FOREWORD

DNV GL 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.

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Changes – Current

This document supersedes the October 2015 edition.
Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

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 $v \leq 0.7$ added.

**Editorial corrections**

In addition to the above stated changes, editorial corrections may have been made.
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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 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, including mountings, necessary for performing the main functions listed in Pt.1 Ch.1 Sec.1 [1.2]
— other pressure vessels containing:
  — toxic fluids
  — fluids with flash point below 100°C
  — fluids with temperature above 220°C
  — fluids with pressure above 40 bar
  — compressed gases where
    \[ p_d \times V \geq 1500 \text{ bar ltr} \]
  — boilers and hot water generators, including mountings
  — thermal-oil heaters
  — oil burners and oil firing equipment.

\[ p_d = \text{design pressure} \]
\[ V = \text{Volume} \]

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 burners and oil 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 Pt.5 Ch.7 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 Pt.4 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 are, in addition to the requirements in this section, to meet the requirements of the rules for classification of ships Pt.6 Ch.4 Sec.10 and Pt.4 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.

2.1.2 A thermal-oil heater is defined as an arrangement in which organic fluids (thermal-oils) 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 burners and oil 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 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 also when the ship heels 4° to either side.
The highest flue (HF) shall remain wetted even when the ship is at the static heeling angles 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.
\[
T = \frac{50 \times V}{D_s \times v'}
\]
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.

2.2.4 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. 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 oil 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

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Pressure equipment

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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.

2.3 Symbols

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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>major dimension of elliptical or rectangular unsupported area</td>
<td>mm</td>
</tr>
<tr>
<td>a_p</td>
<td>diagonal pitch of holes projected on longitudinal axis</td>
<td>mm</td>
</tr>
<tr>
<td>a_o</td>
<td>diminution for calculation of out-of-roundness</td>
<td>mm</td>
</tr>
<tr>
<td>a_v</td>
<td>most probable largest combined vertical acceleration in (10^8) wave encounters(probability level (Q = 10^{-8}))</td>
<td>-</td>
</tr>
<tr>
<td>A</td>
<td>area of reinforcement</td>
<td>mm²</td>
</tr>
<tr>
<td>A_c</td>
<td>compensating area for tube stubs</td>
<td>mm²</td>
</tr>
<tr>
<td>A_p</td>
<td>area supported by a stay</td>
<td>mm²</td>
</tr>
<tr>
<td>A_x</td>
<td>compensating area</td>
<td>mm²</td>
</tr>
<tr>
<td>A_o</td>
<td>sectional area of a stay</td>
<td>mm²</td>
</tr>
<tr>
<td>A_1</td>
<td>sectional area of the stub projecting inside the shell</td>
<td>mm²</td>
</tr>
<tr>
<td>A_2</td>
<td>sectional area of fillet welds attaching the stub to the inside and outside of the shell</td>
<td>mm²</td>
</tr>
<tr>
<td>A_3</td>
<td>aggregate area of the orifice (safety valve – saturated steam)</td>
<td>mm²</td>
</tr>
<tr>
<td>A_4</td>
<td>aggregate area of the orifice (safety valve – superheated steam)</td>
<td>mm²</td>
</tr>
<tr>
<td>b</td>
<td>minor dimension of elliptical or rectangular unsupported area</td>
<td>mm</td>
</tr>
<tr>
<td>b_p</td>
<td>diagonal pitch of holes projected circumferentially</td>
<td>mm</td>
</tr>
<tr>
<td>BCO</td>
<td>Burner cut-off</td>
<td>-</td>
</tr>
<tr>
<td>c</td>
<td>corrosion allowance</td>
<td>mm</td>
</tr>
<tr>
<td>c_1</td>
<td>constructional allowance</td>
<td>mm</td>
</tr>
<tr>
<td>C</td>
<td>factor depending on the method of supports</td>
<td>-</td>
</tr>
<tr>
<td>d</td>
<td>diameter of tube hole or opening</td>
<td>mm</td>
</tr>
<tr>
<td>d_a</td>
<td>mean inner diameter of the two openings</td>
<td>mm</td>
</tr>
<tr>
<td>d_c</td>
<td>calculation diameter of openings/tube holes</td>
<td>mm</td>
</tr>
<tr>
<td>d_e</td>
<td>diameter of the largest circle passing through points of support</td>
<td>mm</td>
</tr>
<tr>
<td>d_i</td>
<td>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</td>
<td>mm</td>
</tr>
<tr>
<td>d_k</td>
<td>root diameter of thread</td>
<td>mm</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
<td>Unit</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>$d_o$</td>
<td>outer diameter of the branch or tube</td>
<td>mm</td>
</tr>
<tr>
<td>$d_p$</td>
<td>mean effective diameter of tube hole (efficiency of ligament)</td>
<td>mm</td>
</tr>
<tr>
<td>$d_s$</td>
<td>shank diameter of a necked-down bolt</td>
<td>mm</td>
</tr>
<tr>
<td>$D$</td>
<td>nominal diameter</td>
<td>mm</td>
</tr>
<tr>
<td>$D_b$</td>
<td>mean sealing or bolt pitch circle diameter</td>
<td>mm</td>
</tr>
<tr>
<td>$D_i$</td>
<td>internal diameter</td>
<td>mm</td>
</tr>
<tr>
<td>$D_m$</td>
<td>mean diameter of plain furnace</td>
<td>mm</td>
</tr>
<tr>
<td>$D_{max}$</td>
<td>maximum mean diameter of the furnace</td>
<td>mm</td>
</tr>
<tr>
<td>$D_{min}$</td>
<td>minimum mean diameter of the furnace</td>
<td>mm</td>
</tr>
<tr>
<td>$D_o$</td>
<td>outside diameter</td>
<td>mm</td>
</tr>
<tr>
<td>$D_s$</td>
<td>allowable steam output</td>
<td>kg/h</td>
</tr>
<tr>
<td>$D_C$</td>
<td>internal diameter at the large end of the cone</td>
<td>mm</td>
</tr>
<tr>
<td>$D_O$</td>
<td>outside diameter of the conical section</td>
<td>mm</td>
</tr>
<tr>
<td>$e$</td>
<td>efficiency of ligament</td>
<td>-</td>
</tr>
<tr>
<td>$e_g$</td>
<td>distance between center lines of girder</td>
<td>mm</td>
</tr>
<tr>
<td>$e_i$</td>
<td>breadth of jointing surface (inspection openings)</td>
<td>mm</td>
</tr>
<tr>
<td>$E$</td>
<td>modulus of elasticity</td>
<td>N/mm²</td>
</tr>
<tr>
<td>$f_G$</td>
<td>coefficient for the calculation of gusset stays</td>
<td>-</td>
</tr>
<tr>
<td>$F_g$</td>
<td>load carried by one girder or gusset stay</td>
<td>N</td>
</tr>
<tr>
<td>$F_B$</td>
<td>force imposed on bolted connection by working pressure</td>
<td>N</td>
</tr>
<tr>
<td>$F_D$</td>
<td>force to close seal under service condition</td>
<td>N</td>
</tr>
<tr>
<td>$F_{D0}$</td>
<td>force to close seal in assembled condition</td>
<td>N</td>
</tr>
<tr>
<td>$F_S$</td>
<td>total load on bolted connection in service</td>
<td>N</td>
</tr>
<tr>
<td>$F'_S$</td>
<td>total load on bolted connection at test pressure</td>
<td>N</td>
</tr>
<tr>
<td>$F_{S0}$</td>
<td>total load on bolted connection in assembled condition with no pressure exerted</td>
<td>N</td>
</tr>
<tr>
<td>$F_Z$</td>
<td>additional force due to loaded condition in connected piping</td>
<td>N</td>
</tr>
<tr>
<td>$g_0$</td>
<td>standard acceleration of gravity (9.81 m/s²)</td>
<td>m/s²</td>
</tr>
<tr>
<td>$h$</td>
<td>vertical distance from load point to top of pressure equipment</td>
<td>m</td>
</tr>
<tr>
<td>$h_d$</td>
<td>height of cylindrical portion of dished end</td>
<td>mm</td>
</tr>
<tr>
<td>$h_g$</td>
<td>height of girder or gusset stay</td>
<td>mm</td>
</tr>
<tr>
<td>$H$</td>
<td>heating surface</td>
<td>m²</td>
</tr>
<tr>
<td>$H_d$</td>
<td>outside height of curvature of dished end</td>
<td>mm</td>
</tr>
<tr>
<td>HWL</td>
<td>high water level (alarm)</td>
<td>-</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
<td>Unit</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>I_s</td>
<td>second moment of area</td>
<td>Nmm²</td>
</tr>
<tr>
<td>k</td>
<td>calculation factor for reinforced openings in spherical, cylindrical and conical shells</td>
<td>-</td>
</tr>
<tr>
<td>k_f</td>
<td>calculation factor for flat end plates</td>
<td>-</td>
</tr>
<tr>
<td>k_o</td>
<td>sealing factor for assembled condition</td>
<td>mm</td>
</tr>
<tr>
<td>k_1</td>
<td>sealing factor for service condition</td>
<td>mm</td>
</tr>
<tr>
<td>K</td>
<td>factor depending on the number of supports</td>
<td>-</td>
</tr>
<tr>
<td>K_C</td>
<td>factor taking into account the stress in the junction (conical shells)</td>
<td>-</td>
</tr>
<tr>
<td>K_D</td>
<td>sealing material deformation factor</td>
<td>N/mm²</td>
</tr>
<tr>
<td>K_S</td>
<td>factor for calculating the aggregate area of orifice for safety valves</td>
<td>-</td>
</tr>
<tr>
<td>l</td>
<td>free length between girder supports</td>
<td>mm</td>
</tr>
<tr>
<td>l_b</td>
<td>supporting length of the branch at openings</td>
<td>mm</td>
</tr>
<tr>
<td>l'_b</td>
<td>supporting length of the internal branch projection at openings</td>
<td>mm</td>
</tr>
<tr>
<td>l_s</td>
<td>supporting length of the shell at openings</td>
<td>mm</td>
</tr>
<tr>
<td>L</td>
<td>calculation length (conical section and furnace)</td>
<td>mm</td>
</tr>
<tr>
<td>L_b</td>
<td>calculation length at the branch (openings)</td>
<td>mm</td>
</tr>
<tr>
<td>L_s</td>
<td>calculation length at the shell (openings)</td>
<td>mm</td>
</tr>
<tr>
<td>LLWL</td>
<td>low low water level (lowest specified water level, burner cut-off (BCO))</td>
<td>-</td>
</tr>
<tr>
<td>LWL</td>
<td>low water level (alarm)</td>
<td>-</td>
</tr>
<tr>
<td>M</td>
<td>bending moment acting on girder at given load</td>
<td>Nmm</td>
</tr>
<tr>
<td>M_C</td>
<td>factor for calculating conical shells</td>
<td>-</td>
</tr>
<tr>
<td>n</td>
<td>number of bolts forming a connection</td>
<td>-</td>
</tr>
<tr>
<td>n_w</td>
<td>integral number of waves</td>
<td>-</td>
</tr>
<tr>
<td>NWL</td>
<td>normal water level</td>
<td>-</td>
</tr>
<tr>
<td>p</td>
<td>pressure</td>
<td>bar</td>
</tr>
<tr>
<td>p_c</td>
<td>calculating pressure</td>
<td>bar</td>
</tr>
<tr>
<td>p_d</td>
<td>design pressure</td>
<td>bar</td>
</tr>
<tr>
<td>p_t</td>
<td>test pressure</td>
<td>bar</td>
</tr>
<tr>
<td>P</td>
<td>electric power</td>
<td>kW</td>
</tr>
<tr>
<td>r</td>
<td>inside knuckle radius of tori-spherical ends</td>
<td>mm</td>
</tr>
<tr>
<td>r_i</td>
<td>inside radius of transition knuckle (conical shell)</td>
<td>mm</td>
</tr>
<tr>
<td>r_s</td>
<td>radius of the flanging at dished ends with openings</td>
<td>mm</td>
</tr>
<tr>
<td>R</td>
<td>inside radius of spherical part of tori-spherical ends</td>
<td>mm</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
<td>Unit</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>ReH</td>
<td>specified minimum upper yield stress at room temperature. If the stress-strain curve does not show</td>
<td>N/mm²</td>
</tr>
<tr>
<td></td>
<td>a defined yield stress, the 0.2% proof stress shall be applied</td>
<td></td>
</tr>
<tr>
<td>Rm</td>
<td>specified minimum tensile strength at room temperature</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Rmt</td>
<td>specified minimum tensile strength at design material temperature</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Ret</td>
<td>specified minimum lower yield stress at design material temperature. If the stress-strain curve</td>
<td>N/mm²</td>
</tr>
<tr>
<td></td>
<td>does not show a defined yield stress, the 0.2% proof stress shall be applied</td>
<td></td>
</tr>
<tr>
<td>Rm,100,000</td>
<td>average stress to produce rupture in 100,000 hours at design material temperature</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Rp1.0</td>
<td>1.0% proof stress</td>
<td>N/mm²</td>
</tr>
<tr>
<td>s</td>
<td>thickness</td>
<td>mm</td>
</tr>
<tr>
<td>sa</td>
<td>actual thickness of the flat plate as built minus corrosion allowance</td>
<td>mm</td>
</tr>
<tr>
<td>sb</td>
<td>thickness of the branch</td>
<td>mm</td>
</tr>
<tr>
<td>spa</td>
<td>thickness of the branch as built minus corrosion allowance</td>
<td>mm</td>
</tr>
<tr>
<td>sg</td>
<td>thickness of girder</td>
<td>mm</td>
</tr>
<tr>
<td>sm</td>
<td>minimum wall thickness of tube stub as calculated without corrosion allowance</td>
<td>mm</td>
</tr>
<tr>
<td>sp</td>
<td>pitch of tubes</td>
<td>mm</td>
</tr>
<tr>
<td>s1</td>
<td>the shorter of any two adjacent pitches</td>
<td>mm</td>
</tr>
<tr>
<td>s2</td>
<td>the longer of any two adjacent pitches</td>
<td>mm</td>
</tr>
<tr>
<td>s1</td>
<td>required thickness at the junction of the cone and the cylinder</td>
<td>mm</td>
</tr>
<tr>
<td>s2</td>
<td>thickness of the shell as calculated</td>
<td>mm</td>
</tr>
<tr>
<td>ssa</td>
<td>actual thickness of the shell as built minus corrosion allowance</td>
<td>mm</td>
</tr>
<tr>
<td>s1</td>
<td>thickness of cylindrical shell as calculated</td>
<td>mm</td>
</tr>
<tr>
<td>s2</td>
<td>thickness of end plate as calculated at the junction with the shell</td>
<td>mm</td>
</tr>
<tr>
<td>S</td>
<td>safety factor</td>
<td>-</td>
</tr>
<tr>
<td>S_k</td>
<td>safety factor against elastic instability</td>
<td>-</td>
</tr>
<tr>
<td>t_d</td>
<td>design temperature</td>
<td>°C</td>
</tr>
<tr>
<td>t_o</td>
<td>temperature difference between saturated and superheated steam</td>
<td>°C</td>
</tr>
<tr>
<td>T</td>
<td>dropping time</td>
<td>sec</td>
</tr>
<tr>
<td>u</td>
<td>percentage of out of roundness</td>
<td>%</td>
</tr>
<tr>
<td>v</td>
<td>joint efficiency</td>
<td>-</td>
</tr>
<tr>
<td>v'</td>
<td>specific volume of water at saturation temperature</td>
<td>m³/kg</td>
</tr>
<tr>
<td>V</td>
<td>Volume (including its attachments up to the first detachable connection or up to the welding seam</td>
<td>m³ or ltr</td>
</tr>
<tr>
<td></td>
<td>connecting the nozzle of the pressure equipment to the piping system)</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>section modulus of one girder</td>
<td>mm³</td>
</tr>
<tr>
<td>X</td>
<td>area requiring compensation at flat end plates (opening)</td>
<td>mm²</td>
</tr>
</tbody>
</table>
### Part 4 Chapter 7 Section 1

#### Rules for classification: Ships — DNVGL-RU-SHIP Pt.4 Ch.7. Edition January 2017

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(X_1)</td>
<td>coefficient considering shell and end plate thickness</td>
<td></td>
</tr>
<tr>
<td>(y)</td>
<td>factor depending on the ratio (b/a)</td>
<td></td>
</tr>
<tr>
<td>(y_i)</td>
<td>factor depending on the ratio (b/a) for calculating inspection openings</td>
<td></td>
</tr>
<tr>
<td>(Y)</td>
<td>area of reinforcement at flat end plates (openings)</td>
<td>(\text{mm}^2)</td>
</tr>
<tr>
<td>(z)</td>
<td>coefficient for section modulus</td>
<td></td>
</tr>
<tr>
<td>(\alpha_c)</td>
<td>half apex angle of the section (conical shells)</td>
<td>(^\circ)</td>
</tr>
<tr>
<td>(\alpha_p)</td>
<td>angle of centre line of cylinder to the centre line of diagonal holes</td>
<td>(^\circ)</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>angle of gusset stay to longitudinal axis of the shell</td>
<td>(^\circ)</td>
</tr>
<tr>
<td>(\beta)</td>
<td>shape factor for dished ends</td>
<td></td>
</tr>
<tr>
<td>(\psi)</td>
<td>difference between angle of slope of the adjoining parts</td>
<td></td>
</tr>
<tr>
<td>(\rho)</td>
<td>density of the fluid</td>
<td>(\text{t/m}^3)</td>
</tr>
<tr>
<td>(\sigma_t)</td>
<td>nominal design stress at design metal temperature</td>
<td>(\text{N/mm}^2)</td>
</tr>
<tr>
<td>(\nu)</td>
<td>Poisson's ratio</td>
<td></td>
</tr>
</tbody>
</table>

#### 2.4 Units

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

- dimensions (lengths, diameters, thicknesses etc.): \(\text{mm}\)
- areas: \(\text{mm}^2\) or \(\text{m}^2\) for heating surface \(H\)
- pressures: \(\text{bar}\)
- temperatures: \(^\circ\text{C}\)
- mechanical properties of materials (ultimate tensile strength, yield strength etc.): \(\text{N/mm}^2\)
- impact energy: \(\text{J}\)
- electric power: \(\text{kW}\).

#### 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**

<table>
<thead>
<tr>
<th>Pressure equipment class</th>
<th>(I)</th>
<th>(II)</th>
<th>(III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam boilers</td>
<td>(p_d &gt; 3.5)</td>
<td>(p_d \leq 3.5)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(p_d &gt; 10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>(t_d &gt; 300)</td>
<td></td>
</tr>
<tr>
<td>Thermal oil heaters</td>
<td>(p_d \leq 10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and</td>
<td>(t_d \leq 300)</td>
<td></td>
</tr>
<tr>
<td>Dust collectors, dust filters, bulk storage tanks</td>
<td>( p_d &gt; 5 ) or ( D_o &gt; 1000 )</td>
<td>( p_d \leq 5 ) and ( D_o \leq 1000 )</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td><strong>Operating fluids for pressure vessels</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquefied gases (propane, butane, etc.), flammable gases, toxic and corrosive media</td>
<td>all</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Refrigerants (see Ch.6 Sec.6 [3.1])</td>
<td>Group 2</td>
<td>Group 1</td>
<td>-</td>
</tr>
<tr>
<td>Steam, compressed air, non-flammable gases</td>
<td>( p_d &gt; 16 ) or ( t_d &gt; 300 )</td>
<td>( p_d \leq 16 ) and ( t_d \leq 300 )</td>
<td>( p_d \leq 7 ) and ( t_d \leq 170 )</td>
</tr>
<tr>
<td>Thermal oils</td>
<td>( p_d &gt; 16 ) or ( t_d &gt; 300 )</td>
<td>( p_d \leq 16 ) and ( t_d \leq 300 )</td>
<td>( p_d \leq 7 ) and ( t_d \leq 150 )</td>
</tr>
<tr>
<td>Liquid fuels, lubricating oils, flammable hydraulic fluids</td>
<td>( p_d &gt; 16 ) or ( t_d &gt; 150 )</td>
<td>( p_d \leq 16 ) and ( t_d \leq 150 )</td>
<td>( p_d \leq 7 ) and ( t_d \leq 60 )</td>
</tr>
<tr>
<td>Water, non-flammable hydraulic fluids</td>
<td>( p_d &gt; 40 ) or ( t_d &gt; 300 )</td>
<td>( p_d \leq 40 ) and ( t_d \leq 300 )</td>
<td>( p_d \leq 16 ) and ( t_d \leq 200 )</td>
</tr>
</tbody>
</table>

**Guidance note:**
For pressure equipment with more than one chamber where the chambers have different pressure equipment classes, the boundaries between the chambers have to 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.

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

3.1 Documentation requirements

3.1.1 Documentation shall be submitted as required by Table 3.

Table 3 Documentation requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure vessel</td>
<td>C010 – Design criteria</td>
<td>— design pressure&lt;br&gt;— design temperature&lt;br&gt;— volume&lt;br&gt;— fluid&lt;br&gt;— additional loads (if applicable)&lt;br&gt;— heating surface of heat exchanger and warm water generator&lt;br&gt;— heating power and discharge temperature of warm water generator&lt;br&gt;— proposed set pressure of safety valve&lt;br&gt;— pressure equipment class</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>C020 – Assembly or arrangement drawing</td>
<td>Including valves and fittings.</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>C030 – Detailed drawing</td>
<td>Cross sectional and plan views. Attachments and supports.</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>C040 – Design analysis</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>C050 – Non-destructive testing (NDT) plan</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td>Propulsion boiler</td>
<td>C010 – Design criteria</td>
<td>— design pressure&lt;br&gt;— design temperature&lt;br&gt;— volume&lt;br&gt;— heating surface&lt;br&gt;— estimated evaporation&lt;br&gt;— proposed set pressure of safety valves&lt;br&gt;— blow-off capacity of safety valves&lt;br&gt;— pressure equipment class</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>C020 – Assembly or arrangement drawing</td>
<td>Including valves and fittings.</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>C030 – Detailed drawing</td>
<td>Including attachments and supports.</td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>C040 – Design analysis</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>C050 – NDT plan</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>I200 – Control and monitoring system documentation</td>
<td></td>
<td>AP</td>
</tr>
<tr>
<td></td>
<td>Z161 — Operation manual</td>
<td></td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Auxiliary boiler</td>
<td>Thermal oil heater</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>----------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| 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 | — 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 |
| C020 — Assembly or arrangement drawing  | Including valves and fittings.                                               | Including valves and fittings.   |
| C030 — Detailed drawing                 | Including attachments and supports.                                         | Fire extinguishing in the heater furnace and at the exhaust gas heated thermal oil heater. |
| C040 — Design analysis                  |                                                                           | Cross sectional and plan views.                                                     |
| C050 — Non-destructive testing (NDT) plan |                                                                           | Calculations of maximum film temperature in the furnace tubes, in accordance with a recognized standard, e.g. DIN 4754. |
| I200 — Control and monitoring system documentation |                                                                           |                                                                                   |
| Z161 — Operation manual                 |                                                                           |                                                                                   |
3.1.2 For general requirements for documentation, see Pt.1 Ch.3 Sec.2.

3.1.3 For a full definition of the documentation types, see Pt.1 Ch.3 Sec.3.

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.

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

3.1.5 Drawing approval of charge air coolers is not required. In respect to the requirements for inspection, testing and certification see Pt.4 Ch.3, Sec. 1 Table 8.

3.2 Certification requirements

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

Table 4 Requirements for pressure equipment classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Approved pressure equipment manufacturer Sec.7 [1.1.1]</th>
<th>Approved material manufacturer</th>
<th>Material certificates</th>
<th>Welding procedure qualification Sec.7 [1.1.2]</th>
<th>Non-destructive testing Sec.7 [4.1]</th>
<th>Heat treatment</th>
<th>Visual and dimensional inspection Sec.7 [4.5]</th>
<th>Hydraulic test Sec.7 [4.6]</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Required</td>
<td>Required</td>
<td>See Table 5</td>
<td>Required</td>
<td>Depending on joint efficiency v</td>
<td>See Sec.7 [3]</td>
<td>Required</td>
<td>Required</td>
</tr>
</tbody>
</table>
3.2.2 Pressure equipment shall be certified as required by Table 5 to Table 9. For definition of the different types of certificates see Pt.1 Ch.3 Sec.5.

### Table 5 Certification requirements for pressure equipment class I

<table>
<thead>
<tr>
<th>Component</th>
<th>Certificate type</th>
<th>Additional description</th>
<th>Issued by</th>
<th>Certification standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure equipment class I</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Plates, dished ends and heads</td>
<td>MC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Pipes and tubes (for shells of pressure equipment and tubes of water tube boilers)</td>
<td>MC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Stays, stay bolts and stay tubes</td>
<td>MC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Smoke tubes (tubes subject to external pressure)</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Tubes in heat exchanger and channel plates in plate heat exchangers</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Flanges, nozzles and branches</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Manhole, headhole and handhole closures</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Reinforcement plates and discs</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Bolts and tie rods</td>
<td>MC</td>
<td>Rm &gt;500 N/mm²</td>
<td>≥M30</td>
<td>Manufacturer</td>
</tr>
<tr>
<td></td>
<td>MC</td>
<td>Alloyed or heat treated</td>
<td>≥M16</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Nuts</td>
<td>MC</td>
<td>Rm &gt;600 N/mm²</td>
<td>≥M30</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Forgings and castings</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
</tbody>
</table>
### Table 6 Certification requirements for pressure equipment class II

<table>
<thead>
<tr>
<th>Component</th>
<th>Certificate type</th>
<th>Additional description</th>
<th>Issued by</th>
<th>Certification standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure equipment class II</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Plates, dished ends and heads</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Pipes and tubes (for shells of pressure equipment and tubes of water tube boilers)</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Stays, stay bolts and stay tubes</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Smoke tubes (tubes subject to external pressure)</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Tubes in heat exchanger and channel plates in plate heat exchangers</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Flanges, nozzles and branches</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Manhole, headhole and handhole closures</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Reinforcement plates and discs</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Bolts and tie rods</td>
<td>MC</td>
<td>Rm &gt;500 N/mm²</td>
<td>≥M30</td>
<td>Manufacturer</td>
</tr>
<tr>
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<td>MC</td>
<td>Alloyed or heat treated</td>
<td>≥M16</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Nuts</td>
<td>MC</td>
<td>Rm &gt;600 N/mm²</td>
<td>≥M30</td>
<td>Manufacturer</td>
</tr>
<tr>
<td>Forgings and castings</td>
<td>MC</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
</tbody>
</table>

### Table 7 Certification requirements for pressure equipment class III

<table>
<thead>
<tr>
<th>Component</th>
<th>Certificate type</th>
<th>Additional description</th>
<th>Issued by</th>
<th>Certification standard</th>
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<tbody>
<tr>
<td>Pressure equipment class III</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Plates, dished ends and heads</td>
<td>TR</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Pipes and tubes (for shells of pressure equipment and tubes of water tube boilers)</td>
<td>TR</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Stays, stay bolts and stay tubes</td>
<td>TR</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
</tbody>
</table>
Smoke tubes (tubes subject to external pressure) | TR | Manufacturer | Rules
---|---|---|---
Tubes in heat exchanger and channel plates in plate heat exchangers | TR | Manufacturer | Rules
Flanges, nozzles and branches | TR | Manufacturer | Rules
Manhole, headhole and handhole closures | TR | Manufacturer | Rules
Reinforcement plates and discs | TR | Manufacturer | Rules
Bolts and tie rods | TR | Rm >500 N/mm² | ≥M30 | Manufacturer | Rules
| TR | Alloed or heat treated | ≥M16 | Manufacturer | Rules
Nuts | TR | Rm >600 N/mm² | ≥M30 | Manufacturer | Rules
Forgings and castings | TR | | | Manufacturer | Rules

### Table 8 Certification requirements for burners

<table>
<thead>
<tr>
<th>Component</th>
<th>Certificate type</th>
<th>Additional description</th>
<th>Issued by</th>
<th>Certification standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burner</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Fuel oil pre-heater</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Fuel oil cooler (MGO)</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
<tr>
<td>Pipes and tubes</td>
<td>TR</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Fittings</td>
<td>TR</td>
<td></td>
<td>Manufacturer</td>
<td>Rules</td>
</tr>
<tr>
<td>Equipment for alarm and safety action</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td>Rules</td>
</tr>
</tbody>
</table>

### Table 9 Certification requirements for control and monitoring systems

<table>
<thead>
<tr>
<th>Component</th>
<th>Certificate type</th>
<th>Additional description</th>
<th>Issued by</th>
<th>Certification standard*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler control, monitoring and safety system</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td></td>
</tr>
<tr>
<td>Thermal oil heater control, monitoring and safety system</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td></td>
</tr>
<tr>
<td>Oil fired water heater control, monitoring and safety system</td>
<td>PC</td>
<td></td>
<td>Society</td>
<td></td>
</tr>
</tbody>
</table>

*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 Pt.1 Ch.3 Sec.4 and Pt.1 Ch.3 Sec.5.

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 ferrous materials.

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 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 Sec.2 Table 1 Certificates for materials of these rules.

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 oil 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.

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---

1.1.2 The materials used shall have certificates according to Sec.1, Table 5 to 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.

Fully killed and fine grain, normal strength structural steels complying with the specifications given in Pt.2 Ch.2 Sec.2 will, however, be accepted for end plates for plate heat exchangers and the following 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

\[ p_d < \frac{15000}{D_o + 2000} \]

where:

\[ p_d = \text{design pressure} \]
\[ D_o = \text{outside diameter} \]

1.2.2 The steel grades VL 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/mm², 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 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:

\[ p_d > \frac{15000}{D_0 + 2000} \]

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

\[ p_d = \text{design pressure} \]

\[ D_0 = \text{outside diameter} \]

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

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.

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

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

2.3.2 Soot-cleaning arrangement

Water tube exhaust gas boilers or economisers of a design where soot deposit may cause 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 economizers 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 oil 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 The heater shall be capable of being drained and ventilated as well from the position outside the immediate area in which the heater is installed.

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.

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 Oil 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).

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

<table>
<thead>
<tr>
<th>Heater Output [kW]</th>
<th>Expansion and overflow pipes Nominal diameter DN</th>
<th>Drainage and venting pipes Nominal diameter DN</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 600</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>≤ 900</td>
<td>32</td>
<td>40</td>
</tr>
<tr>
<td>≤ 1200</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>≤ 2400</td>
<td>50</td>
<td>65</td>
</tr>
<tr>
<td>≤ 6000</td>
<td>65</td>
<td>80</td>
</tr>
</tbody>
</table>

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 oil 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 burner and oil 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 Oil 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 6 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 plate
— 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 may be required. The calculations may be carried out according to a recognised pressure equipment code accepted by the Society.

1.1.3 Pressure equipment subjected to external pressure, except furnaces, fireboxes and uptakes (see [7]), 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.

1.1.4 Parts of pressure equipment not covered by these rules, e.g. flanges, bolts 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.

In general the nominal design stress shall not exceed that given in [2.5].

The allowable stresses for the bolts shall be as specified in the recognised international code accepted by the Society. 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:

- $g_0 = \text{standard acceleration of gravity (9.81 m/s}^2)$
- $h = \text{vertical distance from load point to top of the pressure equipment}$
- $p_c = \text{calculating pressure}$
- $p_d = \text{design pressure}$
- $\rho = \text{density of the fluid}$

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:

- $a_v = \text{most probable largest combined vertical acceleration in } 10^8 \text{ wave encounters (probability level } Q = 10^{-3})$
- $g_0 = \text{standard acceleration of gravity (9.81 m/s}^2)$
- $h = \text{vertical distance from load point to top of pressure equipment}$
- $p_c = \text{calculating pressure}$
- $p_d = \text{design pressure}$
- $\rho = \text{density of the fluid}$
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---

2.4 Design material temperature

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

2.4.2 For boilers the design material 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 design material temperature is, however, not to be taken less than 250°C.

Table 1 Temperature allowances

<table>
<thead>
<tr>
<th>Reference temperature</th>
<th>Minimum temperature allowance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unheated parts</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturation temperature at design pressure</td>
<td>0°C</td>
</tr>
<tr>
<td>Superheated steam temperature</td>
<td>15°C</td>
</tr>
</tbody>
</table>

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 design material temperature cannot be exceeded.

For furnaces, fireboxes and other pressure parts subjected 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.
Table 2 Design temperatures for heated components

<table>
<thead>
<tr>
<th>Component Type</th>
<th>Design Temperature Formula</th>
<th>Minimum Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain tubes</td>
<td>[ t[^\circ C] = \text{saturation temperature} + 4s + 15[^\circ C] ]</td>
<td>but at least 250[^\circ C]</td>
</tr>
<tr>
<td>Corrugated tubes</td>
<td>[ t[^\circ C] = \text{saturation temperature} + 3s + 30[^\circ C] ]</td>
<td></td>
</tr>
<tr>
<td>Tubes heated by exhaust gases</td>
<td>[ t[^\circ C] = \text{saturation temperature} + 2s + 15[^\circ C] ]</td>
<td></td>
</tr>
</tbody>
</table>

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[^\circ C] for finned tubes and 25[^\circ 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[^\circ 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 \( \sigma_t \) is defined as the lowest of the following values:

For pressure equipment operating at a temperature up to and including 50[^\circ 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[^\circ C]:

\[ \sigma_t = \min \left( \frac{R_{eH}}{1.7}, \frac{R_{et}}{1.6}, \frac{R_m}{2.7}, \frac{R_{m,100000}}{1.6} \right) \]

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 design material 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 design material temperature.
- \( \sigma_t \) = nominal design stress at design metal temperature.

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

\[ \sigma_t = \min \left( \frac{R_{p1.0}}{1.7}, \frac{R_{et}}{1.6}, \frac{R_m}{2.7} \right) \]

where:

- \( R_{et} \) = specified minimum lower yield stress at design material 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.
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 design material 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
\( R_{m,100,000} \) = average stress to produce rupture in 100 000 hours at design material temperature
\( \sigma_t \) = nominal design stress at design metal 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 design material 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
\( \sigma_t \) = nominal design stress at design metal 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
\( \sigma_t \) = nominal design stress at design metal 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 design material temperature
\( R_{m,100,000,t} \) = average stress to produce rupture in 100 000 hours at design material temperature
\( R_{p0.2} \) = 0.2% proof stress at room temperature
\( R_{p0.2,t} \) = 0.2% proof stress at design material temperature
\( R_{p1.0,100,000,t} \) = 1.0% creep strain limit at design material temperature
\[ \sigma_t = \text{nominal design stress at design metal temperature} \]

The nominal design stress calculated according to a generally recognised code of practice (e.g. AD-W6/2 or ASME Sec. II, Part D, Table1B) is acceptable for copper and copper alloys.

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:

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

\( R_{mt} = \text{specified minimum tensile strength at design material temperature} \)

\( \sigma_t = \text{nominal design stress at design metal temperature} \)

2.5.8 Values for \( R_m, R_{el}, R_{et}, R_{p1.0} \) 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 shell 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:

\[ s \geq 3 + \frac{D_i}{1500} \]

where:

\( s = \text{nominal thickness} \)

\( s \geq 7 \text{ mm for boilers} \)

\( s \geq 5 \text{ mm for dished ends} \)

\( s \geq 3 \text{ mm for stainless steel and non-ferrous materials} \)

\( D_i = \text{internal diameter} \)

2.6.2 For pressure equipment where the cylindrical part is made of a pipe, a smaller minimum thickness may be accepted.
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:
— \( 0.85 < v \leq 1.0 \) for 100% non-destructive testing (NDT) (RT or UT)
— \( 0.7 < v \leq 0.85 \) for spot or random NDT (RT or UT)
— \( v \leq 0.7 \) 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 \( p_d > 3.5 \) 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 \( > 520 \) N/mm\(^2\) shall have a joint efficiency \( v = 1.0 \).
Joint efficiency \( v \leq 0.7 \) 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 \( v \leq 0.7 \) shall have a specified minimum tensile strength \( \leq 460 \) 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).
3.2 Cylindrical shells

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

\[ s \geq \frac{p_c \cdot D_0}{\nu \cdot \sigma_t + p_c} + c \]

where:
- \( c \) = corrosion margin/allowance see [2.7]
- \( D_0 \) = outside diameter
- \( p_c \) = calculating pressure
- \( s \) = thickness
- \( \nu \) = joint efficiency see [2.9]
- \( \sigma_t \) = nominal design stress at design metal temperature

3.3 Spherical shells

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

\[ s \geq \frac{p_c \cdot D_0}{4 \cdot \nu \cdot \sigma_t + p_c} + c \]

where:
- \( c \) = corrosion margin/allowance see [2.7]
- \( D_0 \) = outside diameter
- \( p_c \) = calculating pressure
- \( s \) = thickness
- \( \nu \) = joint efficiency see [2.9]
- \( \sigma_t \) = nominal design stress at design metal temperature
3.4 Conical shells of circular sections

3.4.1 The thickness of a conical shell shall not be less than:
\[ s \geq \frac{p_c \cdot D_c}{20 \cdot \sigma_t \cdot v - p_c \cos \alpha_c} + c \]
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]
- \( \alpha_c \) = half apex angle of the section
- \( \sigma_t \) = nominal design stress at design metal temperature

3.4.2 The formula in [3.4.1] applies only if the half apex angle \( \alpha_c \) 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):
\[ L = 0.5 \sqrt{\frac{D_0 (s - c)}{\cos \psi}} \]
\[ s \geq \frac{p_c \cdot D_0 \cdot K_C}{20 \cdot \sigma_t \cdot v} + c + c_1 \]
\[ c_1 = \begin{cases} c_1 & \text{if } \frac{s - c}{D_0} \geq 0.005 \\ c_1 & \text{if } \frac{s - c}{D_0} < 0.005 \end{cases} \]

Values of \( K_C \) are given in Table 3 as a function of \( \psi \) and \( r_i/D_0 \).

- \( c \) = corrosion margin/allowance see [2.7]
- \( D_0 \) = 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]
- \( \alpha_c \) = half apex angle of the section
\[ \psi = \text{difference between angle of slope of the adjoining parts} \]

[Diagram](image)

\[ \sigma_t = \text{nominal design stress at design metal temperature} \]

---

**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 \( \psi \) and \( r_i/D_o \)**

<table>
<thead>
<tr>
<th>( \psi )</th>
<th>0.01</th>
<th>0.06</th>
<th>0.08</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
<th>0.30</th>
<th>0.40</th>
<th>0.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>10°</td>
<td>0.70</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>20°</td>
<td>1.00</td>
<td>0.70</td>
<td>0.65</td>
<td>0.60</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>30°</td>
<td>1.35</td>
<td>0.90</td>
<td>0.85</td>
<td>0.80</td>
<td>0.70</td>
<td>0.65</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>45°</td>
<td>2.05</td>
<td>1.30</td>
<td>1.20</td>
<td>1.10</td>
<td>0.95</td>
<td>0.90</td>
<td>0.70</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>60°</td>
<td>3.20</td>
<td>2.00</td>
<td>1.75</td>
<td>1.60</td>
<td>1.40</td>
<td>1.25</td>
<td>1.00</td>
<td>0.70</td>
<td>0.55</td>
</tr>
</tbody>
</table>
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 \( p_c/\sigma_t \times v \) (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 \( \frac{D_o \cdot (s_r - c)}{\cos \alpha_C} \) from the junction.

\[
D_o = \text{outside diameter of the conical section} \\
c = \text{corrosion allowance} \\
s_r = \text{required thickness at the junction of the cone and the cylinder} \\
\alpha_C = \text{half apex angle of the section (conical shells)}
\]

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 shall not be less than:

\[
s \geq \frac{p_c \cdot d_o}{2 \cdot \sigma_t + p_c} + c
\]

where:

- \( c \) = corrosion allowance
- \( d_o \) = outer diameter of the tube
- \( p_c \) = calculating pressure
- \( s \) = wall thickness
- \( \sigma_t \) = nominal design stress at design metal temperature

**3.5.2** The corrosion allowance shall be 1 mm, except for tubes used in boilers with open feed water systems where the corrosion allowance shall be 2.5 mm.

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

#### Table 4 Minimum thickness of tubes

<table>
<thead>
<tr>
<th>Outside diameter of tube (mm)</th>
<th>Minimum thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_o \leq 38 )</td>
<td>1.75</td>
</tr>
<tr>
<td>( 38 &lt; d_o \leq 51 )</td>
<td>2.16</td>
</tr>
<tr>
<td>( 51 &lt; d_o \leq 70 )</td>
<td>2.40</td>
</tr>
<tr>
<td>( 70 &lt; d_o \leq 76 )</td>
<td>2.60</td>
</tr>
<tr>
<td>( 76 &lt; d_o \leq 95 )</td>
<td>3.05</td>
</tr>
<tr>
<td>( 95 &lt; d_o \leq 102 )</td>
<td>3.28</td>
</tr>
<tr>
<td>( 102 &lt; d_o \leq 127 )</td>
<td>3.50</td>
</tr>
</tbody>
</table>
3.5.4 If the tubes are ordered with a minus tolerance, the minimum thickness according to the formula in [3.5.1] and Table 4 shall be increased by the necessary amount. 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.

3.5.5 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
- \( \sigma_t \) = nominal design stress at design metal 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 [3.5.4].

3.6.3 The nominal thickness of the tubes is, however, in no case to be less than given in Table 5.

Table 5 Nominal wall thickness of tubes

<table>
<thead>
<tr>
<th>Outside diameter of tube (mm)</th>
<th>Nominal wall thickness of tube (mm)</th>
<th>2.9</th>
<th>3.2</th>
<th>3.6</th>
<th>4.0</th>
<th>4.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design pressure (bar)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td></td>
<td>11.0</td>
<td>15.0</td>
<td>21.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td></td>
<td>10.0</td>
<td>13.5</td>
<td>18.0</td>
<td>22.0</td>
<td></td>
</tr>
<tr>
<td>63.5</td>
<td></td>
<td>9.0</td>
<td>12.5</td>
<td>16.0</td>
<td>21.0</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
<td>8.0</td>
<td>11.0</td>
<td>15.0</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>76.1</td>
<td></td>
<td>10.0</td>
<td>13.5</td>
<td>17.5</td>
<td>21.0</td>
<td></td>
</tr>
<tr>
<td>82.5</td>
<td></td>
<td>9.0</td>
<td>12.5</td>
<td>16.0</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>88.9</td>
<td></td>
<td>8.5</td>
<td>11.5</td>
<td>15.0</td>
<td>18.0</td>
<td></td>
</tr>
</tbody>
</table>

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 tube 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 \( s_2/(s_1-c) \geq 1.4 \)
  - \( X_1 = 1.0 \) for \( s_2/(s_1-c) \leq 1.0 \)
- \( \sigma_t \) = nominal design stress at design metal temperature
For intermediate values of $s_2/(s_1 - c)$ 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**
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 5 Diagonal drilling**

The dimensions $a_p$ and $b_p$ are to be measured on the median line.
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.
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:

\[
A_c = \text{compensating area} \\
\text{d} = \text{diameter of tube hole} \\
d_p = \text{mean effective diameter of tube hole} \\
s = \text{plate thickness}
\]

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:

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

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:

\[
\sigma_t = \text{nominal design stress at design metal temperature}
\]

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

\[
1.25 \times d_p + 10 \text{ [mm]}
\]

\[
d_p = \text{mean effective diameter of tube hole}
\]
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 zigzag.

![Diagram of Stub connections]

Area \( A_c \) equals twice the area shown cross-hatched.

### 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
- \( s \) = required end plate thickness after dishing
- \( v \) = joint efficiency as defined in [4.1.6]
- \( \beta \) = shape factor for dished ends defined in [4.1.3]
- \( \sigma_t \) = nominal design stress at design metal 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 calculated thickness \( s \).

4.1.2 The formula in [4.1.1] applies to:
- hemispherical ends
- elliptical ends with \( H \geq 0.2 \cdot D_o \)
- tori-spherical ends satisfying the following conditions:
  \[ H_d \geq 0.18 \cdot D_o; \ r \geq 0.1 \cdot D_o; \ r \geq 3 \cdot s; \]
where:
\[
\begin{align*}
  d & = \text{internal diameter [of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical or non-circular openings]} \\
  D_o & = \text{outside diameter} \\
  H_d & = \text{outside height of curvature of dished end} \\
  s & = \text{thickness} \\
  r & = \text{inside knuckle radius of tori-spherical ends} \\
  R & = \text{inside radius of spherical part of tori-spherical ends}
\end{align*}
\]

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 \( 3.5 \times s \). \( s \) 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:
\[
\begin{align*}
  d_i & = \text{internal diameter [of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical or non-circular openings]} \\
  D_o & = \text{outside diameter}
\end{align*}
\]

See also Figure 12.

Guidance note:
The outside height of tori-spherical ends may be determined from the following formula:
\[
H_d = R + s - \sqrt{(R - r)^2 - \left(\frac{D_o}{2} - s - r\right)^2}
\]
4.1.3 The shape factor $\beta$ 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 $\beta$ 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 $d_i/\sqrt{D_o \times (s-c)}$ 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: $(s-c)/D_o \leq 0.1$.

$\beta$ 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.
\[ r_1 = \text{radius of the flanging at dished ends with openings} \]

**Guidance note 1:**
In the case of ends containing only compensated openings, read \( \beta \) from full curves of \( (s - c)/D_o = 0.002 \) to \( (s - c)/D_o = 0.04 \); interpolating as necessary.

**Guidance note 2:**
In the case of ends containing uncompensated openings, read \( \beta \) from the broken line curves \( \frac{d_1}{\sqrt{D_o(s-c)}} = 0.5 \); interpolating as necessary. In no case, \( \beta \) 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 \( \beta \) for dished ends**

4.1.4 The thickness of dished ends without stays, convex to the pressure side shall not be less than
where:
\(c\) = corrosion margin/allowance
\(D_o\) = outside diameter
\(p_c\) = calculating pressure
\(s\) = required end plate thickness after dishing
\(v\) = joint efficiency as defined in [4.1.6]
\(\beta\) = shape factor for dished ends defined in [4.1.3]
\(\sigma_t\) = nominal design stress at design metal 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 \(p_d = p_c / SF\)

\[
SF = \begin{cases} 
3.7 & \text{for } \frac{s - c}{R} \leq 0.001; \\ 3.0 & \text{for } \frac{s - c}{R} \geq 0.003 
\end{cases}
\]

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 minimum 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
- \( \sigma_t \) = nominal design stress at design metal temperature

The thickness shall not be less than the thickness of the firebox.

**4.2.3** The minimum 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
- \( \sigma_t \) = nominal design stress at design metal temperature
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 as given in Figure 15.
The inside fillet weld may only be omitted for small boilers not accessible for welding from the inside.
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.

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. The minimum throat thickness should be related to the shell thickness as specified in Table 6:

**Table 6 Minimum throat thickness**

<table>
<thead>
<tr>
<th>Shell thickness (mm)</th>
<th>Minimum throat thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s &lt; 12$</td>
<td>4.5</td>
</tr>
<tr>
<td>$12 \leq s \leq 16$</td>
<td>5</td>
</tr>
<tr>
<td>$16 &lt; s$</td>
<td>6</td>
</tr>
</tbody>
</table>

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:

$$k_f \leq 14 \cdot \frac{\sigma_t}{\psi_c}$$
$k_f$ 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
- \(\sigma_t\) = nominal design stress at design metal temperature

For determining $k_f$, see Figure 16.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure16.png}
\caption{Calculation factor $k_f$}
\end{figure}
5.2.2 The formula in [5.2.1] is based on the following conditions:
\[ p_c \leq 30 \text{ bar} \]
\[ s_1 \leq s \leq 5 \, s_1 \]
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 \( \sqrt{D_o \cdot (s_1 - s)} \) from the end plate, where \( D_o = \text{outside diameter of cylindrical shell} \).

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 \( b/a \)
- \( \sigma_t \) = nominal design stress at design metal 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].
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

<table>
<thead>
<tr>
<th>Type of support</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated plain bar stays or stay tubes with a centre distance of more than 200 mm, Figure 20 (a) and Figure 21</td>
<td>0.45</td>
</tr>
</tbody>
</table>

**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 |
- Un-stayed 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

<table>
<thead>
<tr>
<th>Ratio b/a</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rectangular areas</td>
</tr>
<tr>
<td>1.0</td>
<td>1.10</td>
</tr>
<tr>
<td>0.75</td>
<td>1.26</td>
</tr>
<tr>
<td>0.5</td>
<td>1.40</td>
</tr>
<tr>
<td>0.25</td>
<td>1.52</td>
</tr>
</tbody>
</table>
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 \( d \leq 50 \text{ mm} \)
- 14.0 mm when \( d > 50 \text{ mm} \)

\( d = \) 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.
Figure 21 Typical attachment of stay tubes

**Guidance note 2:**
Stay tubes should be lightly expanded before and after welding.

---end---of---guidance---note---

**Guidance note 3:**
For stay tubes exposed to flame or gas temperatures exceeding 600°C the ends should be dressed flush with the welds.

---end---of---guidance---note---
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: $0.125 \times d + 12.5$
- for welded tubes: $0.125 \times d + 9$ for gas entry temperatures $> 800^\circ C$
  $0.125 \times d + 7$ for gas entry temperatures $\leq 800^\circ C$

$d =$ 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:

$$s = b \cdot \sqrt[3]{\frac{P_c}{10 \cdot \sigma_t}} + c$$

with a minimum of 15 mm for manhole covers.

- $a =$ major dimension of elliptical area
- $b =$ minor dimension of elliptical area
- $c =$ corrosion allowance
$e_t = \text{breadth of jointing surface}$

$p_c = \text{calculating pressure}$

$s = \text{thickness}$

$y_i = \text{factor depending on the ratio } b/a \text{ for calculating inspection openings (see Table 9)}$

$\sigma_t = \text{nominal design stress at design metal temperature}$

---

**Figure 23 Covers**

**Table 9 Coefficient $y_i$**

<table>
<thead>
<tr>
<th>$b/a$</th>
<th>1.0</th>
<th>0.75</th>
<th>0.5</th>
<th>0.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_i$(1)\</td>
<td>0.55</td>
<td>0.63</td>
<td>0.72</td>
<td>0.79</td>
</tr>
</tbody>
</table>

\(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.
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
- \( \sigma_t \) = nominal design stress at design metal 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 \( 8 \times s_g \) 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 may be approved.

![Figure 25 Opening arrangement](image)

6.2 Openings not requiring reinforcement

6.2.1 Reinforcements are not required for isolated openings provided

\[ d_i \leq 0.3\sqrt{(D_i + s_o)s_o} \]

with a maximum of 150 mm.
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\[ D_i = \text{for a cylindrical or spherical shell:} \]
\[ = \text{for a conical shell:} \]
\[ = \text{for a tori-spherical end:} \]
\[ = \text{for a semi-ellipsoidal end:} \]

\[ d_a = \text{mean inner diameter of the two openings} \]

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

\[ s_a = \text{thickness of the shell plate or end plate as built minus corrosion allowance} \]

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

\[ d_a + 3\sqrt{(D_i + s_a)s_a} \]

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:

\[ d_i = \text{internal diameter of an opening or branch for a circular opening or the chord length in the plane being considered for elliptical openings} \]

\[ k = \text{calculation factor for reinforced openings in spherical, cylindrical and conical shells} \]

\[ k = 1 \text{ for spherical shells and for planes passing through the generatrix for cylindrical and conical shells} \]

\[ k = 0.7 \text{ for planes normal to the generatrix for cylindrical and conical shells} \]

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

\[ s_s = \text{thickness of the shell as calculated} \]

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.

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:

\[ L_s = \sqrt{(D_i + s_a)s_a} \]

where:
- \( D_i \) = internal diameter of the shell or sphere
- \( L_s \) = calculation length at the shell
- \( s_a \) = 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 \( s_a/D_i \leq 0.02 \), two-thirds of the area of compensation required shall be at a distance less than:

\[ \frac{d_i}{2} + 0.35\sqrt{(D_i + s_a)s_a} \]

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
- \( s_a \) = 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:

\[ A \geq k\left(\frac{d_i}{2} + s_b\right)s_s \]

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.

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

\[
\text{Area } A = \frac{\sqrt{(D_i + s_{sa}) s_{sa}}}{0.8 \sqrt{(d_i + s_{ba}) s_{ba}}}
\]

\[
k = \frac{1}{s_b}
\]

\[
s_s = \text{thickness of the shell as calculated}
\]

\[
s_b = \text{thickness of the branch}
\]

\[
k = \frac{1}{s_b}
\]

\[
k = \frac{1}{s_b}
\]
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 [3.5]. 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 is, however, not to 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
- \( s_o \) = thickness of the branch

6.5 Welded branch connections

6.5.1 Acceptable welded branch connections are shown in Figure 27. Alternative methods of attachment may be accepted provided details are submitted for consideration.

For acceptable flange welding details, see rules for classification of ships Ch.6 Sec.9 and Ch.6 Sec.6 [5].
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Pressure equipment

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram 1" /></td>
<td>Generally used for small branch to shell diameter ratios. The welding procedure employed is to ensure sound root condition.</td>
</tr>
<tr>
<td><img src="image2.png" alt="Diagram 2" /></td>
<td>Single root run technique and double root run technique.</td>
</tr>
</tbody>
</table>

- The welding procedure employed is to ensure sound root condition.
- Generally used for small branch to shell diameter ratios.
- Single root run technique and double root run technique.
- No weld root gap.
- Finished size bored after welding.
- The welding procedure employed is to ensure sound root condition.
- Single root run technique and double root run technique.

Mathematical equations:
- \( L = \frac{s_b}{3} \text{ min.} \), but not less than 6 mm.
- \( L = s_b \text{ min.} \), but not less than 6 mm. Preference should be given to the details shown in Diagram 2 if \( s_b \) exceeds about 16 mm.
- \( L = s_b \text{ min.} \), but not less than 6 mm. Backing strip to be removed after welding.
- Generally used for small branch to shell diameter ratios.
- The welding procedure employed is to ensure sound root condition.
The welding procedure employed is to ensure sound root conditions.

$L = \frac{s_b}{3}$ min., but not less than 6 mm

$s \leq 25$ mm

$h = 6 - 13$ mm

$B + h = s_b$

Generally used when $s_b$ is approximately equal to $\frac{s}{2}$
Notes to Figure 27 (e2):

1) Fillet welds are not suitable in cases where there are fluctuating loads.
2) Weld detail (e2) shall not be used for openings that require reinforcement i.e. the required reinforcement for the openings shall be integrated in the shell plate.
3) Thickness of more than 16 mm will be evaluated in each different case when welding procedure is submitted.
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B + h = s_b or s_d
whichever is the lesser
E = 10 mm min.

Telltale hole about 6 mm

E = 10 mm min.
(B + h) + the smaller of
E or (s_d + h) = 2 s_b
(B + h) = s_b (min)
Also valid for h = 0
(no fillet weld on inside)

Telltale hole about 6 mm
Tell-tale hole about 6 mm

\[ t = 1.5 \text{ mm} - 3 \text{ mm} \]

\[ E = 10 \text{ mm min.} \]

\[ L = \frac{s_b}{3} \text{ min.}, \text{ but not less than 6 mm} \]

Excess weld metal to be removed before filling reinforcing plate.

\[ L = \frac{s_b}{3} \text{ min.} \]

\[ \text{but not less than 6 mm} \]

\[ E = 10 \text{ mm min.} \]

The bore should be such that there is adequate accessibility for sound deposition of the internal fillet.

\[ 30° \geq 50 \text{ mm} \]

\[ R_d \]

\[ 6 \text{ mm} \]

\[ s \]

See notes
Figure 27 Details of branch connections

Studded connections, weld details k, l, m and n are acceptable for use only on class II and III pressure equipment with limitations as listed below.

1) Weld details k and l are only accepted for shell thickness up to 16 mm in carbon manganese steels with specified minimum tensile strength not exceeding 430 N/mm² and when design temperature of the pressure equipment is maximum 120°C. Weld detail m is accepted on the same conditions, but only for shell thickness up to 10 mm.

2) Weld detail k, l and m shall not be used for openings which require reinforcement, i.e. the required reinforcement for the openings shall be integrated in the shell plate.

3) The size of fillet welds L as indicated shall be equal to the smaller of s or s_d but not less than 6 mm.

4) The threaded depth shall not be less than diameter of screw or stud.
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:

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

where:
- \( d \) = diameter of tube hole or opening
- \( s \) = thickness of the flat plate calculated from the formula in [5.3.1] for the part of the plate under consideration 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 shell.

![Figure 28 Compensation of openings in flat plates](image)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d_i )</td>
<td>internal diameter of an opening or branch for a circular opening</td>
</tr>
<tr>
<td>( L_b )</td>
<td>calculation length at the branch the smaller of the two values ( 2.5 \times s_a ) or ( (2.5 \times s_{ba} + s_r) )</td>
</tr>
<tr>
<td>( L_s )</td>
<td>calculation length at the shell the greater of the two values ( d/4 ) or ( (s_a + 75) ) mm</td>
</tr>
<tr>
<td>( s )</td>
<td>thickness as defined in [6.6.1]</td>
</tr>
</tbody>
</table>
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\[ s_a = \text{thickness of the flat plate as built minus corrosion allowance (reinforcement plates to be considered, if applicable)} \]

\[ s_b = \text{thickness of the branch calculated according to [3.5.1]} \]

\[ s_{ba} = \text{thickness of the branch as built minus corrosion allowance} \]

\[ X = \text{area requiring compensation marked XXX} \]

\[ Y = \text{area of reinforcement marked ///} \]

### 7.1 Plain furnaces

#### 7.1.1 The design of a plain furnace shall be checked to ensure that neither membrane yield nor elastic instability occur.

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

\[
p_c \leq 20 \frac{R_{et} s - c}{s} \left( \frac{D_m}{L} \right) \left( 1 + 0.1 \cdot \frac{D_m}{L} \right) \left( 1 + 0.03 \frac{s - c}{s} \right) \left( 1 + 5 \cdot \frac{D_m}{L} \right)
\]

where

- \( c = \text{corrosion margin/allowance} \)
- \( D_m = \text{mean diameter of plain furnace} \)
- \( L = \text{calculation length of the furnace between two effective points of support, see [7.3.1] and [7.4.1]} \)
- \( p_c = \text{calculating pressure} \)
- \( R_{et} = \text{specified minimum lower yield stress at design material temperature. If the stress-strain curve does not show a defined yield stress, the 0.2\% proof stress shall be applied} \)
- \( s = \text{thickness} \)
- \( S = \text{safety factor} \)
  - \( S = 2.75 \) for horizontal furnaces
  - \( S = 2.5 \) for vertical furnaces
- \( u = \text{percentage of out of roundness. The value of } u \text{ to be used in the formula shall be taken as 1.5 for new furnaces} \)

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

\[
p_c \leq 20 \frac{E}{S_k} \left[ \frac{s - c}{D_0} \left( \frac{s - c}{D_0} \right)^3 \left( \frac{n_w}{1 - v^2} \right)^2 \left( n_w^2 + 1 + \frac{2n_w^2 - 1 - v}{n_w^2 + 1} \right) \right]^3 \left( 1 - v^2 \right) \left( 1 + \frac{n_w}{1 - v^2} \right)^2 \left( 1 \right)
\]

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Pressure equipment

DNV GL AS
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 design material temperature, see Table 10
- \( L \) = calculation length of the furnace 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 \( S_K = 4.5 \)
- \( \nu \) = Poisson’s ratio

\( n_w \) shall be chosen to minimise \( p_c \).

For usual dimension of furnaces, \( p_c \) 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:

\[ u = \frac{200(D_{\text{max}} - D_{\text{min}})}{D_{\text{max}} + D_{\text{min}}} \]

where:

\( D_{\text{max}} \) = maximum mean diameter of the furnace
\( D_{\text{min}} \) = 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**

<table>
<thead>
<tr>
<th>Design material temperature (°C)</th>
<th>20</th>
<th>250</th>
<th>300</th>
<th>350</th>
<th>400</th>
<th>500</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>E N/mm² · 10⁵</td>
<td>2.12</td>
<td>1.95</td>
<td>1.91</td>
<td>1.87</td>
<td>1.83</td>
<td>1.74</td>
<td>1.65</td>
</tr>
</tbody>
</table>

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 minimum thickness of corrugated furnaces of type Fox after corrugation may 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 design material 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:

\[ I_x = \frac{p_c \cdot D_m^3 \cdot L}{133 \cdot 10^7} \]

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](image)

**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 32.

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.

![Diagram of furnace support details]

**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: $S_K = 3.5$. 

<table>
<thead>
<tr>
<th>$H_d/D_0$</th>
<th>$Z/D_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.169</td>
<td>0.07</td>
</tr>
<tr>
<td>0.2</td>
<td>0.08</td>
</tr>
<tr>
<td>0.25</td>
<td>0.1</td>
</tr>
<tr>
<td>0.3</td>
<td>0.12</td>
</tr>
<tr>
<td>0.4</td>
<td>0.16</td>
</tr>
<tr>
<td>0.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>
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
- \( A_{\sigma} \) = sectional area of a stay
- \( p_c \) = calculating pressure
- \( \sigma_t \) = nominal design stress at design metal temperature

\( \sigma_t = 70 \text{ N/mm}^2 \) for stay tubes
\( \sigma_t = \frac{R_m}{5.9} \) for stay bolts
\( \sigma_t = \frac{R_m}{5.7} \) 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 33.

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:

\[ s_g \cdot h_g \geq \frac{f_G \cdot F_g}{a_t \cdot \cos \alpha} \]

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

- \( \alpha \) = angle of gusset stay to longitudinal axis of the shell

- \( \sigma_t \) = nominal design stress at design metal temperature

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

---end---of---guidance---note---

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

1 Shell
2 End plate
SECTION 5 MOUNTINGS 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 mountings are secured by studs, the studs shall have full thread holding in the plate for a length of at least one diameter. Holes for studs shall not penetrate the whole thickness of the plate. For welded branch connections, see Sec.4 [6.5]

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.

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 at the same time 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 is to be carried out.

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 lowest, safe-working water level.

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 oil supply cut-off.

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 oil 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. oil 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 oil 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

<table>
<thead>
<tr>
<th>Item</th>
<th>Alarm and safety action (stated by an x)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alarm</td>
<td>Automatic shutdown (safety action) of electrical heating with alarm</td>
</tr>
<tr>
<td>Fluid</td>
<td>Temperature high</td>
<td>x</td>
</tr>
</tbody>
</table>

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.

---end---of---guidance---note---

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.

---end---of---guidance---note---

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 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 oil fired auxiliary boilers**

<table>
<thead>
<tr>
<th>Item</th>
<th>Alarm</th>
<th>Automatic shutdown (safety action) of boiler with alarm</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water level, not double pressure boiler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low water level LWL</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowlow water level LLWL</td>
<td></td>
<td>x</td>
<td>Independent safety system</td>
</tr>
<tr>
<td>High water level HWL</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water level double pressure boilers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary system LWL</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary system LLWL</td>
<td></td>
<td>x</td>
<td>Independent safety system</td>
</tr>
<tr>
<td>Secondary system LWL</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary system HWL</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circulation</td>
<td>Stopped</td>
<td>x</td>
<td>Forced circulation boilers</td>
</tr>
<tr>
<td>Steam</td>
<td>Pressure high</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Pressure higher</td>
<td></td>
<td>x</td>
<td>When the automatic control system does not cover the entire load range from zero load.</td>
</tr>
<tr>
<td>Temperature high</td>
<td></td>
<td>x</td>
<td>For superheated steam &gt;350°C</td>
</tr>
<tr>
<td>Feed water</td>
<td>Salinity high</td>
<td>x</td>
<td>Shut-down of feed water pumps</td>
</tr>
<tr>
<td>Condensate</td>
<td>Oil content high</td>
<td>x</td>
<td>Shut-down of feed water pumps</td>
</tr>
</tbody>
</table>

4 Exhaust gas boilers or economisers

4.1 Instruments and Monitoring

4.1.1 Exhaust gas boilers or economisers with extended surface water tubes are, in addition to the monitoring given in Table 2, to be monitored as listed below:

- Stand-by circulating pump, when required according to Sec.3 [2.3.1], to 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 [2.3.2], 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 to be given in case of soot fire.
5 Water heaters

5.1 Monitoring

5.1.1 Monitoring shall be arranged according to Table 3.

Table 3 Monitoring of oil-fired water heaters

<table>
<thead>
<tr>
<th>Item</th>
<th>Alarm and safety action (stated by an x)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alarm</td>
<td>Automatic shutdown (safety action) of heater with alarm</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low level LLWL</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Temperature high</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Pressure high</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Pressure low</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Circulation low</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

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 oil 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 4.
### Table 4 Monitoring of thermal-oil heaters

<table>
<thead>
<tr>
<th>Item</th>
<th>Alarm and safety action (stated by an x)</th>
<th>Automatic shutdown (safety action) of thermal oil heater with alarm</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alarm</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Thermal-oil</td>
<td>Temperature outlet high</td>
<td>x</td>
<td>Oil fired heater, separate for each coil</td>
</tr>
<tr>
<td></td>
<td>Temperature outlet high</td>
<td>x</td>
<td>Heater heated by exhaust gases, separate for each coil 1)</td>
</tr>
<tr>
<td></td>
<td>Flow low</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure low</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Flue gas of oil fired heaters</td>
<td>Temperature high</td>
<td>x</td>
<td>Fire alarm</td>
</tr>
<tr>
<td></td>
<td>Thermal oil leakage</td>
<td>x</td>
<td>Leakage detector located at heater casing</td>
</tr>
<tr>
<td>Exhaust gas of main or auxiliary engines</td>
<td>Temperature high</td>
<td>x</td>
<td>Soiling by soot deposits</td>
</tr>
<tr>
<td></td>
<td>Thermal oil leakage</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Expansion tank</td>
<td>Level low</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level low</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level high</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temperature high</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quick drainage valve open or emergency shut-off valve closed</td>
<td>x</td>
<td>3)</td>
</tr>
<tr>
<td>Forced draught</td>
<td>Fan stopped</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

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 oil burner at the oil 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
- pressure drop in thermal-oil between heater inlet and outlet
- thermal-oil temperature at heater outlet and inlet
— 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 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 have to 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 5, which depend on the oil throughput of the oil burner, are complied with.

#### Table 5 Safety times

<table>
<thead>
<tr>
<th>Oil throughput (kg/h)</th>
<th>Safety times (s) (maximum) 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At start-up</td>
</tr>
<tr>
<td>up to 30</td>
<td>10</td>
</tr>
</tbody>
</table>
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 have to interrupt the oil supply during operation (automatic restart possible), if an automatic shutdown of the oil burner occurs as specified in Table 6.

### Table 6 Monitoring of oil burners

<table>
<thead>
<tr>
<th>Item</th>
<th>Alarm and safety action (stated by an x)</th>
<th>Automatic shutdown (safety action) of oil burner with alarm</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alarm</td>
<td>Automatic shutdown (safety action) of oil burner</td>
<td>Comments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(stated by an x)</td>
<td></td>
</tr>
<tr>
<td>Heavy fuel oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature or viscosity high</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature or viscosity low</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine gas oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature high</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combustion air supply</td>
<td>Insufficient air supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam or compressed air atomizer</td>
<td>Insufficient supply of atomizing medium steam or air</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Oil pressure atomizer</td>
<td>Insufficient oil pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotary cup atomizer</td>
<td>Insufficient rotary speed of spinning cup or alternatively primary air pressure low</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Burners with return line</td>
<td>Pressure in the return line high</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flame</td>
<td>Ignition failure during start-up</td>
<td>x ¹)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flame failure during operation</td>
<td>x ¹)</td>
<td></td>
</tr>
</tbody>
</table>

1) In multi burner applications each burner to have separate monitoring devices and individual automatic quick closing valves.
<table>
<thead>
<tr>
<th></th>
<th>Burner not in operating position</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burner casing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control power supply</td>
<td>Failure</td>
<td>x</td>
</tr>
<tr>
<td>Induced draft fan</td>
<td>Failure</td>
<td>x</td>
</tr>
<tr>
<td>Flaps in the flue gas duct</td>
<td>Closed</td>
<td>x</td>
</tr>
<tr>
<td>Limiters at the heat generator</td>
<td>Actuated</td>
<td>x</td>
</tr>
</tbody>
</table>

1) Interlock of the burner. No automatic restart allowed. Manual reset of the interlock at the burner control panel required.

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 DNVGL-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 can be accepted for circumferential welds when the second side is inaccessible for welding and the following conditions are satisfied:

— class III pressure equipment, or class II when the cylindrical part is seamless
— welding procedures are qualified with backing strip
— non-corrosive media.

For pressure vessels in refrigerating plants, permanent backing strips will be accepted when the following conditions are satisfied:

— seamless cylindrical part
— design with backing strip shall be verified by a recognized pressure vessel code accepted by the Society
— fatigue assessment shall be carried out
— 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.

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

2.2.6 Before welding is commenced, it shall be ascertained that the plate edges are in alignment within the following limits:
— 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.

Figure 1 Welded joints

2.2.7 If the plates are of unequal thickness, and the difference between the surfaces exceeds that given in [2.2.6] 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.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---
2.2.8 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.

2.2.9 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:

\[
\frac{D + 1250}{200} \text{(mm)}
\]

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 media, 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 inset 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

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Plate thicknesses above which post-weld heat treatment is required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boilers</td>
</tr>
<tr>
<td>VL 360-0A-0N</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 410-0A-0N</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 460-0A-0N</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 490-0A-0N</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 360-1 FN</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 410-1 FN</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 460-1 FN</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 490-1 FN</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 510-1 FN</td>
<td>20 mm</td>
</tr>
<tr>
<td>VL 0.3 Mo</td>
<td></td>
</tr>
<tr>
<td>VL 1 Cr 0.5 Mo</td>
<td></td>
</tr>
<tr>
<td>VL 2.25 Cr 1 Mo</td>
<td></td>
</tr>
</tbody>
</table>
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**

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Soaking temperature °C</th>
<th>Time at soaking temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn steel grades</td>
<td>520 - 580</td>
<td>60 minutes per 25 mm thickness.</td>
</tr>
<tr>
<td>VL 0.3 Mo</td>
<td>530 - 580</td>
<td>Minimum 30 minutes</td>
</tr>
<tr>
<td>VL 1 Cr 0.5 Mo</td>
<td>600 - 650</td>
<td></td>
</tr>
<tr>
<td>VL 2.25 Cr 1 Mo</td>
<td>650 - 700</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Heat treatment of plates after hot or cold forming

3.2.1 For manufacturers performing hot/cold forming and/or heat treatment on hot/cold formed parts appropriate manufacturer approval 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, VL 0.3 Mo, VL 1 Cr 0.5 Mo and VL 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 VL 1 Cr 0.5 Mo and VL 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

<table>
<thead>
<tr>
<th>Intended application</th>
<th>Steel type/grade</th>
<th>Deformation degree for which heat treatment may be waived</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure vessels operated at ambient temperatures or feedstock temperatures down to -10°C</td>
<td>All</td>
<td>≤ 5%</td>
</tr>
<tr>
<td>Pressure vessels operated at charging media temperatures below -10°C, as well as gas tanks with design temperatures below 0°C</td>
<td>VL 3.5Ni, VL 5Ni, VL 9Ni</td>
<td>≤ 5%</td>
</tr>
<tr>
<td></td>
<td>C and C-Mn Alloy(other than above)</td>
<td>≤ 3%</td>
</tr>
</tbody>
</table>

Guidance note:
For the calculation of the theoretical plastic deformation see Pt.2 Ch.4 Sec.6, 5.2.6.

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

3.2.4 For manufacturers performing hot/cold forming and/or heat treatment on hot/cold formed parts an appropriate manufacturer approval of the process is required.

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 $0.7 < v \leq 0.85$, 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 $v \leq 0.7$ visual inspection of all welded joints shall be carried out.

4.1.4 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.

4.1.5 For non-ferromagnetic materials or materials with changes in magnetic permeability penetrant testing replaces magnetic particle testing in [4.1.1].

4.1.6 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 DNVGL-CG-0051 as a minimum.

4.1.7 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 DNVGL-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 DNVGL-CG-0051.
UT shall not be carried out on welds with thickness < 10 mm if not qualified and accepted down to 8 mm.

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 DNVGL-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:

\[ B = 2.4 - 4.0 \frac{kA}{m} \]

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 DNVGL-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>
<thead>
<tr>
<th>Table 4 Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Testing method</strong></td>
</tr>
<tr>
<td>Visual testing</td>
</tr>
<tr>
<td>Magnetic particle testing</td>
</tr>
<tr>
<td>Penetrant testing</td>
</tr>
<tr>
<td>Radiographic testing</td>
</tr>
<tr>
<td>Ultrasonic testing</td>
</tr>
</tbody>
</table>

\(^1\) For thickness > 10 mm
\(^2\) For thickness ≤ 10 mm
1) Except for imperfection types as follows, for which level C may apply: excess weld metal, excess convexity, excess throat thickness and excessive penetration.

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 DNVGL-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 $0.85 < \alpha \leq 1.0$ 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.

4.4.2 For joint efficiency $0.7 < \alpha \leq 0.85$ 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. 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 [3.3].
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 [3.1.7], 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 have to be performed at the manufacturer’s workshop and documented by a test certificate from 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 $R_{mv}/2.0$ 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 Mountings shall be tested by hydraulic pressure twice the design pressure, with the exception of feed check and feed stop valves for boilers and steam-heated steam generators, which shall be tested to 2.5 times the design pressure, or twice the maximum pressure which can be developed in the feed line in normal
service, whichever is the greater. The test pressure needs not exceed the working pressure by more than 70 bar.

4.7 Performance test

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 oil 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 oil 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 $\text{CO}_2$, possibly $\text{O}_2$, 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 test certificate from the Society regarding examination of the oil 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.
Guidance note:
The number, type and locations of openings should be as given in Table 1.

Table 1 Examination holes and manholes for pressure equipment

<table>
<thead>
<tr>
<th>No.</th>
<th>External diameter</th>
<th>Form of pressure equipment</th>
<th>Types and number of holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>450 mm and less</td>
<td>Length of cylindrical body or diameter of spherical shape up to 1500 mm inclusive</td>
<td>2 SIGHTHOLES. Where the length is more than 1500 mm, additional sight-holes shall be provided.</td>
</tr>
<tr>
<td></td>
<td>More than 450 mm up to 800 mm inclusive</td>
<td>Length of cylindrical body or diameter of spherical shape up to 1500 mm inclusive</td>
<td>2 SIGHTHOLES. Where the length is more than 1500 mm, additional sight-holes shall be provided.</td>
</tr>
<tr>
<td>2 a)</td>
<td>More than 800 mm up to 1400 mm inclusive</td>
<td>Length of cylindrical body or spherical shape up to 2000 mm inclusive</td>
<td>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.</td>
</tr>
<tr>
<td>2 b)</td>
<td>Length of cylindrical body greater than 1500 mm up to 2000 mm inclusive</td>
<td>1 HEADHOLE in the central third of the length of the cylindrical body or 2 HANDHOLES each located either near or on the ends.</td>
<td></td>
</tr>
<tr>
<td>2 c)</td>
<td>Length of cylindrical body greater than 2000 mm</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>3 a)</td>
<td>More than 800 mm up to 1400 mm inclusive</td>
<td>Length of cylindrical body or spherical shape up to 2000 mm inclusive</td>
<td>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.</td>
</tr>
<tr>
<td>3 b)</td>
<td>Length of cylindrical body more than 2000 mm</td>
<td>1 MANHOLE or siting of inspection holes as in the case of 2c) above.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>More than 1400 mm</td>
<td>Length of cylindrical body unlimited</td>
<td>1 MANHOLE.</td>
</tr>
</tbody>
</table>

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CHANGES – HISTORIC

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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