produced gas cylinders certified as part of a batch which are π, UN or DOT marked will be accepted for fixed fire extinguishing systems on condition the approval, manufacturing and testing procedure of the applied standard is fully complied with.

5.2 Design

5.2.1 The gas cylinders shall be designed according to a recognised international standard accepted by the Society, e.g. EN14208, EN13322, ISO 9809 or CFR 49.

5.2.2 The approval of the design shall be based on the design requirements and approval process as specified in the applied standard.

5.3 Fabrication

5.3.1 The gas cylinders shall be manufactured to the same standard which form basis of the design.

All forming, heat treatment, prototype testing and product testing shall meet with the requirements of the applied standard.

5.4 Certification

5.4.1 The gas cylinders shall be delivered on board with a product certificate according to [3.2.3].

5.4.2 When certified by the Society the design shall be approved on case by case basis or by an obtained type approval.

5.4.3 When certified by a recognised certification authority according to national regulations the gas cylinders shall be documented by means of certificates identifying the serial no. of each cylinder. The certificates shall be made available to the attending surveyor.

6 Operating instructions and signboards

6.1 General

6.1.1 Manufacturers of pressure vessels, boilers, hot or warm water generators, thermal oil heaters, oil firing equipment etc. shall supply operating and maintenance instructions and manuals together with the equipment.

6.1.2 An easily legible signboard shall be mounted at the control platform giving the most important operating instructions for boilers, hot or warm water generators, thermal oil heaters, oil firing equipment etc.

6.1.3 At the operating station for the burner a readily visible signboard shall be placed with the following instructions:

CAUTION!

NO BURNER TO BE FIRED BEFORE

THE FURNACE HAS BEEN PROPERLY PURGED

SECTION 2 MATERIALS

1 Material requirements

1.1 General

1.1.1 Materials for pressure equipment together with their valves, fittings, etc. shall meet the requirements given in the relevant chapters and sections for pressure equipment in Pt.2 Ch.2.

1.1.2 The materials to be used for the design and fabrication of the pressure equipment shall be suitable for the environmental and specific service conditions and applicable fluids. The materials shall be resistant to corrosion and wear during the intended service life time for the pressure equipment.

Guidance note:

The traditional stainless steels, including type 316 or 316L, should not be considered suitable for use in seawater systems. However, certain stainless steels with higher contents of chromium, molybdenum and nitrogen have improved resistance to localised corrosion. These steels include high molybdenum austenitic steels and ferritic austenitic (duplex) steels. Even these steels cannot be immune to attack under all situations; avoidance of stagnant seawater conditions and removal of welding oxides are some of the important factors to the successful use.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.1.3 The materials used shall have certificates according to Sec.1 Table 5 to Sec.1 Table 8.

1.2 Boilers and pressure vessels

1.2.1 Rolled steels for boilers and pressure vessels shall comply with the specifications given in Pt.2 Ch.2 Sec.3.

Killed normal strength structural steels complying with the specifications given in Pt.2 Ch.2 Sec.2 may, however, be accepted for unwelded end plates of class II and III plate heat exchangers. Killed and fine grain treated structural steels complying with the specifications given in Pt.2 Ch.2 Sec.2 may be accepted for the following welded class III pressure equipment:

— pressure vessels intended for water or non-flammable hydraulic liquids if the fluid temperature is less than 95°C
— other pressure vessels where

$$p_d < \frac{15\,000}{D_0 + 2\,000}$$

where:

p_d = design pressure

D_o = outside diameter

1.2.2 The steel grades NV 360-0A, 410-0A and 460-0A will be accepted only for pressure equipment class II and III with a material thickness of maximum 25 mm.

1.2.3 Steel grades complying with recognised national or international standards with chemical composition and mechanical properties differing from the specifications referred to above, and with minimum specified tensile strength not exceeding 550 N/mm^2, may be accepted subject to approval in each case. In such cases the values of the mechanical properties used for deriving the allowable stress shall be subject to agreement by the Society.

1.2.4 Materials for pressure equipment designed for material temperatures below 0°C shall fulfil the requirements for low temperature service in Pt.2 Ch.2 and Pt.5 Ch.7 Sec.6. Alternative concepts for the prevention of brittle fracture at low temperatures (with the exemption of applications in accordance with Pt.5 Ch.7) are subject to approval in each case.

1.2.5 Grey cast iron is in general not to be used for the following:

— class I and II pressure equipment
— class III pressure equipment where:

$$p_d > \frac{15\,000}{D_0 + 2\,000}$$

— pressure vessels containing toxic fluids and fluids with a flash point below 100°C.

p_d = design pressure

D_o = outside diameter

However, for bolted heads, covers or closures not forming a major part of the pressure equipment, grey cast iron may be used for $p_d \leq 10$ bar.

The use of grey cast iron in economisers will be subject to special consideration.

1.2.6 Nodular cast iron of the ferritic/pearlitic and pearlitic type is in general subject to the limitation of use as grey cast iron as specified in [1.2.5].

1.2.7 Nodular cast iron of the ferritic type with specified minimum elongation of 12%, shall not be used for temperatures exceeding 350°C.

1.3 Thermal-oil heaters

1.3.1 Tubes and pipes for thermal-oil heaters shall be seamless steel tubes and pipes or welded steel tubes and pipes which are approved as equivalent to seamless types.

SECTION 3 ARRANGEMENT

1 General

1.1 Access and inspection openings

1.1.1 Pressure equipment shall have openings in sufficient number and size for internal examination, cleaning and maintenance operations such as fitting and expanding of tubes.

Guidance note:

Pressure equipment in closed refrigerant circuits or in process pressure vessels for gas installation may be accepted without inspection openings.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.1.2 For size, number, type and location of openings see App.A.

1.1.3 Detachable ends or covers and suitably located, removable pipe connections may be used as inspection openings.

1.1.4 All drums, headers and other large components of boilers shall be provided with openings, adequate in number and size, to allow access for fabrication, cleaning and internal inspection.

1.1.5 Shell boilers with a shell diameter of 1400 mm or greater shall be designed to permit entry of a person and shall be provided with a manhole for this purpose.

Also boilers with a shell diameter less than 1400 mm which are capable of being entered by a person shall be provided with a manhole. Boilers with a shell diameter between 800 mm and 1400 mm shall be provided with a headhole as a minimum requirement.

1.1.6 Special consideration shall be taken to the accessibility for inspection of welded connections subjected to high bending stresses, e.g. corner welds between flat plates and cylindrical shells or furnaces and attachment welds of stays.

In case of circumferential corner welds not more than one single length equal to half the shell diameter, or a number of lengths totalling one shell diameter are hidden by tube nests, handholes for inspection of welds are sufficient.

1.1.7 In all cases it shall be possible to inspect the bottom of the shell and the longitudinal welds. Handholes are sufficient for the inspection of the boiler’s lower endplate in case of vertical shell boilers.

1.1.8 Fired boilers including exhaust gas heated boilers/economisers shall be fitted with adequate number and size of openings and facilities for internal inspection and cleaning of the flue gas and exhaust gas side.

1.2 Draining and venting

1.2.1 All pressure equipment shall be capable of being depressurised and completely emptied or drained. Particular attention shall be given to the adequate drainage of compressed air vessels.

1.2.2 Suitable connections for the execution of hydraulic pressure tests and a vent at the uppermost point shall be provided.

1.3 Positioning

1.3.1 Pressure vessels, boilers and heaters shall be installed on foundations of substantial strength and in such a position that there is sufficient access for cleaning, examination and repair anywhere on the outside.

1.4 Marking

1.4.1 Each pressure equipment shall be permanently and legibly marked on the pressure part or on a nameplate permanently attached to a principal pressure part to show its identity and origin.

1.4.2 The marking of pressure vessels shall show at least the following particulars:

— manufacturer's name and address
— type designation and serial number
— year of manufacture
— maximum allowable working pressure
— hydrostatic test pressure.

1.4.3 The marking of boilers shall show at least the following particulars:

— manufacturer's name and address
— type designation and serial number
— year of manufacture
— maximum allowable working pressure
— hydrostatic test pressure
— allowable steam production for steam generators
— maximum allowable temperature of super-heated steam provided that the steam generator is fitted with a super heater with no shut-off capability
— maximum allowable discharge temperature for hot water generators
— maximum allowable heating power for hot water generators.

1.4.4 The marking of thermal oil heaters shall show at least the following particulars:

— manufacturer's name and address
— type designation and serial number
— year of manufacture
— maximum allowable heating power
— maximum allowable working pressure
— maximum allowable discharge temperature
— minimum flow rate
— liquid capacity.

1.4.5 The marking of thermal oil expansion vessels and deaerator vessels shall show at least the following particulars:

— manufacturer's name and address
— type designation and serial number
— year of manufacture
— maximum allowable working pressure
— maximum allowable working temperature
— capacity.

For expansion vessels with an open connection to the atmosphere, the maximum allowable working pressure shall be shown on the nameplate as "0" or "Atm.", even though a gauge pressure of 2 bar is taken as the design basis.

2 Boilers

2.1 Instruments

2.1.1 All oil-fired boilers shall be provided with instrumentation permitting local surveillance.

2.2 Positioning

2.2.1 The clearance between boiler with uptake and tanks for fuel oil, lubricating oil and cargo oil and cargo hold bulkheads shall be adequate for free circulation of air to keep the temperature of the oil well below the flashpoint and to avoid unacceptable heating of the cargo.

Alternatively the tank surfaces and bulkheads shall be insulated.

Guidance note:

The following clearances are considered to be sufficient:

— Distance between fuel oil tanks or hold bulkheads to:

— flat surfaces of boilers and uptakes: 500 mm

— cylindrical surfaces of boilers and uptakes: 300 mm.

— Vertical distance from top of boiler to nearest deck: 1300 mm.

— For watertube boilers, distance between the tank top and the underside of the bottom of the combustion chamber space: 750 mm.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.2.2 If oil-fired boilers are placed in the engine casing or in the funnel, the arrangements shall be such that oil spray, in the case of leakage, will be intercepted and will not reach heated surfaces beneath. Coamings for stairs, pipe openings, etc. shall be of ample height.

Platforms shall be fitted with sufficient drains to a waste-oil tank in the double bottom. These drains shall be fitted in addition to those specified for drip trays of oil tanks and fuel-oil pump units.

2.3 Exhaust gas boiler or economisers

2.3.1 Circulation systems for exhaust gas boilers

One stand-by pump is required when forced circulation is necessary for operation of the exhaust gas boiler.

2.3.2 Feed water systems for economisers

Suitable equipment shall be fitted to prevent steam from being generated, e.g. when the feed water flow is suddenly stopped.

Guidance note:

This may take the form of a circulating line from the economiser to a feedwater tank to enable the economiser to be cooled or of a flue gas bypass enabling the economiser to be completely isolated from the gas flow.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.3.3 Soot-cleaning arrangement

Water tube exhaust gas boilers or economisers of a design where soot deposit may create a problem regarding fire hazard, e.g. exhaust gas boilers with extended surface tubes shall have a soot-cleaning arrangement for use in the operation mode. In such cases, the soot cleaners shall be equipped with automatic start and arranged for sequential operation and possibility for manual over-ride.

Guidance note:

For extended surface tubes, soot deposits may create a problem when exhaust gas velocity is less than 12 m/s at normal operating condition.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Exhaust gas collecting pipes shall be provided with drain. The drainage system shall be capable of draining all water when the water washing or water fire extinguishing system in the exhaust gas boiler or economisers are in operation.

Necessary protection shall be made, so that water cannot enter into any of the engines.

The drainage shall be led to a tank of suitable size.

3 Components and equipment in thermal-oil installations

3.1 General

3.1.1 The main inlet and main outlet pipes for thermal-oil at the fired heater and at the heater heated by exhaust gases shall have stop-valves, arranged for local manual and remote controlled operation from an easily accessible location outside the heater room.

3.1.2 Heater shall be capable of being drained and vented.

The draining and venting of heaters heated by exhaust gases shall be possible from the position outside the immediate area of installation.

3.1.3 The heater regulation and the burner management shall be capable of ensuring that, under all operating conditions, the thermal-oil temperature at no place in the heater will exceed a temperature which would cause an unacceptable rate of deterioration of the thermal-oil.

3.1.4 The plant arrangement shall ensure that the temperature of thermal-oil coming into direct contact with air will be below 50°C in order to prevent excessive oxidation.

3.1.5 Copper and copper alloys, which lead due to their catalytic effect to an increased ageing of the thermal oil, shall be avoided or oils with specific additives shall be used.

3.1.6 An expansion vessel shall be placed at a high level in the system. The space provided for expansion shall be such that the increase in the volume of the thermal oil at the maximum thermal oil temperature can be safely accommodated. The following shall be regarded as minimum requirements: 1.5 times the increase in volume for volumes up to 1000 litres, and 1.3 times the increase for volumes over 1000 litres. The volume is the total quantity of thermal oil contained in the system up to the lowest liquid level in the expansion vessel.

3.1.7 The expansion tanks shall have overflow pipes leading to the collecting tank.

3.1.8 Fast gravity discharge of the oil into a separate collecting tank shall be possible.

3.1.9 Heaters, expansion tank and pressure vessels in thermal oil systems shall be fitted with means enabling them to be completely drained.

3.1.10 Sensors for the temperature measuring and monitoring devices shall be introduced into the system through welded-in immersion pipes.

3.1.11 Grey cast iron is unacceptable for equipment items in the hot thermal oil circuit and for safety valves.

3.1.12 Notices shall be posted at the control stations of the circulating pumps stating that the pumps shall be in operation at least for 10 minutes after stop of burners.

3.2 Heaters

3.2.1 The furnace of the oil-fired thermal oil heater shall be fitted with an interface to a fixed fire-extinguishing system. Manual release shall be arranged locally and remote controlled.

3.2.2 The thermal-oil heater heated by exhaust gases shall be fitted with interfaces to a fixed fire extinguishing and a cooling system. A drenching system providing at least 5 ltr/m²/min of water may be accepted.

3.2.3 Soot cleaning arrangements shall be fitted in accordance with [2.3].

3.2.4 The exhaust gas intake shall be arranged in a way that the thermal oil cannot penetrate the engine or the turbocharger in case of a leakage in the heater, fire extinguishing or the cleaning medium cannot penetrate during heater cleaning, respectively. The drain shall be led to a suitable location.

3.2.5 The heater shall be so designed and installed that all tubes may be easily and readily inspected for signs of corrosion and leakage.

3.2.6 Fired heaters shall be provided with inspection openings for examination of the combustion chamber.

3.2.7 Heaters heated by exhaust gas shall be provided with manholes serving as inspection openings at the exhaust gas intake and outlet.

3.2.8 The thermal-oil heater shall be arranged with the possibility for bypassing the exhaust by means of damper(s).

The dampers will not be accepted as a means for controlling the temperature of the thermal-oil heaters.

The bypass may be internal or external to the heater. In either case, the arrangements shall be such that fire extinguishing in the heater is possible without stopping the propulsion of the vessel.

Guidance note:

For heaters with smooth surface heater tubes. Temperature control by means of exhaust gas dampers may be accepted on the condition that it can be shown that a minimum gas velocity of 12 m/s through the heater is maintained, throughout the control range.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.3 Expansion tank

3.3.1 All vessels, including those open to the atmosphere, shall be designed for a pressure of at least 2 bar, unless provision has to be made for a higher working pressure. Excepted from this requirement are tanks designed and dimensioned according to Hull Structures Pt.3

3.3.2 The dimensions of the expansion, overflow, drainage and venting pipes shall be applied according to Table 1.

Table 1 Nominal diameter of expansion, overflow, drainage and venting pipes depending on the output of the heater

Heater Output[kW]	*Expansion and overflow pipes Nominal diameter DN*	*Drainage and venting pipes Nominal diameter DN*
≤ 600	25	32
≤ 900	32	40
≤ 1200	40	50
≤ 2400	50	65
≤ 6000	65	80

3.3.3 The quick drainage valve shall be arranged for remote control from the machinery central control position.

3.4 Pre-pressurised systems

3.4.1 Pre-pressurised systems shall be equipped with an expansion vessel which content is blanketed with an inert gas. The inert gas supply to the expansion vessel has to be guaranteed.

3.4.2 The pressure in the expansion vessel shall be indicated and safeguarded against overpressure.

3.4.3 A pressure limiter shall be provided at the expansion vessel which gives an alarm and shuts-down and interlocks the burner at a set pressure below the set-pressure of the safety valve.

3.5 Safety arrangements

3.5.1 Each heater shall be equipped with at least one safety valve having a blow-off capacity of at least equal to the increase in volume of the thermal oil at the maximum heating power. During blow-off the pressure shall not increase above 10% over the maximum allowable working pressure.

3.6 Control and monitoring system

3.6.1 Circulation pumps and heater burners shall be arranged for start and stop from the local control panel and remote stop from an easily accessible location outside the thermal-oil heater room.

3.7 Insulation and shielding

3.7.1 All insulation shall be covered with an outer barrier, which shall be impervious to liquid. In areas and locations where pipes may be exposed to mechanical impact, the outer barrier shall be made of galvanised steel plates or aluminium plates of sufficient impact strength to resist deformations from normal wear and strain.

4 Oil or gas burner and firing equipment

4.1 General

4.1.1 The type and design of the burner and its atomizing and air turbulence equipment shall ensure virtually complete combustion of different liquid fuels intended to be burnt.

4.1.2 Equipment used, especially pumps and shut-off devices, shall be suitable for the particular application and for the fuel oils in use.

4.1.3 Burners shall be designed, fitted and adjusted in such a manner as to prevent the flame from causing damage to the surfaces or tubes of the heat generator which border the combustion space. Parts of the heat generator which might otherwise suffer damage shall be protected by refractory lining.

4.1.4 The firing system shall be arranged as to prevent the flame from blowing back into the boiler or engine room and to allow unburned fuel to be safely drained.

4.1.5 Observation openings shall be provided at suitable points on the heat generator or burner through which the ignition flame, the main flame and the lining can be observed.

4.1.6 Every burner shall be equipped with an igniter. The ignition shall be initiated immediately after purging. In the case of low-capacity burners of monoblock type (permanently coupled oil pump and fan) ignition may begin with start-up of the burner unless the latter is located in the roof of the chamber.

4.1.7 Where burners are blown through after shut-down, provision shall be made for the safe ignition of the residual oil ejected.

4.1.8 Burners, which can be retracted or pivoted, shall be provided with a catch to hold the burner in the swung out position. Additionally the requirement according to Sec.6 Table 7 shall be observed.

4.2 Fuel oil supply

4.2.1 By means of a hand-operated quick-closing shut-off device mounted at the fuel oil manifold it shall be possible to isolate the fuel supply to the burners from the pressurized fuel lines. Depending on design and method of operation a quick-closing shut-off device may also be required directly in front of each burner.

4.2.2 The equipment for fuel oil preheating shall enable the heat generator to be started up with the facilities available on board.

4.2.3 Where only steam-operated pre-heaters are present, fuel which does not require preheating has to be available to start up the burner.

4.2.4 Any controllable heat source may be used to preheat the fuel oil. Preheating with open flame is not permitted.

4.2.5 If electric pre-heaters are applied, the requirements according to Ch.8 Sec.8 [1.3.7] apply.

4.2.6 Temperature or viscosity control of the fuel shall be done automatically. For monitoring purposes, a thermometer or viscosimeter shall be fitted to the fuel oil pressure line in front of the burners.

4.2.7 The fuel oil supply temperature shall be selected so as to avoid excessive foaming, the formation of vapour or gas and also the formation of deposits on the heating surface.

4.2.8 Fuel oil circulating lines shall be provided to enable the preheating of the fuel oil prior to the start-up of the heat generators.

4.2.9 When a change is made from heavy to light oil, the light oil shall not be passed through the heater or be excessively heated (alarm system).

4.2.10 Ignition of burners shall take place at reduced fuel oil supply. Fuel oil shall not be supplied before ignition device produces sufficient energy for safe ignition.

4.2.11 For steam-atomising burners and when steam blowing is used for cleaning of the burners, effective precautions shall be taken in order to prevent fuel oil from penetrating into the steam system.

4.3 Combustion air supply

4.3.1 The boiler or heater shall ensure a sufficient air supply during all working conditions.

4.3.2 During all normal operating conditions, the air/fuel ratio and the air distribution between burners shall be such that a reliable and nearly complete combustion takes place.

4.3.3 Before ignition of first burner, the boiler shall be purged to such an extent that air quantity through the boiler is at least the greater of:

— three times the volume of the flue gas (from the burner to the chimney), or
— five times the furnace volume of the boiler.

This condition is considered as satisfied if the pre-purge is carried out for 15 s, the amount of air being equal to the air flow corresponding to the nominal output of the burner.

4.3.4 Post-purge after stopping the last burner is advised. This operation does not, however, replace the pre-purge.

4.3.5 When the boiler is installed in the same room as other large air consumers (e.g. internal combustion engines or air compressors), ventilation shall be arranged so that no disturbance in the air supply to the boiler occurs.

4.3.6 Where an installation comprises several burners supplied with combustion air by a common fan, each burner shall be fitted with a shut-off device (e.g. a flap). Means shall be provided for retaining the shut-off device in position and its position shall be indicated.

4.4 Exhaust gas ducting

4.4.1 Oil-fired boilers are in general not to have flaps or other arrangements which may interfere with the draught in funnels or uptakes.

4.4.2 Dampers in uptakes and funnels should be avoided. Any damper which may be fitted shall be so installed that no oil supply is possible when the cross-section of the purge line is reduced below a certain minimum value. The position of the damper has to be indicated at the boiler control platform.

4.4.3 Where dampers or similar devices are fitted in the air supply duct, care has to be taken to ensure that air for purging the combustion chamber is always available unless the oil supply is necessarily interrupted.

4.5 Marking

4.5.1 The following information shall be stated on a durable manufacturer's name plate attached to the burner:

— manufacturer's name and address
— type and size
— serial number
— year of manufacture
— min./max. oil flow
— fuel oils to be used
— degree of protection.

SECTION 4 GENERAL DESIGN REQUIREMENTS

1 General

1.1 Application

1.1.1 The requirements in this section apply to pressure equipment under internal and external pressure and subjected mainly to static loadings.

1.1.2 Where fatigue is considered to be a possible mode of failure, fatigue calculations is required. The calculations shall be carried out according to a recognised pressure equipment code accepted by the Society.

1.1.3 Pressure equipment subjected to external pressure shall be calculated according to Pt.5 Ch.7 Sec.22 [2.4], the Society's rules for underwater technology or a recognised international standard accepted by the Society. For calculation of furnaces, fireboxes and uptakes, see [7].

1.1.4 Parts of pressure equipment not covered by these rules, e.g. flanges and tube plates in heat exchangers, end plates in plate heat exchangers or parts having geometrical properties outside the limits of application of the calculating formulae, shall be designed and calculated according to a recognised international code accepted by the Society.

The nominal design stress shall not exceed that given in [2.5].

Strength calculations for bolts shall either be carried out in accordance with [9] or in accordance with recognized international standards accepted by the Society.

The allowable stresses for the bolts shall be as specified in [9] or as defined in the international code accepted by the Society, given that all applicable bolt and material requirements of the applied design code are fulfilled.

The use of high strength materials shall be limited to grades lower than 12.9 of the metric grades steel bolts.

1.1.5 The rules do not take into account thermal stresses. It is a condition for approval that the thermal stresses are accounted for by a sufficiently flexible construction and a sufficiently slow heating up and cooling down period.

In special cases an analysis of thermal stresses may be required to be submitted for approval.

1.1.6 For terms used in stress analysis, equivalent stress and stress limits, see Pt.5 Ch.7 Sec.4 [6.1.3].

1.1.7 Where parts of pressure equipment cannot be calculated with satisfactory accuracy and if empirical data are insufficient, strain gauge measurements and/or hydraulic burst pressure tests according to standards and procedures accepted by the Society and carried out in the presence of a surveyor, alternatively by a laboratory accepted by the Society.

Information on test pressure, testing method and results obtained shall be submitted for approval.

Numerical methods (FE-analysis) to demonstrate that the allowable stresses are not exceeded are also acceptable. The failure theory used shall be in line with the rules. The definition of the mesh, the boundary conditions, the linearization and the software used for calculation shall be described in the report submitted for approval.

2 Design criteria

2.1 Design pressure

2.1.1 The design pressure p_d is defined as the pressure at the top of the pressure equipment and shall not be less than the highest nominal set pressure of the safety valve(s).

The design pressure shall not be less than the maximum allowable working pressure.

Guidance note:

It is advised that a suitable margin should be provided above the pressure at which the pressure equipment will normally be operated to avoid unnecessary lifting of the safety valve(s).

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.2 Calculating pressure

2.2.1 The calculating pressure p_c is the pressure used for the purpose of determining the thickness of the pressure equipment section or component under consideration.

2.2.2 The calculating pressure shall be taken as the design pressure with additional pressure due to static head of the fluid exceeding 3% of the design pressure.

$$p_c = \max\left\{p_d; p_d + \left(\frac{\rho \cdot g_0 \cdot h}{100} - 0.03 \cdot p_d\right)\right\}$$

where:

g_0	=	standard acceleration of gravity (9.81 m/s²)
h	=	vertical distance from load point to top of the pressure equipment
p_c	=	calculating pressure
p_d	=	design pressure
ρ	=	density of the fluid

2.2.3 In special cases, see guidance note, the calculations are also to be carried out with a calculating pressure taking dynamic loads due to the ship's motions from wave actions into account.

The calculating pressure shall be

$$p_c = p_d + \left(\frac{\rho \cdot g_0 \cdot h}{100}\left(1 + \frac{a_v}{g_0}\right) - 0.03 \cdot p_d\right)$$

where:

a_v	=	most probable largest combined vertical acceleration in 10^8 wave encounters (probability level Q = 10^{-8})
g_0	=	standard acceleration of gravity (9.81 m/s²)
h	=	vertical distance from load point to top of pressure equipment
p_c	=	calculating pressure
p_d	=	design pressure
ρ	=	density of the fluid

Values for a_v may be as given in Pt.3 Ch.4 Sec.3, Pt.3 Ch.4 Sec.6, Pt.3 Ch.4 Sec.7 or Pt.5 Ch.7 Sec.4 [6.1.2]. When this calculating pressure is used a 15% increase in the nominal design stress as given in [2.5] will be permitted.

Guidance note:

The above calculating pressure may be determining for the scantlings of large vertical low pressure storage tanks, e.g. bulk mud and cement tanks.

Tanks for liquefied gases should meet the requirements in the rules for classification of ships: Pt.5 Ch.7 Sec.4.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.3 Other loadings

2.3.1 In the design of pressure equipment it may be necessary to take into account the effect of the following loads in addition to the calculating pressure:

— additional loads due to pressure testing
— loads from supports and connected piping
— loads from different thermal expansion
— fluctuating pressure and temperatures
— shock loads due to water hammer or surging of vessel's content.

All additional loads (load cycles, etc.) taken into account shall be specified in the documentation.

Guidance note:

The effect of loadings from supports and connected piping on the shell may be calculated according to appendix A and G of PD 5500, or another standard accepted by the Society.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.3.2 Loads due to the contents and the structural weight of the pressure equipment and to the movement of the ship and vibrations shall not give rise to stress levels above the nominal design stress in the pressure equipment's shell. Walls in the region of supports or brackets shall be fitted with doubling plates. The corners of the plates shall be rounded adequately to avoid increased welding stress. Exceptions shall be agreed with the Society.

Guidance note:

The corners of the doubling plates should be rounded by a radius not less than three times the wall thickness of the plates.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.4 Calculating temperature

2.4.1 The calculating temperature is defined as the temperature in the middle of the shell thickness. The calculating temperature shall not be taken less than the maximum temperature of the internal fluid (design temperature t_d).

2.4.2 For boilers the calculating temperature is made up of a reference temperature and in addition a temperature allowance in accordance with the Table 1 unless a lower temperature is justified by detailed calculations. The calculating temperature shall, however, not be taken less than 250°C.

Table 1 Temperature allowances

Reference temperature	*Minimum temperature allowance*		
	Unheated parts	*Heated parts subjected mainly to:*	
		convection heat	*radiant heat*
Saturation temperature at design pressure	0°C	25°C	50°C
Superheated steam temperature	15°C	35°C	50°C

The temperature allowance of unheated parts for superheated steam may be reduced to 7°C provided that special measures are taken to ensure that the calculating temperature cannot be exceeded.

For furnaces, fireboxes and other parts subjected to external pressure and to similar rates of heat transfer, the reference temperature shall be the saturation temperature at design pressure of the internal fluid and the temperature allowance as specified in Table 2. The calculating temperature shall not be taken less than 250°C.

Table 2 Calculating temperatures for heated components under external pressure

Component		*Calculating temperature t_c [°C]*
For tubes exposed to fire (firetubes)	plain tubes	saturation temperature + 4·s + 15°C
	corrugated tubes	saturation temperature + 3·s + 30°C
For tubes heated by exhaust gases		saturation temperature + 2·s + 15°C

For economiser tubes the reference temperature shall be the maximum temperature of the internal fluid and the temperature allowance shall not be less than 35°C for finned tubes and 25°C for plain tubes.

2.4.3 Drums and headers of thickness exceeding 30 mm shall not be exposed to combustion gases having an anticipated temperature exceeding 650°C, unless they are efficiently cooled by closely arranged tubes accommodated therein.

2.5 Nominal design stress

2.5.1 For carbon, carbon-manganese and low-alloy steels the nominal design stress σ_t is defined as the lowest of the following values:

For pressure equipment operating at a temperature up to and including 50°C:

$$\sigma_t = \min\left\{\frac{R_{eH}}{1.7}; \frac{R_m}{2.7}\right\}$$

For pressure equipment operating at a temperature higher than 50°C:

$$\sigma_t = \min\left\{\frac{R_{eH}}{1.7}; \frac{R_{et}}{1.6}; \frac{R_m}{2.7}; \frac{R_{m,100\,000}}{1.6}\right\}$$

where:

R_{eH}	=	specified minimum upper yield stress at room temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied
R_{et}	=	specified minimum lower yield stress at calculating temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied
R_m	=	specified minimum tensile strength at room temperature

$R_{m,100000}$ = average stress to produce rupture in 100 000 hours at calculating temperature

σ_t = nominal design stress at calculating temperature

2.5.2 For austenitic stainless steel the nominal design stress is defined as the lowest of

$$\sigma_t = \min\left\{\frac{R_{p1.0}}{1.7}; \frac{R_{p1.0,\,t}}{1.6}; \frac{R_m}{2.7}\right\}$$

where:

R_m = specified minimum tensile strength at room temperature

$R_{p1.0}$ = 1.0% proof stress at room temperature

$R_{p1.0,t}$ = 1.0% proof stress at calculating temperature

σ_t = nominal design stress at calculating temperature

2.5.3 For steel castings the nominal design stress is defined as the lowest of

$$\sigma_t = \min\left\{\frac{R_{et}}{2.1}; \frac{R_m}{3.3}; \frac{R_{m,\,100\,000}}{2.0}\right\}$$

where:

R_{et} = specified minimum lower yield stress at calculating temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied

R_m = specified minimum tensile strength at room temperature

$R_{m,100000}$ = average stress to produce rupture in 100 000 hours at calculating temperature

σ_t = nominal design stress at calculating temperature

2.5.4 For ferritic nodular cast iron with special requirements (see Pt.2 Ch.2 Sec.9 Table 3 the nominal design stress is defined as the lowest of

$$\sigma_t = \min\left\{\frac{R_{et}}{3.0}; \frac{R_m}{4.8}\right\}$$

where:

R_{et} = specified minimum lower yield stress at calculating temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied

R_m = specified minimum tensile strength at room temperature

σ_t = nominal design stress at calculating temperature

2.5.5 For grey cast iron the nominal design stress shall not exceed

$$\sigma_t = \frac{R_m}{10}$$

where:

R_m = specified minimum tensile strength at room temperature

σ_t = nominal design stress at calculating temperature

2.5.6 For copper alloys the nominal design stress shall not exceed

$$\sigma_t = \min\left\{\frac{R_m}{4}; \frac{R_{mt}}{4}; \frac{R_{p0.2}}{1.7}; \frac{R_{p0.2,\,t}}{1.6}; \frac{R_{m,\,100\,000,\,t}}{1.5}; \frac{R_{p1.0,\,100\,000,\,t}}{1.0}\right\}$$

where:

R_m	=	specified minimum tensile strength at room temperature
R_{mt}	=	specified minimum tensile strength at calculating temperature
$R_{m,100000,t}$	=	average stress to produce rupture in 100 000 hours at calculating temperature
$R_{p0.2}$	=	0.2% proof stress at room temperature
$R_{p0.2,t}$	=	0.2% proof stress at calculating temperature
$R_{p1.0,100000,t}$	=	1.0% creep strain limit at calculating temperature
σ_t	=	nominal design stress at calculating temperature

Alternatively,the nominal design stress according to a recognised code is acceptable for copper and copper alloys, if the time and temperature dependent failure mechanism is taken into account (e.g. AD-W6/2 or ASME Sec.II, Part D, Table 1B).

2.5.7 For aluminium alloys the nominal design stress shall not exceed the lowest value of:

$$\sigma_t = \min\left\{\frac{R_{et}}{1.5}; \frac{R_{mt}}{4.0}\right\}$$

where:

R_{et}	=	specified minimum lower yield stress at calculating temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied
R_{mt}	=	specified minimum tensile strength at calculating temperature
σ_t	=	nominal design stress at calculating temperature

2.5.8 Values for R_m, R_{eH}, R_{et}, $R_{p1.0}$ and $R_{m/100000}$ are given for different grades of rolled steel in Pt.2 Ch.2 Sec.3 and for steel tubes in Pt.2 Ch.2 Sec.5.

Where other materials are proposed, the values of mechanical properties to be used for deriving the nominal design stresses are subject to consideration by the Society.

If higher values for R_{et} than given in Pt.2 Ch.2 Sec.3 are used for deriving the nominal design stress, the requirements given in Pt.2 Ch.2 Sec.3 [2.4.4] shall be complied with.

2.5.9 For boilers the nominal design stress shall not exceed 170 N/mm^2 with respect to the protective magnetite layer.

Guidance note:

The mechanical properties used for deriving the nominal design stress are specified minimum values according to the material specification. If higher values are measured in material tests, these may therefore not be used to determine the design stress.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.6 Minimum thickness of shells and dished ends

2.6.1 The nominal thickness after forming of any shell or dished end shall not be less than:

For carbon and low-alloy steel:

$$s \geq 3 + \frac{D_a}{1\,500}$$

For stainless steel and non-ferrous materials (in case where a corrosion allowance is not required):

$$s \geq 2 + \frac{D_a}{1500}$$

where:

D_a	=	external diameter of the shell or the cylindrical part of the dished end
s	=	nominal thickness
		s ≥ 7 mm for boilers
		s ≥ 5 mm for carbon-manganese steels and nickel alloy steels of type C independent tanks for gas cargo and process pressure vessels
		s ≥ 3 mm for austenitic steels of type C independent tanks for gas cargo and process pressure vessels
		s ≥ 7 mm for aluminium alloys of type C independent tanks for gas cargo

2.7 Corrosion allowance

2.7.1 For carbon and low-alloy steels, the minimum corrosion allowance c shall be 1.0 mm, unless other values are specified.

For austenitic steels or titanium no corrosion allowance will in general be required.

Where adverse corrosion or erosion conditions exist a greater allowance may be required.

For pressurised parts with more than 30 mm material thickness made from carbon or carbon manganese steels the corrosion allowance can be exempted.

2.8 Tolerance and fabrication allowance

2.8.1 The calculated thicknesses according to the formulae are the minimum required.

Minus tolerance on wall thickness and a possible reduction in wall thickness due to forming shall be added to the calculated thicknesses.

For assessment of a design, e.g. reinforced openings or dished ends, the minus tolerance and fabrication allowance shall be deducted from the design wall thickness.

2.9 Joint efficiency

2.9.1 Joint efficiencies v used in the formulae in [3.2], [3.3] and [3.4] shall be taken as:

— 0.85<v≤1.0 for 100% non-destructive testing (NDT) (RT or UT)
— 0.7<v≤0.85 for spot or random NDT (RT or UT)
— v≤0.7 for visual inspection.

Joint efficiency v>0.7 can be used independent from pressure equipment class with the following limitations:

— Drums, headers and pipes (D_o > 142 mm or s > 25 mm) of water tube boilers with pd >3.5 bar shall have a joint efficiency v=1.0.
— Pressure equipment for LNG, refrigerant group 2 and toxic fluids shall have a joint efficiency v=1.0.
— Pressure equipment made from carbon and carbon-manganese steels with a specified minimum tensile strength >550 N/mm^2 shall have a joint efficiency v=1.0.

Joint efficiency v≤0.7 is limited to pressure equipment class III

— Pressure vessels of pressure equipment class III made from carbon and carbon-manganese steels and calculated with a joint efficiency v≤0.7 shall have a specified minimum tensile strength ≤460 N/mm^2.

2.9.2 For the scope of NDT depending on the joint efficiency see Sec.7 [4.1].

3 Shells, headers and tubes

3.1 Conditions

3.1.1 The formulae given in [3.2], [3.3] and [3.4] are based on the following conditions:

— The ratio of the outside radius to the inside radius does not exceed 1.5.
— In the case of shells consisting of sections of different thicknesses, the median lines of the sections shall be in line with each other at each longitudinal joint within the limits of tolerances specified in Sec.7 [2.3] (see Figure 1).

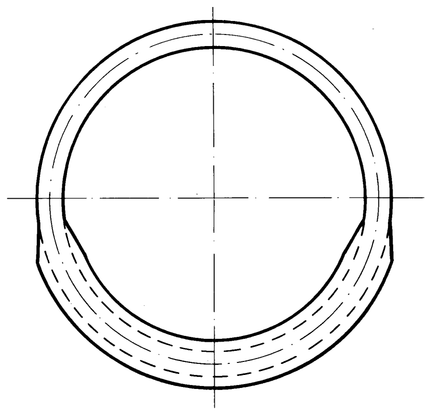


Figure 1 Shell section

3.2 Cylindrical shells

3.2.1 The thickness of a cylindrical shell shall not be less than:

$$s \geq \frac{p_c \cdot D_o}{20 \cdot \sigma_t \cdot v + p_c} + c$$

where:

c	=	corrosion margin/allowance see [2.7]
D_o	=	outside diameter
p_c	=	calculating pressure
s	=	thickness
v	=	joint efficiency see [2.9]
σ_t	=	nominal design stress at calculating temperature

3.3 Spherical shells

3.3.1 The thickness of a spherical shell shall not be less than:

$$s \geq \frac{p_c \cdot D_o}{40 \cdot \sigma_t \cdot v + p_c} + c$$

where:

c	=	corrosion margin/allowance see [2.7]
D_o	=	outside diameter
p_c	=	calculating pressure
s	=	thickness
v	=	joint efficiency see [2.9]
σ_t	=	nominal design stress at calculating temperature

3.4 Conical shells of circular sections

3.4.1 The thickness of a conical shell shall not be less than:

$$s \geq \frac{p_c \cdot D_c}{20 \cdot \sigma_t \cdot v - p_c} \frac{1}{\cos\alpha_c} + c$$

where:

c	=	corrosion margin/allowance see [2.7]
D_C	=	internal diameter at the large end of the cone
p_c	=	calculating pressure
s	=	thickness
v	=	joint efficiency see [2.9]
α_C	=	half apex angle of the section
σ_t	=	nominal design stress at calculating temperature

3.4.2 The formula in [3.4.1] applies only if the half apex angle α_C does not exceed 75° and the thickness s obtained is less than one sixth of the external diameter at the large end of the cone.

3.4.3 Conical shells may be constructed of several ring sections of decreasing thickness and the formula in [3.4.1] shall be applied to each section.

3.4.4 The thickness of the large end of a cone/cylinder or cone/cone junction and adjoining parts of the shells within a distance L from the junction shall be determined by the following formula (for dimensions see Figure 2):

$$L = 0.5\sqrt{\frac{D_0(s-c)}{\cos\psi}}$$

$$s \geq \frac{p_c \cdot D_o \cdot K_C}{20 \cdot \sigma_t \cdot v} + c + c_1$$

$$c_1 = \left\{c_1 = 0 \text{ mm for } \frac{s-c}{D_0} \geq 0.005\,;\ c_1 = 1 \text{ mm for } \frac{s-c}{D_o} < 0.005\right\}$$

Values of K_C are given in Table 3 as a function of ψ and r_i/D_O.

c	=	corrosion margin/allowance see [2.7]

D_O	=	outside diameter of the conical section
K_C	=	factor taking into account the stress in the junction
L	=	calculation length
p_c	=	calculating pressure
r_i	=	inside radius of transition knuckle $r_i = 0.01 \times D_C$ in the case of butt welded junctions
s	=	thickness
v	=	joint efficiency see [2.9]
α_C	=	half apex angle of the section
ψ	=	difference between angle of slope of the adjoining parts
σ_t	=	nominal design stress at calculating temperature

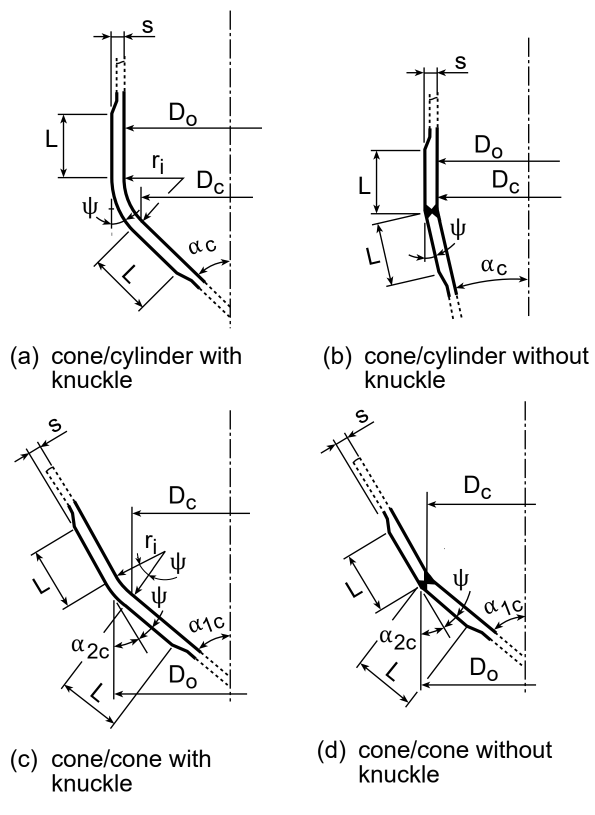


Figure 2 Junction arrangements

The thickness of the junction or knuckle and the adjacent parts shall not be less than that for the cone determined by the formula in [3.4.1].

If the difference in angle of slope exceeds 30°, welded junctions are not permitted. In these cases, knuckle connections with a minimum inside radius r_i of 0.06 D_O shall be applied.

Table 3 Values of K_C as a function of Ψ and r_i/D_o

ψ	*Values of K_C for r_i / D_O for ratios of*								
	0.01	*0.06*	*0.08*	*0.10*	*0.15*	*0.20*	*0.30*	*0.40*	*0.50*
10°	0.70	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
20°	1.00	0.70	0.65	0.60	0.55	0.55	0.55	0.55	0.55
30°	1.35	0.90	0.85	0.80	0.70	0.65	0.55	0.55	0.55
45°	2.05	1.30	1.20	1.10	0.95	0.90	0.70	0.55	0.55
60°	3.20	2.00	1.75	1.60	1.40	1.25	1.00	0.70	0.55
75°	6.80	3.85	3.50	3.15	2.70	2.40	1.55	1.00	0.55

3.4.5 The thickness of conical sections having a half apex angle of more than 75° shall be determined as for a flat plate.

3.4.6 Cone and cylinder forming a junction at the small end of a cone shall have the thickness of the adjoining parts determined by

$$s_r = M_c \times s$$

where:

M_C	=	factor for calculating as a function of the ratio p_c/σ_t x v (see Figure 3)
s	=	thickness of the cylinder determined by formula in [3.2.1]
s_r	=	required thickness at the junction of the cone and the cylinder

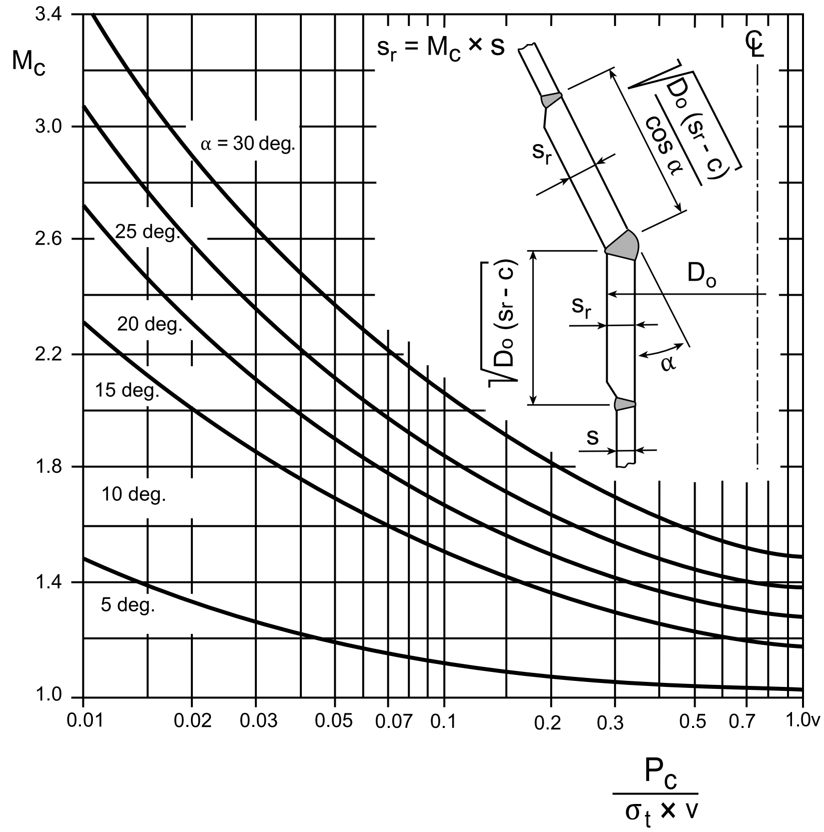


Figure 3 Values of M_C for small end cone-cylinder junction

The above formula applies only for junctions with half apex angles of the cone less than 30°.
In no case is s_r to be less than the thickness for the cone determined by the formula in [3.4.1]. The increased cylinder thickness s_r shall extend a minimum distance $\sqrt{D_o \cdot (s_r - c)}$ from the junction and the increased cone thickness s_r shall extend a minimum distance $\sqrt{\frac{D_o \cdot (s_r - c)}{\cos\alpha_c}}$ from the junction.

D_O	=	outside diameter of the conical section
c	=	corrosion allowance
s_r	=	required thickness at the junction of the cone and the cylinder
α_C	=	half apex angle of the section (conical shells)

Cone or cylinder connections at the small end of cones with half apex angles exceeding 30° shall be manufactured by means of knuckle transitions. The thickness of the knuckle will be considered in each case.

3.5 Tubes subjected to internal pressure

3.5.1 The wall thickness of straight tubes with an outer diameter d_o ≤ 127 mm shall not be less than:

$$s \geq \frac{p_c \cdot d_o}{20 \cdot \sigma_t + p_c} + c$$

where:

c	=	corrosion allowance c = 0 mm for stainless steel and non-ferrous materials c = 1 mm for carbon and low alloy steels c = 2.5 mm for boiler tubes used in boilers without adequate feed water treatment and degassing
d_o	=	outer diameter of the tube
p_c	=	calculating pressure
s	=	wall thickness
σ_t	=	nominal design stress at calculating temperature.

Welded tubes shall be manufactured and tested with a joint efficiency of v = 1.0.

3.5.2 The thickness for boiler, superheater, re-heater and economiser tubes, however, shall in no case be less than the values given in Table 4.

Table 4 Minimum thickness of boiler, superheater, re-heater and economiser tubes under internal pressure

Outside diameter of tube (mm)	*Minimum thickness (mm)*
$d_o \leq 38$	1.75
$38 < d_o \leq 51$	2.16
$51 < d_o \leq 70$	2.40
$70 < d_o \leq 76$	2.60
$76 < d_o \leq 95$	3.05
$95 < d_o \leq 102$	3.28
$102 < d_o \leq 127$	3.50

3.5.3 Where tubes are bent, the thickness of the thinnest part of the tubes shall not be less than the calculated thickness, unless it can be demonstrated that the method of bending results in no decrease in strength at the bend as compared with the straight tube. In connection with any new method of bending, the manufacturer shall prove that this condition is satisfied.

3.5.4 Tubes strength welded to tube plates will be specially considered with respect to sufficient thickness for sound welding.

3.6 Tubes subjected to external pressure

3.6.1 The wall thickness of tubes with outside diameter 100 mm and less shall not be less than:

$$s \geq \frac{p_c \cdot d_o}{16 \cdot \sigma_t} + c$$

where:

c	=	corrosion allowance
d_o	=	outer diameter of the branch or tube
p_c	=	calculating pressure
s	=	thickness
σ_t	=	nominal design stress at calculating temperature

3.6.2 For corrosion allowance shall be as given in [3.5.2]. For additional thickness due to minus tolerances and bending, see [3.5.3].

3.6.3 The maximum external design pressure of boiler tubes depending on the outside tube diameter and the nominal wall thickness shall not be higher than given in Table 5.

Table 5 Maximum external design pressure for boiler tubes

Maximum outside diameter of tube (mm)	*Nominal wall thickness of tube (mm)*				
	2.9	*3.2*	*3.6*	*4.0*	*4.5*
	Maximum external design pressure (bar)				
51	11.0	15.0	21.0		
57	10.0	13.5	18.0	22.0	
63.5	9.0	12.5	16.0	21.0	
70	8.0	11.0	15.0	19.5	
76.1		10.0	13.5	17.5	21.0
82.5		9.0	12.5	16.0	19.5
88.9		8.5	11.5	15.0	18.0

For stay tubes, see [8].

3.7 Heat exchanger tubes

3.7.1 The wall thickness of heat exchanger tubes shall be capable to withstand all applicable design loads and design requirements resulting from e.g.

— internal pressure
— external pressure
— buckling due to axial tube stress (pressure and/or restrain of thermal expansion)
— requirement due to sufficient tubesheet/tube joining (e.g. by expanding, welding, brazing).

Calculation according to [3.5] and [3.6] is applicable for heat exchanger tubes where only internal and external pressure shall be taken into consideration.

For heat exchanger tubes where buckling due to axial stress has to be taken into consideration, a recognised pressure equipment code accepted by the Society shall be used (e.g. EN13445, AD2000, PD5500, ASME VIII Div.1) for all design loads and design requirements, whereas the nominal design stress shall not exceed that given in [2.5].

3.7.2 A general allowance for corrosion and wear is not required for the heat exchanger tubes unless environmental conditions depending on the specific fluids and/or abrasive flow conditions require special consideration for corrosion and/or wear. In this case the allowance shall be especially specified by the manufacturer.

3.7.3 Where tubes are bent, the thickness of the thinnest part of the tubes shall not be less than the calculated thickness, unless it can be demonstrated that the method of bending results in no decrease in strength at the bend as compared with the straight tube. In connection with any new method of bending the manufacturer shall prove that this condition is satisfied.

3.8 Scantlings of boiler shells with set in end plates

3.8.1 The thickness of the cylindrical shell shall be determined in accordance with the requirements in [3.2.1].

For drums and headers in watertube boilers, the efficiency of ligaments between tube holes shall be taken in accordance with [3.9].

For shell boilers where set-in end plates are used, see Figure 15, the thickness of the shell plates within a distance 250 mm from the end plate is, however, not to be less than determined from the following formula:

$$s_1 \geq \frac{p_c \cdot D_o}{20 \cdot \sigma_t \cdot X_1 + p_c} + c$$

where:

c	=	corrosion allowance
D_o	=	outside diameter of the shell or shell section
p_c	=	calculating pressure
s_1	=	thickness of cylindrical shell as calculated without corrosion allowance
s_2	=	thickness of end plate as calculated at the junction with the shell without corrosion allowance
X_1	=	coefficient considering ratio of shell and end plate thickness
		X_1 = 0.8 for $(s_2\text{-}c)/(s_1\text{-}c) \geq 1.4$
		X_1 = 1.0 for $(s_2\text{-}c)/(s_1\text{-}c) \leq 1.0$
σ_t	=	nominal design stress at calculating temperature

For intermediate values of $(s_2\text{-}c)/(s_1 - c)$ the values of X_1 shall be found by linear interpolation.

The required shell thickness shall be obtained through an iteration process.

3.9 Efficiency of ligaments between tube holes

3.9.1 When drilling holes parallel to the axis, the efficiency e of ligament is given by:

— for equal spacing of holes

$$e = \frac{s_p - d_p}{s_p}$$

— for irregular spacing of holes

$$e = \frac{s_{p1} + s_{p2} - 2 \cdot d_p}{s_{p1} + s_{p2}}$$

where:

d_p	=	mean effective diameter of tube hole
e	=	efficiency of ligament
s_p	=	pitch of tubes holes
s_{p2}	=	the longer of any two adjacent pitches
s_{p1}	=	the shorter of any two adjacent pitches

For irregular spacing, the value of the double pitch (s_{p1} + s_{p2}), giving the lowest efficiency, shall be applied. The value of one pitch is in no case to be taken as being greater than twice the other pitch.

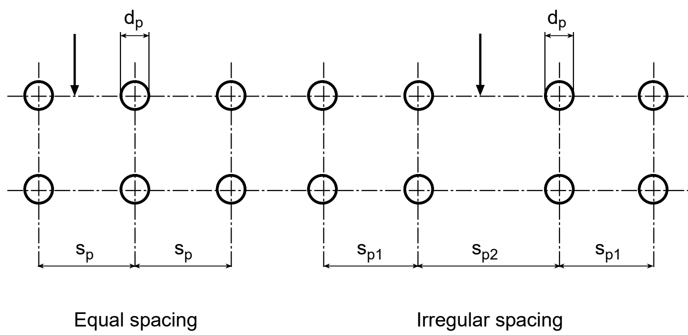


Figure 4 Parallel drilling

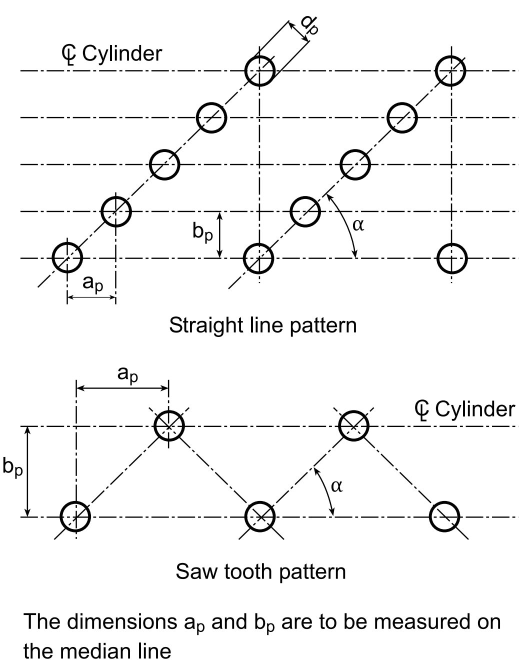


Figure 5 Diagonal drilling

3.9.2 Provided that the spacing between holes, in the case of a circumferential drilling, gives an efficiency of ligaments, calculated according to the formulae in [3.9.1], less than one half of the efficiency of longitudinal ligaments, twice the efficiency of circumferential ligaments shall be used. The pitch of tubes for circumferential drilling shall be measured along the median line.

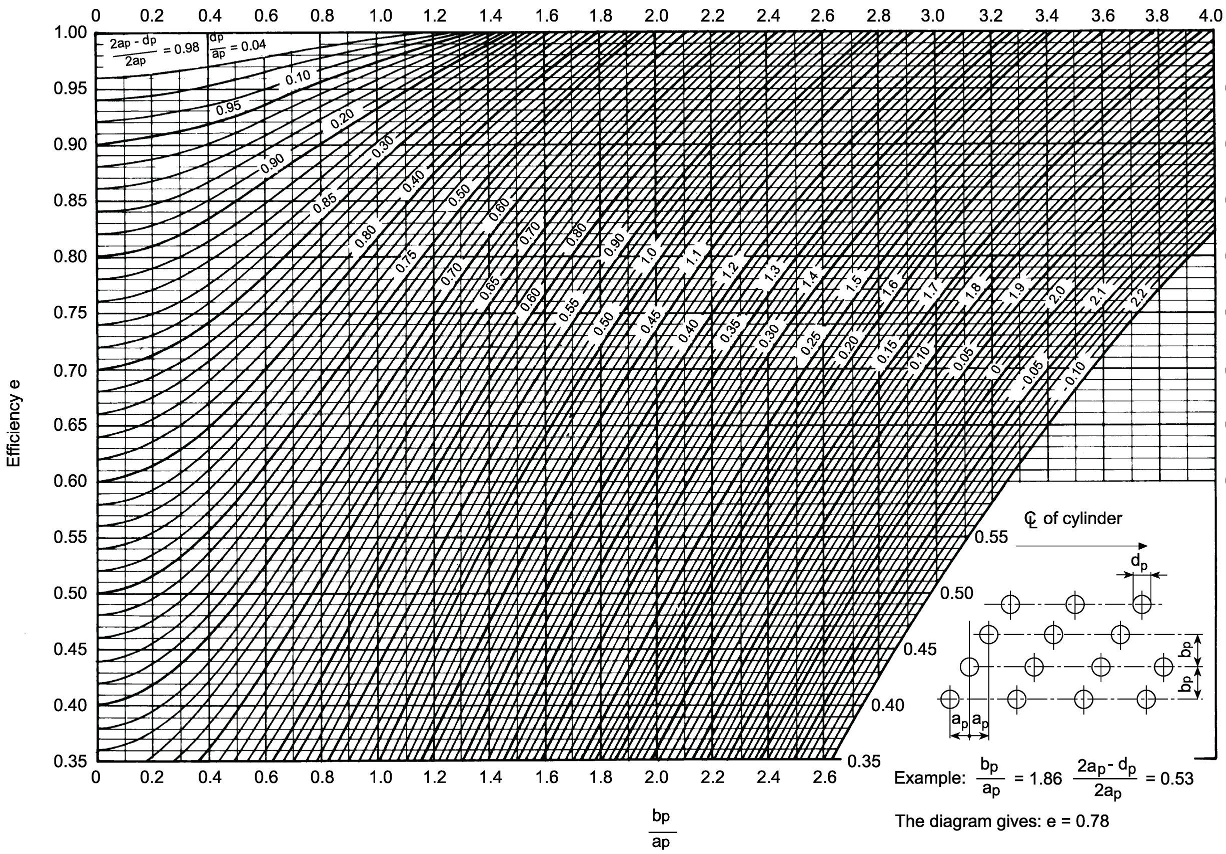


Figure 6 Ligament efficiencies — diagonal drilling

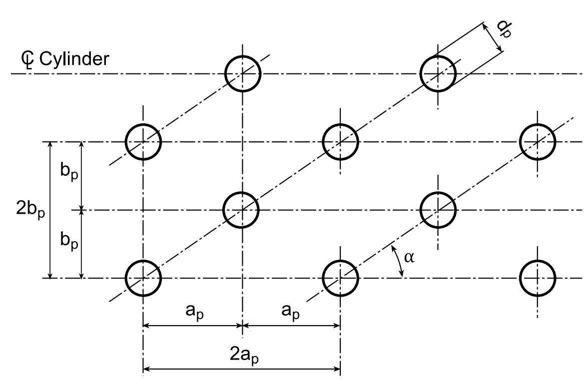


Figure 7 Regularly staggered spacing

3.9.3 When drilling holes along a diagonal line, the efficiency of corresponding ligaments is given in Figure 6 with the ratio b_p/a_p as abscissa and the ratio $(2 \times a_p - d_p)/(2 \times a_p)$ used as parameter.

a_p	=	diagonal pitch of holes projected on longitudinal axis
b_p	=	diagonal pitch of holes projected circumferentially
d_p	=	mean effective diameter of tube hole

The figure applies to regular spacing of tube holes arranged along a straight line or in a saw-tooth pattern as shown in Figure 5.

In case of a regularly staggered spacing of tube holes, i.e. the centres are arranged on diagonal and circumferential lines as well as on lines parallel to the longitudinal axis, as shown in Figure 7, the smallest value e of all ligament efficiencies (longitudinally, circumferentially and diagonally) is given in Figure 8 by the ratio b_p/a_p as abscissa and the ratio $(2 \times a_p - d_p)/(2 \times a_p)$ or d_p/a_p used as parameter.

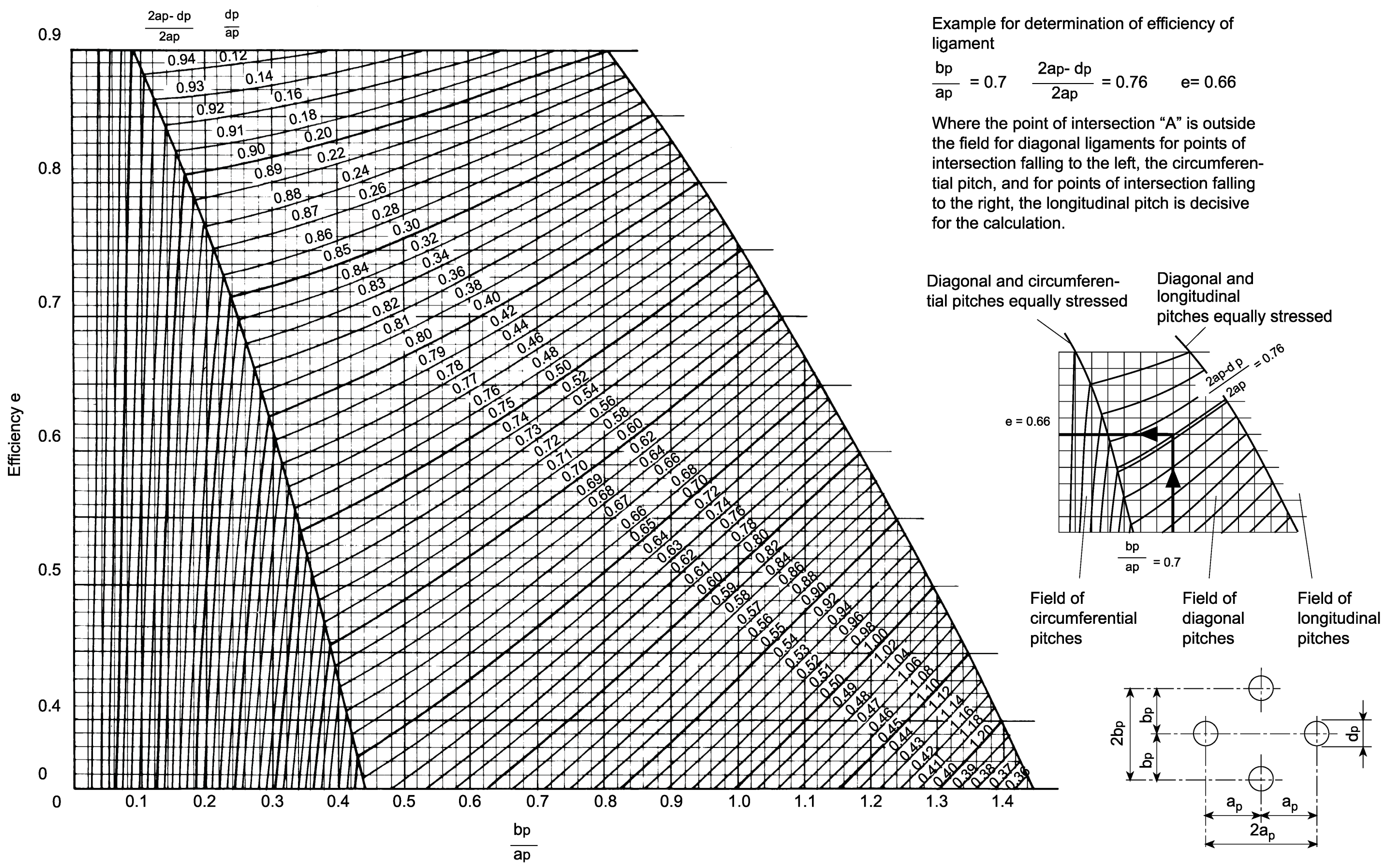


Figure 8 Ligament efficiencies — staggered drilling

3.10 Compensating effect of tube stubs

3.10.1 Where a drum or header is drilled for tube stubs fitted by strength welding, the effective diameter d_p of holes shall be taken as: $d_p = d - A_c/s$

where:

A_c	=	compensating area
d	=	diameter of tube hole
d_p	=	mean effective diameter of tube hole
s	=	plate thickness

The compensating area A_c shall be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header (see Figure 9), and shall be calculated as follows:

For a set-through stub: $A_c = 2(s_{ba} - s_m)(s + L_b) + A_1 + A_2$

For a set-on stub: $A_c = 2(s_{ba} - s_m) L_b + A_2$

$$L_b = 0.8\sqrt{(d_i + s_{ba})s_{ba}}$$

where:

A_c	=	compensating area
A_1	=	sectional area of the stub projecting inside the shell within the distance h from the inner surface of the shell with a maximum of $2 \times s_{ba} \times L_b$
A_2	=	sectional area of fillet welds attaching the stub to the inside and outside of the shell
d_i	=	internal diameter of the tube stub
L_b	=	calculation length at the branch (openings)
s	=	plate thickness
s_{ba}	=	wall thickness of the tube stub as built minus corrosion allowance
s_m	=	minimum wall thickness of tube stub as calculated without corrosion allowance

Where the material of the tube stub has a nominal design stress lower than that of the shell, the compensating sectional area of the stub shall be multiplied by the ratio

$$\frac{\sigma_t \text{ of the stub}}{\sigma_t \text{ of the shell}}$$

where:

σ_t	=	nominal design stress at calculating temperature

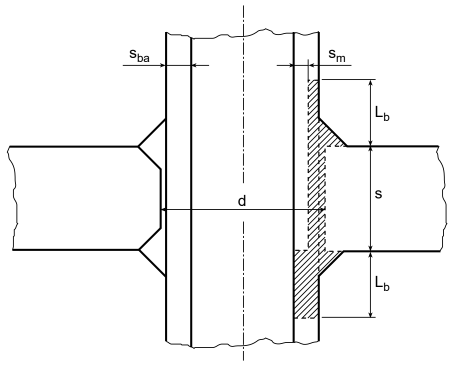
No credit will be given for the additional strength of a material having a nominal design stress greater than that of the shell.

3.10.2 The minimum pitch for roller-expanded boiler tubes, measured along the median line, shall not be less than

$1.25\ d_p + 10$ [mm]

d_p	=	mean effective diameter of tube hole

3.10.3 If more than three stay bolts pierce a cylindrical shell in the same longitudinal direction, the efficiency in this line shall not be lower than that of the longitudinal weld, otherwise the stays shall be arranged in zig-zag.



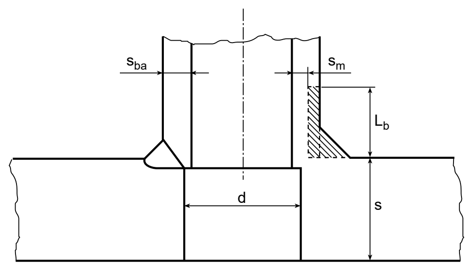


Figure 9 Stub connections

4 Dished ends

4.1 Conditions

4.1.1 The thickness of dished ends without stays, concave to the pressure side, shall not be less than

$$s \geq \frac{p_c \cdot D_o \cdot \beta}{20 \cdot \sigma_t \cdot v} + c$$

where:

c	=	corrosion margin/allowance
D_o	=	outside diameter
p_c	=	calculating pressure
s	=	minimum plate thickness after forming
v	=	joint efficiency as defined in [4.1.6]
β	=	shape factor for dished ends defined in [4.1.3]
σ_t	=	nominal design stress at calculating temperature

The thickness s shall not be less than the thickness required for a seamless, un-pierced, cylindrical shell of the same diameter and material, except where the end plate is a complete hemisphere.

The required thickness shall be obtained through an iteration process.

The thickness of the flanged portion (spherical section of the dished end calculated according to [3.3]) may be less than the minimum plate thickness s for the dished end after forming.

4.1.2 The formula in [4.1.1] applies to:

— hemispherical ends
— elliptical ends with $H_d \geq 0.2\ D_o$
— tori-spherical ends satisfying the following conditions:
$H_d \geq 0.18\ D_o$; $r \geq 0.1\ D_o$; $r \geq 3\ s$;

where:

d	=	internal diameter [of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical or non-circular openings]
D_o	=	outside diameter
H_d	=	outside height of curvature of dished end
s	=	thickness
r	=	inside knuckle radius of tori-spherical ends
R	=	inside radius of spherical part of tori-spherical ends

See also Figure 10 and Figure 11.

The radius R of the dished end shall not exceed the outside diameter D_o of the endplate.

The length of the cylindrical part of the end, with the exception of hemispherical ends, shall be at least 3.5 times the required thickness s. s being taken as the thickness of the unpierced plate even if the endplate is provided with a cut-out.

The formula in [4.1.1] is not valid for ends with openings exceeding $d_i/D_o = 0.5$ where:

d_i	=	internal diameter [of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical or non-circular openings]
D_o	=	outside diameter

See also Figure 12.

Guidance note:

The outside height of tori-spherical ends may be determined from the following formula:

$$H_d = R + s - \sqrt{(R - r)^2 - \left(\frac{D_o}{2} - s - r\right)^2}$$

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

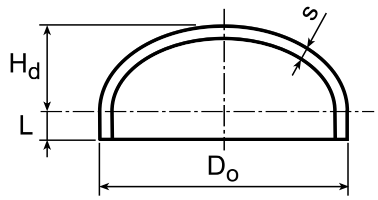


Figure 10 Elliptical end

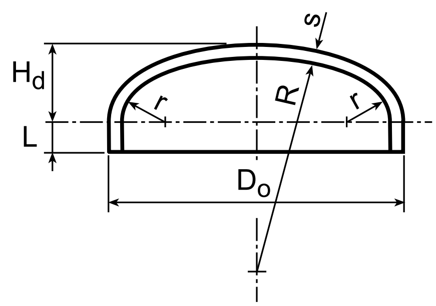


Figure 11 Torispherical end

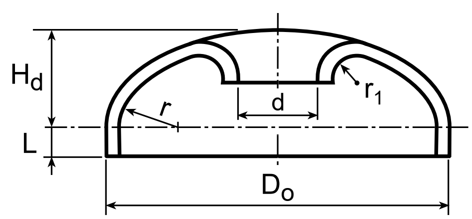


Figure 12 End with opening

4.1.3 The shape factor β to be used in the formula in [4.1.1] shall be determined from the curves in Figure 13 depending on the ratio H_d/D_o as follows:

— Plain ends without openings or with openings reinforced in accordance with [6.3] or with small openings not requiring reinforcement according to [6.2], the shape factor β depends on the ratio $(s - c)/D_o$ as well as on the H_d/D_o ratio. The unbroken line curves shall be used and trial calculations may be necessary.

For ends with un-reinforced openings and for flanged openings, the shape factor shall be as given in Figure 13, depending on the ratio H_d/D_o and with $di/\sqrt{(D_0 \times (s-c))}$ as a parameter, where d_i is the diameter of the largest opening in the end plate (in the case of an elliptical opening, the larger axis of the ellipse).

In addition, the following conditions shall be satisfied: $(s - c)/D_0 \leq 0.1$.

β shall not be less than given for a plain end with the same $(s - c)/D_o$-ratio.

The radius r_1 of the flanging shall not be less than 25 mm. See Figure 12.

r_1 = radius of the flanging at dished ends with openings

Guidance note 1:

In the case of ends containing only compensated openings, read β from full curves of $(s - c)/D_o = 0.002$ to $(s - c)/D_o = 0.04$; interpolating as necessary.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Guidance note 2:

In the case of ends containing uncompensated openings, read β from the broken line curves $\frac{d_i}{\sqrt{D_o(s-c)}} = 5.0$to $\frac{d_i}{\sqrt{D_o(s-c)}} = 0.5$; interpolating as necessary. In no case, β should be taken as smaller than the value for a similar un-pierced end.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

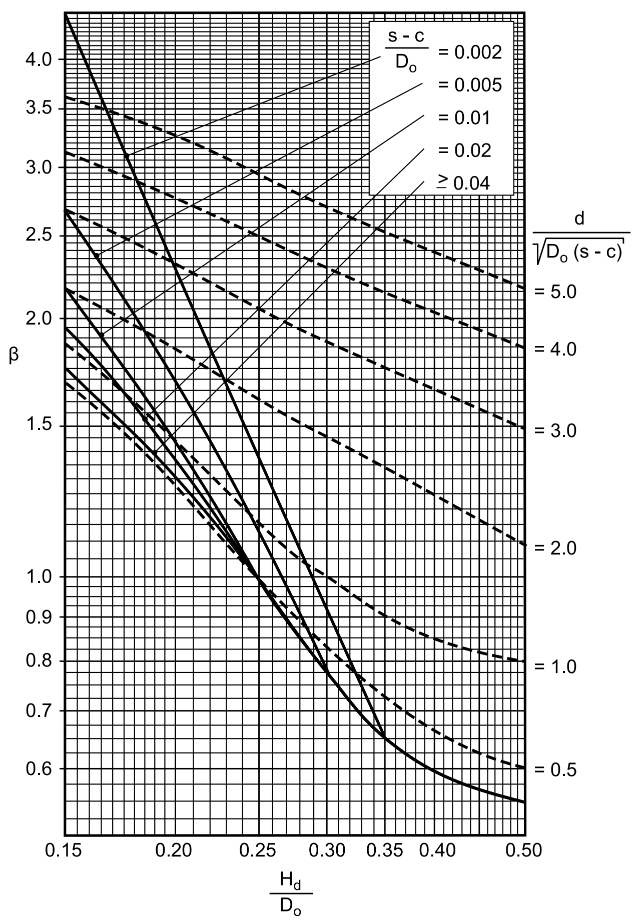


Figure 13 Graph of shape factor β for dished ends

4.1.4 The thickness of dished ends without stays, convex to the pressure side shall not be less than

$$s \geq \frac{p_c \cdot D_o \cdot \beta}{16 \cdot \sigma_t \cdot v} + c$$

where:

c	=	corrosion margin/allowance
D_o	=	outside diameter
p_c	=	calculating pressure
s	=	minimum plate thickness after forming
v	=	joint efficiency as defined in [4.1.6]
β	=	shape factor for dished ends defined in [4.1.3]
σ_t	=	nominal design stress at calculating temperature

4.1.5 In addition the spherical section of the end shall be checked against elastic instability. The pressure p_c corresponding to elastic instability shall be determined from the following formula:

$$p_c = 2.4 \cdot E \cdot \left(\frac{s-c}{R}\right)^2$$

where:

c = corrosion allowance

E = modulus of elasticity

p_c = calculating pressure

R = inside radius of spherical part of tori-spherical ends

s = thickness

The design pressure shall not exceed p_d = p_c / S_F

$$SF = \left\{3.7 \text{ for } \frac{s-c}{r} \leq 0.001;\ 3.0 \text{ for } \frac{s-c}{r} \geq 0.003\right\}$$

Intermediate values may be interpolated.

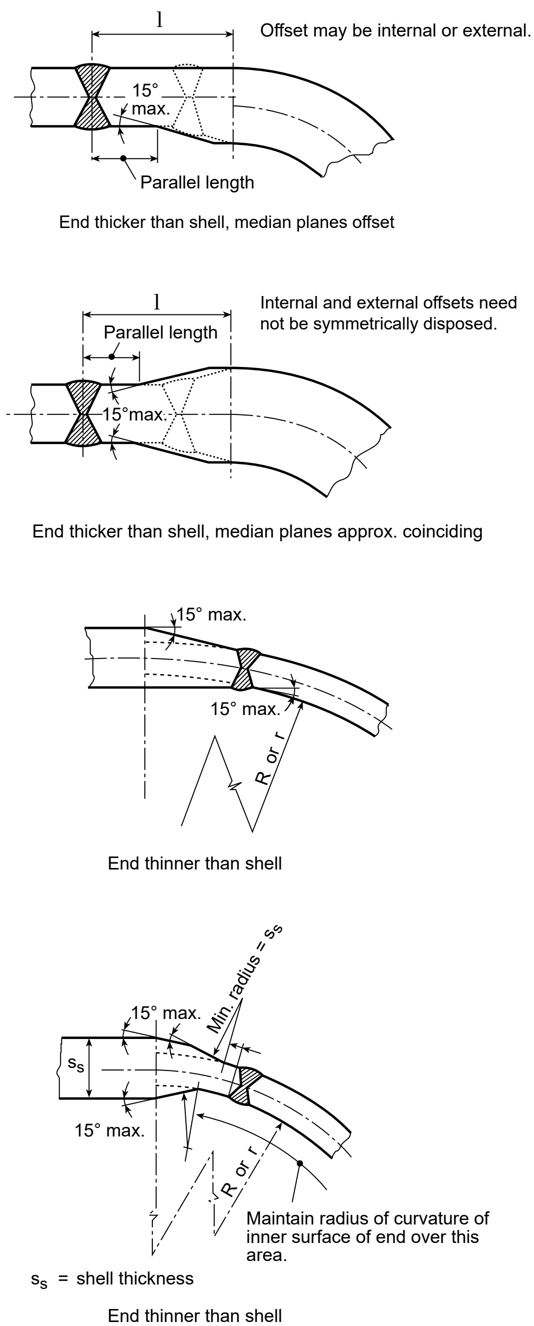


Figure 14 Dished ends — cylindrical shell connections

4.1.6 For tori-spherical and elliptical ends dished from one plate, v = 1. For hemispherical ends, v shall be taken as given in [2.9.1].

For tori-spherical and elliptical ends made of welded plates, v shall be taken as given in [2.9.1], except that v = 1 may be used also for class II and III pressure equipment for welded seams situated within the area 0.6 D_o of the spherical part.

4.1.7 Examples of connections between dished ends and cylindrical shells are shown in Figure 14.

Alternative methods of attachment may be accepted provided details are submitted for consideration.

4.2 Dished ends for vertical boiler fireboxes

4.2.1 The internal radius, R_i, of the spherical part of the dished end shall not be greater than the external diameter of the cylindrical firebox.

The inside radius of the flange to the cylindrical firebox shall not be less than four times the thickness of the dished end with a minimum of 65 mm.

4.2.2 The thickness of dished ends for vertical boiler fireboxes subjected to pressure on the convex side and without support from stays of any kind shall be determined from the following formula:

$$s \geq \frac{p_c \cdot D_o}{12 \cdot \sigma_t} + c$$

where:

D_o = outside diameter

c = corrosion allowance

p_c = calculating pressure

s = required end plate thickness after dishing

σ_t = nominal design stress at calculating temperature

4.2.3 The thickness of dished ends for vertical boiler fireboxes subjected to pressure on the convex side and supported by a central uptake shall be determined from the following formula:

$$s \geq \frac{p_c \cdot D_o}{20 \cdot \sigma_t} + c$$

where:

D_o = outside diameter

c = corrosion margin/allowance

p_c = calculating pressure

s = required end plate thickness after dishing

σ_t = nominal design stress at calculating temperature

4.2.4 The thickness of the cylindrical part of the dished end shall not be less than the thickness required for a cylindrical firebox of the same diameter and material, except where the dished end is a complete hemisphere.

5 Flat end plates

5.1 General

5.1.1 Where a flat plate is flanged for connection to other parts, the inside radius of flanging shall not be less than:

— for connection with the boiler shell: twice the thickness of the plate with a minimum of 38 mm
— for connection with a furnace or with the shell of fireboxes: the thickness of the plate with a minimum of 25 mm.

5.1.2 Where the flange curvature is a point of support, this shall be taken at the commencement of curvature, or at a line 3.5 times the thickness of the plate measured from outside of the plate, whichever is nearer to the flange.

Where a flat plate is welded directly to a shell, the point of support shall be taken at the inside of the shell.

5.1.3 The length of the cylindrical part of the flanged end plate shall not be less than 3.5 times the thickness of the end plate.

5.1.4 Where un-flanged flat plates are connected to a cylindrical shell by welding, the weld shall be a full penetration weld, welded from both sides. The inside fillet weld shall have concave profile and shall merge into the plate without undercutting or abrupt irregularity. The minimum throat thickness shall be related to the shell thickness as specified in [6] and shall be as given in Figure 15.

Guidance note:

The shape of internal fillet welds should be concave. The ratio of leg length l_1/l_2 should be approximately 4:3.

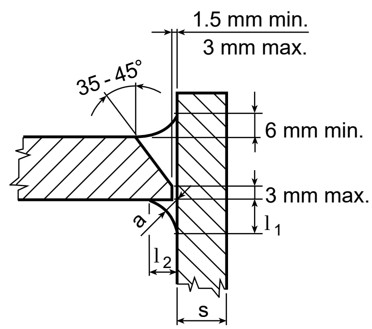
---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Table 6 Minimum throat thickness

Shell thickness (mm)	*Minimum throat thickness (mm)*
s < 12	4.5
12 ≤ s ≤ 16	5
16 < s	6

The inside fillet weld may only be omitted for small boilers not accessible for welding from the inside.

The weld details of shell flanges shall be in accordance with Pt.4 Ch.6 Sec.9.



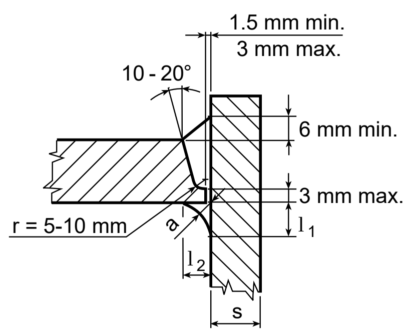


Figure 15 Attachment of un-flanged flat end plates or tube plates to shell (examples)

5.1.5 For un-flanged flat end plates the ratio of end plate thickness to shell thickness shall not exceed 2.0. Where inside fillet weld is omitted the ratio shall not exceed 1.4.

5.2 Un-stayed flat end plates

5.2.1 The thickness of an un-stayed flat end plate shall be determined by the following formula:

$$k_f \leq 14 \cdot \frac{\sigma_t}{p_c}$$

k_f is a calculation factor depending upon $(s_1 - c)/(s - c)$ and $100 \times (s_1 - c)/D_i$ where:

c = corrosion allowance

D_i = internal diameter of cylindrical shell

k_f = calculation factor for flat end plates

P_c = calculating pressure

s = thickness of end plate

s_1 = thickness of cylindrical shell

s_2 = thickness of end plate as calculated at the junction with the shell

σ_t = nominal design stress at calculating temperature

For determining k_f, see Figure 16.

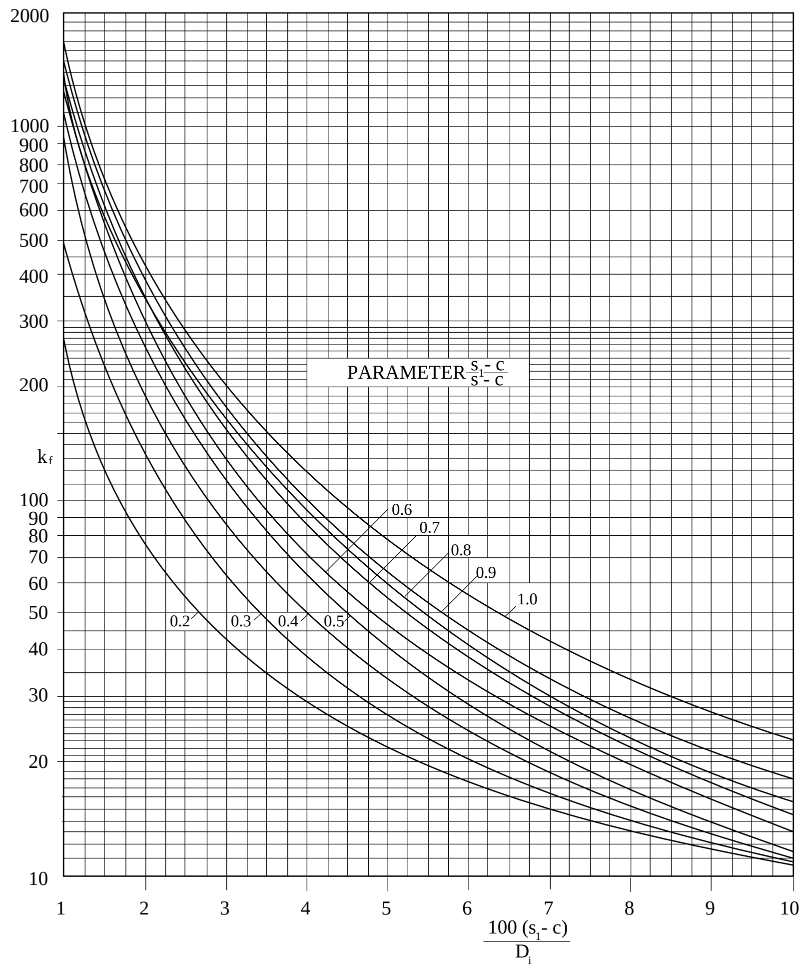


Figure 16 Calculation factor k_f

5.2.2 The formula in [5.2.1] is based on the following conditions:

$p_c \leq 30$ bar

$s_1 \leq s \leq 5\, s_1$

Cases where p_c, s and s_1 are outside these limits, will be specially considered.

5.2.3 If s_1 is locally increased to obtain a reduction of s, the increased shell thickness shall extend at least a length $\sqrt{D_o \cdot (s_1 - c)}$ from the end plate, where D_o = outside diameter of cylindrical shell.

5.2.4 Examples of acceptable connections between flat end plates and cylindrical shells are shown in Figure 17.

Alternative methods of attachment may be accepted provided details are submitted for consideration.

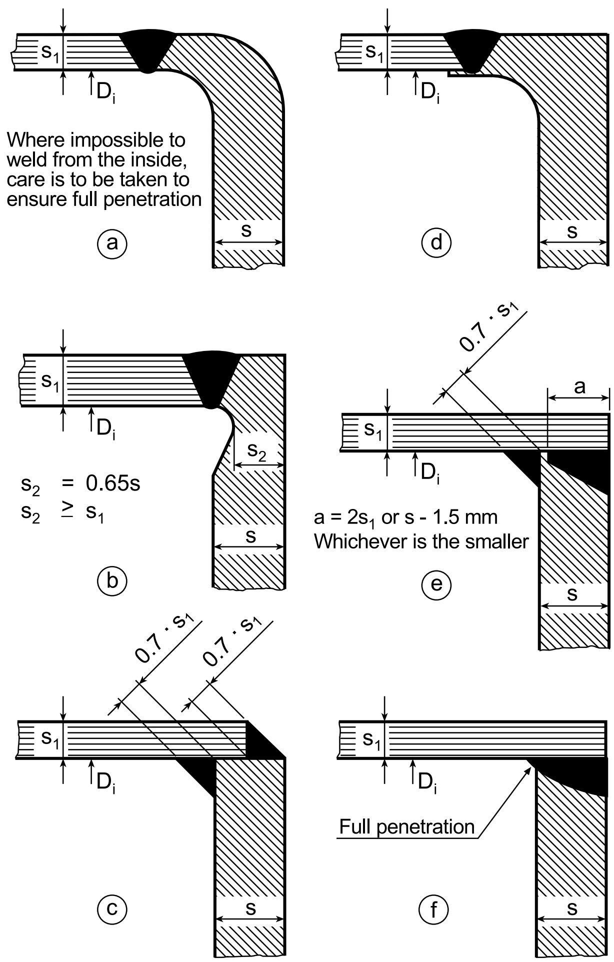


Figure 17 Acceptable methods of attaching flat end plates to cylindrical shells

5.3 Scantlings of flat plates supported by stays

5.3.1 The thickness of stayed flat plates shall not be less than the greater of the values determined by the following formulae:

$$s \geq K \cdot C \cdot d_e \sqrt{\frac{p_c}{10 \cdot \sigma_t}} + c$$

or

$$s \geq y \cdot C \cdot b \sqrt{\frac{p_c}{10 \cdot \sigma_t}} + c$$

where:

b	=	minor dimension of elliptical or rectangular unsupported area
c	=	corrosion allowance

C = factor depending on the method of supports

d_e = diameter of the largest circle passing through points of support

K = factor depending on the number of supports

K = 1.0 for four or more evenly distributed points of support

K = 1.1 for three points of support

K = 1.56 for annular areas, i.e. areas supported only by a cylindrical shell and uptake or a cylindrical shell and lower part of the fire boxes (two points of support)

p_c = calculating pressure

s = thickness

y = factor depending on the ratio b/a

σ_t = nominal design stress at calculating temperature

5.3.2 The value of the factor C shall be as given in Table 7.

Where different methods of support are used, the factor C shall be taken as the mean of the values for the respective methods adopted.

5.3.3 For parts supported by bar stays or stay tubes, d_e is the diameter of the largest circle passing through not less than three points of support. The three points of support considered shall not be situated on the same side of any diameter of this circle.

5.3.4 For parts situated near the edge of the plate or around a furnace, d_e is the diameter of the circle tangent to the support at the cylindrical shell or furnace (see [5.1.2]) and passing through the centres of at least two other supports.

The three points of support considered shall not be situated on the same side of any diameter of this circle.

When, in addition to the above main circle, a sub-circle of diameter equal to 0.75 times the diameter of the main circle can be drawn passing through two points of support and such that its centre lies outside the main circle, the thickness shall be determined from formula in [5.3.1] using b as indicated in Figure 18 and y determined from the table in [5.3.5].

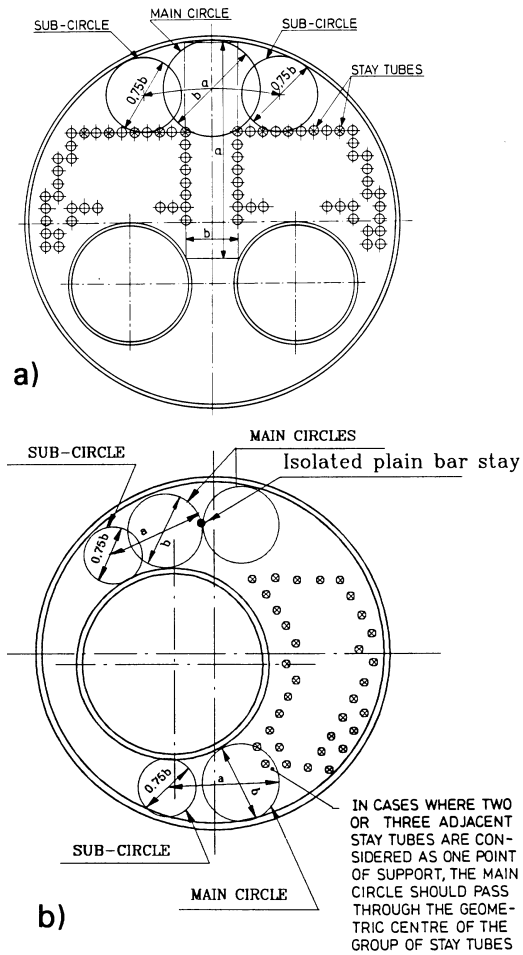


Figure 18 Use of sub-circles and rectangular areas

5.3.5 The ratio y takes into account the increase in stress for rectangular or elliptical areas, compared with circular areas as a function of the ratio b/a according to Table 8 or Figure 19.

5.4 Tube plates with stay tubes and tubes within tube nests

5.4.1 Stay tubes are tubes welded into the tube plates in accordance with Figure 21, having a weld depth equal to the tube thickness + 3 mm.

These stay tubes are not required within tube nests except when the tube nests comprise tubes which are expanded only. In this case stay tubes are however to be used in the boundary rows in sufficient numbers to carry the flat plate loadings outside the tube area.

For loadings on stay tubes and required area, see [8].

Table 7 Value of factor C

Type of support	*C*
Isolated plain bar stays or stay tubes with a centre distance of more than 200 mm, Figure 20 (a) and Figure 21	0.45
Note: An example of an isolated plain bar stay is given in Figure 18 b	
Non-isolated plain bar stays or stay tubes	0.39
Bar stays welded to reinforced plate or plate fitted with washer, Figure 20 (b) and (c)	0.35
Gusset stays	0.30
Tube bank with plain tubes welded at both ends, Figure 22	0.30
Flat end plate or tube plate attachment to cylindrical shell	
Flanged end plate	0.32
Set-in end plate with internal fillet weld. End plate thickness divided by shell plate thickness (Figure 15):	
≤ 1.4	0.33
> 1.4 ≤ 1.6	0.36
> 1.6 ≤ 1.8	0.39
> 1.8	0.42
Set in end plate with no internal fillet weld	0.45
Flat end plate attachment to furnace and uptake	
With internal fillet weld:	
Plain furnace	0.30
Corrugated furnace with corrugations less than 50 mm deep	0.32
Corrugated furnace with corrugations 50 mm deep or greater:	
length > 4 m	0.37
length ≤ 4 m	0.34
Bowling hoop furnace	0.32
With no internal fillet weld	0.45
Top plates of fireboxes supported by continuous welded girders	0.51

Table 8 Value of factor y

Ratio b/a	*y*	
	Rectangular areas	*Elliptical areas*
1.0	1.10	1.0
0.75	1.26	1.15
0.5	1.40	1.30
0.25	1.52	1.43
≤0.1	1.56	

Intermediate values shall be interpolated.

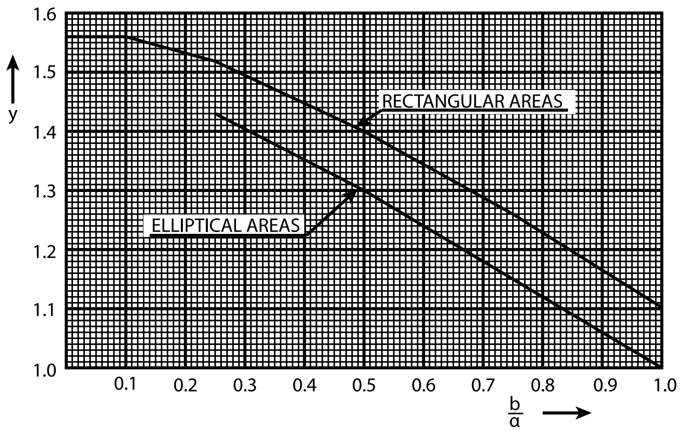


Figure 19 Determination of factor y

5.4.2 The thickness of tube plates within tube nests with welded plain tubes, Figure 22, shall not be less than calculated according to formula in [5.3.1] using b as the pitch of the plain tubes and y = 1.56. The thickness shall not be less than 10 mm.

5.4.3 For tube plates with tubes and stay tubes the thickness shall be calculated according to [5.3.1] and shall not be less than:

12.5 mm	when d ≤ 50 mm
14.0 mm	when d > 50 mm

d = diameter of tube hole

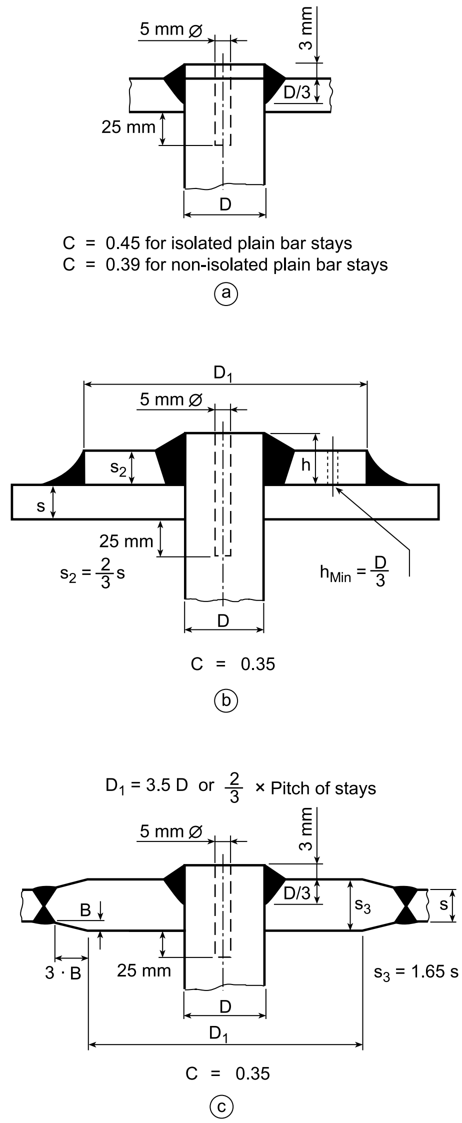


Figure 20 Stay connections

Guidance note 1:

The ends of the stays should be dressed flush with the welds when exposed to flame or temperature exceeding 600°C.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

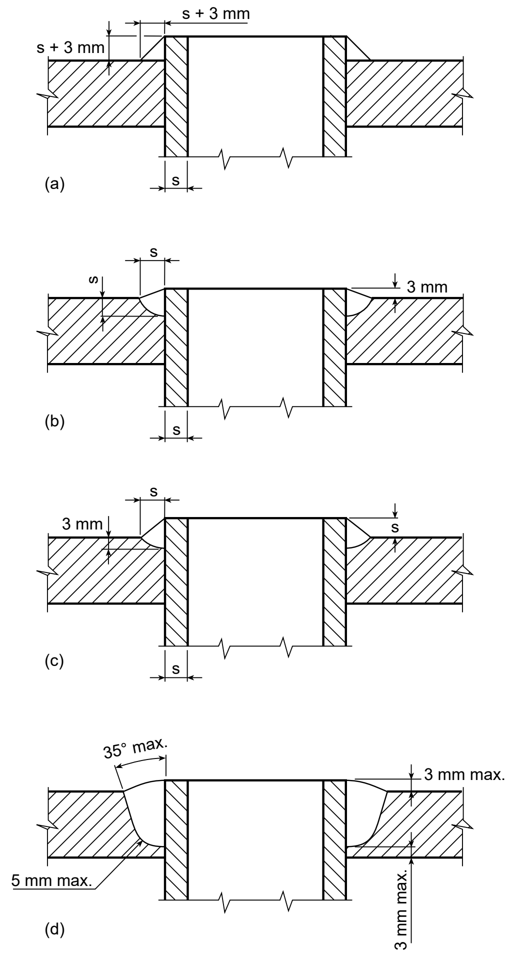


Figure 21 Typical attachment of stay tubes

Guidance note 2:

Stay tubes should be lightly expanded before and after welding.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Guidance note 3:

For stay tubes exposed to flame or gas temperatures exceeding 600°C the ends should be dressed flush with the welds.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

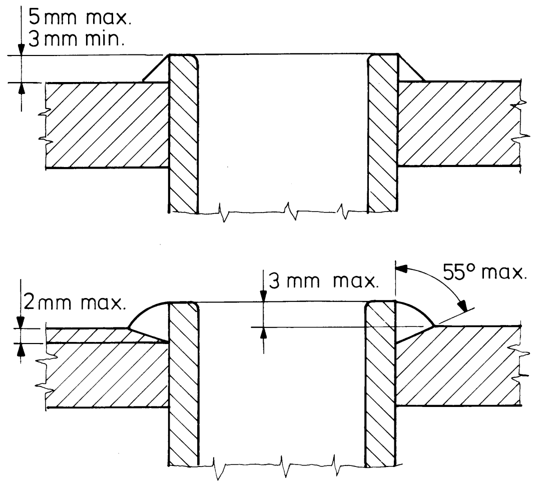


Figure 22 Typical attachment of welded plain tubes

Guidance note 4:

Tubes should be lightly expanded before and after welding.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Guidance note 5:

The ends of the tubes should be dressed flush with the welds when exposed to flame or temperature exceeding 600°C.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

5.4.4 The spacing of tube holes shall be such that the minimum width of any ligament between tube holes is not less than:

for expanded tubes:	0.125 × d + 12.5	
for welded tubes:	0.125 × d + 9	for gas entry temperatures > 800°C
	0.125 × d + 7	for gas entry temperatures ≤ 800°C

d = diameter of tube hole

5.5 Covers for inspection openings and manholes

5.5.1 The rules apply to flat circular and oval covers formed from steel plate and of the internal type, as shown in Figure 23.

5.5.2 The thickness shall not be less than:

$$s = b \cdot y_i \sqrt{\frac{p_c}{10 \cdot \sigma_t}} + c$$

with a minimum of 15 mm for manhole covers.

a = major dimension of elliptical area

b = minor dimension of elliptical area

c = corrosion allowance

e_i = breadth of jointing surface

p_c = calculating pressure

s = thickness

y_i = factor depending on the ratio b/a for calculating inspection openings (see Table 9)

σ_t = nominal design stress at calculating temperature

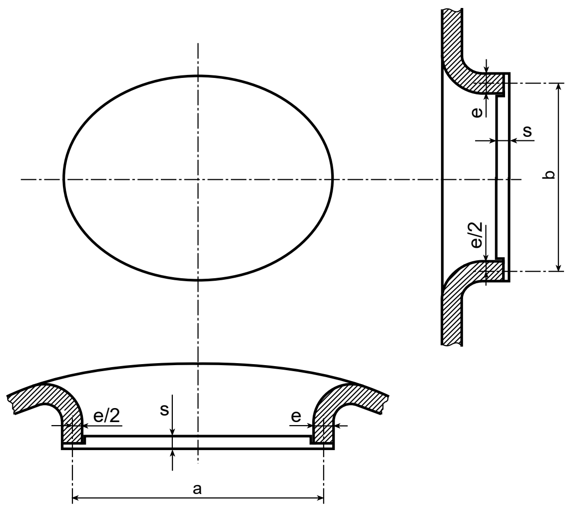


Figure 23 Covers

Table 9 Coefficient yi

b/a	*1.0*	*0.75*	*0.5*	*0.25*
y_i[1)]	0.55	0.63	0.72	0.79
1) the coefficient y_i includes already the coefficients for the support and the screw force				

5.6 Straps and girders

5.6.1 The supporting steel girders on flat endplates shall be properly welded to the combustion chamber crown continuously. They shall be arranged in such a way that the welds can be competently executed and the circulation of water is not obstructed.

5.6.2 The unsupported girder shown in Figure 24 shall be treated as a simply supported beam of length *l*. The support afforded by the plate material may also be taken into consideration.

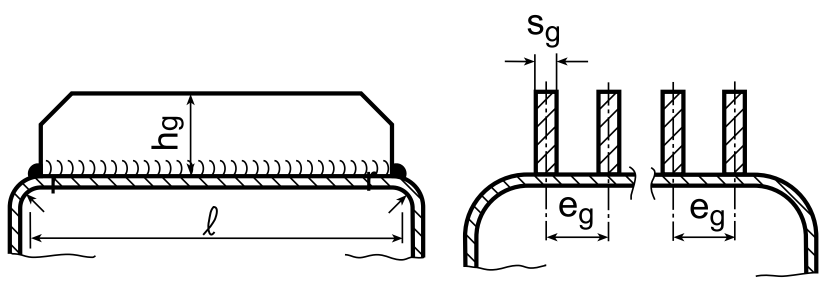


Figure 24 Unsupported girder

5.6.3 The maximum bending moment is given by the expression:

$$M = F_g \cdot \frac{l}{8}$$

where:

$$F_g = p_c \cdot l \cdot \frac{e_g}{10}$$

e_g = distance between center lines of girders

F_g = load carried by one girder

l = free length between girder supports

M = bending moment acting on girder at given load

p_c = calculating pressure

5.6.4 The required section modulus of a ceiling girder is given by:

$$W = \frac{M}{1.3 \cdot \sigma_t \cdot z} \leq \frac{s_g \cdot h_g^2}{6}$$

where:

h_g = height of girder

M = bending moment acting on girder at given load

s_g = thickness of girder

σ_t = nominal design stress at calculating temperature

z = coefficient for section modulus

The coefficient z for the section modulus takes account of the increase in the section modulus due to the flat plate forming part of the ceiling plate. It may in general be taken as z = 5/3.

For the height h_g a value not exceeding 8 × s_g shall be inserted in the formula.

6 Openings and compensations

6.1 General

6.1.1 The rules apply only when the following conditions are simultaneously satisfied:

— Openings are circular, elliptical or around with a ratio of major to minor inside diameters not exceeding 2.
— The axis of the branch is not having an angle with the normal to the shell greater than 15°.
— For cylindrical, conical and spherical shells:
  — the major inside diameter of the opening is not exceeding one third of the shell inner diameter.
— For dished ends:
  — the major inner diameter of the opening is not exceeding one half of the outside diameter of the end
  — the opening is so situated that in projection its outer extremity or that of its reinforcement is at least one tenth of the end external diameter from the outer surface of the cylindrical shell, see Figure 25
  — in case of multiple openings, the distance between the openings shall comply with the requirement in Figure 25.
— For opening in flat plates. See [6.6] for requirements of reinforcement.

6.1.2 The rules do not apply to multiple openings in cylindrical shells where the distance between the axes is less than 1.5 times the average diameter of the openings.

6.1.3 Openings not complying with the requirements in [6.1.1] and [6.1.2] will be subjected to special consideration.

Calculations according to a recognised international code accepted by the Society shall be submitted.

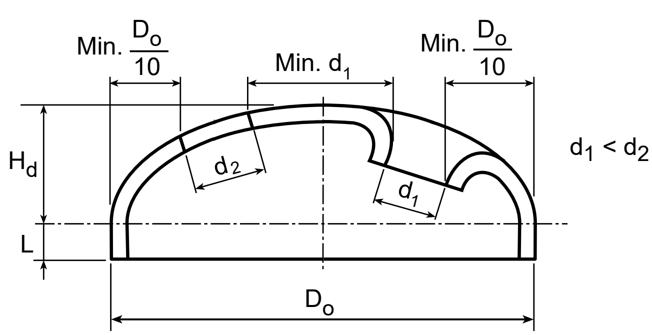


Figure 25 Opening arrangement

6.2 Openings not requiring reinforcement

6.2.1 Reinforcements are not required for isolated openings provided

$$d_i \leq 0.3\sqrt{(D_i + s_{sa})s_{sa}}$$

with a maximum of 150 mm.

D_i =	for a cylindrical or spherical shell:	the internal diameter

	= for a conical shell:	twice the distance along the shell normal, from the point where the axis of the opening intersects the inner surface, to the shell axis
	= for a tori-spherical end:	twice the inner radius of the spherical part
	= for a semi-ellipsoidal end:	twice the inner radius of curvature at centre of head
d_a	= mean inner diameter of the two openings	
d_i	= internal diameter of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical or non-circular openings	
s_{sa}	= thickness of the shell plate or end plate as built minus corrosion allowance	

An opening is considered isolated if its centre is at a distance greater than

$$d_a + 3\sqrt{(D_i + s_{sa})s_{sa}}$$

from the centre of another opening.

6.3 Openings requiring reinforcement

6.3.1 Openings not conforming to [6.2.1] shall be reinforced in accordance with [6.3.2] and [6.3.3].

6.3.2 On each side of the centre line of the opening the required area of reinforcement is:

$$k\left(\frac{d_i}{2} + s_b\right)s_s$$

where:

d_i = internal diameter of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical openings

k = calculation factor for reinforced openings in spherical, cylindrical and conical shells

k = 1 for spherical shells and for planes passing through the generatrix for cylindrical and conical shells

k = 0.7 for planes normal to the generatrix for cylindrical and conical shells

s_b = thickness of the branch calculated from the formula in [3.5.1] with c=0. For elliptical or round reinforcement rings the chord length in the plane being considered shall be used in determining s_b

s_s = thickness of the shell as calculated

For openings fitted with an internal cover such that the bore is not subjected to pressure, the required area of reinforcement on each side of the opening is:

$$\frac{k \cdot d_i \cdot s_s}{2}$$

Guidance note:

Generatrix is a line parallel to the centre line of the cylindrical or conical shells.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

For oval openings in cylindrical and conical shells the reinforcement shall be determined in a plane passing through the generatrix (Figure 26 a, k = 1) and in a plane normal to the generatrix (Figure 26 b, k = 0.7). For spherical shells the reinforcement shall be determined in a plane passing through the major diameter of the opening. All planes shall pass through the centre of the opening and shall be normal to the wall.

6.3.3 Only material located within the following limits will be accepted as reinforcement:

— For the shell, measured from the outer surface of the branch along the outer surface of the shell:

$$L_s = \sqrt{(D_i + s_{sa})s_{sa}}$$

where:

D_i	=	internal diameter of the shell or sphere
L_s	=	calculation length at the shell
s_{sa}	=	thickness of the shell as built minus corrosion allowance

— For the branch, and internal protrusion, if fitted, measured from the relevant surface of the shell:

$$L_b = 0.8\sqrt{(d_i + s_{ba})s_{ba}}$$

where:

d_i	=	internal diameter of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical openings
L_b	=	calculation length at the branch
s_{ba}	=	thickness of the branch as built minus corrosion allowance

The area A, available as reinforcement on each side of the centre line of the opening, is shown shaded in Figure 26.

When $s_{sa}/D_i \le 0.02$, two-thirds of the area of compensation required shall be at a distance less than:

$$\frac{d_i}{2} + 0.35\sqrt{(D_i + s_{sa})s_{sa}}$$

where:

d_i	=	internal diameter of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical openings
D_i	=	internal diameter of the shell
s_{sa}	=	thickness of the shell or flat plate as built minus corrosion allowance

measured from the axis of the opening on the external surface of the shell.

The reinforcement is adequate if:

$$A \ge k\left(\frac{d_i}{2} + s_b\right)s_s$$

where:

A	=	area of reinforcement
d_i	=	internal diameter of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical openings
k	=	calculation factor for reinforced openings in spherical, cylindrical and conical shells
s_b	=	thickness of the branch

s_s = thickness of the shell as calculated

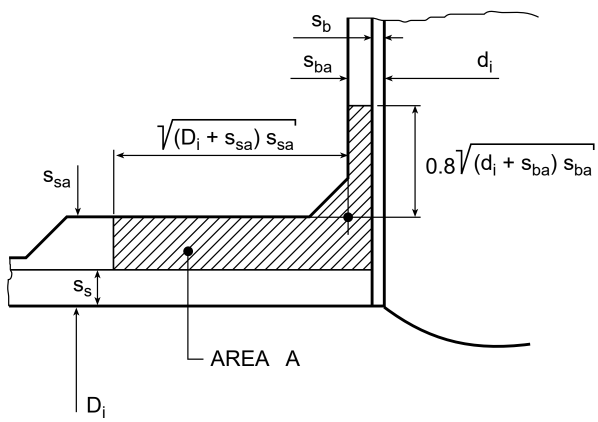
6.3.4 Where two openings or branches are sufficiently closely spaced for the limits of compensation in the shell to overlap, the limits of compensation shall be reduced so that no overlap is present.

6.3.5 Material in the reinforcement, or in a branch, shall have the same mechanical properties as that in the shell. In no case is the reinforcement, or the branch, to be made from a material having a nominal design stress less than 0.6 times the nominal design stress for the shell. Where material with a lower nominal design stress than that of the shell is used for reinforcement, its effective area shall be assumed reduced in the ratio of the nominal design stresses at design temperature.

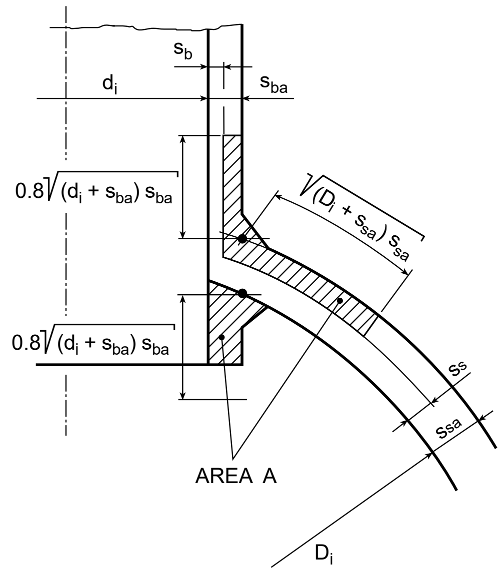
No reduction will be accepted for material with a nominal design stress greater than that of the shell.

6.3.6 Reinforcements, not in compliance with the requirements above may be approved if justified by a detailed calculation according to a recognised standard accepted by the Society.

Additional reinforcement may be required where closing appliances can cause deformation of the shell.



a) Reinforcement area, K=1



b) Reinforcement area, K = 0.7

Figure 26 Reinforcement area

6.4 Minimum thickness of nozzles and branches

6.4.1 The wall thickness of nozzles and branches shall not be less than determined by [3.2.1] or [3.5].

6.4.2 Additional thickness may be necessary on account of loads from connected piping and vibrations. For class I and II pressure equipment the nominal wall thickness of nozzles and branches shall, however, not be less than:

$$s_b \geq 0.04 \cdot d_o + 2.5$$

but need not be greater than the thickness of the immediate connecting part (e.g. shell, dished end, flat endplate).

d_o	=	outer diameter of the branch or tube
s_b	=	thickness of the branch

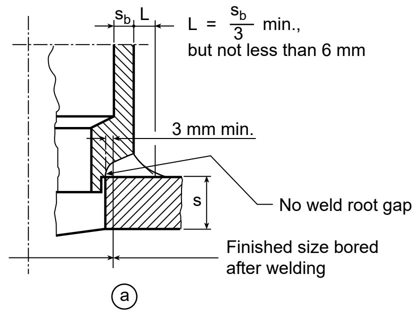
6.5 Welded branch connections

6.5.1 Acceptable welded branch connections for full penetration welding are shown in Figure 26.

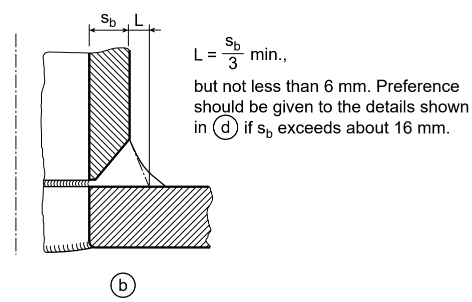
Alternative methods of attachment may be accepted provided details are submitted for consideration.

Piping flanges shall be in accordance with a recognised standard.

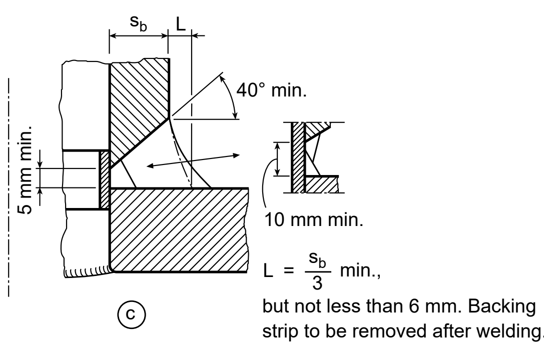
For acceptable flange welding details, see Ch.6 Sec.9 Figure 4



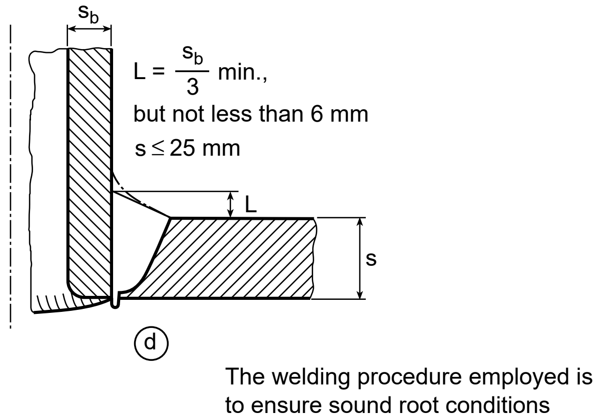
Generally used for small branch to shell diameter ratios



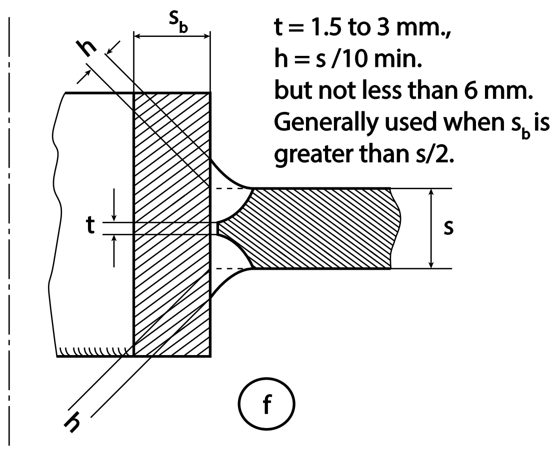
The welding procedure employed is to ensure sound root condition



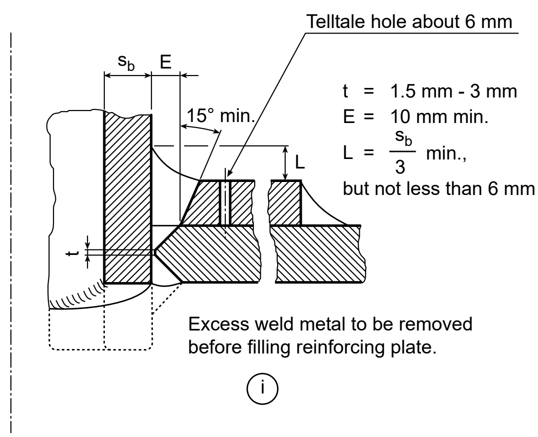
Single root run technique and double root run technique



s_b
$L = \frac{s_b}{3}$ min.,
but not less than 6 mm
$s \leq 25$ mm
L
s
d
The welding procedure employed is
to ensure sound root conditions



s_b
t = 1.5 to 3 mm.,
h = s /10 min.
but not less than 6 mm.
Generally used when s_b is
greater than s/2.
h
t
s
f



Telltale hole about 6 mm
s_b
E
15° min.
t = 1.5 mm - 3 mm
E = 10 mm min.
$L = \frac{s_b}{3}$ min.,
but not less than 6 mm
L
t
Excess weld metal to be removed
before filling reinforcing plate.
i

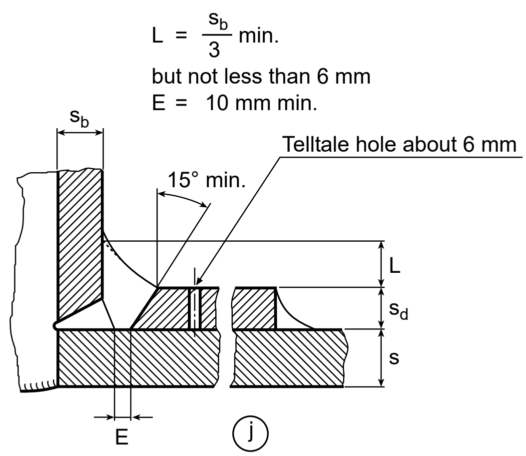


Figure 27 Details of branch connections

6.6 Openings in flat plates

6.6.1 The maximum diameter of an un-reinforced opening in a flat plate shall be determined from the following formula:

$$d = 8 \cdot s_a \cdot \left(\frac{1.5 \cdot s_a^2}{s^2} - 1.0 \right)$$

where:

d	=	diameter of tube hole or opening
s	=	thickness of the flat plate calculated from the formula in [5.2.1] for un-stayed flat endplates or [5.3.1] for the part under consideration of a flat plate supported by stays, each with c = 0.
s_a	=	thickness of the flat plate as built minus corrosion allowance

6.6.2 Openings larger than those permitted according to [6.6.1] shall be reinforced.

Compensation is adequate when the area Y is equal to or greater than the area X requiring compensation. See Figure 28.

6.6.3 The material in the branch, or in the pad reinforcement, shall have the same mechanical properties as that in the flat plate. In no case is the material to have a nominal design stress less than 0.6 times the nominal design stress of the flat plate.

Where material with a lower nominal design stress than that of the flat plate is used for reinforcement, its effective area shall be reduced in the ratio of the nominal design stresses at design temperature.

No reduction will be accepted for material with a nominal design stress greater than that of the flat plate.

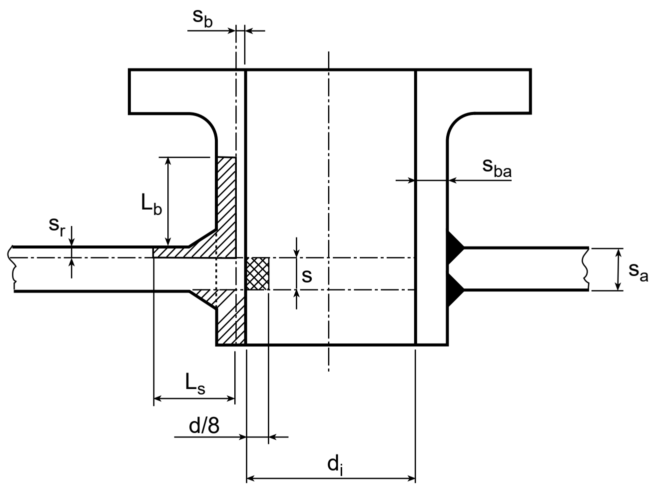


Figure 28 Compensation of openings in flat plates

d_i = internal diameter of an opening or branch for a circular opening

L_b = calculation length at the branch the smaller of the two values 2.5 s_a or (2.5 s_{ba} + s_r)

L_s = calculation length at the shell the greater of the two values $d_i/4$ or (s_a + 75) mm

s = thickness as defined in [6.6.1]

s_a = thickness of the flat plate as built minus corrosion allowance (reinforcement plates to be considered, if applicable)

s_b = thickness of the branch calculated according to [3.5.1]

s_{ba} = thickness of the branch as built minus corrosion allowance

X = area requiring compensation marked XXX

Y = area of reinforcement marked ///

7 Fired and unfired cylindrical shells under external pressure

7.1 Plain cylindrical shells

7.1.1 The design of a plain cylindrical shells shall be checked to ensure that neither membrane yield nor elastic instability occur. The lower value of the calculating pressure p_c is essential in establishing the permissible external overpressure.

7.1.2 For calculation against membrane yield, the calculating pressure shall not exceed that determined by the following formula:

$$p_c \leq 20 \cdot \frac{R_{et}}{S}\frac{(s-c)}{D_m}\frac{1+0.1\cdot\frac{D_m}{L}}{1+0.03\cdot\frac{D_m}{s-c}\frac{u}{1+5\cdot\frac{D_m}{L}}}$$

where

c = corrosion margin/allowance

D_m = mean diameter of plain cylindrical shell

L = calculation length of the plain cylindrical shell between two effective points of support, see [7.3.1] and [7.4.1]

p_c = calculating pressure

R_{et} = specified minimum lower yield stress at calculating temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied

s = thickness

S = safety factor

S = 2.75 for horizontal furnaces

S = 2.5 for vertical furnaces

R_{et}/S according to [2.5] for plain unfired cylindrical shells

u = percentage of out of roundness. The value of u to be used in the formula shall be taken as 1.5 for new plain cylindrical shells

7.1.3 For calculation against elastic instability, the calculating pressure shall not exceed that determined by the following formula:

$$p_c \leq 20\frac{E}{S_k}\left[\frac{\frac{s-c}{D_o}}{\left(n_w^2-1\right)\left(1+\left(\frac{n_w}{z}\right)^2\right)^2}+\frac{\left(\frac{s-c}{D_o}\right)^3}{3\left(1-\nu^2\right)}\left(n_w^2-1+\frac{2n_w^2-1-\nu}{\left(\frac{n_w}{z}\right)^2+1}\right)\right]$$

with;

$$z = 0.5 \cdot \pi \cdot \frac{D_o}{L}$$

n_w may be estimated by the following formula:

$$n_w = 1.63\left[\left(\frac{D_o}{L}\right)^2\frac{D_o}{s-c}\right]^{\frac{1}{4}}$$

where:

c = corrosion allowance

D_o = outside diameter

E = modulus of elasticity at calculating temperature, see Table 10

L = calculation length of the plain cylindrical shell between two effective points of support, see [7.3.1] and [7.4.1]

n_w = integral number of waves; n > 2 and n > z

p_c = calculating pressure

s = thickness

S_K = safety factor against elastic instability S_K = 4.5

ν = Poisson's ratio

n_w shall be chosen to minimise p_c.

For usual dimension of plain cylindrical shells, p_c or $s - c$ may be determined from Figure 29.

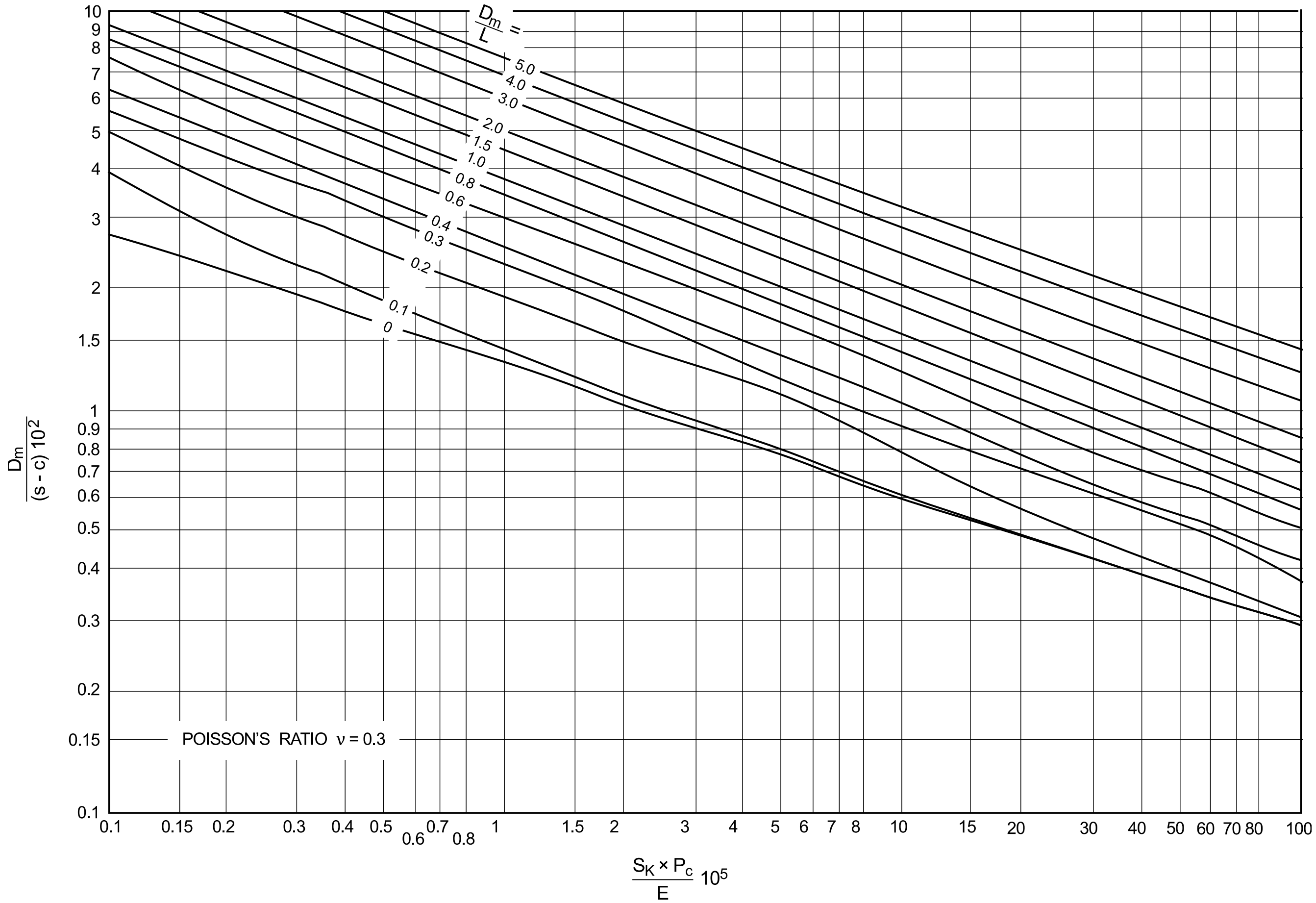


Figure 29 Required thickness by calculation against elastic instability

7.1.4 The nominal thickness of plain furnaces shall not be less than 7 mm for horizontal and vertical furnaces.

The nominal thickness shall not exceed 22 mm. The nominal thickness of furnaces which are heated by flue gases <1000°C shall not exceed 30 mm.

7.1.5 For ovality the percentage of out-of-roundness is:

$$u = \frac{200\left(D_{\max} - D_{\min}\right)}{D_{\max} + D_{\min}}$$

where:

D_{max}	=	maximum mean diameter of the furnace
D_{min}	=	minimum mean diameter of the furnace
u	=	percentage of out of roundness

For local flat parts the percentage of out-of-roundness is:

$$u = 400\,\frac{a_o}{D_o}$$

where:

a_o	=	diminution for calculation of out-of-roundness
D_o	=	outside diameter
u	=	percentage of out of roundness

See Figure 30.

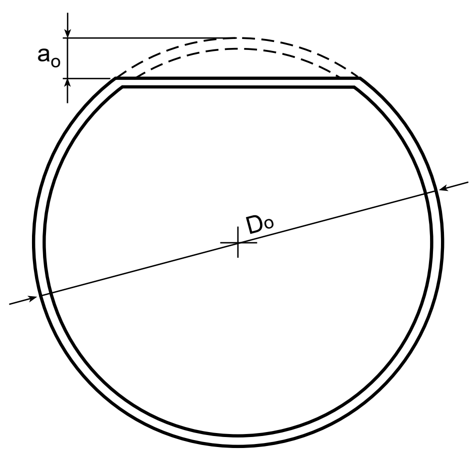


Figure 30 Local flat parts

7.1.6 Values of E for carbon and carbon-manganese steels may be obtained from the following table:

Table 10 Modulus of elasticity for steel

Calculating temperature (°C)	*20*	*250*	*300*	*350*	*400*	*500*	*600*
E $N/mm^2 \cdot 10^5$	2.12	1.95	1.91	1.87	1.83	1.74	1.65

For intermediate temperatures linear interpolation shall be used.

7.1.7 Plain furnaces shall not exceed 3 m in length. If corrugations are used to provide flexibility, at least one-third of the furnace length shall be corrugated.

7.2 Corrugated furnaces

7.2.1 Check against elastic instability is in general not required for usual form of corrugations.

7.2.2 The thickness of corrugated furnaces of type Fox after corrugation shall be determined from the following formula:

$$s \geq \frac{p_c \cdot D_i}{20 \cdot \frac{R_{et}}{S}} + 1 \text{ mm}$$

where:

D_i = minimum internal diameter

p_c = calculating pressure

R_{et} = specified minimum lower yield stress at calculating temperature. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress shall be applied

s = thickness

S = safety factor

S = 2.8 for corrugated fire tubes

7.2.3 Consideration will be given to a more accurate calculation taking depth, pitch, cross sectional area and second moment of area of the corrugations into account.

The calculation may be carried out according to a recognised international Code accepted by the Society. The factors of safety are in general not to be less than that given in [7.1.2] and [7.1.3].

7.2.4 The nominal thickness shall not exceed 22 mm and shall not be less than 10 mm.

7.3 Stiffeners

7.3.1 Stiffening rings considered to give effective points of support, shall have a second moment of area not less than given by the following formula:

$$I_x = \frac{p_c \cdot D_m^3 \cdot L}{1.33 \cdot 10^7}$$

where:

D_m = mean diameter of plain furnace

I_x = second moment of area

L = calculation length of furnace

p_c = calculating pressure

For I_x a length of the furnace of $0.55\sqrt{D_m \cdot s}$ at both sides of the stiffening ring can be considered additionally.

7.3.2 The thickness of stiffening rings shall be kept to the minimum required. For limiting dimensions see Figure 31. Stiffening rings shall extend completely around the circumference of the furnace, and shall be welded to the furnace with full penetration weld.

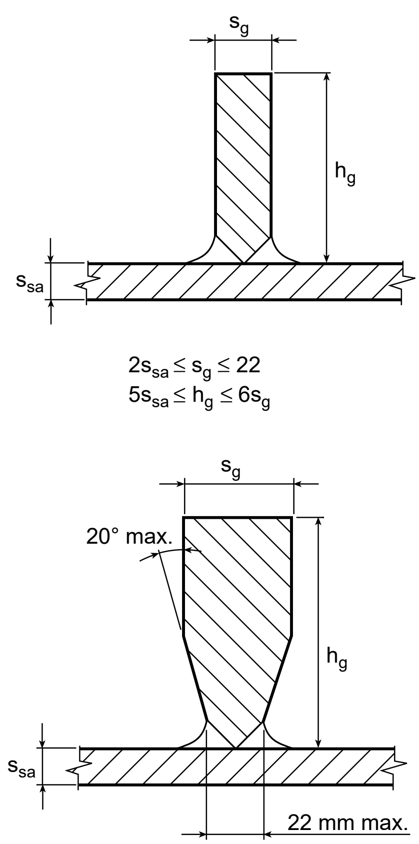


Figure 31 Furnace stiffeners

7.4 Fireboxes for vertical boilers

7.4.1 The required thickness of plain fireboxes in vertical boilers is given in [7.1].

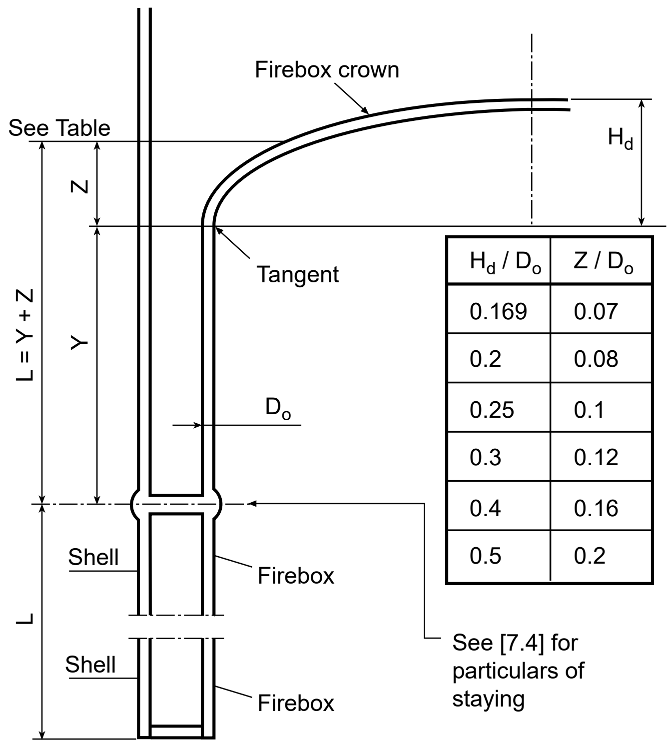
The length of the firebox shall be taken as the length between points of substantial support, as indicated in Figure 31.

A circumferential row of stays connecting the firebox to the shell is considered as a substantial support, if the diameter of the stays is not less than 22 mm or twice the thickness of the firebox, whichever is the greater, and the pitch of the stays at the firebox does not exceed 14 times the wall thickness of the firebox.

7.5 Openings in furnaces

7.5.1 Reinforcement of openings in cylindrical furnaces shall satisfy the requirements in [6] except that:

— pad type reinforcement is not permitted
— the required reinforcement may be based on the calculated thickness of the furnace assuming an internal pressure equal to the design pressure of the boiler.



H_d / D_o	Z / D_o
0.169	0.07
0.2	0.08
0.25	0.1
0.3	0.12
0.4	0.16
0.5	0.2

Figure 32 Support details

7.6 Internal uptakes in vertical boilers

7.6.1 The thickness of internal uptakes in vertical boilers shall not be less than determined by the formulae in [7.1].

The corrosion allowance, c, shall be 4 mm.

The safety factors may be taken as follows:

— against membrane yield: S = 2.0
— against elastic instability: S_K = 3.5.

8 Stays

8.1 Stay tubes and bar stays

8.1.1 The minimum required sectional area shall be determined from the following formula:

$$A_\sigma = \frac{A_p \cdot p_c}{10 \cdot \sigma_t}$$

where:

A_p	=	area supported by a stay
A_σ	=	sectional area of a stay
p_c	=	calculating pressure
σ_t	=	nominal design stress at calculating temperature
		σ_t = 70 N/mm² for stay tubes
		σ_t = Rm/5.9 for stay bolts
		σ_t = Rm/5.7 for longitudinal stays

For a stay tube or stay bar, the area to be supported shall be the area enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays embraced, see Figure 32.

The calculation may be carried out in the un-corroded condition and not taking minus tolerances into account.

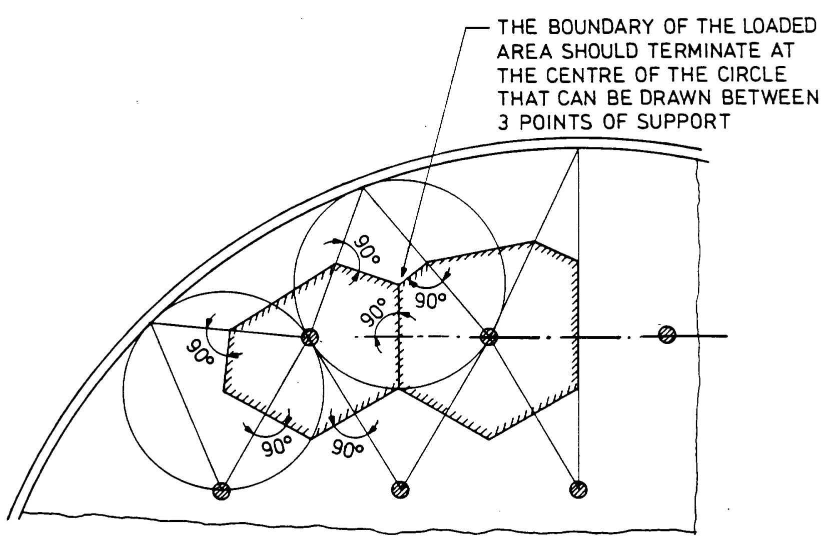


Figure 33 Loaded area on stays

8.1.2 For top and sides of combustion chambers, the distance between stays and the commencement of curvature of tube plates and back plates at their flanges shall not be less than the distance between rows of stays.

8.1.3 For stays on furnaces for vertical boilers, see [7.4].

8.2 Gusset stays

8.2.1 The support of flat end plates with only few gusset stays could lead to unacceptable local deformation of the shell. Therefore the total load shall be divided into a large number of gusset stays.

Each gusset stay supporting the flat end plate of the boiler shall be designed to carry the whole load due to the pressure on the area supported.

Gusset stays shall have a maximum angle of 30° to the longitudinal axis of the boiler. The minimum cross-section of the gusset stay shall be determined as follows:

$$s_g \cdot h_g \geq \frac{f_G \cdot F_g}{\sigma_t \cdot \cos\alpha}$$

where:

f_G = coefficient for the calculation of gusset stays

- f_G = 1.0 for plain furnace
- f_G = 1.0 for corrugated furnace which is separated from the gusset stay
- f_G = 1.2 for corrugated furnace which is located near to the gusset stay

F_g = load carried by one gusset stay

h_g = height of gusset stay

s_g = thickness of gusset stay

- $s_g \leq 1.5 \times$ shell plate thickness,
- $s_g \geq 0.5 \times$ shell plate thickness and
- $s_g \geq 0.5 \times$ end plate thickness

α = angle of gusset stay to longitudinal axis of the shell

σ_t = nominal design stress at calculating temperature

Guidance note:

The thickness of the gusset stay should not exceed the shell plate thickness.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

The welding seams between gusset stay, shell and endplate shall be carried out as full penetration welds.

The design of the gusset stay shall be in accordance with Figure 34.

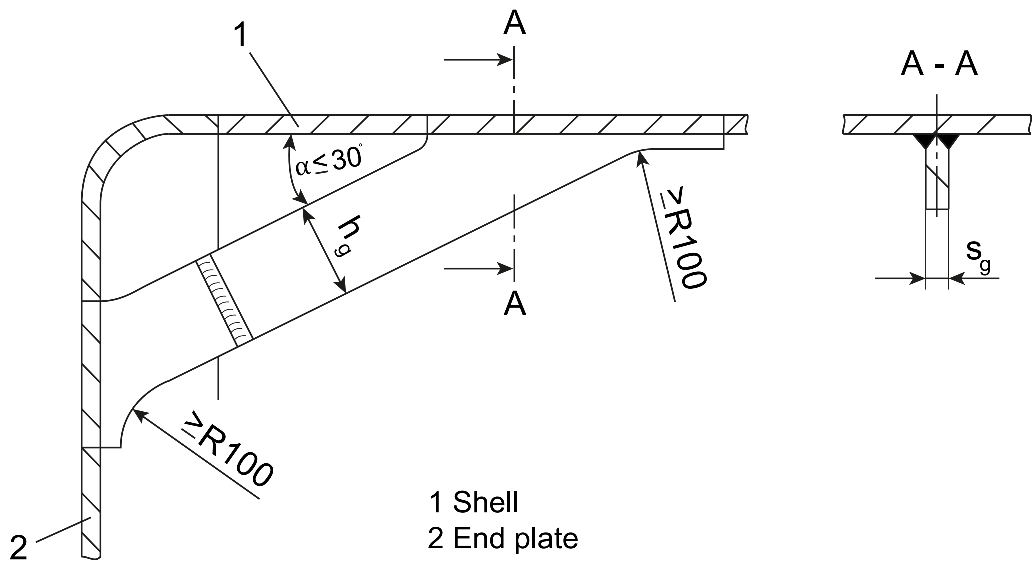


Figure 34 Details of welded gusset stays

9 Screws and bolts

9.1 General

9.1.1 The following requirements relate to screws and bolts which, as force-transmitting connecting elements, are subjected to tensile stresses due to the internal pressure of the pressure equipment. Normal operating conditions are assumed.

Where standard pipe flanges are used, the strength requirements for the flanges are considered to be satisfied if these flanges comply with a standard recognized by the Society. Details related to recognised standards accepted by the Society and acceptable flange welding details are given in Ch.6 Sec.9 [3.1.2] and Ch.6 Sec.9 [5.1] .

9.1.2 Bolts with a shank diameter d_s < 10 mm are not allowed.

Bolts shall not be located in the path of heating gases.

At least 4 bolts shall be used to form a connection.

To achieve small sealing forces, the sealing material shall be made as narrow as possible.

All bolts bigger than metric size M 30 shall be necked-down bolts.

9.1.3 Particular attention shall be spent for bolted connections with a high stress utilization of the bolts related to the allowable stresses. In such cases an elastic bolted connection with necked-down bolts shall preferably be applied. Necked-down bolts shall be used where the bolts are exposed to service temperatures of over 300°C or shall withstand internal pressure ≥ 40 bar.

Necked-down bolts are bolts with a shank diameter d_s = 0.9 x d_k (d_k being the root diameter). The connection with necked-down bolts shall be designed in accordance with a standard recognized by the Society. In the calculation, special allowance shall be made for shank diameters d_s < 0.9 x d_k.

9.2 Calculating temperature

9.2.1 The calculating temperatures of the bolts depend on the type of joint and the insulation. If no temperature has been calculated for the individual joint, the following calculating temperatures shall be applied, see Table 11.

Table 11 Calculating temperatures (for temperatures > 50°C)

Condition	*Calculating temperature t_c [°C]*
loose flange + loose flange	t_d - 30°C
fixed flange + loose flange	t_d - 25°C
fixed flange + fixed flange	t_d - 15°C

The temperature reductions allow for the drop in temperature at insulated, bolted connections. For non-insulated bolted joints, a further temperature reduction is not permitted due to the higher thermal stresses imposed on the entire bolted joint.

9.3 Nominal design stress

9.3.1 The values of the nominal design stress σ_t are shown in Table 12.

Table 12 Nominal design stress σ_t

Condition	*Nominal design stress σ_t [N/mm^2] for necked-down bolts*	*Nominal design stress σ_t [N/mm^2] for full-shank bolts*
Service condition	$R_{eH,t}$ / 1.5	$R_{eH,t}$ / 1.8
Test pressure and zero pressure / bolting-up condition	$R_{eH,20°}$ / 1.1	$R_{eH,20°}$ / 1.3

9.4 Quality coefficient

9.4.1 Full-shank bolts shall have a surface finish as specified in ISO 898-1. Necked-down bolts shall be machined all over.

9.4.2 In case of unmachined, plane-parallel surfaces, φ = 0.75. Where the bearing surfaces of the mating parts are machined, a value of φ = 1.0 may be applied.

9.4.3 Bearing surfaces which are not plane-parallel (e.g. on angle sections) are not permitted.

9.5 Design allowance

9.5.1 The design allowance c_1, considering the notch effect of the thread profile in relation to the root diameter, shall be as shown in Table 12.

For necked-down bolts c_1 = 0.

Table 13 Design allowance c_1

Condition	*Design allowance c_1 [mm]*
for service conditions of full-shank bolts; required root diameter of thread d_k ≤ 20 mm required root diameter of thread d_k > 20 mm and ≤ 40 mm required root diameter of thread d_k > 40 mm	3 5 - 0.1 x d_k 1
for service conditions of necked-down bolts	0
for test pressure	0
for bolting-up condition	0

9.6 Calculation

9.6.1 General

Bolted joints shall be designed for the following load conditions:

— service conditions (at calculating pressure p_c and calculating temperature t_c)
— load at test pressure (test pressure p_t and calculating temperature t_c = 20°C) and
— bolting-up condition at zero pressure (calculating pressure p_c = 0 bar and calculating temperature t_c = 20°C) .

Factors k_o, k_1 and K_D depend on the type, design and shape of the joint and the kind of fluid. The relevant values are shown in the Table 14 and Table 15.

Gaskets shall be suitable for the intended fluids under design pressure and design temperature conditions.

The bolt design shall be based on the greatest root diameter of the thread determined in accordance with the three load conditions specified above.

9.6.2 Root diameter

The necessary root diameter of a bolt in a bolted joint comprising n bolts is given by:

$$d_k = \sqrt{\frac{4 \cdot F_S}{\pi \cdot \sigma_t \cdot \varphi \cdot n}} + c_1$$

where:

c_1	=	design allowance
d_k	=	root diameter of thread
F_S	=	total load on bolted connection in service
n	=	number of bolts forming connection
φ	=	surface finish coefficient
σ_t	=	nominal design stress at calculation temperature.

9.6.3 Service conditions

The load on a circular bolted flange connection shall be calculated as follows:

$$F_S = F_B + F_D + F_Z$$

$$F_B = \frac{p_c}{10} \cdot \frac{\pi}{4} \cdot D_b^2$$

$$F_D = \frac{p_c}{10} \cdot \pi \cdot D_b \cdot k_1 \cdot 1.2$$

Where the arrangement of the bolted connection deviates significantly from the circular, special consideration and due allowance shall be given for the specific gasket dimensions and the resulting applicable bolt forces.

The additional force F_Z shall be calculated due to the pressure load of connected piping. F_Z = 0 in the case of bolted joints with no connected pipes (e.g. blind flanges). Where connecting pipes are installed in a very flexible way (e.g. by the use of suitable compensators or other flexible elements) and the service conditions are ≥ 0°C and < 400°C, F_Z may be determined as an approximation by applying the expression:

$$F_Z \approx \frac{p_c}{10} \cdot \frac{\pi}{4} \cdot d_i^2$$

where:

d_i	=	inside diameter of connected tube
D_b	=	mean gasket diameter or bolt pitch circle diameter (in case of full face gasket)
F_B	=	force imposed on bolted connection by the calculating pressure
F_D	=	force to close seal under service conditions
F_S	=	total load on bolted connection in service
F_Z	=	additional force due to in connected piping under service conditions
k_1	=	sealing factor for service condition (see Table 15)
p_c	=	calculating pressure
φ	=	surface finish coefficient
σ_t	=	nominal design stress at calculating temperature.

9.6.4 Test pressure

The load on a bolted joint shall be calculated as follows:

$$F'_S = \frac{p_t}{p_c} \cdot \left(F_B + \frac{F_D}{1.2}\right) + F'_Z$$

where:

F_B	=	force imposed on bolted connection by the calculating pressure
F_D	=	force to close seal under service condition
F'_S	=	total load on bolted connection at test pressure
F'_Z	=	additional force due to loaded conditions in connected piping under test pressure (if applicable)
p_c	=	calculating pressure
p_t	=	test pressure.

For calculating the root diameter of the thread, F_S shall be substituted by F'_S in [9.6.2].

9.6.5 Bolting-up condition

The load on a bolted joint shall be calculated as follows:

$$F_{So} = F_{Do}$$

$$F_{Do} = \pi \cdot D_b \cdot k_o \cdot K_D$$

For calculating the root diameter of the thread, F_S shall be substituted by F'_{So} in [9.6.2].

In the zero-pressure bolting-up condition, the force F_{Do} shall be exerted on the bolts during assembly to effect a closed union with the gasket material and to close the gap at the flange bearing surfaces.

If the force exerted in bolting-up condition $F_{Do} > F_S$, this value may be replaced by the following, where malleable gasket materials with or without metal elements are used.

$$F'_{Do} = 0.2 \cdot F_{Do} + 0.8 \cdot \sqrt{F_S \cdot F_{Do}}$$

where:

D_b	=	mean gasket diameter or bolt pitch circle diameter (in case of full face gasket)
F_{Do}	=	compression force on gasket to ensure tight joint in bolting-up condition
F'_{Do}	=	compression force on gasket to ensure tight joint in bolting-up condition, if $F_{Do} > F_S$
F_S	=	total load on bolted connection in service
F_{So}	=	total load on bolted connection in bolting-up condition with no pressure imposed
F_Z	=	additional force due to loaded conditions in connected piping
k_o	=	sealing factor for bolting-up condition (see Table 15)
K_D	=	sealing material deformation factor (see Table 15 and 16).

Table 14 Gasket coefficients

Gasket type	*Description*	*Material*	*Gasket coefficient* [1)]					
			for liquids			*for gases and vapours*		
			bolting-up [2)]		*service*	*bolting-up* [2)]		*service*
			k_0	$k_0 \times K_D$	k_1	k_0	$k_0 \times K_D$	k_1
			[mm]	*[N/mm]*	*[mm]*	*[mm]*	*[N/mm]*	*[mm]*
Soft gaskets	flat gaskets acc. to DIN EN 1514-1	impregnated sealing material	-	20 b_D	b_D	-	-	-
		rubber	-	b_D	0.5 b_D	-	2 b_D	0.5 b_D
		PTFE	-	20 b_D	1.1 b_D	-	25 b_D	1.1 b_D
	expanded graphite without metal insert	graphite	-	- [4)]	- [4)]	-	25 b_D [3)]	1.7 b_D
	expanded graphite with metal insert	graphite	-	- [4)]	- [4)]	-	20 b_D	1.3 b_D
	fibre material without asbestos with matrix (h_D < 1 mm)	fibre material	-	- [4)]	- [4)]	-	40 b_D	2 b_D

Gasket type	Description	Material	Gasket coefficient [1)]					
			for liquids			for gases and vapours		
			bolting-up [2)]		service	bolting-up [2)]		service
			k_0	$k_0 \times K_D$	k_1	k_0	$k_0 \times K_D$	k_1
			[mm]	[N/mm]	[mm]	[mm]	[N/mm]	[mm]
	fibre material without asbestos with matrix ($h_D \geq$ 1 mm)	fibre material	-	- [4)]	- [4)]	-	35 b_D	2 b_D
Combined metal and soft gaskets	spiral wound gasket	carbon or stainless steel, monel	-	15 b_D	b_D	-	50 b_D	1.3 b_D
	corrugated gasket	Al	-	8 b_D	0.6 b_D	-	30 b_D	0.6 b_D
		Cu, Ms	-	9 b_D	0.6 b_D	-	35 b_D	0.7 b_D
		mild steel	-	10 b_D	0.6 b_D	-	45 b_D	1.0 b_D
	metal-jacketed gasket	Al	-	10 b_D	b_D	-	50 b_D	1.4 b_D
		Cu, Ms	-	20 b_D	b_D	-	60 b_D	1.6 b_D
		mild steel	-	40 b_D	b_D	-	70 b_D	1.8 b_D
Metal gaskets	flat gasket	-	0.8 b_D	-	b_D + 5	b_D	-	b_D + 5
	diamond gasket	-	0.8	-	5	1	-	5
	oval gasket	-	1.6	-	6	2	-	6
	round gasket	-	1.2	-	6	1.5	-	6
	ring-joint gasket	-	1.6	-	6	2	-	6
	u-shaped gasket	-	1.6	-	6	2	-	6
	corrugated gasket	-	0.4 $\sqrt{Z}$	-	9 + 0.2 Z	0.5 $\sqrt{Z}$	-	9 + 0.2 Z
	membrane welded gasket	-	0	-	0	0.5 $\sqrt{Z}$	-	0
Grooved steel gaskets with soft covering on both sides	PTFE coating on soft steel	PTFE	-	- [4)]	- [4)]	-	15 b_D	1.1 b_D
	PTFE coating on stainless steel	PTFE	-	- [4)]	- [4)]	-	15 b_D	1.1 b_D
	graphite coating on soft steel	graphite	-	- [4)]	- [4)]	-	20 b_D	1.1 b_D

Gasket type	Description	Material	Gasket coefficient [1]					
			for liquids			for gases and vapours		
			bolting-up [2]		service	bolting-up [2]		service
			k_0	$k_0 \times K_D$	k_1	k_0	$k_0 \times K_D$	k_1
			[mm]	[N/mm]	[mm]	[mm]	[N/mm]	[mm]
	graphite coating on low-alloy high temperature steel	graphite	-	- [4]	- [4]	-	15 b_D	1.1 b_D
	graphite coating on stainless steel	graphite	-	- [4]	- [4]	-	20 b_D	1.1 b_D
	silver coating on high-temperature stainless steel	silver	-	- [4]	- [4]	-	125 b_D	1.5 b_D
Spiral gaskets with soft filling	PTFE filling with one or both side ring reinforcement	PTFE	-	- [4]	- [4]	-	50 b_D	1.4 b_D
	graphite filling withone side or both side ring reinforcement	graphite	-	- [4]	- [4]	-	40 b_D	1.4 b_D
1	applicable to flat, machined, sound, sealing surfaces							
2	where k_0 connot be specified the product ko K_D is given here							
3	shall be a gastight grade							
4	as long as no values for liquids are available the values for gases/vapours may be used							

where:

b_D = width of gasket

h_D = height of gasket

Z = number of teeth.

Table 15 Deformation coefficients

Materials	*Deformation coefficient K_D [N/mm²]*
aluminium, soft	92
copper, soft	185
soft iron	343
steel, St 35	392
alloy steel, 13CrMo44	441
austenitic steel	491
Note: at room temperature K_D shall be substituted by the deformation coefficient at 10% compression δ_{10} or alternatively by the tensile strength R_m.	

SECTION 5 EQUIPMENT, VALVES AND FITTINGS

1 General

1.1 Construction

1.1.1 Construction and arrangement of valves and cocks shall be such that it can be seen without difficulty whether they are open or shut.

All valves shall be closed with a right-hand motion (clockwise rotation).

1.1.2 Valves exceeding 50 mm in diameter shall be fitted with outside screws, and the covers shall be secured by bolts or studs. Valves with screw-on bonnets shall be safeguarded to prevent unintentionally loosening of the bonnet.

1.1.3 Where equipment, valves and fittings are secured by studs, the studs shall have full thread holding in the plate for a length of a least one diameter. Holes for studs shall not penetrate the whole thickness of the plate. For welded branch connections, see Sec.4 [6.5].

Appliances for controlling pressure or temperature are no substitute for safety valves.

1.1.4 Valve cones of safety valves shall be capable of being lifted at all times.

1.1.5 Warm water generating plants shall be designed as closed system with external pressure generation and membrane expansion vessel. Water shall be circulated by forced circulation.

2 Safety valves

2.1 Valves on boilers

2.1.1 Boilers shall have not less than two safety valves with a total discharge capacity equal to or greater than the total design evaporation in normal and shut-off condition. The safety valves shall be fitted to the saturated steam space or, in case of boilers which do not have their own steam space, to the highest point of the boiler or in the immediate vicinity respectively.

2.1.2 Superheaters shall have at least one safety valve on the outlet side. Where a boiler is fitted with an integral superheater without an intervening stop valve, the safety valve(s) on the superheater may be considered as boiler safety valve(s). The safety valves shall be so proportioned and positioned that when relieving, sufficient steam is forced through the superheater to prevent damage to the heater. At least 75% of the required safety valve capacity shall be placed on the boiler. Where a superheater, re-heater or economiser is fitted with a valve between one of these and the boiler, the unit shall have appropriate safety valves. Such safety valves shall not be regarded as safety valves for the boiler.

2.1.3 All the safety valves on each boiler may be fitted in one chest, which shall be separate from any other valve chest. The chest shall be connected directly to the shell by a strong and stiff neck. Safety valve chests shall have drain pipes leading the drain to the bilge or to a tank, clear of the boiler. No valves or cocks shall be fitted in these drain pipes.

2.1.4 The design of the safety valves shall be such that they cannot unintentionally be loaded beyond the set pressure, and in the event of fracture cannot lift out of their seats.

For safety valves operating at pressures below 17.5 bar, it should be possible for the valves to be turned round on their seats.

2.1.5 Easing gear shall be provided for lifting the safety valves on a boiler and shall be operable from the boiler or engine room platforms. It shall be possible to monitor the proper function of the safety valves (opening and closing) visually and audible from a safe point.

The superheater safety valve(s) are also to be provided with easing gear, but this may be operable only from an accessible place in the boiler room, free from steam danger.

2.1.6 The aggregate area of the orifices through the seatings of the safety valves (for full lift valves, the net area through seats after deducting the guides and other obstructions, when the valves are fully lifted) on each boiler shall not be less than:

For saturated steam:

$$A_3 = \frac{K_s \cdot E_s}{p_d + 1}$$

where:

A_3	=	aggregate area of the orifice
E_s	=	designed evaporation
K_S	=	factor for calculating the aggregate area of orifice for safety valves K_S = 21 for valves of the ordinary type having a lift of at least 1/24 of the internal diameter of the seating K_S = 14 for valves of high-lift type having a lift of at least 1/16 of the internal diameter of the seating K_S = 10.5 for valves of improved high-lift type having a lift of at least 1/12 of the internal diameter of the seating K_S = 5.25 after special approval for valves of full-lift type having a lift of at least 1/4 of the internal diameter of the seating
p_d	=	design pressure

For superheated steam:

$$A_4 = A_3\left(1 + 0.0018 \cdot t_D\right)$$

where:

A_3	=	aggregate area of the orifice
A_4	=	aggregate area of the orifice
t_D	=	temperature difference between saturated and superheated steam

If a discharge capacity test, carried out in presence of the surveyor, proves that the capacity exceeds that indicated by the constant K_S, consideration will be given to the use of a lower value of K_S based on up to 90% of the measured capacity.

For full-lift safety valves, the cross-sectional area of the waste-steam pipe and passages shall not be less than twice the aggregate-valve area where K_S = 5.25, and not less than three times the aggregate-valve area where K_S has a lower value.

2.1.7 Notwithstanding the requirements in [2.1.6], the safety valves fitted to any boiler (and integral superheater) shall be capable of discharging all the steam which can be generated without causing a pressure rise of more than 10% in excess of the design pressure.

2.1.8 Safety valves of ordinary type with seats of less than 38 mm inside diameter shall not be used. For full lift safety valves the inside seat diameter shall not be less than 20 mm.

2.1.9 The pipe design of the waste steam pipe shall take into consideration possible pressure build up in the line.

Two or more safety valves may have a common waste-steam pipe, the cross-sectional area of which shall not be less than the total cross-sectional areas of the branch waste-steam tube. The valves shall be such that the back pressure from one blowing valve will not influence the functioning of the other valve(s). Bellow type safety valves will satisfy this requirement.

2.1.10 Where boilers are not fitted with superheater, the safety valves shall be set to open at a pressure of not more than 3% above the approved design pressure, and in no case at a pressure higher than:

— the design pressure of the steam piping, or
— the least sum of the design pressure of machinery connected to the boiler and the pressure drop in the piping between this machinery and the boiler.

2.1.11 Where boilers are fitted with superheaters, the safety valves on the superheater shall be set to a pressure not higher than:

— the design pressure of the steam piping, or
— the least sum of the design pressure of machinery connected to the boiler and the pressure drop in the piping between this machinery and the boiler.

The safety valves on the boiler drum shall be set to a pressure not less than the superheater valve setting plus 0.35 bar plus the pressure drop through the superheater, when the boiler stop valves are closed and the superheater safety valves are relieving at their rated capacity. In no case, however, are the safety valves to be set to a pressure higher than 3% above the design pressure of the boiler.

2.1.12 Tests for accumulation of pressure shall be carried out. The boiler pressure shall not rise more than 10% above the design pressure, when the boiler stop valve is closed under full firing conditions. The boiler shall be fired to steady state, and then maintained for 5 minutes. This test is also applicable for exhaust gas boilers with steam space. During this test, no more feed water shall be supplied than is necessary to maintain a safe working water level.

2.2 Valves on pressure vessels other than boilers and on steam-heated steam generators

2.2.1 Pressure vessels or systems of pressure vessels (see [2.2.3]) shall have safety valves, except as provided for in [2.2.4].

2.2.2 Pressure vessels intended to operate completely filled with liquid shall have a liquid relief valve unless otherwise protected against overpressure. Calorifiers shall be fitted with a safety valve at the cold water inlet.

2.2.3 Pressure vessels connected together in a system by piping of adequate capacity containing no valve that can isolate any pressure vessel, may be considered as a system of pressure vessels for the application of safety valves.

2.2.4 Where the compressor for air receivers is fitted with a safety valve, so arranged and adjusted that the receivers cannot be subjected to pressures greater than the design pressure, such receivers need not be fitted with safety valves if they are fitted with fusion plugs for quick release of pressure in case of fire. The melting point of the fusion plug shall be approximately 100°C.

The same regulation may apply to other pressure vessels, when the source of pressure is external to the pressure vessel and is under such positive control that the pressure cannot exceed the design pressure at operating temperature.

2.2.5 When a pressure vessel is fitted with heating coils, and fracture in the coils may increase the normal pressure of the fluid in the pressure vessel, the relieving capacity of the safety valve shall be sufficient for the case of fracture of one tube.

2.2.6 The total capacity of the safety valves, fitted to any pressure vessel or system of pressure vessels, shall be sufficient to discharge the maximum quantity of fluid (liquid or gaseous) that can be generated or supplied without occurrence of a rise in the pressure of more than 10% above the design pressure.

2.2.7 Steam-heated steam generators shall be protected from excessive pressure resulting from failure of the high-pressure heating tubes. For this purpose, it may be required that the area of the safety valves be somewhat greater than that calculated in the formula in [2.1.6], unless other protective devices are provided to control the supply of steam to the heating tubes.

The safety valves shall be set to open at a pressure of not more than 3% above the design pressure.

2.2.8 The use of bursting discs or a combination of bursting discs and safety valves instead of safety valves is subject to consideration in each individual case.

2.3 Protection of condensers against overpressure

2.3.1 Vacuum condensers shall be protected against overpressure by one or more of the following means:

— safety valve(s) set to open at the design pressure
— bursting disc(s) with bursting pressure equal to the design pressure
— automatic shut-off of steam exhausting into the condenser (steam dump valve, exhaust steam from turbines) if the pressure exceeds the design pressure. In addition, an independent high pressure alarm set to warn at a pressure lower than the automatic shut-off pressure shall be fitted.

2.3.2 For atmospheric condensers, the air vent shall have a size that accommodates the maximum steam flow assuming no cooling water supply to the condenser. Alternatively, one of the means given in [2.3.1] shall be provided.

2.3.3 If vacuum can occur by e.g. condensating steam an appropriate safety device is necessary.

3 Stop valves and check valves

3.1 Valves on boilers

3.1.1 Feed water intakes of main boilers or auxiliary boilers for essential services and each steam-heated steam generator shall have a stop valve and a check valve.

3.1.2 The feed water stop valve shall be attached directly to the boiler or to the economiser, if this forms an integral part of the boiler, and the valve neck shall be of sufficient length to clear valve of boiler lagging and sheathing. Where the arrangements necessitate the use of nozzles between the boiler and the valve, these pipes shall be as short as possible, and shall be of substantial thickness. The check valve shall be placed as near the stop valve as practicable.

3.1.3 Feed water shall be discharged into the boiler in such a manner that it does not impinge directly on surfaces exposed to hot gases.

3.1.4 Nozzles for feed inlets on water-tube boilers with design pressure exceeding 40 bar shall be provided with a thermal sleeve to minimize thermal stresses. Similar arrangements shall be provided for de-superheater inlets and outlets, if the de-superheated steam conditions results in a residual superheat of 60°C or higher at any rating.

3.1.5 Each steam outlet, except for safety valves and superheater inlet and re-heater inlet and outlet, shall be fitted with a stop valve located as near to the boiler as practicable.

3.2 Valves on pressure vessels other than boilers and steam-heated steam generators

3.2.1 Each pressure pipe shall be fitted with a stop valve located on the shell or as near to the pressure vessel as practicable. In a system of pressure vessels (see [2.2.3]), each system shall be fitted with stop valves.

3.2.2 In general, not more than three pressure vessels should be grouped together. Starting air receivers which are opened in service shall be capable of being shut-off individually. Devices incorporated in piping (e.g. water and oil separators) do not require shut-off devices.

4 Blow-down valves and test valves for boiler water

4.1 Blow-down valves

4.1.1 Each boiler shall be fitted with a blow-down valve secured directly to the shell.

Where this is not practicable for water-tube boilers, the valve may be placed immediately outside the boiler casing with a heavy gauge steel pipe fitted between the boiler and the valve. The pipe and valve shall be adequately supported, and the pipe, if exposed to furnace heat, shall be protected by brickwork or other heat-resisting material, so arranged that the pipe may be inspected and shall not be constrained against expansion.

4.1.2 The internal diameter of the valve and its connections to the sea shall not be less than 25 mm and need not exceed 38 mm.

4.1.3 Blow-down cocks fitted with taper plugs shall be of the bolted cover type with separately packed glands, and shall not be used with pressures over 13 bar.

4.2 Test valves

4.2.1 At least one valve for testing boiler water shall be fitted directly to each boiler in a convenient position. It shall not be fitted on the water-gauge mountings or its nozzles.

Guidance note:

An adequate monitoring and a proper treatment of the feed water and boiler water should be carried out.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

5 Gauges

5.1 Water gauges

5.1.1 Every boiler and steam heated steam generator designed to contain water at specified levels shall be fitted with at least two independent means of indicating the water level, one of which shall be a glass gauge. The other means shall be either an additional glass gauge or an approved equivalent device.

Water and steam drums exceeding 4 metres in length and placed athwartships shall have a glass water gauge at or near each end of the drum.

5.1.2 The water level indicators shall be so located that the water level can be ascertained despite the movement and inclination of the ship at sea.

5.1.3 The water gauges shall be readily accessible and positioned so that the water level is clearly visible. Water gauges shall be so located that the lowest visible water level in the glass is at the low low water level (BCO).

In the case of water-tube boilers, the glass water gauges shall be located so that water is just showing when the water level in the steam drum is just above the top row of tubes when the boiler is cold (generally about 25 mm above). The length of the glass water gauges shall be sufficient for verifying the water levels in case of alarm and low low water level (BCO).

In boilers where all tubes are not entirely submerged in water when cold, the glass water gauges shall be placed in positions which indicate satisfactorily that the water content is sufficient for safe working.

The combustion chamber top of a cylindrical, horizontal boiler and the furnace crown of a vertical boiler shall be clearly marked in a position adjacent to the glass water gauge. Water gauges shall be fitted with cocks or valves at each end of the glass gauge. The cocks shall be accessible for closing from positions free from danger in the event of the glass breaking.

5.1.4 Mountings for glass water gauges shall be fitted directly to the boiler plating or to stand pillars or columns. Stand pillars and columns shall be bolted directly to the boiler shell, but they may also be connected to the boiler by means of pipes. These pipes shall be fitted with terminal valves or cocks secured directly to the boiler shell. Valves and cocks shall have fixed hand-wheels or handles, and shall be provided with means for clearly indicating whether they are open or closed.

The upper ends of pipes, connecting the water gauge column to the boiler, shall be arranged such that there is no pocket or bend where an accumulation of water can lodge. They shall not pass through the uptake if they can be otherwise arranged. If, however, this condition cannot be complied with, they may pass through it by means of a passage at least 50 mm clear of the pipe all round and open for ventilation at both ends.

5.1.5 Heated pressure equipment in which a reduction of the liquid level can result in unacceptably high temperatures in the pressure equipment walls shall be fitted with a device for indicating the level of the liquid.

5.2 Pressure gauges

5.2.1 Each boiler and superheater shall be provided with a separate steam-pressure gauge. The gauges shall be placed where they can easily be seen. The highest permissible working pressure shall be marked off on the pressure gauge in red.

5.2.2 Each pressure vessel which can be shut-off and every group of vessels with a shut-off device shall be equipped with a pressure gauge, also capable of being shut-off. The measuring range shall cover the test pressure and the maximum allowable working pressure shall be marked with a red mark.

SECTION 6 INSTRUMENTATION AND AUTOMATION

1 General

1.1 Cross reference

1.1.1 For general requirements for instrumentation and automation, see Ch.9. Additional requirements for gas-fired boiler installations on liquefied gas carriers, see the rules for classification of ships Pt.5 Ch.7 Sec.16 [6].

1.2 Manual operation

1.2.1 For heat generators and burners, which are operated automatically, means for operation and supervision shall be provided which allow a manual operation with the following minimum requirements by using an additional control level. The following safety functions shall remain active:

— the shut-down in case of low water level at steam boilers with a defined highest flue at their heating surface (e.g. fired steam boilers and exhaust gas boilers with a temperature of the exhaust gas >400°C)
— the shut-down in case of high temperature at hot water generators
— the shut-down in case of high temperature and/or low flow on the oil side at the oil-fired thermal oil heater
— the flame monitoring at burners

1.2.2 The monitoring of the oil content of the condensate or of the ingress of foreign matters into the feeding water of steam systems may not lead to a shut-down of the feeding pumps in steam systems during manual operation.

1.2.3 Thermal oil heaters heated by exhaust gas may be operated without temperature and flow monitoring during manual operation if the maximum allowable discharge temperature can be kept.

1.2.4 The safety equipment not required for manual operation may only be deactivated by means of a key-operated switch. The actuation of the key-operated switch shall be indicated at the local control panel and at the alarm monitoring control system.

1.2.5 Manual operation requires constant and direct supervision of the system.

2 Pressure vessels

2.1 Monitoring

2.1.1 Monitoring of electrically heated pressure vessels shall be arranged according to Table 1.

Table 1 Monitoring of electrically heated pressure vessels

Item		*Alarm and safety action (stated by an x)*		*Comments*
		Alarm	*Automatic shutdown (safety action) of electrical heating with alarm*	
Fluid	Temperature high		x	

3 Boilers

3.1 Automatic control

3.1.1 When a combustion control system is fitted, the feed water control system shall have a control range at least equal to that of the combustion control system.

During all normal load variations, the water level shall be kept within the dynamic and stationary limits for reliable operation.

Guidance note:

On water tube boilers, the feed-water supply should preferably be continuous, because such boilers have a high rate of evaporation in relation to their water content.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.1.2 When a combustion control system is fitted, the steam pressure shall be kept within limits appropriate to the steam consuming machinery over the entire control range.

Guidance note:

Routine work, such as cleaning of burners and filters, soot blowing, change over to stand-by pumps, etc. should preferably be possible without switching off the automatic system.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.2 Monitoring

3.2.1 Monitoring shall be arranged according to Table 2.

3.2.2 Boilers which are operated under constant attending, are at least to have alarm and shut-down at low low water level and at stop of circulation.

3.2.3 For main boilers, monitoring shall be according to the rules for classification of ships Pt.6 Ch.2 Sec.2 Table 6.

Table 2 Monitoring of fired auxiliary boilers

Item		Alarm and safety action (stated by an x)		Comments
		Alarm	Automatic shutdown (safety action) of boiler with alarm	
Water level, not double pressure boiler	Low water level LWL	x		
	Low low water level LLWL		x	Sensor independent from water level control
	High water level HWL	x		
Water level double pressure boilers	Primary system LWL	x		
	Primary system LLWL		x	Sensor independent from water level control
	Secondary system LWL	x		
	Secondary system HWL	x		
Circulation	Stopped		x	Forced circulation boilers
Steam pressure	Pressure high	x		
	Pressure higher		x	When the automatic control system does not cover the entire load range from zero load.
Superheated steam temperature	Temperature high		x	$t_d > 350°C$
Feed water	Salinity high[1)]	x		Additional action: interruption of feed water supply
Condensate	Oil content high[1)]	x		Additional action: interruption of feed water supply
1) Monitoring for salinity and/or oil is only required, if a contamination of steam or condensate by salt or oil is possible				

4 Exhaust gas boilers

4.1 Instruments and Monitoring

4.1.1 Exhaust gas boilers with smoke tubes, plain water tubes or extended surface water tubes, shall be monitored as listed in Table 3.

Table 3 Monitoring of exhaust gas boilers

Item		*Alarm and safety action (stated by an x)*		*Comments*
		Alarm	*Automatic shutdown (safety action) of boiler with alarm*	
Water level	Low low water level LLWL	x		Sensor independent from water level control
	High water level	x		
Circulation	Stopped	x		Forced circulation boilers
Steam pressure	Pressure high	x		
Superheated steam temperature	Temperature high	x		t_d > 350°C
Feed water	Salinity high[1)]	x		Additional action: interruption of feed water supply
Condensate	Oil content high[1)]	x		Additional action: interruption of feed water supply
1) Monitoring for salinity and/or oil is only required, if a contamination of steam or condensate by salt or oil is possible.				

4.1.2 The pressure for steam pressure high shall be measured directly at the pressure part of the boiler exposed to the exhaust gas.

4.1.3 Exhaust gas boilers with extended surface water tubesshall, in addition to the monitoring given in , Table 3 be monitored as listed below:

— Stand-by circulating pump, when required according to Sec.3 [2.3.1], shall be equipped with automatic start activated by low flow in the circulating system. Alarm to be given when the pump is started.
— Soot cleaners, when required in Sec.3 [2.3.3], shall be equipped with automatic start and arranged for sequential operation.
— Alarm for high gas temperature located after the exhaust gas boiler or economiser. The alarm shall be given in case of soot fire.

5 Water heaters

5.1 Monitoring

5.1.1 Monitoring shall be arranged according to Table 4.

Table 4 Monitoring of fired water heaters

Item		*Alarm and safety action (stated by an x)*		*Comments*
		Alarm	*Automatic shutdown (safety action) of heater with alarm*	
Water	Low low water level LLWL		x	
	Temperature high		x	
	Pressure high		x	
	Pressure low		x	For water heaters with external pressure generation (e.g. membrane expansion vessel)
	Circulation low		x	

6 Thermal-oil Heaters

6.1 Automatic control

6.1.1 Automatic control of thermal-oil outlet temperature shall to be able to keep the oil temperature within the limits for safe operation under all load conditions.

6.1.2 The temperature set point shall be at a sufficiently low level to keep all peak temperatures, dependent on regulating system transients or on heat transfer functions, below the safe temperature limit of the thermal oil.

6.1.3 Start-up of the burner shall be prevented by interlocks if the circulating pump is at standstill.

6.1.4 An alarm shall be given when the engine delivering the exhaust gas for heating the thermal oil heater is started and the flow of the thermal oil through the heater is below its minimum value (e.g. at standstill of the circulation pump, closed shut-off valves).

6.2 Monitoring

6.2.1 Monitoring shall be arranged according to Table 5.

Table 5 Monitoring of thermal-oil heaters

Item		*Alarm and safety action (stated by an x)*		*Comments*
		Alarm	*Automatic shutdown (safety action) of thermal oil heater with alarm*	
Thermal-oil	Temperature outlet high		x	Fired heater, separate for each coil
	Temperature outlet high	x		Heater heated by exhaust gases, separate for each coil 1)
	Flow low		x	2)
	Pressure high		x	for pre-pressurised systems
Flue gas of fired heaters	Temperature high		x	
	Thermal oil leakage		x	Leakage detector located at heater casing
Exhaust gas of main or auxiliary engines	Temperature high	x		Fire alarm
	Temperature high	x		Soiling by soot deposits
	Thermal oil leakage	x		Leakage detector located at heater casing
Expansion tank	Level low low		x	
	Level low	x		
	Level high	x		
	Temperature high	x		
	Quick drainage valve open or emergency shut-off valve closed	x		3)
Forced draught	Fan stopped		x	

1) Individual monitoring of the coils connected in parallel may be dispensed with if the maximum exhaust gas temperature is lower than the maximum allowable film temperature of the thermal oil.
2) An alarm to be tripped in case of low flow at the heater heated by exhaust gas.
3) At the same time a non-safety related shut-down of the burner at the fired heater should be carried out.

6.3 Indicators

6.3.1 Thermal-oil heaters shall be equipped with instruments for continuous indication of:

— total thermal-oil flow at heater outlet
— thermal-oil temperature at heater inlet and outlet
— flue gas or exhaust gas outlet temperature

— thermal oil pressure at the heater.

Thermal-oil expansion vessels shall be equipped with a device for continuous indication of level with a mark indicating the lowest allowable liquid level.

7 Oil or gas burners

7.1 General

7.1.1 Heat generators without constant and direct supervision shall be operated with automatic firing systems.

7.1.2 The correct sequence of safety functions when the burner is started up or shut down shall be automatic and implemented in a dedicated control system unit (e.g. burner control box).

7.1.3 If air supply is continuous and above 20% of the air flow at full load, a new ignition after normal stop of burner is acceptable, irrespective of the restrictions given in [1.2.1].

7.2 Automatic quick-closing valves

7.2.1 Two automatic quick-closing valves shall be provided at the fuel oil supply line to the burner.

7.2.2 The return line of burners with return lines has also to be provided with an automatic quick-closing valve. The valve in the return line may be dispensed with if the return line is not under pressure and no oil is able to flow back when the burner is shut down.

7.2.3 For the fuel oil supply line to the ignition burner one automatic quick-closing valve will be sufficient, if the fuel oil pump is switched off after ignition of the burner.

7.2.4 In an emergency it shall be possible to close the automatic quick-closing valves from the local heat generator control panel and - where applicable - from the engine control room.

7.2.5 During operational stop of burners, including the pre-purge time before ignition, safe shut-off of fuel oil shall be ensured. If the fuel oil will be under pressure during operational stop of burners, the shut-off valve shall be duplicated. A single shut-off valve will be accepted if the burners are drained off.

7.3 Safety time

7.3.1 Every burner shall be equipped with a safety device for flame monitoring suitable for the particular fuel oil in use (spectral range of the burner flame shall be observed).

7.3.2 The safety device for flame monitoring shall ensure that the safety times given in Table 6, which depend on the oil throughput of the burner, are complied with.

Table 6 Safety times

Oil throughput (kg/h)	*Safety times (s) (maximum)* [1)]	
	At start-up	*In operation*
up to 30	10	10
above 30	5	1

1) The safety time is the maximum permissible period of time during which the fuel oil may be delivered into the combustion space without a flame burning.

7.3.3 Measures shall be taken to ensure that the safety time for the main flame is not prolonged by the action of the igniter (e.g. ignition burner).

7.4 Monitoring

7.4.1 The automatic quick-closing devices shall not release the oil supply to the burner during start up and shall interrupt the oil supply during operation (automatic restart possible), if an automatic shutdown of the burner occurs as specified in Table 7.

Table 7 Monitoring of burners

Item		*Alarm and safety action (stated by an x)*		*Comments*
		Alarm	*Automatic shutdown (safety action) of burner with alarm*	
Heavy fuel oil	Temperature or viscosity high	x		
	Temperature or viscosity low	x		
Marine gas oil	Temperature high	x		
Combustion air supply	Insufficient air supply		x	2
Steam or compressed air atomizer	Insufficient supply of atomizing medium steam or air		x	
Oil pressure atomizer	Insufficient oil pressure		x	2
Rotary cup atomizer	Insufficient rotary speed of spinning cup or alternatively primary air pressure low		x	
Burners with return line	Pressure in the return line high		x	
Flame	Ignition failure during start-up		x 1)	In multi burner applications each burner to have separate monitoring devices and individual automatic quick closing valves
	Flame failure during operation		x 1)	
Burner casing	Burner not in operating position		X	

Control power supply	Failure		x	
Induced draft fan	Failure		x	
Flaps in the flue gas duct	Closed		x	
Limiters at the heat generator	Actuated		x [1)]	

1) Interlock of the burner. No automatic restart allowed. Manual reset of the interlock at the burner control panel required.

2) one sensor (air pressure or oil pressure) will be sufficient for oil pressure atomising burners, if the oil pump and the air fan are arranged on one shaft and it is secured by the arrangement that in case of a failure of the air fan the oil pump cannot supply fuel to the nozzle any more.

7.4.2 The tripping of the safety and monitoring devices has to be indicated at the local control panel of the burner or heat generator.

SECTION 7 MANUFACTURE, WORKMANSHIP AND TESTING

1 Manufacture

1.1 General

1.1.1 Manufacturers of pressure equipment of class I and II as listed below shall be approved by the Society in accordance with DNV-CP-0261 *Pressure equipment*.

— Welded pressure equipment.
— Pressure equipment with pressed parts manufactured by the pressure equipment manufacturer.
— Pressure equipment where heat treatment is necessary in the manufacturing process.
— Seamless gas cylinders.

1.1.2 Welding shall be carried out by approved welders, see Pt.2 Ch.4 Sec.3, and in accordance with approved drawings and specifications.

For class I and II pressure equipment, welding procedures shall be qualified as specified in Pt.2 Ch.4 Sec.5 or according to a recognised international code accepted by the Society.

2 Workmanship

2.1 Cutting of plates

2.1.1 Flame, water jet, laser or plasma cutting of the plates is normally to be used. Shearing of plates shall not be used, unless the sheared edge is removed by machining for a distance of one quarter of the plate thickness, minimum 3 mm.

2.2 Welded joints

2.2.1 Only full penetration butt welds are acceptable for longitudinal and circumferential main joints. Circumferential main joints other than butt welds are acceptable for shell to flat end and to tube plate connections, see Sec.4.

2.2.2 The joints shall be welded from both sides of the plates unless otherwise approved.

Circumferential joints in headers, pipes and tubes may be welded from one side only with or without backing strip. The design of the joint and the method of welding shall provide full penetration, and it shall be demonstrated that the welding method gives a weld free from significant defects. If a backing strip is used, it shall be removed after welding and prior to any required non-destructive tests.

However, permanent backing strips for circumferential welds may be accepted for the following pressure equipment when the second side is inaccessible for welding:

— small pressure equipment with an outer diameter of less than 450 mm
— pressure vessels in refrigerating plants
— outer shells of vacuum insulated tanks.

Permanent backing strips shall be accepted when the following conditions are satisfied:

— class III pressure equipment or class II pressure equipment with a welding joint efficiency of ≤ 0.85
— welding procedures are qualified with backing strip
— non-corrosive fluids
— design with backing strip shall be verified by a recognized pressure vessel code accepted by the Society

— fatigue assessment shall be carried out if it is considered to be a possible mode of failure.

Where ultrasonic testing is required by the rules but cannot be performed, another equivalent method of NDT shall be applied.

2.2.3 Wherever practicable, no attachment shall be welded on in the immediate vicinity of a welded joint. If this cannot be avoided, the welds shall cross each other completely.

2.2.4 Where ends are made of welded plates, the welds shall be so arranged that they are exposed to the least possible stress. Welded joints passing through flanged curvatures shall be at right angles to these.

2.2.5 Unless the pressure equipment is stress-relieved after welding (see [3.1]), not more than two weld seams shall meet at one point.

Guidance note:

Whenever possible, openings in or near welded joints should be avoided.

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2.2.6 If the plates are of unequal thickness, and the difference between the surfaces exceeds:

— 10% of the plate thickness with a maximum of 3 mm for longitudinal joints
— 10% of the plate thickness plus 1 mm with a maximum of 4 mm for circumferential joints.

for the thicker plate, the thicker plate shall have a smooth taper with a slope not exceeding 15°, see Figure 1.

Guidance note:

In the case of pressure equipment for which full radiographic examination is required, it is advised that the thicker plate be made with a parallel section of the same thickness as the thinner plate. The width L of this parallel section should be at least 30 mm. E should not exceed 10% of B. The greatest acceptable value of E is 3 mm.

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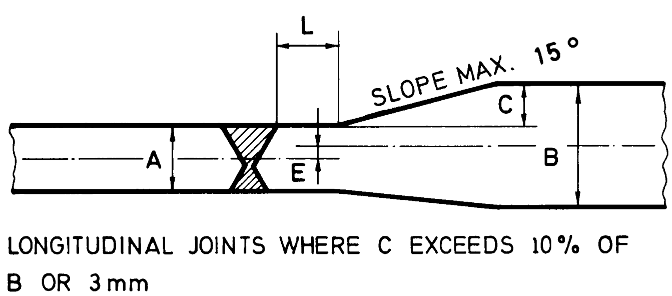

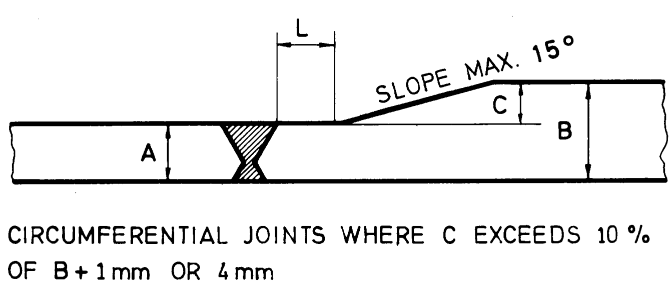

Figure 1 Welded joints

2.2.7 Wherever practicable, the welding shall be carried out in the downhand position. In the case of circumferential joints in cylindrical shells, means shall be adopted to ensure compliance with this requirement.

2.2.8 Welds shall have a smooth finish and shall merge into the plate without abrupt irregularity. The surface of the weld metal shall at no point to fall below the surface of adjoining plates. The reinforcements of the weld shall not exceed 20% of the plate thickness, with a maximum of 4 mm on either side of the plate.

2.3 Tolerances for shells

2.3.1 Shells for class I and II welded pressure equipment shall be within the limits for out-of-roundness and local departure from circularity after heat treatment has been carried out as given in [2.3.4] and [2.3.5] respectively.

2.3.2 The measurement of out-of-roundness may be carried out either when the shell is laid flat on its side or when set up on end. When the shell is checked whilst lying on its side, each measurement for diameter shall be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter shall be averaged, and the amount of out-of roundness calculated from the average values so determined.

2.3.3 Measurements may be made on the inside or outside of the shell. If the shell is made of plates of unequal thicknesses, the measurements shall be corrected for the plate thickness to determine the diameters at the middle line of the plates.

2.3.4 The difference between the maximum and minimum diameter at any cross section of a shell welded longitudinally, shall not exceed 1% of the nominal internal diameter, D, with a maximum of:

$$\frac{D + 1250}{200}(mm)$$

2.3.5 There shall be no flat or peak at joints, and any local departure from circularity shall be gradual.

Irregularities in profile, checked by a 20 degree gauge, shall not exceed 5% of the plate thickness plus 3 mm. This maximum value may be increased by 25%, if the length of the irregularities does not exceed the lesser of 1 metre and one quarter of the length of the shell between two circumferential joints.

2.4 Fitting of tubes

2.4.1 The tube holes in water tube boilers shall be made in such a way that an effective tightening of the tubes is attained. Where the tube ends are not normal to the tube plates, there is either to be a neck or the tube hole ends shall be made parallel for a depth of at least 13 mm, measured in a plane through the axis of the tube at the hole. Where the tubes are practically normal to the tube plates, the depth of this parallel seating shall not be less than 10 mm.

The tubes shall be carefully fitted in the holes by means of expanding and belling, expanding and welding, strength welding or by other approved methods. The tubes belled end shall project through the neck or bearing part of the holes by at least 6 mm. They shall be secured to prevent drawing out at each end, and if this is done by bell-mounting only, the included angle of belling shall not be less than 30°.

2.4.2 The tubes in smoke tube boilers shall have their ends firmly expanded and flared, expanded and beaded, expanded and welded or strength-welded.

2.4.3 If tubes are welded to the tube plate in accordance with Sec.4 Figure 21 and Sec.4 Figure 22, the unwelded portion of the tube within the tube hole shall be in full contact with the tube plate.

2.5 Doors and plugs

2.5.1 Doors and crossbars shall be of steel, and jointing surfaces shall be machined. Doors in boilers shall be of the internal type. The clearance between the manhole frame and the spigot or recess shall not exceed 1.5 mm all round.

2.5.2 For smaller circular openings in headers and similar fittings, a suitable type of plug may be used.

3 Heat treatment

3.1 Post-weld heat treatment

3.1.1 Pressure equipment including boilers shall be thermally stress relieved after welding when the material thicknesses at any welded connection exceed the limits given in Table 1 for the steel grade in question.

Pressure equipment intended for service with fluids liable to cause stress corrosion cracking in service shall be stress relieved independent of material thickness. For ammonia as operating fluid, see Rules for classification of ships Pt.5 Ch.7 Sec.17 [2].

3.1.2 When welded joints connect parts of different thickness, the thickness to be considered in applying the limits given in Table 1 for heat treatment after welding shall be:

— the thinner of two adjacent butt-welded plates including dished end and flanged plate to shell connections
— where flat plates are inserted into the shell: the greater of the thickness of the shell and 2/3 of the thickness of the flat plate
— the thickness of shell or flat plate, as appropriate, in nozzle or pad attachment welds
— the thickness of nozzle neck at joint in nozzle neck to flange connections
— the thickness of pressure part, at point of attachment where a non-pressure part is welded to a pressure part.

Table 1 Post-weld heat treatment

Steel grade	*Plate thicknesses above which post-weld heat treatment is required*	
	Boilers	*Unfired pressure vessels*
NV 360-0A-0N NV 410-0A-0N NV 460-0A-0N NV 490-0A-0N	20 mm 20 mm 20 mm 20 mm	30 mm 30 mm 30 mm 30 mm
NV 360-1 FN NV 410-1 FN NV 460-1 FN NV 490-1 FN NV 510-1 FN	20 mm 20 mm 20 mm 20 mm 20 mm	38 mm 38 mm 38 mm 38 mm 38 mm
NV 0.3 Mo NV 1 Cr 0.5 Mo NV 2.25 Cr 1 Mo	20 mm All thicknesses to be heat treated	

3.1.3 The heat treatment shall be carried out after welding of the seams and of all attachments to the shell and ends prior to the hydraulic pressure test.

3.1.4 Wherever possible, pressure equipment shall be heat treated by heating as a whole in an enclosed furnace. The furnace shall be fitted with instruments for measuring and recording the actual temperatures of the pressure equipment during the heat treatment process.

3.1.5 Where it is found necessary to adopt special methods of heat treatment, full particulars shall be submitted for consideration.

3.1.6 Thermal stress relieving shall be carried out by heating the pressure equipment uniformly and slowly to a suitable temperature, followed by cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C. Below this temperature the pressure equipment may be cooled in still air. Suitable soaking temperatures and time at temperature are stated in Table 2.

The heating and cooling processes and the soaking period shall be recorded in a temperature-time diagram.

Table 2 Soaking temperatures and time at temperature

Steel grade	*Soaking temperature °C*	*Time at soaking temperature*
C and C-Mn steel grades	520 - 580	60 minutes per 25 mm thickness. Minimum 30 minutes
NV 0.3 Mo	530 - 580	
NV 1 Cr 0.5 Mo	600 - 650	
NV 2.25 Cr 1 Mo	650 - 700	

3.2 Heat treatment of plates after hot or cold forming

3.2.1 For manufacturers performing cold forming with exceeding the limits for the deformation degree as specified in Table 3 or hot forming and/or heat treatment on hot/cold formed parts appropriate manufacturer approval of the process is required.

3.2.2 For components which have been hot formed or locally heated for forming, the following requirements apply:

Components of carbon and carbon-manganese steels, NV 0.3 Mo, NV 1 Cr 0.5 Mo and NV 2.25 Cr 1 Mo shall be normalised on the completion of the operation, except that the heat treatment may be omitted if the forming operation has been carried out at a temperature within the normalising range.

The steel grades NV 1 Cr 0.5 Mo and NV 2.25 Cr 1 Mo are in addition to be tempered.

3.2.3 Where the deformation degree mentioned in Table 3 is exceeded after cold forming and the product will be subject to subsequent welding, a suitable heat treatment shall be performed before welding is carried out.

If the acceptable degree of cold deformation is exceeded, renewed heat treatment of the final product is required in order to restore the delivery condition specified for the material in question.

Subject to a case by case approval and for special cases, stress relieving heat treatment may be accepted in lieu of full heat treatment. For such cases, the impact toughness shall be qualified for

— the artificial aged condition
— the stress relieved condition

both for the applicable maximum strain. Artificial ageing shall be carried out on the strained material at 250°C for one hour.

Table 3 Conditions where heat treatment after cold forming may be waived

Intended application	*Steel type/grade*	*Deformation degree for which heat treatment may be waived*
Pressure vessels operated at ambient temperatures or feedstock temperatures down to -10°C	All	≤ 5%
Pressure vessels operated at charging fluid temperatures below -10°C, as well as gas tanks with design temperatures below 0°C	NV 3.5Ni NV 5Ni NV 9Ni	≤ 5%
	C and C-Mn Alloy(other than above)	≤ 3%

Guidance note:

For the calculation of the theoretical plastic deformation see Pt.2 Ch.4 Sec.6 [5.2.6].

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3.3 Heat treatment of tubes after bending

3.3.1 Tubes shall be heat treated after bending when required in Ch.6 Sec.10 [3].

4 Testing

4.1 Extent of non-destructive testing

4.1.1 For pressure equipment designed with a joint efficiency of 0.85 < v ≤ 1.0 NDT shall be carried out as follows:

a) All longitudinal butt welded joints in drums, shells and headers shall be subjected to 100% radiographic testing.
b) 25% of the length of circumferential butt welded joints in drums, shells and headers shall be subjected to radiographic testing.
c) 10% of the total number of circumferential butt welded joints in pipes and tubes shall be subjected to radiographic testing.
d) For set-in flat plates the cylindrical shell shall be ultrasonically tested for lamellar tearing in way of the circumferential weld to the flat plate. For shell plate thickness 15 mm and less the extent of testing shall be at least 10% and for greater thickness at least 20% of the total length of the weld. The internal fillet weld shall be 100% magnetic particle tested for surface flaws.
e) For nozzles and branches with outside diameter exceeding 100 mm, all weld connections to shell and reinforcement rings shall be subjected to magnetic particle testing. For outside diameters 100 mm and less, spot testing shall be carried out. The magnetic particle testing is also to cover weld joints between reinforcement rings and shell.
f) All welded joints shall be subjected to visual inspection.

4.1.2 For pressure equipment designed with a joint efficiency of 0.7 < v ≤ 0.85, NDT shall be carried out as follows:

a) Longitudinal butt weld joints in drums, shells and headers shall be subjected to radiographic testing at the rate of 20% of the length. All crossings between longitudinal and circumferential joints shall be included in the testing.
b) All welded joints shall be subjected to visual inspection.

4.1.3 For pressure equipment designed with a joint efficiency of v ≤ 0.7 visual inspection of all welded joints shall be carried out.

4.1.4 Areas of flat plates which are additionally loaded by residual welding stresses perpendicular to the plate (see e.g. details a, b, d of Sec.4 Figure 17) shall be ultrasonically tested for the absence of laminar imperfections before welding. The tests shall be carried out in the welding seam area of the plate with a minimum width of three times the shell thickness. For the procedure and acceptance criteria see [4.2.4].

4.1.5 For furnaces and fireboxes NDT shall be carried out as follows:

a) 10% of the length of longitudinal butt welded joints shall be subjected to radiographic testing.
b) 10% of the length of circumferential butt welded joints shall be subjected to radiographic testing.
c) 25% of the length of T-welds and corner welds shall be subjected to ultrasonic testing.

4.1.6 For non-ferromagnetic materials or materials with changes in magnetic permeability penetrant testing replaces magnetic particle testing in [4.1.1].

4.1.7 For carbon and carbon-manganese steels of grades given in Pt.2 Ch.2 Sec.3 Table 3 with thickness less than 38 mm, the radiographic and ultrasonic testing may be carried out before post-weld heat treatment. Magnetic particle or penetrant testing shall be carried out when all heat treatment has been completed.

Ultrasonic testing may be used in lieu of radiographic testing for thicknesses equal to or above 10 mm, and shall be carried out as specified in written procedures established in compliance with class guideline DNV-CG-0051 as a minimum.

4.1.8 The requirements for NDT of welded joints for thermal oil piping can be found in Ch.6 Sec.10 [1.5].

4.2 Performance of non-destructive testing

4.2.1 For carbon and carbon-manganese steel with thicknesses greater than 30 mm and for alloy steels the NDT is normally to be carried out not earlier than 48 hours after completion of the welds in question. For carbon and carbon-manganese steels with thicknesses 30 mm and less the time limit may be reduced to 24 hours.

4.2.2 All testing shall be carried out by qualified and certified personnel. The NDT operators and the supervisors shall be certified according to a Third Party certification scheme based on EN ISO 9712 or ASNT Central Certification Program (ACCP). SNT-TC-1A may be accepted if the NDT company`s written practice is reviewed and accepted by the Society. The certificate shall clearly state the qualifications as to which testing method, level and within which industrial sector the operator is certified.

NDT operators shall be certified level 2 in the testing method and industrial sector concerned. Supervisors shall be certified level 3 in the testing method and industrial sector concerned.

4.2.3 Radiographic testing shall be carried out according to procedures that as a minimum comply with relevant parts of class guideline DNV-CG-0051.

For radiographic testing, X-ray source shall be used whenever possible. Gamma-ray sources may be used when qualified through examination by the Society. RT may be replaced by ultrasonic testing and vice versa, when methodologically justifiable and in agreement with the Society.

Processing and storage shall be such that the radiographs maintain their quality throughout the agreed storage time. The radiographs shall be free from imperfections due to processing.

4.2.4 For ultrasonic testing the following apply:

The welded connections in question shall be tested for laminations, transverse and longitudinal defects in accordance with procedures that as a minimum comply with class guideline DNV-CG-0051.

UT shall not be carried out on welds with thickness < 10 mm if not qualified and accepted down to 8 mm.

The following acceptance criteria apply to the absence of laminar imperfections at flat plates in the welding area (three times the shell thickness) of the connection to the shell:

— maximum permissible flaw size area (A_{max}): 100 mm²
— maximum permissible length parallel to edge (L_{max}): 30 mm
— minimum discontinuity length considered (L_{min}): 15 mm
— permissible number of discontinuities per length: 3 per meter

4.2.5 For magnetic particle testing the following apply:

The welded connections in question shall be tested in accordance with procedures that as a minimum comply with class guideline DNV-CG-0051.

The object may be directly or indirectly magnetised.

AC yoke or prods shall be used. Care shall be taken to avoid local heating of the test surface. Prods shall be of the type soft prods, lead tipped or aluminium alloy.

Use of permanent magnets is not permitted.

Required magnetic field strength:

$$2.4 - 4.0\frac{kA}{m}$$

The testing on each area shall be performed with the magnetic field shifted in at least two directions approximately perpendicular to each other.

4.2.6 For penetrant testing the following apply:

The welded connections in question shall be tested in accordance with procedures that as a minimum comply with class guideline DNV-CG-0051.

Colour contrast penetrants shall be used for welds in as welded condition.

For smooth (flush grinded welds) fluorescent penetrants may be used.

The surface temperature during testing shall be within the temperature range 10 to 50°C, if not, a procedure qualification test using ASME comparison blocks shall be carried out.

The penetration time shall be at least 15 minutes.

4.3 Acceptance criteria for non-destructive testing and repair of defects

4.3.1 As the test methods differ in their limitations and/or possibilities of recording and documentation, special acceptance criteria are given for each method where necessary.

Alternative evaluations ensuring an equivalent level of quality may in special cases be considered.

4.3.2 Acceptance criteria for welds in pressure vessels see Table 4:

Table 4 Acceptance criteria

Testing method	*Acceptance level*
Visual testing	EN ISO 5817 – Level B[1)]
Magnetic particle testing	EN ISO 23278 – Level 2x
Penetrant testing	EN ISO 23277 – Level 2x
Radiographic testing	EN ISO 10675 – Level 1
Ultrasonic testing [2)]	EN ISO 11666 – Level 2

1) Except for imperfection types as follows, for which level C may apply: excess weld metal, excess convexity, excess throat thickness and excessive penetration. For linear misalignment of longitudinal and circumferential welded plates the requirements as specified in [2.2.6] apply.

2) All imperfections from which the reflected echo amplitude exceeds the evaluation level shall be characterized and all that are characterized as planar, e.g. cracks, lack of fusion, incomplete penetration, shall be rejected.

4.3.3 NDT shall be reported as required and specified in class guideline DNV-CG-0051 and all essential control parameters shall be given.

4.3.4 Defects which exceed the acceptance limits shall be completely removed and repaired according to an approved repair procedure. Magnetic particle testing is normally to be used to ensure complete removal of defects prior to repair welding.

4.3.5 When unacceptable defects are found in areas with less than 100% testing, the extent of testing shall be doubled compared to the initial area. If this increased testing reveals more unacceptable defects, the entire area of the weld shall be tested.

4.4 Welding production test

4.4.1 For joint efficiency $0.85 < v \leq 1.0$ welding production test (WPT) shall be performed for each longitudinal welded joint. For large units, having more than 50 m of longitudinal welded joint, the number of tests may be reduced to one for each 100 m of production welded joint, provided the tests show uniform and satisfactory results. In any case at least one WPT shall be carried out for each pressure equipment.

For pressure equipment which is part of the cargo containment system of liquefied gas tankers the welding production test requirements for process pressure vessels and cargo tanks as specified in Pt.5 Ch.7 Sec.6 [5.5] apply.

4.4.2 For joint efficiency $0.7 < v \leq 0.85$ with shell thickness equal to or greater than 16 mm, one WPT representing the longitudinal welded joints shall be performed for each pressure equipment. Where similar pressure equipment is produced in series, one WPT may represent a test group of 5 vessels, but not more than 50 m of production weld joint. In such cases, the plate thicknesses in the test group shall not differ by more than 5 mm and the thickest plate shall be used for preparation of the test assembly.

4.4.3 WPT for circumferential seams is not required, except where a pressure equipment has circumferential joints only or where the process for welding the circumferential joints is significantly different from that used for the longitudinal joints. The WPT for circumferential seams shall be carried out on a separate test piece (test ring or flat test piece) with the same materials, dimensions, thicknesses and welding procedure as the original joint. In such cases the number of tests shall be the same as specified for longitudinal weld joints in [4.4.1] and [4.4.2].

4.4.4 The test assembly for WPT consists of two plates, and each plate shall have a width of minimum 150 mm. The length shall be sufficient for making all test specimens required according to [4.4.10] and for possible retest purposes. Plates for the test assembly shall be cut from the plates forming the appropriate part of the pressure equipment, and shall be stamped by the surveyor before being detached. Alternatively the test plates may be cut from another plate from the same cast, with the same thickness and in the same heat treatment condition as the plate used for the pressure equipment.

4.4.5 For longitudinal welded joints, the two plates forming the test assembly shall be tack welded to the pressure equipment and welded together so that the joint of the test plates forms a direct continuation of the production weld joint. The orientation of the test plates shall be so that the rolling direction is parallel to the rolling direction of the adjacent plates of the pressure equipment.

4.4.6 For circumferential joints the joint of the test assembly is as far as possible to be a simulation of the production weld.

4.4.7 The welding of the test assembly shall be carried out at the same time as the production welding and by the same welder, using the same welding parameters.

4.4.8 The test assembly shall be heat treated together with the pressure equipment or one of the vessels which it represents.

4.4.9 The weld deposit shall be machined flush with the plate surface on both sides of the test assembly.

4.4.10 The following tests are required from each test assembly:

— one root and one face bend test when plate ≤10 mm thick
— two side bend tests when plate >10 mm thick
— Charpy V-notch impact tests with the notch located in the centre of the weld and in the fusion line
— macro section examination.

In addition one butt weld tensile test is required from one test assembly for each pressure equipment. Where one test assembly represents more vessels, only one tensile test is required. The necessary test specimens shall be cut from the welded test assembly as shown in Figure 2.

4.4.11 Bend tests shall be performed as described in Pt.2 Ch.1 Sec.3 [3.4].

The acceptance criteria are given in Pt.2 Ch.4 Sec.5 [5.2.1].

4.4.12 Six Charpy V-notch impact test specimens shall be cut transversely to the weld with the centre of the specimen as near as practicable to a point midway between the surface and the centre of the thickness. Three specimens shall be located with the notch in the centre of the weld and three specimens with the notch in the fusion line. The average value and single specimen values for absorbed energy in fusion line are normally to be in accordance with the transverse and longitudinal requirements of the base material, whichever is applicable. The results of weld metal impact tests shall be in accordance with the transverse test requirements given for the base material.

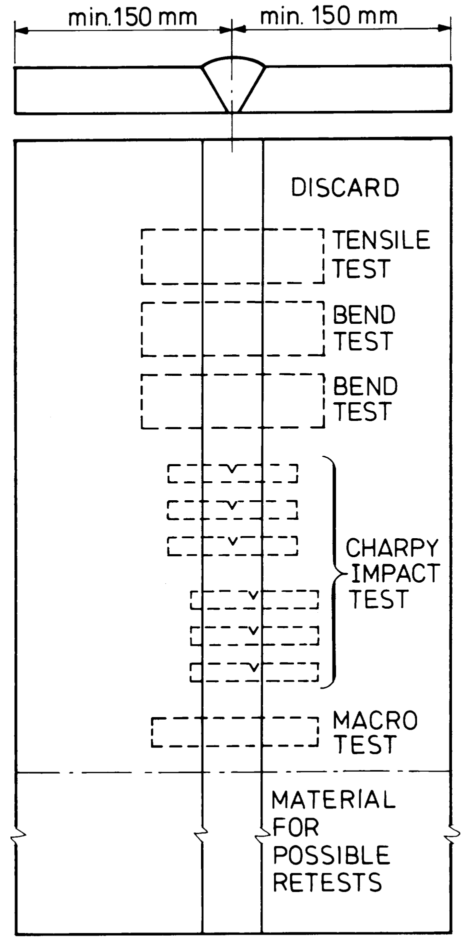

Figure 2 Welding production tests

Impact tests which do not meet the prescribed energy requirements in fusion line may still be accepted provided drop-weight tests are carried out with satisfactory results. When drop-weight test is used, two test specimens from the weld shall be tested and both specimens shall show no-break performance.

Additional testing according to Pt.2 Ch.4 will also be acceptable.

Where the thickness of the material does not permit standard Charpy V-notch test specimens with width 10 mm, the largest obtainable of sub size specimens with width 7.5 or 5 mm shall be used. In that case the requirement on absorbed energy will be reduced to respectively 5/6 and 2/3 of the value specified for standard test specimens.

4.4.13 The complete cross section of the welded joint shall be etched for macro-examination. Cracks or lack of fusion are not accepted.

4.4.14 The butt weld tensile test specimen shall be in compliance with Pt.2 Ch.1 Sec.3 [3.1.8], type B for testing of the weld as a whole. Where the thickness of the plate exceeds 30 mm, the tensile test may be performed using several test specimens, each with a thickness of at least 30 mm. The whole thickness of the joint shall be tested.

The tensile strength obtained shall be not less than the minimum tensile strength required for the plate material.

4.5 Constructional check

4.5.1 On completion the pressure equipment shall be subjected to a constructional check at the manufacturer's works in the presence of the surveyor, checking that the dimensions, thicknesses, materials, weldings etc. are in accordance to the approved drawings.

4.5.2 Material test certificates in accordance with these rules shall be presented.

4.5.3 For burners for heat generators the following examinations shall be performed at the manufacturer's workshop and documented by a product certificate issued by the Society:

— visual inspection and completeness check
— pressure test of the oil pre-heater
— pressure test of the burner
— insulation resistance test
— high voltage test
— functional test of the safety related equipment.

4.6 Hydraulic test

4.6.1 On completion, boilers shall be tested to a pressure of at least 1.5 times the design pressure or the calculated test pressure.

4.6.2 As an alternative to the test prescribed in [4.6.1] the following pressure tests may be carried out for boilers where feasible:

Each component of the boiler shall be tested on completion of the work, including heat treatment, to at least 1.5 times the design pressure or the calculated test pressure. In the case of drums and headers fitted with tubes, this test may be made before drilling tube holes, but after the attachment of nozzles and similar fittings. When all components have been tested as prescribed above, the completed boiler shall be tested to 1.25 times the design pressure.

4.6.3 Pressure equipment other than boilers shall be tested on completion to at least 1.5 times the design pressure or the calculated test pressure.

4.6.4 The pressure test shall be such that it does not result in general membrane stress in any part of the pressure equipment during the test exceeding $R_{eH}/1.1$ for materials with a definite yield stress or $R_m/2.0$ for materials without a definite yield stress.

4.6.5 Hydraulic testing shall be performed in the presence of a surveyor, unless otherwise agreed. The test pressure shall be applied and maintained for at least 30 minutes to permit visual examination of all surfaces and joints. The pressure equipment shall exhibit no sign of general plastic yielding or leakage.

4.6.6 Thermal-oil installations, with their system pressure vessels, headers, heat exchangers etc. shall be pressure tested to at least 1.5 times the design pressure or the calculated test pressure, minimum 10 bar, the test being carried out at the manufacturers. Expansion vessels with a design pressure of 2 bar shall be pressure tested to 1.5 times the design pressure.

After assembly, but before insulation work on board commences, a pneumatic tightness test with a pressure of 1.5 to 2 bar shall be performed.

4.6.7 Equipment, valves and fittings with a design temperature above 120°C and designed for a specific pressure/temperature combination shall be tested by hydraulic pressure at twice the maximum allowable working pressure, with the exception of feed water check and feed water stop valves for boilers and steam-heated steam generators, which shall be tested to 2.5 times the maximum allowable working pressure or twice the maximum pressure which can be developed in the feed water line in normal service, whichever is the greater.

The safety factor for pressure testing in respect of the 20°C yield strength value shall not fall below 1.1.

4.7 Function test after installation on board

4.7.1 After installation on board, boilers and steam-heated steam generators shall be function tested. The test shall include the instrumentation, automatic equipment and remote control systems. For boiler accumulation test, see Sec.5 [2.1.12].

4.7.2 Thermal-oil heating installations shall be function and capacity tested according to an approved test programme.

The test procedure shall include flow measurements for each coil, covering the whole range of heater loads. The heater system charge shall be a thermal-oil which will allow maximum heater rating to be tested.

4.7.3 The complete system of heat generator and burner including the switchboard has to be function tested as follows, especially the required purging time has to be identified and the manual operation has to be demonstrated:

— completeness check for the required components of the equipment
— functional test of all safety relevant equipment
— functional test of the burner control box
— identification of maximum and minimum burner power
— identification of flame stability on start-up, at maximum and at minimum burner power under consideration of combustion chamber pressure. Unspecified pressure changes are not permitted
— proof regarding required purging of flues and safety times
— in case the burner is operated with different fuel oils the proper change-over to another fuel oil quality and especially the safe operation of the flame monitoring, the quick closing devices and the preheater, if existing, shall be checked
— proof regarding combustion properties like CO_2-, possibly O_2-, CO-volumetric content and soot number at minimum, mean and maximum power, in case of statutory requirements.

The correct combustion at all settings as well as function of safety equipment has to be verified. A product certificate from the Society regarding examination of the burner at the manufacturer's shop shall be presented to the surveyor during functional testing.

APPENDIX A TYPES AND MINIMUM DIMENSIONS OF THE INSPECTION OPENINGS IN PRESSURE EQUIPMENT

1 Definitions and dimensions

1.1 Examination holes

1.1.1 Sightholes are holes whose inside diameter is at least 50 mm and whose neck height does not exceed 50 mm.

1.1.2 Handholes are holes into which a lamp can be inserted. A handhole shall have a width of span of at least 90 × 120 mm or an inside diameter of 100 mm. The height of the neck or ring shall not exceed 65 mm and in the case of a conical shape 100 mm. If only one handhole is provided, it shall not be less than 100 × 120 mm.

1.1.3 Headholes are holes into which the head, an arm and a lamp can be introduced simultaneously. Their dimensions shall be at least 220 × 320 mm or 320 mm in inside diameter. The height of the neck or ring shall not exceed 100 mm.

1.1.4 Where neck heights exceed the limiting values given in [1.1.1] to [1.1.3], the size of hole shall be increased to give an adequate inspection facility.

1.2 Manholes

1.2.1 Manholes are holes permitting entry and exit of a person not carrying any auxiliary equipment. They shall not be less than 300 × 400 mm or 400 mm in inside diameter. Where the neck height of a manhole is >150 mm, the size of the manhole shall be suitably increased.

2 Locations

2.1 Inspection openings

2.1.1 The number, type and locations of inspection openings shall be as given in Table 1.

Table 1 Inspection openings for pressure equipment

No.	*External diameter*	*Form of pressure equipment*	*Types and number of holes*
1	450 mm and less	Length of cylindrical body or diameter of spherical shape up to 1500 mm inclusive	2 SIGHTHOLES. Where the length is more than 1500 mm, additional sight-holes shall be provided.
2 a)	More than 450 mm up to 800 mm inclusive	Length of cylindrical body or diameter of spherical shape up to 1500 mm inclusive	1 HANDHOLE suitably placed or 2 SIGHTHOLES, in the case of a cylindrical body the latter could each be sited either near the ends (within sight of the longitudinal joint and of the base) or else at the centre of the ends.
2 b)		Length of cylindrical body greater than 1500 mm up to 2000 mm inclusive	1 HEADHOLE in the central third of the length of the cylindrical body or 2 HANDHOLES each located either near or on the ends.
2 c)		Length of cylindrical body greater than 2000 mm	The number of inspection holes shall be increased accordingly. For a length of less than 3000 mm it is, however, sufficient to site a headhole in the centre of the cylindrical body. On the cylindrical body the greatest distance between the headholes shall not exceed 3000 mm, those between handholes 2000 mm. The latter is each to be located either near or in the ends.
3 a)	More than 800 mm up to 1400 mm inclusive	Length of cylindrical body or spherical shape up to 2000 mm	1 HEADHOLE (in the case of a cylindrical body this is located in the central third of its length) or 2 HANDHOLES near or in the ends.
3 b)		Length of cylindrical body more than 2000 mm	1 MANHOLE or siting of inspection holes as in the case of 2c) above.
4	More than 1400 mm	Length of cylindrical body unlimited	1 MANHOLE.

CHANGES – HISTORIC

July 2020 edition

Amendments August 2020, entering into force 1 January 2021

Topic	*Reference*	*Description*
Compliance documents for equipment, valves and fittings	Sec.1 Table 8	Correction of typing error in cross reference of compliance standard for equipment, valves and fittings with PN rating to Ch.6 Sec.9 [3.2.1].

Changes July 2020, entering into force 1 January 2021

Topic	*Reference*	*Description*
Definitions for components of steam boiler plants	Sec.1 [2.1]	Clarification of system boundaries and definitions for components of boiler plants.
Definition of the low low water level and highest flue	Sec.1 [2.2.3]	Definitions and requirements have been moved in the correct sequence.
Pressure equipment classes	Sec.1 Table 2	Clarification of DNV GL pressure equipment class for certain fluids.
Forced draft fans for propulsion boiler	Sec.1 Table 9	Certification requirement added.
Material requirements	Sec.2 [1.1.2]	Subsection for suitable materials for environmental and service conditions added.
De-oxidation practice for normal structural steels	Sec.2 [1.2.1]	Subsection has been made more specific for the use of structural steels for unwelded end plates of class II and III plate heat exchangers and general use for welded class III pressure equipment.
Materials for low temperature service	Sec.2 [1.2.4]	Definition of criteria for use of alternative brittle fracture avoidance concepts added.
Access and inspection openings for refrigerant installations	Sec.3 [1.1.1]	Guidance note added to define exemptions for the installation of inspection openings.
Prevention of steam generation at economizer (feed water preheater)	Sec.3 [2.3.2]	Subsection on feed water systems for economisers added.
Calculation temperature	Sec.4	'Design material/metal temperature' has been modified to 'calculation temperature' in the whole chapter.
Nominal design stress for copper alloys	Sec.4 [2.5.6]	Addition has been made that time and temperature dependent failure mechanism shall be considered.
Corrosion allowance for stainless steel	Sec.4 [2.6.1]	No corrosion allowance is required for stainless steels.

Topic	*Reference*	*Description*
Tubes subject to internal pressure / welding joint efficiency	Sec.4 [3.5.1]	Max. outside diameter (127 mm) of tubes under external pressure and a required joint efficiency of v = 1.0 have been added.
Openings and compensations	Sec.4 [6.3.6]	Acceptance for detailed calculations according to a recognized standard accepted by the Society added.
Design of welded branch connections	Sec.4 [6.5.1]	Non-convenient figures have been removed.
Implementation of strength calculation method for bolted pressurized connections	Sec.4 [9]	New subsection. In order to avoid unfavorable mixing of different pressure vessel codes basic design principles which are harmonized with Pt.2 are implemented.
Instrumentation and monitoring of exhaust gas boilers	Sec.6 [4.1]	Table 3 *Monitoring of exhaust gas boilers* has been added.
Indicators for pressure drop at thermal oil heaters	Sec.6 [6.3.1]	The thermal-oil flow is indicated by a separate flow indicator at the heater outlet.
Monitoring of oil burners	Sec.6 Table 7	Detailed requirement regarding the arrangement of fan, pump and air pressure switch or oil pressure switch has been added.
Backing strips	Sec.7 [2.2.2]	Conditions for the acceptance of backing strips made more detailed.
Welding production tests	Sec.7 [4.4.1]	Reference to Pt.5 Ch.7 Sec.6 [5.5] added.

July 2019 edition

Changes July 2019, entering into force 1 January 2020

Only editorial corrections have been made.

January 2018 edition

Changes January 2018, entering into force 1 July 2018.

Topic	*Reference*	*Description*
Harmonisation of hydraulic pressure test requirements for valves / equipment of boilers	Sec.7 [4.6.7]	Procedure for the testing of equipment, valves and fittings with design temperature above 120°C specified.
Inconsistent thickness requirements for nozzles and branches	Sec.4 [6.4.1] Sec.4 [6.4.2]	Sec.4 [6.4.1] separated in Sec.4 [6.4.1] for general wall thickness and Sec.4 [6.4.2] for taking additional loads into account.
Inconsistency of minimum wall thickness requirements	Sec.4 [2.6.1] and [2.6.2]	— Sec.4 [2.6.1]: minimum thickness of shells and dished ends completed by requirements for stainless steel and non-ferrous materials. Requirements for type C independent tanks and process pressure vessels according to IGC added. — Sec.4 [2.6.2]: deleted.

Topic	*Reference*	*Description*
Reinforcing plates for supports	Sec.4 [2.3.2]	Loads for installation and support that shall considered for the design of the pressure equipment.
Requirements for material testing	Sec.1 [3.2.2]	Guidance note added for material certification of parts directly welded to pressurised parts of the pressure equipment.
UT Testing for plates	Sec.7 [4.1.4]	Ultrasonic testing for flat plates loaded by residual welding stress specified.
Other changes	Sec.1 [1.1.2]	Expression "including mountings" deleted for pressure vessels, because it is covered by the scope of Ch.6. Term "mountings" modified to "equipment, valves and fittings" and added also to thermal oil heaters.
	Sec.1 Table 8	Table created for certification requirements for equipment, valves and fittings.
	Sec.3 [3.2.2]	Requirement for drenching system restored.
	Sec.4 [2.5.2]	Calculation of the nominal design stress for austenitic stainless steels modified from specified minimum lower yield stress at design material temperature to 1.0% proof stress at design material temperature.
	Sec.4 [3.5.2]	Expression "open feed water system" modified to system "without adequate feed water treatment and degassing".
	Sec.4 [4.1.1]	Explanation for 's' modified to "minimum plate thickness after forming" and "calculated thickness" modified to "minimum plate thickness after forming" in the text.
	Sec.4 [4.1.4]	Explanation for 's' modified to "minimum plate thickness after forming".
	Sec.4 [4.2.4]	Last sentence in Sec.4 [4.2.2] deleted and new para added regarding the thickness of the cylindrical parts of dished ends.
	Sec.4 [6.6.1]	Use of the calculation of openings extended to stayed and unstayed flat plates.
	Sec.4 [7]	Heading made more generic to cover the calculations of fired and unfired cylindrical shells under external pressure.
	Sec.5 [1.1.3]	Term "mounting" modified to "equipment, valves and fittings".
	Sec.5 [2.1]	Location for the installation of safety valves at steam boilers added.
	Sec.6 Table 2	For "salinity high" and "oil content high" "shut-down of feed water pump" has been modified to 'interruption of feed water supply' and monitoring is only necessary if contamination with salt or oil is possible.
	Sec.7 [4.4.3]	Procedure for WPT of circumferential welding seams specified.
	App.A [2]	Number, type and location of inspection openings made mandatory.

January 2017 edition

Main changes January 2017, entering into force July 2017

• Sec.1 Pressure equipment

- Sec.1 [1.2.2]: Reference to Pt.4 Ch.6 Sec.6 has been added for pressure equipment in refrigeration plants.
- Sec.1 Table 2: Differentiation between flammable gases and non-flammable gases has been added.
- Sec.1 [2.5.1]: Guidance note has been added.
- Sec.1 [2.5.2]: Text and table moved to Sec.1 [3.2.1].
- Sec.1 [3.1.4]: Guidance note has been added.
- Sec.1 [3.1.5]: Drawing approval for charge air cooler has been dispensed with.
- Sec.1 Table 5 to Table 7 and Table 9: Explanations have been added and typing errors have been corrected.
- Sec.1 Table 6: Certification requirements for plates, dished ends and heads of pressure equipment class II changed to certificate type MC issued by manufacturer.
- Sec.1 Table 7: Certification requirement for plates, dished ends and heads of pressure equipment class III changed to certificate type TR issued by manufacturer.
- Sec.1 [3.2.3]: Special requirements for gas cylinders in fixed fire extinguishing systems added.
- Sec.1 [5]: Approval and certification requirements for gas cylinders for fixed fire extinguishing systems modified.

• Sec.2 Materials

- Sec.2 [1.1.1]: Guidance note has been added.
- Sec.2 [1.2.1]: Low temperature limit for rolled steels deleted.

• Sec.3 Arrangement

- Sec.3 [3.2.1]: Requirement for the approval of the fixed fire extinguishing system removed.
- Sec.3 [3.2.2]: Water delivery requirement for the fixed fire extinguishing system removed.

• Sec.4 General design requirements

- Sec.4 [2.9.1]: Specific joint efficiencies modified to joint efficiency ranges.
- Sec.4 [3.7]: Specific requirements for minimum wall thickness of heat exchanger tubes deleted, applicable design loads and design requirements with reference to other pressure equipment codes added.
- Sec.4 [5.2.2]: Transfer errors for coefficient Y_i corrected.
- Sec.4 [8.2.1]: Transfer errors corrected and requirements for gusset stay design revised.

• Sec.5 Mountings and fittings

- Sec.5 [4.2.1]: Guidance note has been added.

• Sec.7 Manufacture, workmanship and testing

- Sec.7 [1.1.1]: Reference to DNVGL-CP-0261 *Pressure equipment* added and application limited to welded, pressed and heat treated pressure equipment and seamless gas cylinders.
- Sec.7 [4.1.3]: Requirements for non-destructive testing (NDT) for joint efficiency v≤0.7 added.

October 2015 edition

This is a new document.

The rules enter into force 1 January 2016.

Amendments January 2016

• General

— Only editorial corrections have been made.

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