RULES
FOR THE CLASSIFICATION OF SHIPS

Part 10 - BOILERS, HEAT EXCHANGERS
AND PRESSURE VESSELS

2009

CROATIAN REGISTER OF SHIPPING

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By decision of the General Committee of Croatian Register of Shipping,

RULES FOR THE CLASSIFICATION OF SHIPS
PART 10 – BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

has been adopted on 8th May 2009 and shall enter into force on 1st July 2009

REVIEW OF AMENDMENTS IN RELATION TO PREVIOUS EDITION OF THE RULES

RULES FOR THE CLASSIFICATION OF SHIPS
Part 10 – Boilers, heat exchangers and pressure vesselss

All major changes throughout the text in respect to the Rules for technical supervision of sea-going ships, Part 10 - Boilers, heat exchangers and pressure vesselss, 2007 edition are shaded.

Items not being indicated as corrected have not been changed.

The grammatical and print errors, have also been corrected throughout the text of the subject Rules but are not indicated as a correction.

NOTE: *Due to change of the structure of the Technical Rules (separation of statutory from classification rules), the previously issued Rules for technical supervision of sea-going ships, Part 10 - Boilers, heat exchangers and pressure vesselss, are now re-categorized as the part of the classification rules.*

By such change, Part 10 – Boilers, heat exchangers and pressure vesselss, will no longer be issued as the part of the R ules for technical supervision of sea-going ships.

The subject Rules include the requirements of the following international Organisations:

International Maritime Organization (IMO)

Conventions:	International Convention for the Safety of Life at Sea 1974 (SOLAS 1974) and all subsequent amendments up to and including the 2006 amendments (MSC.216(82)) Protocol of 1988 relating to the International Convention for the Safety of Life at Sea 1974, as amended (SOLAS PROT 1988)

International Association of Classification Societies (IACS)

Unified Requirements (UR):	P1 (2001, rev. 5), P6 (2005)
Technische Regeln für Dampfkessel (TRD):	TRD 300 (8/2001), TRD 301 (10/1997), TRD 303 (5/1991), TRD 305 (8/1996), TRD 306 (6/1977), TRD 401 (9/2000), TRD 411 (2/1997)
AD - Merkblätter:	B1 (6/1986), B3 (10/1990), B9 (7/1995)
International Standard Organization (ISO):	ISO 4705-1983, ISO/DIS 2694

Contents

1 GENERAL

1.1 APPLICATION

1.1.1 The present Part of the Rules for the classification of ships applies to boilers, heat exchangers and pressure vessels, other than:

.1 water heating boilers (see 1.3.2.1 and 1.3.2.3),
.2 decompression tanks,
.3 standard type cylinders for storage of compressed gases (see 1.3.2.4),
.4 assemblies and components of units that are not selfcontained pressure vessels,
.5 units comprising pressure pipe systems installed outside boilers, heat exchangers and pressure vessels,
.6 air coolers designed to operate at a working pressure in the air space less than 0,1 MPa,
.7 heat exchangers and vessels subjected exclusively to liquid pressure (see 1.3.2.1 and 1.3.2.3).

1.1.2 The present Part of the Rules also applies to oil burning installations.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to general terminology of the Rules are given in the Rules for the classification of Ships, *Part 1-General requirements,* Chapter 1-General.

For the purpose of the present Part of the Rules the following definitions have been adopted:

1.2.1 **Automatic boiler oil burning installation** - is an installation for combustion of oil fuel, the operation of which is controlled automatically without any direct attendance of the operating personnel.

1.2.2 **Auxiliary steam boilers for essential services** - are the boilers which supply steam to the auxiliary machinery and equipment ensuring propulsion of the ship and safety of navigation, there being no other sources of power available on board ship for driving the stated machinery and equipment in case the boilers cease to operate.

1.2.3 **Working pressure** - is the maximum permissible gauge pressure under normal conditions on continuous running, excluding permissible short-time pressure rises such as may be occasioned by the operation of a safety valve or other protective devices.

1.2.4 **Design boiler capacity** - is the maximum amount of steam that can be generated by the boiler at design parameters during one hour on continuous running.

1.2.5 **Design wall temperature** - is the average wall-thickness temperature used in calculation of allowable stresses in dependence upon the temperature of medium and heating conditions.

1.2.6 **Design pressure** - is the gauge pressure used in strength calculation.

1.2.7 **Walls of boilers, heat exchangers and pressure vessels** - are the walls of steam and water (gas and liquid) spaces between the stop valves, including the walls of branch pieces and valve bodies.

1.3 SCOPE OF SUPERVISION

1.3.1 General requirements

1.3.1.1 The general provisions relating to the procedure of classification, supervision during construction and surveys, as well as general provisions relating to the technical documentation, are given in the Rules, *Part 1 - General requirements,* Chapter 2 and 5.

1.3.1.2 Boilers, heat exchangers and pressure vessels are classified in accordance with Table 1.3.1.2, depending on parameters and design features.

1.3.2 Scope of Supervision

1.3.2.1 Subject to supervision of the *Register*, in the process of construction are:

.1 steam boilers as well as exhaust gas boilers, steam superheaters and economizers operating at working pressure of 0,07 MPa and over;
.2 heat exchangers and vessels which under operating conditions are filled fully or partially with gas or vapour at working pressure of 0,07 MPa and over and which have a capacity of 0,025 m^3 and over or the product of pressure in MPa with capacity in m^3 is 0,03 MPa m^3 and over;
.3 evaporators of main and auxiliary boilers for essential services;
.4 condensers of main and auxiliary machinery;
.5 oil burning installations of boilers;
.6 water heating boilers designed for water temperature above 115°C;
.7 water, fuel and lubricating oil coolers and filters of main and auxiliary machinery;
.8 automatic devices for control of salinity of boiler feed water;
.9 thermal fluid boilers.

1.3.2.2 Exempted from supervision of the *Register* in the process of construction are the heat exchangers and pressure vessels indicated in 1.1.1.2 and 1.1.1.6.

Table 1.3.1.2

Item	ClassI.	Class II.	Class III.
Boilers (including exhaust gas boilers and water heating boilers designed for water temperatures above 115°C), steam super-heaters and steam accumulators, thermal fluid boilers.	$p > 0{,}35$	$p \leq 0{,}35$	–
Steam generators	$p > 1{,}6$	$p \leq 1{,}6$	–
Pressure vessels and heat exchangers with liquid fuels	$p > 1{,}6$ or $t > 150$	$p \leq 1{,}6$ $t \leq 150$	$p \leq 0{,}7$ $t \leq 60$
Pressure vessels and heat exchangers with steam, compressed air, gases or thermal oils	$p > 1{,}6$ or $t > 300$	$p \leq 1{,}6$ $t \leq 300$	$p \leq 0{,}7$ $t \leq 170$
Pressure vessels and heat exchangers with water or oils	$p > 4{,}0$ or $t > 300$	$p \leq 4{,}0$ $t \leq 300$	$p \leq 1{,}6$ $t \leq 200$
Pressure vessels and heat exchangers	$s > 35$	$16 < s \leq 35$	$s \leq 16$
Pressure vessels and heat exchangers with toxic or explosive working medium	any parameters	–	–
Symbols specified in Table:: p - design pressure, [MPa], t - design wall temperature, [°C], s - wall thickness, [mm].			

1.3.2.3 Water heating boilers designed for water temperature above 115°C shall comply, as regards the material used and scantlings of elements, with the requirements for steam boilers (boilers heated by fuel or electrically), or heat exchangers (boilers heated by steam of hot liquids) specified in the present Part of the Rules.

Filters and coolers of main and auxiliary machinery shall comply, as regards the material used and scantlings of elements, with the requirements for heat exchangers and pressure vessels in the present Part of the Rules.

1.3.2.4 Cylinders designed for storage of compressed gases used in various systems and units for the purposes of ship's operation, shall be manufactured to the current standards under the supervision of the *Register* or body recognized by the *Register*, taking into consideration requirements of chapter 6 of the present Part of the Rules.

1.3.2.5 The scope of supervision of the heat exchangers and pressure vessels incorporated into refrigerating plants is specified in 1.1.3, 1.3.2 and 1.3.3 of *Part 11 - Refrigerating Plants*.

1.3.3 Components subject to supervision

1.3.3.1 The components given in Table 1.3.3.1 are subject to the supervision of the *Register* in the process of manufacture to ensure compliance with the technical requirements of 1.3.4, which is to be approved by the *Register*.

Table 1.3.3.1

Nos.	Elements of boilers, heat exchangers and pressure vessels
1	2
1.	**Boilers, steam superheaters, economizers and steam generators**
1.1	Shells, end plates, tube plates, drums, headers and chambers
1.2	Heated and non-heated steel tubes
1.3	Furnaces and elements of combustion chambers
1.4	Long and short stays, girders
1.5	Bodies of mountings and fittings (see 1.3.3.2)
2.	**Heat exchangers and pressure vessels**
2.1	Shells, distributors, end plates, headers and covers
2.2	Tube plates
2.3	Tubes
2.4	Long and short stays
2.5	Bodies of fittings (see 1.3.3.2)

1.3.3.2 Certificate for material, issued by the manufacturer, may be accepted, for material of mountings and fittings, instead of Certificate for material issued by *Register* if the conditions stated in table 1.3.3.2 are fulfilled.

Table 1.3.3.2

Material[1)]	Working temperature [°C]	DN – nominal diameter [mm] p – working pressure [MPa]
Steel, cast steel	> 300	DN ≤ 32
Steel, cast steel, nodular cast iron	≤ 300	DN ≤ 250 and $p \cdot$DN ≤ 250
Copper alloys	≤ 225	$p \cdot$DN ≤ 150
1) For the fittings made of grey cast iron, Certificate for material issued by *Register* is not required.		

1.3.4 Technical documentation

1.3.4.1 The following technical documentation shall be submitted to the *Register*, before manufacture of boilers, heat exchangers and pressure vessels:

.1 construction drawings with sections and details giving all necessary data for checking the calculations and structures(scantlings, materials, working parameters, location and dimensions of weld seams, fastenings, etc.);

.2 construction drawings for the components listed in table 1.3.3.1 unless all necessary data are shown in drawings mentioned in 1.3.4.1.1;

.3 arrangement drawings for mountings and fittings and their specifications;

.4 strength calculations made in accordance with the present Part of the Rules for components subject to pressure other than mountings, fittings, flanges and fastenings, if the latter complies with the standards approved by the *Register*;

.5 calculation of the diameters of safety valves;

.6 welding process;

.7 drawings of oil burning installations with the description of their mode of operation;

.8 data of heat treatment, of inspection of welded joints, and of hydraulic tests;

.9 data of intended use of pressure vessel and heat exchanger and of working media

1.3.4.2 Documentation on the automatic control system,protective devices and alarms, as well as on automatic oil burning installations, shall be submitted in accordance with the *Rules, Part 1. - General requirements*, Supervision during construction, 2.10.

1.3.4.3 Documentation on thermal fluid boilers shall be submitted in accordance with 3.5.

1.4 MATERIALS

1.4.1 Materials intended for manufacture of components of boilers, heat exchangers and pressure vessels shall satisfy the requirements of the *Rules Part 25 – Metallic materials*.

Materials for components of boilers, heat exchangers and pressure vessels class I and II are subject to the supervision of the *Register*.

1.4.2 Steels according to *Rules, Part 25 - Metallic materials*, 3.5, may be used for manufacture of components of boilers, heat exchangers and pressure vessels. Carbon and carbon-manganese steels are permitted at design temperatures up to 400°C and low-alloy steels up to 500°C.

The use of these steels at temperatures above the specified values, is permitted if their mechanical properties and mean 100000 hour creep strength satisfy the standards and are guaranteed by the manufacturer at the elevated temperature. At design temperatures above 500°C, in general, alloy steels shall be used, which is subject to special consideration by the *Register* in each case.

1.4.3 For manufacture of components of heat exchangers and pressure vessels, steels according to *Rules, Part 25 - Metallic materials*, 3.6 and 3.7 may be used. Steels according to *Rules, Part 25 - Metallic materials*, 3.3 may be used for manufacture of components of heat exchangers and pressure vessels, with the condition that for class I vessels they must be killed. Steels according to *Rules, Part 25 - Metallic materials*, 3.2 may be used for manufacture of components of class III heat exchangers and pressure vessels.

1.4.4 Steel pipes according to *Rules, Part 25 - Metallic materials*, 3.10.2 and 3.10.3 may be used for manufacture of boilers and heat exchangers. The use of welded steel pipes is allowed, if it is proved that they are equivalent to seamless pipes.

For manufacture of heat exchangers, steel pipes according to *Rules, Part 25 - Metallic materials*, 3.10.4 and 3.10.5 may be used.

1.4.5 Steel forgings according to *Rules, Part 25 - Metallic materials*, 3.11.5 may be used for manufacture of components and mountings and fittings of boilers, heat exchangers and pressure vessels.

For heat exchangers and pressure vessels, steel forgings according to Rules, *Part 25 - Metallic materials*, 3.11.6 may be used, and for class II and III heat exchangers and pressure vessels, steel forgings according to *Rules, Part 25 -Metallic materials*, 3.11.2 may be used.

1.4.6 Steel castings according to *Rules, Part 25 - Metallic materials*, 3.12.4 may be used for manufacture of boiler fittings and mountings, and of components and mountings and fittings of heat exchangers and pressure vessels.

For heat exchangers and pressure vessels, steel castings according to *Rules, Part 25 – Metallic materials*, 3.12.5 may be used.

For class III heat exchangers and pressure vessels, steel castings according to *Rules, Part 25 - Metallic materials*, 3.12.2 may be used.

l.4.7 For manufacture of boiler mountings and fittings, and of components and mountings and fittings of heat exchangers and pressure vessels, nodular cast iron according to *Rules, Part 25 - Metallic materials*, 3.13.3 may be used for working pressures ≤ 40 bar and working temperatures ≤ 300°C. Diameter of fittings must be DN ≤ 175 mm.

1.4.8 Gray cast iron according to *Rules, Part 25 - Metallic materials*, 3.13.2 may be used for manufacture of mountings and fittings which are not exposed to dynamic loads, for working pressures ≤ 10 bar, working temperatures ≤ 200°C and the diameter of fittings must be ≤ 175 mm.

Manufacture of components for non-heated surfaces of boilers, with diameter ≤ 200 mm, made of gray cast iron is allowed for working pressures ≤ 10 bar and for working temperatures ≤ 200°C.

Gray cast iron may be used for manufacture of components of class III heat exchangers and pressure vessels.

The use of gray cast iron in manufacture of exhaust gas economisers is subject to special consideration by the *Register* in each case.

1.4.9 Copper alloys according to *Rules, Part 25 - Metallic materials*, 4.2 may be used for manufacture of boiler mountings and fittings, and components and mountings and fittings of heat exchangers and pressure vessels, for working pressures ≤ 25 bar and working temperatures ≤ 225°C.

Copper alloy pipes according to *Rules, Part 25 - Metallic materials*, 4.1 may be used for manufacture of heat exchangers.

1.4.10 Gray cast iron and copper alloys may not be used for mountings and fittings of thermal fluid boilers.

1.5 MANUFACTURE OF WELDED PRESSURE VESSELS

1.5.1 Class I and II boilers, heat exchangers and pressure vessels must be manufactured by works approved by the *Register*.

Welding is to be carried out by approved welders (in accordance with *Rules, Part 26 – Welding*, 1.3).

1.5.2 Cutting of plates must be by flame cutting. Shearing of plates is not to be used unless the sheared edge is removed by machining for a distance of ¼ of the plate thickness, minimum 3 mm.

1.5.3 Shells and dished ends are formed by hot or cold forming, which should not impair the quality of material.

Forming must be carried out by machine.

1.5.4 Weld preparation on elements may be done by machining or by flame cutting.

The prepaired edge surfaces should be examined for any defect in material.

1.5.5 Welding and methods of inspection of welded joints shall comply with *Rules Part 26. - Welding*, 3.2.

1.5.6 Main butt joints with full penetration shall generally be used. Structures using fillet joints or joints affected by bending stresses are subject to special consideration by the *Register* in each case.

1.5.7 Typical examples of allowable welded joints are given in the Appendix to this Part of the Rules.

1.6 HEAT TREATMENT

1.6.1 Components in which the material structure may undergo changes after welding or plastic working shall be subjected to the appropriate heat treatment.

When heat treating a welded structure, the requirements of the *Rules Part 26. - Welding*, 3.2.3 shall be duly observed.

1.6.2 Heat treatment is indicated for:

.1 plate steel elements of boilers, vessels and heat exchangers, which are subjected during manufacture to cold stamping, bending and flanging resulting in plastic deformation of surface fibres exceeding 5 percent;

.2 elements subjected to hot forming, with the temperatures during this process being lower than that of normalization;

.3 elements assembled by welding in order to be thermally stress relieved, according to table 1.6.2.3.

Elements manufactured from carbon and carbon manganese steels are to be normalised, and elements manufactured from chrom molybden steels are to be normalised and tempered.

Table 1.6.2.3

Steel grade	**Plate thickness above which post weld heat treatment is required [mm]**	
	Boilers	Pressure vessels
Carbon and carbon manganese steels	20	30
Chrom molybden steels	All thicknesses	All thicknesses
Other alloyed steels	subject to special consideration	subject to special consideration

1.7 HYDRAULIC TESTS

1.7.1 Upon completion of manufacture or assembly, all elements of boilers, heat exchangers and pressure vessels shall be subjected to hydraulic tests in accordance with Table 1.7.1.

1.7.2 Hydraulic test shall be carried out upon completion of all welding operations and heat treatment and prior to application of insulation and protective coatings.

Table 1.7.1
Hydraulic test

Nos.	Elements	Test pressure p_{pr}, MPa	
		After manufacture or assembly without mountings and fittings	After assembly with mountings and fittings installed
1	2	3	4
1.	Boilers, steam superheaters, economizers and elements thereof	1,5 p_r but not less than: p_r + 0,1	1,25 p_r but not less than: p_r + 0,1
2.	Continuous flow boilers	1,1 x water inlet pressure when operating at the maximum allowable working pressure and maximum steam output	–
3.	Heat exchangers, pressure vessels and elements thereof	1,5 p_r but not less than: p_r + 0,1	–
4.	Hot water generators	1,5 p_r, but not less than 0,4	–
5.	Oil burning installation elements subject to oil fuel pressure	–	1,5 p_r, but not less than 0,5
6.	Boiler mountings	As per 1.3 of Part 9 - Machinery but not less than 2 p_r	To be tested for tightness at 1,25 p_r
7.	Boiler feed valves	2,5 p_r	To be tested for tightness at 1,25 p_r
8.	Mountings and fittings of heat exchangers and pressure vessels	As per 1.3 of Part 9 - Machinery	To be tested for tightness at 1,25 p_r
9.	Thermal fluid boilers	1,5 p_r but not less than 1	To be tested for tightness at 0,2
10.	Condensers	1,5 p_r water side 0,1 steam side	–

Symbols:
p_{pr} – test pressure, MPa;
p_r – working pressure, MPa, but not less than 0,1 MPa;

Note:
1) For testing of internal combustion engine coolers see Table 1.3.3 *Part 9 - Machinery*.

1.7.3 Where detailed inspection of surfaces to be tested is difficult or impossible after assembling the individual components and units, they are to be tested prior to assembling.

1.7.4 Stresses is elements which are pressure tested according to table 1.7.1, should not exceed 0,9 times the yield stress of material.

1.7.5 Gas space of wasteheat boilers shall be tested by air pressure of 0,01 MPa.

1.7.6 Heat exchangers and vessels incorporated in refrigerating plants shall be tested as specified in the *Rules Part 11 - Refrigerating Plants*, 9.1.

1.8 BOILER ROOMS

1.8.1 Boiler rooms shall satisfy the requirements of the *Rules, Part 7 - Machinery Installations*, 1.11, 1.12 and 1.13.

2 STRENGTH CALCULATIONS

2.1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 The wall thicknesses obtained by calculation are the lowest permissible values under normal operating conditions. The standards and methods of strength calculation do not take into account the manufacture tolerances for thicknesses which shall be added as special allowances to the design thickness values.

Additional stresses due to external loads (axial forces, bending and torsional moments) acting upon the element under calculation (in particular, loads to its own weight, the weight of attached elements and the like) shall be specially taken into account as required by the *Register*.

2.1.1.2 Dimensions of structural elements of boilers, heat exchangers and pressure vessels, for which no strength calculation methods are given in the present Rules, shall be determined on the basis of experimental data and proved theoretical calculations and are subject to the special consideration by the *Register*.

2.1.2 Design pressure

2.1.2.1 The design pressure shall generally be taken equal to the working pressure of the medium and is to be not less than the highest set pressure of any safety valve.

The hydrostatic pressure shall be taken into account in the design pressure calculations when it exceeds 0,05 MPa.

2.1.2.2 For the forced-circulation boilers, the design pressure shall be determined with the consideration for the hydrodynamic resistances in boiler elements at the design steam capacity.

2.1.2.3 Flat walls subjected to pressure on both sides shall be designed for the higher pressure acting on the walls.

The walls with curved surfaces subjected to pressure on both sides shall be designed for the maximum internal and external pressures. If it is certain that in service both pressures will occur simultaneously, differential pressure may be used as design pressure.

Where the pressure on side of the wall with flat or curved surface is below the atmospheric pressure, the design pressure shall be taken as equal to the maximum pressure acting on the other side of the wall plus 0,1 MPa.

2.1.2.4 For economisers the design pressure shall be taken as equal to the sum total of the working pressure in the boiler steam drum and the hydrodynamic resistances in the economizer, tubing, mountings and fittings at boiler design steam capacity.

2.1.2.5 For the heat exchangers and pressure vessels incorporated in refrigerating plants, the design pressure shall be taken as specified in the *Rules, Part 11. - Refrigerating Plants*, Table 2.2.2.

2.1.3 Design temperature

2.1.3.1 The design wall temperature shall be taken as not lower than that indicated in Table 2.1.3.1.

Table 2.1.3.1
Design temperature

Nos.	Boiler, heat exchanger and pressure vessel elements and working conditions	Design wall temperature, °C
1.	**Elements exposed to radiant heat**	
1.1	Boiler tubes	$t_s + 50$
1.2	Steam superheater tubes	$t_s + 50$
1.3	Corrugated furnaces	$t_s + 3s + 30$
1.4	Plain furnaces, headers, combustion chambers	$t_s + 4s + 30$
2.	**Elements heated by hot gases but protected against radiant heat effect[1)]**	
2.1	Shells, end plates, headers, chambers, tube plates and boiler tubes	$t_s + 25$
2.2	Headers and steam superheater tubes	$t_s + 35$
2.3	Economiser finned tubes	$t_s + 35$
2.4	Economiser plain tubes	$t_s + 25$
3.	**Elements heated by steam or fluids**	t_m
4.	**Non-heated elements[2)]**	t_s

Notes:
1) see 2.1.3.3
2) see 2.1.3.2

Symbols:
t_s = maximum temperature of heated mediums under consideration,[°C]
t_m = maximum temperature of heating fluid
s = wall thickness, [mm]

2.1.3.2 The walls are considered to be non-heated in the following cases:

.1 the walls separated from the combustion space or uptake by a fire -resistant insulation, the distance between walls and insulation being 300 mm and over, or

.2 the walls protected by a fire-resistant insulation not exposed to radiant heat.

2.1.3.3 The walls are considered to be protected from the radiant heat effect in the following cases:

.1 the walls are protected by fire-resistant insulation, or

.2 the walls are protected by a closely spaced row of tubes (with a clearance between tubes up to 3 mm), or

.3 the walls are protected by two staggered rows of tubes, with a longitudinal pitch equal to a maximum of two outside tube diameters or by three or more staggered rows of tubes with a longitudinal pitch equal to a maximum of two and a half outside tube diameters.

2.1.3.4 The design temperature for heated walls of boiler and non-heated walls of steam-conducting boiler elements shall not be less than 250°C.

2.1.3.5 The design wall temperature for heat exchangers and pressure vessels operating under coolant pressure shall be taken as equal to 20°C, if higher temperatures may not occur.

2.1.4 Mechanical characteristics of materials and allowable stresses

The minimum value for the allowable stress σ_d [N/mm^2] produced by the following relations is applicable:

2.1.4.1 Rolled and forged steels:

– For design temperatures up to 350°C

.1 $\frac{R_{m/20^o}}{2,7}$ $R_{m/20^o}$ - guaranteed minimum tensile strength [N/mm^2] at room temperature;

.2 $\frac{R_{eH,t}}{1,6}$ $R_{eH,t}$ - guaranteed yield point or minimum $\sigma_{0,2}$ proof stress at design temperature t;

– For design temperatures above 350°C

$\frac{R_{m/100000,t}}{1,5}$ $R_{m/100000,t}$ - mean 100000 hour creep strength at design temperature t.

2.1.4.2 Grey cast iron:

$$\frac{R_{m/20^o}}{11}$$

Cast steel:

1. $\frac{R_{m/20^o}}{3,2}$ 2. $\frac{R_{eH,t}}{2}$ 3. $\frac{R_{m/100000,t}}{2}$

Nodular cast iron:

1. $\frac{R_{m/20^o}}{4,8}$ 2. $\frac{R_{eH,t}}{3}$

2.1.4.3 Non ferrous metals

$\frac{R_{m,t}}{4}$ $R_{m,t}$ – guaranteed minimum tensile strength at design temperature t.

2.1.4.4 When non-ferrous metals and their alloys are used, it is to be taken into account that heating during working or welding tends to relieve them of the strengthening effects realized under cold conditions. Therefore, the strength characteristics to be used for strength calculations of components and assemblies manufactured from such materials shall be those applied to their heat treated condition.

2.1.4.5 Elements subjected to external pressure

1. Smooth firetubes:

Horizontal $\frac{R_{eH,t}}{2,5}$ Vertical $\frac{R_{eH,t}}{2}$

2. Corrugated firetubes

$$\frac{R_{eH,t}}{2,8}$$

3. Tubes heated by exhaust gases

$$\frac{R_{eH,t}}{2}$$

2.1.4.6 Mechanical characteristics of materials must be taken in accordance with *Rules, Part 25 - Metallic materials*.

2.1.5 Ligament efficiency factor and efficiency factor of welded joints

2.1.5.1 Efficiency factor of welded joints should be taken equal to:

Class of the pressure vessel	Efficiency factor
I.	1,0
II.	0,8
III.	0,6

2.1.5.2 The ligament efficiency factor of cylindrical walls weakened by holes of the same diameter shall be taken as equal to the lowest of the following three values:

.1 the ligament efficiency factor of cylindrical walls weakened by a longitudinal row or a field of unstaggered, equally-pitched holes (fig.2.1.5.2-1) as determined from the formula:

$$\varphi = \frac{t-d}{t} \quad (2.1.5.2.1)$$

.2 the ligament efficiency factor, reduced to the longitudinal direction of cylindrical walls weakened by a transverse row or a field of equally-pitched holes (fig.2.1.5.2.-1), as determined from the formula:

$$\varphi = 2\,\frac{t_1-d}{t_1} \quad (2.1.5.2.2)$$

.3 the ligament efficiency factor, reduced to the longitudinal direction of cylindrical walls weakened by a field of staggered and equally-spaced holes, as determined from diagram 2.1.5.2-3.

where:

φ – ligament efficiency factor of walls weakened by holes;

d – diameter of hole for expanded tubes or inside diameter of welded-on tubes and upset nozzles, [mm];

t – pitch between two adjacent hole centres in longitudinal direction, [mm];

t_1 – pitch between two adjacent hole centres in the transverse (circumferential) direction, measured at centre of wall thickness, [mm];

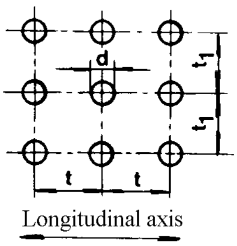


Fig. 2.1.5.2-1

2.1.5.3 Where rows or fields of equally - pitched holes contain holes of alternate diameters, in formulae for ligament efficiency factor determination the value d shall be replaced by a value equal to the arithmetic mean of two largest adjacent hole diameters.

In case of unequal pitch between holes of equal diameter, the formulae for ligament efficiency factor determination shall be used with the lowest values of t and t_1.

2.1.5.4 Where welded joints have holes, the ligament efficiency factor shall be taken as equal to the product of the efficiency factor of welded joints by the ligament efficiency factor of the wall weakened by holes.

2.1.5.5 For seamless cylindrical walls not weakened by welds or rows/fields of holes, the ligament efficiency factor of welded joints are to be taken equal to 1. In no case may the factor, φ, be taken higher than 1.

2.1.5.6 The ligament efficiency factor of walls weakened by holes for expanded tubes shall be taken as not less than 0,3 as determined in item 2.1.5.2. Calculations involving lower ligament efficiency factor values shall be subject to the special consideration by the *Register* in each case.

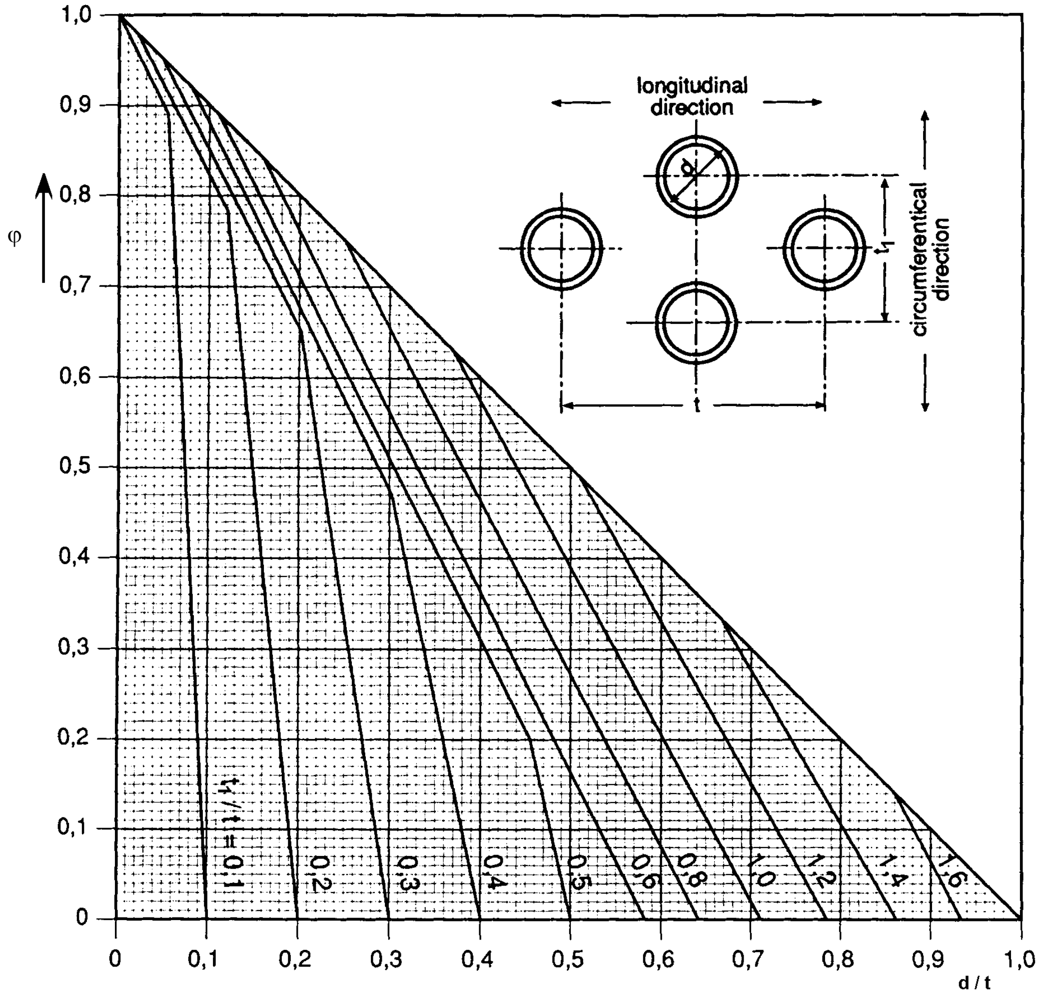


Fig. 2.1.5.2-3

2.1.5.7 Where cylindrical walls are manufactured from plates of various thickness, jointed together by longitudinal welds, wall thickness calculation shall be made for each plate separately, taking into account the weakenings.

2.1.5.8 For longitudinally welded tubes the efficiency factor of welded joints is subject to special consideration by the *Register* in each case.

2.1.6 Design thickness allowances

2.1.6.1 In all cases where the design wall thickness allowance is not expressly specified, it shall be 1 mm. For the steel walls over 30 mm in thickness, as well as for walls manufactured from corrosion-resistant non-ferrous alloys or high alloy materials and for the materials adequately protected against corrosion e.g. by plastic covering or facing, no allowance is to be provided for design wall thickness value, in agreement with the *Register*.

2.1.6.2 For heat exchangers and pressure vessels which are inaccessible for internal inspection or the walls which are heavily affected by corrosion or wear, the allowance may be increased if required by the *Register*.

2.2 CYLINDRICAL ELEMENTS

2.2.1 Elements subjected to internal pressure

2.2.1.1 The requirements given below apply to design of drums, shells and headers, with the following conditions:

$$\frac{D_v}{D_u} \le 1{,}7$$

$$\frac{D_v}{D_u} \le 2, \text{ if } s \le 80 \text{ mm}$$

where:

- s – wall thickness, [mm];
- D_v – outside diameter, [mm];
- D_u – inside diameter, [mm].

2.2.1.2 The thickness of cylindrical walls shall not be less than that calculated from the formulae:

$$s = \frac{D_v \cdot p}{2 \cdot \sigma_d \cdot \varphi + p} + c \text{ [mm]} \quad (2.2.1.2.1)$$

or

$$s = \frac{D_u \cdot p}{2 \cdot \sigma_d \cdot \varphi - p} + c \text{ [mm]} \quad (2.2.1.2.2)$$

where:

- s – wall thickness, [mm];
- p – design pressure, [MPa] (see 2.1.2)
- σ_d – allowable stress (see 2.1.4), [N/mm^2];
- φ – efficiency factor (see 2.1.5);
- c – allowance for corrosion (see 2.1.6), [mm].

2.2.1.3 Minimum allowable wall thickness of cylindrical shells

For welded and seamless shell rings the minimum allowable wall thickness is 5 mm.

For non-ferrous metals, stainless steels and cylinder diameters up to 200 mm, smaller wall thicknesses may be permitted.

The wall thickness of drums into which tubes are expanded is to be such as to provide a cylindrical expansion length of at least 16 mm.

2.2.1.4 Reinforcement of openings in cylindrical shells

Weakening effects due to cutouts or individual branch pipes are to be taken into account by area compensation in accordance with the expression:

$$p\left(\frac{A_p}{A_\sigma} + \frac{1}{2}\right) \le \sigma_d \quad (2.2.1.4\text{-}1)$$

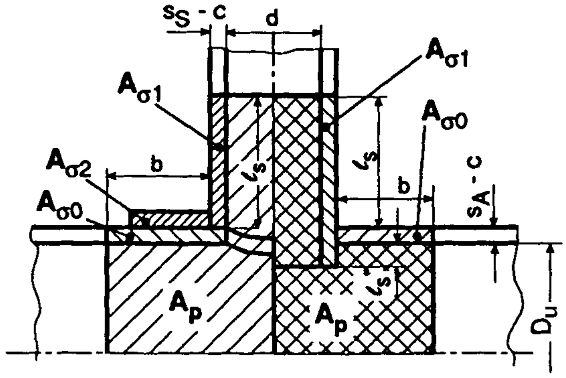


Fig. 2.2.1.4-1

where:

- A_σ – supporting cross-sectional area, (see fig. 2.2.1.4-1), [mm^2];
- A_p – area under pressure, (see fig. 2.2.1.4-1), [mm^2];
- s_A – necessary wall thickness at edge of opening or cutout, [mm];
- s_s – wall thickness of branch pipe, [mm];

The values of the supporting lengths may not exceed:

$$b = \sqrt{(D_u + s_A - c)(s_A - c)} \quad (2.2.1.4\text{-}2)$$

$$l_s = 1{,}25\sqrt{(d + s_s - c)(s_s - c)} \quad (2.2.1.4\text{-}3)$$

$$l_s' = 0{,}5\, l_s \quad (2.2.1.4\text{-}4)$$

Cutouts exert a mutual effect if the ligament:

$$l \le 2\sqrt{(D_u + s_A - c)(s_A - c)} \quad (2.2.1.4\text{-}5)$$

where:

- l – width of ligament between two branch pipes, (see fig.2.2.1.4-2), [mm];

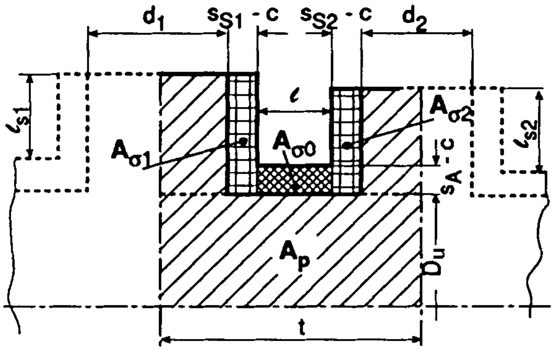


Fig. 2.2.1.4-2

Where materials for the branch or reinforcing plate with lower mechanical strengths than that of the parent component are used, the effective supporting cross-sectional area should be reduced in the ratio of the relevant mechanical strengths.

In the calculation, the allowable stress in the reinforcement may not be greater than that for the parent material.

In the calculation, the thickness of disc-shaped reinforcements may not be made greater than the wall thickness of the parent material.

In the case of tubular reinforcements, the following wall thickness ratio is applicable:

$$\frac{s_S - c}{s_A - c} \le 2 \qquad (2.2.1.4\text{-}6)$$

2.2.2 Elements subjected to external pressure

2.2.2.1 Requirements in this item apply to the design of smooth and corrugated cylindrical shells and tubes with an outside diameter of more than 200 mm which are subjected to external pressure.

2.2.2.2 Design of smooth firetubes

Calculation of resistance to plastic deformation:

$$p \le \sigma_d \frac{2\,(s-c)}{d} \cdot \frac{1+0{,}1\,\dfrac{d}{l}}{1+0{,}03\,\dfrac{d}{s-c}\cdot\dfrac{u}{1+5\,\dfrac{d}{l}}} \qquad (2.2.2.2\text{-}1)$$

Calculation of resistance to elastic buckling:

$$p \le 2\left\{\frac{E_t}{S_k}\cdot\frac{\dfrac{s-c}{d_a}}{\left(n^2-1\right)\left[1+\left(\dfrac{n}{z}\right)^2\right]^2}+\frac{\left(\dfrac{s-c}{d_a}\right)^3}{3\left(1-v^2\right)}\cdot\left[n^2-1+\frac{2n^2-1-v}{1+\left(\dfrac{n}{z}\right)^2}\right]\right\} \qquad (2.2.2.2\text{-}2)$$

where:

$$z = \frac{\pi d_a}{2l} \qquad (2.2.2.2\text{-}3)$$

d – mean diameter of smooth tube, [mm];
d_a – outside diameter of smooth tube, [mm];
l – length of tube or distance between two effective stiffeners (see item 2.2.2.3), [mm];
E_t – modulus of elasticity at design temperature, (see Table 2.5.2.5-1), [N/mm^2];
u – out of roundness of tube (see item 2.2.2.4), [%];
S_k – safety factor against elastic buckling (see item 2.2.2.4);
v – Poisson coefficient (0,3 for steel);
n – intiger value which represents the number of buckled folds occurring round the periphery in the event of failure ($n \ge 2$, $n > z$).

Remark: n is to be chosen as to reduce p to its minimum value; n can be estimated by applying the formula:

$$n = 1{,}63\,\sqrt[4]{\left(\frac{d_a}{l}\right)^2\cdot\frac{d_a}{s-c}} \qquad (2.2.2.2\text{-}4)$$

Other symbols are the same as in 2.2.1.2.

2.2.2.3 Stiffening

.1 Stiffening with stiffening rings

The second moment of area of the stiffening ring is to be not less than given by the following formula:

$$I = \frac{pd^3 l}{1{,}33\cdot 10^7} \qquad [\text{mm}^4] \qquad (2.2.2.3\text{-}1)$$

The symbols are the same as in 2.2.2.2.

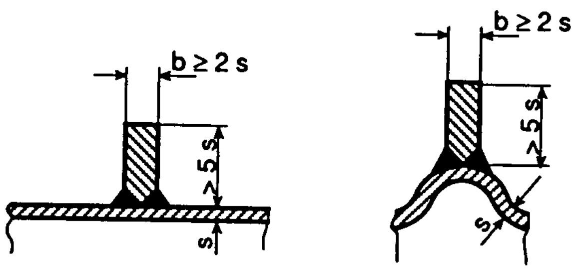


Fig. 2.2.2.3-1

.2 Stiffening with stays

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 greater, and the pitch of the stays at the firebox does not exceed 14 times the wall thickness of the firebox.

.3 Connection of firebox to shell in vertical boilers
The minimum thickness of the ring which connects the bottom of the furnace to the shell and sustains the whole vertical load on the furnace is to be determined by the following formula:

$$s = \sqrt{\frac{pD_u\left(D_u - D_v\right)}{10000}} + c \qquad (2.2.2.3\text{-}3)$$

where:

D_u – internal diameter of boiler shell, [mm],
D_v – outside diameter of the firebox where it joins the ring, [mm].

If the bottom of the furnace is connected to the shell as shown in fig. 2.2.2.3-3, the thickness of the ring is to be at least 20% greater than determined by the formula 2.2.2.3-3.

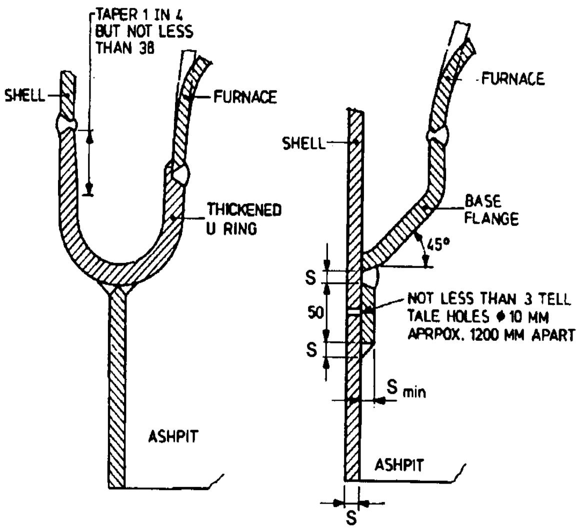
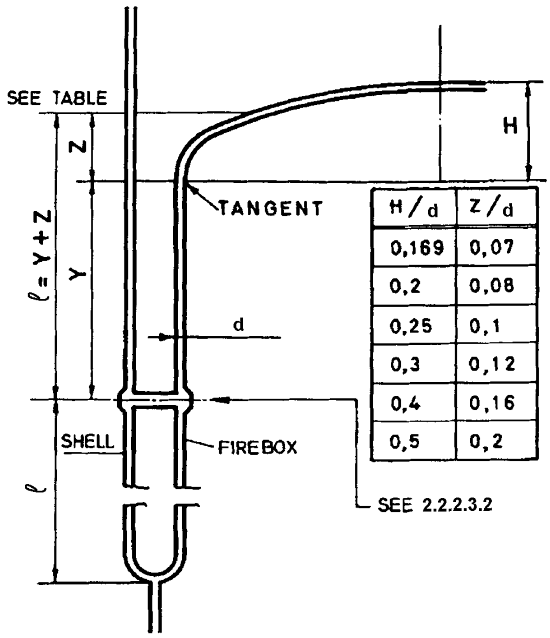


Fig. 2.2.2.3-3

.4 Maximum unstiffened length



H/d	Z/d
0,169	0,07
0,2	0,08
0,25	0,1
0,3	0,12
0,4	0,16
0,5	0,2

Fig. 2.2.2.3-4

The length *l* between two stiffeners may not exceed 6*d*.

The greatest unsupported length shall not exceed 6 m or, in the first pass form the front end plate 5 m. Stiffenings of the type shown in fig. 2.2.2.3-1 are to be avoided in the flame zone, i.e. up to 2 · d behind the lining.

2.2.2.4 Out of roundness (u):

$$u = \frac{2\left(d_{max} - d_{min}\right)}{d_{max} + d_{min}} \cdot 100 \quad [\%] \quad (2.2.2.4\text{-}1)$$

where d_{max} and d_{min} are the maximum and the minimum mean diameter of the furnace.

In the case of new smooth tubes the value u = 1,5% is to be taken.

In the case of used firetubes, u is to be determined by the formula:

$$u = \frac{4a}{d} \cdot 100 \qquad (2.2.2.4\text{-}2)$$

where:

a - greatest deviation from cylindrical shape (see Fig.2.2.2.4), [mm]

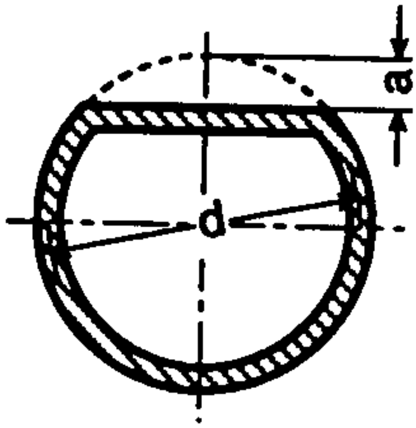


Fig 2.2.2.4

Safety factor (S_k) is to be taken as follows:

for $u \le 1{,}5\%$ $S_k = 3$
for $1{,}5\% \le u \le 2\%$ $S_k = 4$

2.2.2.5 Corrugated furnaces of Fox or Morrison type shall not have a wall thickness less than that determined from the formulae:

$$s = \frac{p \cdot D_B}{2 \cdot \sigma_d} + c \ , \quad [\text{mm}] \qquad (2.2.2.5)$$

where:

D_B – minimum inside diameter of the furnace over the corrugated portion, [mm];
p, σ_d and c – see 2.2.1.2.

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

2.2.2.6 Where the length of plain portion of a corrugated furnace from the front end wall to the commencement of the first corrugation, exceeds 250 mm, the wall thickness over this portion shall be obtained from item 2.2.2.2.

2.2.2.7 The thickness of plain furnaces shall not be less than 7 mm nor more than 20 mm. The thickness of corrugated furnaces shall not be less than 10 mm nor more than 20 mm.

For elements made of non-ferrous metals and stainless steels, smaller wall thicknesses are allowable, subject to that actual thickness is greater than twice the calculated wall thickness. Wall thickness shall not be smaller than 3 mm.

2.3 CONICAL ELEMENTS

2.3.1 The conical sections having an angle of inclination to the vessel axis of more than 75° are to be considered as flat plates.

Conical sections may be butt welded to cylinders without a knuckle radius where the angle ψ does not exceed 30°.

The minimum thickness of cylinder, knuckle and conical section subjected to internal pressure at the junction and within the distance L from the junction is to be determined by formula (2.3.1-1), and the minimum thickness of conical section subjected to internal pressure at a distance greater than L from the junction is to be determined by formula (2.3.1-2).

$$s = \frac{D_v \cdot p \cdot y}{4 \cdot \sigma_d \cdot \varphi} + \text{c}, \quad [\text{mm}] \qquad (2.3.1\text{-}1)$$

$$s = \frac{D \cdot p}{2 \cdot \sigma_d \cdot \varphi - p} \cdot \frac{1}{\cos\ \alpha} + c, \quad [\text{mm}] \qquad (2.3.1\text{-}2)$$

$$L = 0{,}5 \sqrt{\frac{D_v \cdot s}{\cos\psi}} \qquad (2.3.1\text{-}3)$$

where:

D – design diameter, [mm]; (see figs. 2.3.1-1 to 2.3.1-4)
D_v – outside diameter, [mm]; (see figs 2.3.1-1 to 2.3.1-4)
y – shape factor (see table 2.3.1);
$\alpha, \alpha_1, \alpha_2$ and ψ – angles [°] (see figs. 2.3.1-1 to 2.3.1-4);
r – radius of transition knuckle, [mm];
p, σ_d, φ, c – see 2.2.1.2.

Remark: Efficiency factor of welded joint should be taken 1, if the welded joint is at a distance greater than L from the junction. If this is not fulfilled, the efficiency factor is to be taken according to item 2.1.5.1.

Table 2.3.1
Shape factor

α [°]	**Shape factor *y* at r/D_v**											
	0,01	**0,02**	**0,03**	**0,04**	**0,06**	**0,08**	**0,10**	**0,15**	**0,20**	**0,30**	**0,40**	**0,50**
10	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
20	2,0	1,8	1,7	1,6	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1,1
30	2,7	2,4	2,2	2,0	1,8	1,7	1,6	1,4	1,3	1,1	1,1	1,1
45	4,1	3,7	3,3	3,0	2,6	2,4	2,2	1,9	1,8	1,4	1,1	1,1
60	6,4	5,7	5,1	4,7	4,0	3,5	3,2	2,8	2,5	2,0	1,4	1,1
75	13,6	11,7	10,7	9,5	7,7	7,0	6,3	5,4	4,8	3,1	2,0	1,1
Note: For conical sections without knuckle transition r/D_v = 0,01 is to be taken when determining shape factor *y*.												

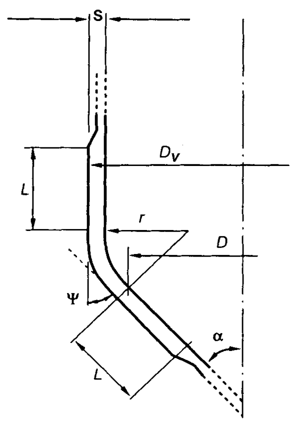


Fig. 2.3.1-1

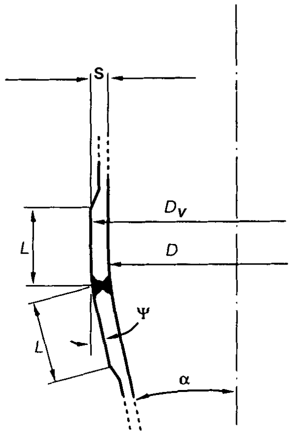


Fig. 2.3.1-2

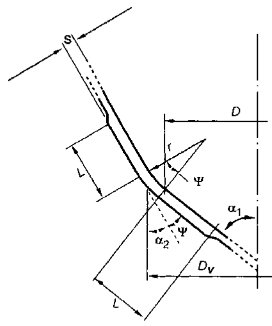


Fig. 2.3.1-3

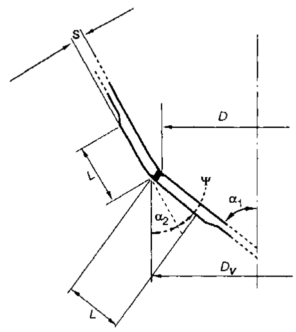


Fig. 2.3.1-4

2.3.2 Wall thickness, s (mm), of conical elements subjected to external pressure shall be determined in accordance with 2.3.1 provided that:

.1 efficiency factor of welded joints $\varphi = 1$;

.2 allowance for corrosion, $c = 2$ mm;

.3 design diameter, D, is calculated from the formula:

$$D = \frac{d_1 + d_2}{2} \cdot \frac{1}{\cos\alpha}, \quad \text{[mm]} \quad (2.3.2.3)$$

where:

d_1 and d_2 – are the respective maximum cone diameters, mm;

.4 with $\alpha < 45^o$ it shall be provided that no elastic concave deformation of the walls will appear.

Pressure, p_1 (MPa), at which concave elastic deformation of the wall occurs, shall be determined in accordance with the formula:

$$p_1 = 26\, E\, 10^{-6}\, \frac{D}{\ell_1} \left[\frac{100\,(s-c)}{D} \right]^2 \sqrt{\frac{100\,(s-c)}{D}}, \quad (2.3.2.4)$$

where:

E – modulus of elasticity, [N/mm^2];

l_1 – length of conical part or distance between points of cone supports [mm].

In order to prevent the elasticity of the cone walls bulging, $p_1 > p$ should be fulfilled (where p is design pressure, MPa).

2.4 FLAT WALLS, END PLATES, COVERS AND TUBE PLATES

2.4.1 Unstayed surfaces

2.4.1.1 The thickness, s, of flat end plates unsupported by stays, as well as that of covers (figs. 2.4.1.1-1 to 2.4.1.1-7 and 1.1 to 1.7 of Appendix), shall not be less than that determined from the formula:

$$s = A\, D \sqrt{\frac{p}{\sigma_d}} + c, \quad \text{[mm]} \quad (2.4.1.1.1)$$

where:

A – design factor according to Table 2.4.4.1;

D – design diameter (figs. 2.4.1.1-2 to 2.4.1.1-7 and 1.2 to 1.7 of Appendix), [mm].

For end plates shown in figs. 2.4.1.1-1 and 1.1 of Appendix, the design diameter shall be:

$D = (D_u - r)$, [mm] (2.4.1.1.2)

For rectangular and oval covers (see fig. 2.4.1.1-8), the required wall thickness shall be:

$$s = Aby \sqrt{\frac{p}{\sigma_d}} + c, \quad \text{[mm]} \quad (2.4.1.1\text{-}3)$$

where:

D_u – inside diameter, [mm];

a,b – clear supporting or design widths of rectangular or elliptical plates, b allways designating the shorter side or axis (see fig. 2.4.1.1-8), [mm];

r – inner corner radius of a flange or radius of a stress relieving groove, [mm];

σ_d – allowable stress (see 2.1.4), [N/mm^2];

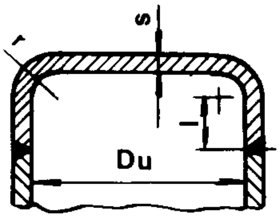
c – allowance for corrosion (see 2.1.6), [mm];

y – ratio according to Table 2.4.1;

Table 2.4.1
Values of ratio y

Shape	Ratio b/a[1]				
	1,0	0,75	0,5	0,25	≤ 0,1
Rectangle	1,1	1,26	1,4	1,52	1,56
Ellipse	1	1,15	1,3	1,43	–

[1] Intermediate values are to be interpolated linearly.



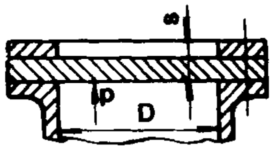
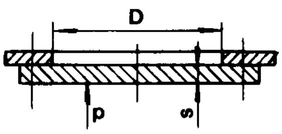


Fig. 2.4.1.1-1Fig. 2.4.1.1-2



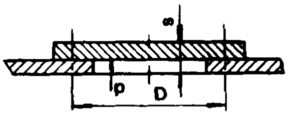
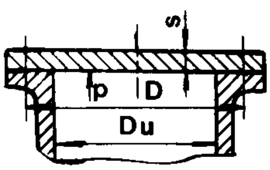


Fig. 2.4.1.1-3 **Fig. 2.4.1.1-4**



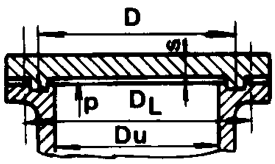


Fig 2.4.1.1-5 **Fig. 2.4.1.1-6**

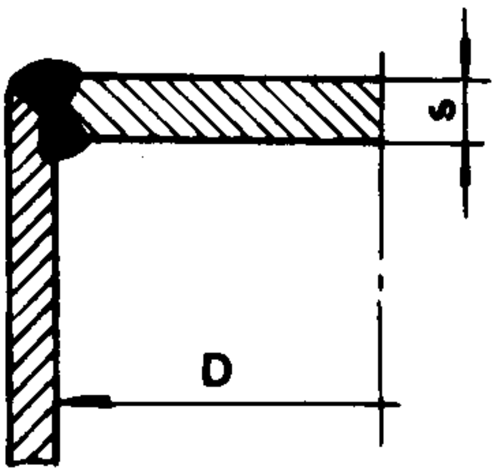


Fig. 2.4.1.1-7

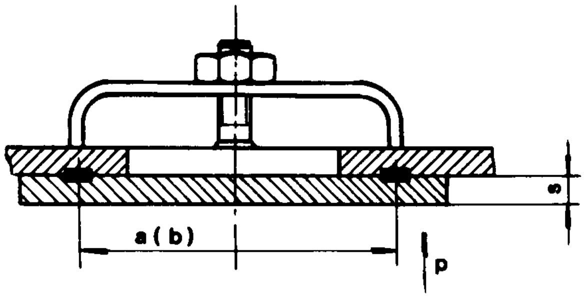


Fig. 2.4.1.1-8

2.4.1.2 The thickness, s, of end plates shown in fig. 1.2 of Appendix shall not be less than that determined from formula 2.4.1.1.1.

Besides, the following conditions are to be satisfied:

.1 for circular end plates

$$0{,}77\, s_1 \geq s_2 \geq \frac{1{,}3p}{\sigma_d} \left(\frac{D}{2} - r \right) \quad (2.4.1.2.1)$$

.2 for rectangular end plates:

$$0{,}55\, s_1 \geq s_2 \geq \frac{1{,}3p}{\sigma_d} \cdot \frac{ab}{a+b}, \quad (2.4.1.2.2)$$

where:

s_1 – thickness of cylindrical part of shell, [mm];

s_2 – thickness of end plate in the relieving groove area, [mm].

Other symbols used are the same as in 2.4.1.1. In no case shall the value s_2 be less than 5 mm.

2.4.2 Walls reinforced by stays

2.4.2.1 Flat walls (figs. 2.4.2.1-2 and 2.4.2.1-3) reinforced by long and short stays, corner stays, stay tubes or top girders shall not have thickness less than that determined from the formula:

$$s = A \cdot D \sqrt{\frac{p}{\sigma_d}} + c, \text{ [mm]} \quad (2.4.2.1\text{-}1)$$

where:

A – design factor, in accordance with Table 2.4.4.2.
If the wall area in question is reinforced by stays having different factor A values, formula 2.4.2.1.1 is used with the arithmetic mean of these factor values;

D – design assumed diameter (fig 2.4.2.1-2 and 2.4.2.1-3), [mm]
In case of uniform distribution of stays

$$D = \sqrt{t_1^2 + t_2^2}, \quad (2.4.2.1.2)$$

In case of non-uniform distribution of stays

$$D = \frac{t_3 + t_4}{2} \qquad (2.4.2.1.3)$$

In case of flat top plates of combustion chambers supported by welded on girders, *D* is to be taken as distance between inside faces of girders.

In all other cases value *D* shall be taken equal to diameter of the largest circle which can be drawn through the centres of three stays or through the centres of stays and the commencement of curvature of flanging if the radius of latter is as specified in 2.4.3. If unflanged flat plate is welded to a shell, the point of support is to be taken at the inside of the shell.

t_1, t_2, t_3 and t_4 = pitch or stay-to - stay distance (see fig. 2.4.2.1-1)

t_1, t_2, t_3, t_4 – korak ili razmak izmedju ukrućenja [mm], (vidi Sliku 2.4.2.1-1).

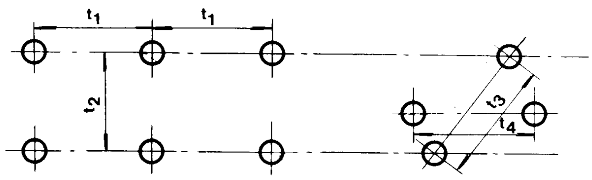


Fig. 2.4.2.1-1

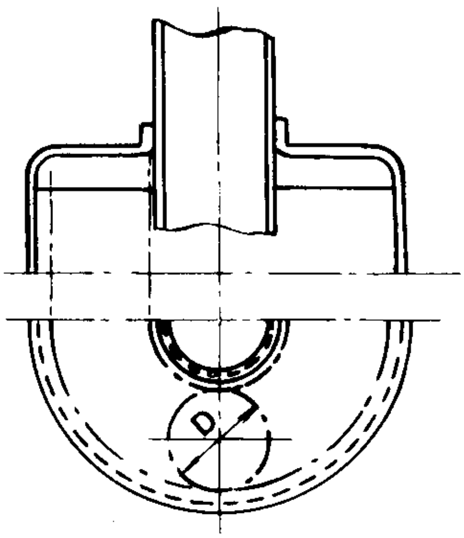


Fig. 2.4.2.1-2

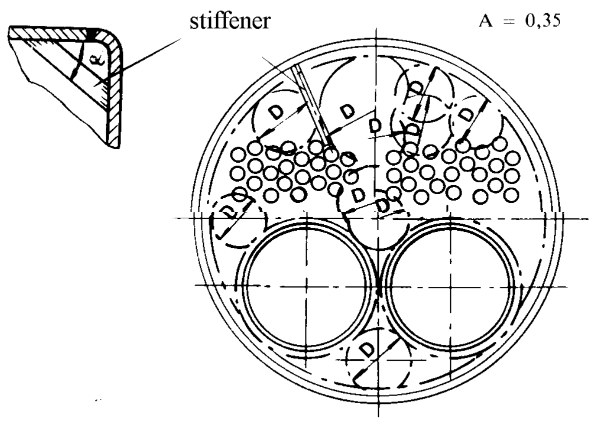


Fig. 2.4.2.1-3

2.4.3 Flanging of flat walls

2.4.3.1 In flat wall and end plate calculations, the flanging is only taken into account when the flanging radii are not less than those given in Table 2.4.3.1.

Table 2.4.3.1

Radius of flanging, [mm]	Outside diameter of end plate, [mm]
1	2
25	up to 350
30	351 - 500
35	501 - 950
40	951 - 1400
45	1401 - 1900
50	over 1900

Minimum flanging radius shall not be less than 1,3 times the wall thickness.

2.4.3.2 Where a flat plate is flanged for connection to the boiler shell, the inside radius of flanging is not to be less than 2s with a minimum of 38 mm.

For connection with a furnace, the inside radius of flanging is not to be less than s with a minimum of 25 mm.

The length of the cylindrical part of the flanged end plate is not to be less than 2,5 *s*.

s - thickness of the flat plate, [mm].

2.4.3.3 Where a flat plate has the inspection opening strengthened by flanging, the depth *H* of the flange, measured from the outer surface of the plate, is to be not less than:

$$H = \sqrt{s \cdot b} \qquad (2.4.3.3)$$

where:

b - minor axis of an opening, [mm].

2.4.3.4 Where unflanged flat plates are connected to a cylindrical shell by welding, the weld is to be a full penetration weld.

The ratio of end plate thickness to shell thickness is not to exceed 1,8.

2.4.4 Design coefficient A

Table 2.4.4-1

Type of end-plate or cover	*A*
– flat, forged end plates (fig. 1.1 of Appendix) – flat, flanged end plates (fig. 2.4.1.1-1) – encased, tightly supported plates, bolted at their circumference (fig. 2.4.1.1-2 to 2.4.1.1-5) – inserted, flat plates welded on both sides (fig. 1.4 of Appendix)	0,35
– welding-neck end plates with stress relieving groove (fig. 1.2 of Appendix)	0,4
– loosely supported plates (covers) (fig. 2.4.1.1-8) – inserted, flat plates welded on one side	0,45
– plates, bolted at their circumference (fig. 2.4.1.1-6) D_L/D = 1,0 D_L/D = 1,1 D_L/D = 1,2 D_L/D = 1,3	 0,45 0,5 0,55 0,6

Table 2.4.4-2

Type of stiffening	*A*
– annular, flat end plates flanged on both sides and with a longitudinal central stay (fig. 2.4.2.1-2)	0,5
– boiler shell, header or combustion chamber wall, stay plate or tube area (fig. 2.4.2.1-3)	0,35
– stay bolts and stay tubes outside tube arrays (isolated)	0,45
– stay bolts and stay tubes, with maximum distance between stiffeners of 200 mm (fig. 2.4.2.1-1)	0,4
– top combustion chamber plates, with welded steel girders (fig. 2.8.1)	0,51

2.4.5 Boiler tube plates

2.4.5.1 Stay tubes are not required within tube nests except when the tubes in tube nests are expanded only.

Stay tubes are to be used in the boundary rows in sufficient number to carry the tube plate loadings outside the tube area.

2.4.5.2 The minimum thickness of tube plates with expanded tubes is to be 12 mm, and with welded tubes 10 mm.

The minimum width of ligament between tube holes is to be:

a) for expanded tubes – 0,125 d + 12,5 [mm];
b) for welded tubes – 0,125 d + 9 [mm], for gas entry temperatures >800°C;
– 0,125 d+ 7 [mm], for gas entry temperatures ≤800°C;

d = diameter of tube hole, [mm].

2.4.6 Reinforcement of openings in flat plates

2.4.6.1 Where the actual wall thickness is larger than that required by formulae 2.4.1.1.1 and 2.4.2.1.1, the maximum diameter of a non-reinforced opening shall be determined from the formula:

$$d = 8 \cdot s_1 \left(1{,}5 \cdot \frac{s_1^2}{s^2} - 1\right), \quad (2.4.6.1)$$

where:

d – diameter of non-reinforced opening, [mm],
s_1 – actual wall thickness minus corrosion allowance , [mm],
s – design wall thickness obtained from the formulae 2.4.1.1.1 and 2.4.2.1.1, with c=0, [mm].

2.4.6.2 Edge reinforcement shall be provided for openings of larger dimensions than those indicated in 2.4.6.1.

Compensation of opening with branch pipe is adequate if the compensating area, denoted by ///// is equal or greater than the area requiring compensation, denoted by xxx (see Fig. 2.4.6.2).

Where material with a lower nominal design stress than that of the flat plate is used for reinforcement, the effective area of compensation is to be reduced in the ratio of the relevant design stresses.

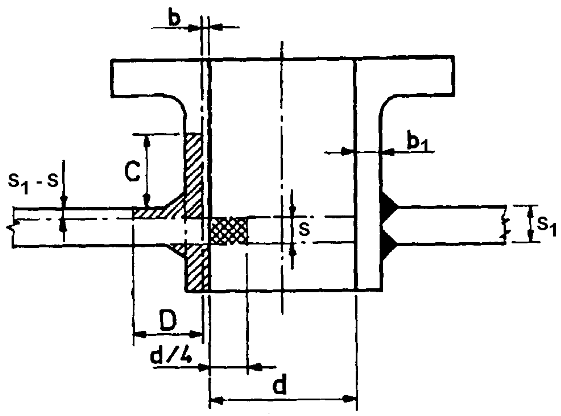


Fig. 2.4.6.2

b_1 – actual thickness of the branch minus corrosion allowance, [mm];
b – thickness of the branch calculated from the formula in 2.9.2, [mm];
D – greater of $d/2$, or s_1+75 [mm];
C – smaller of 2,5 s_1, or 2,5 $b_1 + (s_1 - s)$.

2.5 SPHERICAL SHELLS AND DISHED ENDS

2.5.1 Wall thickness of spherical shell subject to internal pressure is to be not less than:

$$s = \frac{pD_v}{4\sigma_d \varphi + p} + c \quad \text{[mm]}, \quad (2.5.1)$$

with: $\frac{D_v}{D_u} \le 1{,}5$

Symbols are the same as in 2.2.1.1 and 2.2.1.2.

2.5.2 Dished end plates under internal and external pressure

2.5.2.1 The following requirements apply to the design of unstayed dished end plates, with the relations:

$R_u \le D_v$
$r_u \ge 0{,}1\ D_v$
$H \ge 0{,}18\ D_v$
$h = 3{,}5\ s$ (except for hemispherical end plates).

The height of the cylindrical portion, *h*, need not exceed the following values:

s [mm]	*h* [mm]
≤ 50	150
50 < *s* ≤ 80	120
80 < s≤ 100	100
100 < *s* ≤ 120	75
120 <	50

Where openings in dished ends are flanged, the radius of flanging is to be not less than 25 mm.

Symbols:

R_u – inside radius of torispherical dished end, [mm]
D_v – outside diameter of dished end, [mm]
r_u – internal knuckle radius of torispherical dished end, [mm]
H – height of end plate curvature , [mm]
s – wall thickness of end plate , [mm]

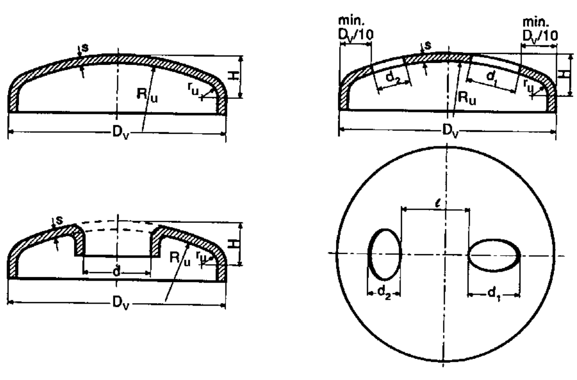


Fig. 2.5.2.1

2.5.2.2 Wall thickness of the dished end subjected to internal pressure is to be not less than:

$$s = \frac{D_v p \beta}{4\sigma_d \varphi} + c \quad \text{[mm]} \quad (2.5.2.2)$$

where:

β – design coefficient taken from diagram 2.5.2.2.

Diameter of opening, *d*, is measured along a line passing through the centers of the end plate and the opening. In the case of opening concentric with the end plate, *d* is the maximum opening diameter.

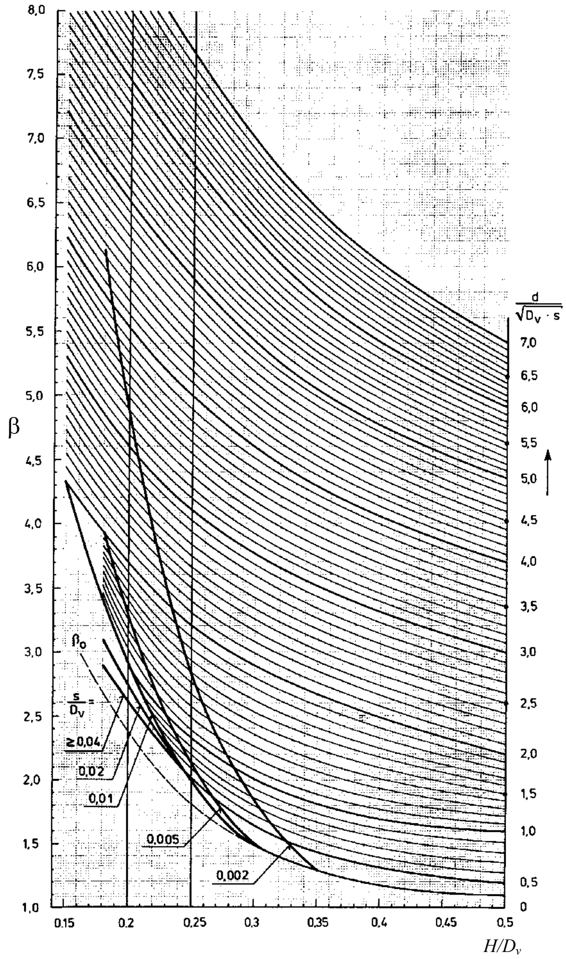


Fig. 2.5.2.2

2.5.2.3 The unpierced end means an end which has no openings or one with openings located at a distance of not less than 0,1 D_v from the outside outline of the cylindrical portion and measuring no more than 4 *s* in diameter, or which are adequately reinforced.

The width of the ligament *l*, between two adjacent, non reinforced openings must be at least equal to the sum of the opening radii measured along the line connecting the centers of the openings. If the width of ligament is less than that defined above, the wall thickness is to be dimensioned as though no ligament were present, or the edges of the openings are to be adequately reinforced.

2.5.2.4 Reinforcement of openings in the spherical section

Openings in the spherical section are adequately reinforced if the following expression is satisfied:

$$p \cdot \left(\frac{A_p}{A_\sigma} + \frac{1}{2} \right) \leq \sigma_d \,, \qquad (2.5.2.4\text{-}1)$$

The areas A_p and A_σ are shown in Fig. 2.5.2.4-1.

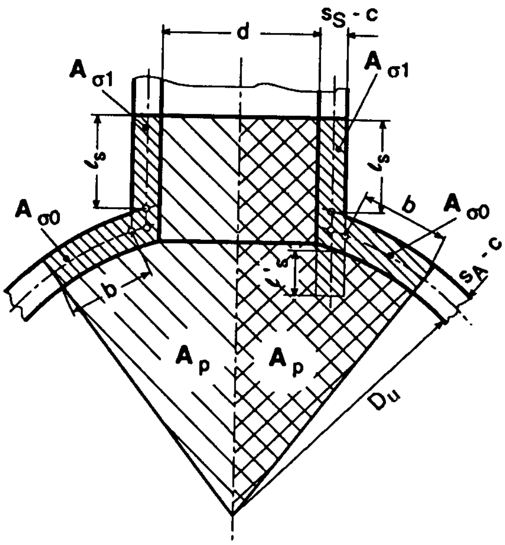


Fig. 2.5.2.4-1

Symbols are the same as in 2.2.1.4.
The supporting lengths used in the calculation may not exceed the following values:

$$b = \sqrt{(D_u + s_A - c)(s_A - c)} \,, \qquad (2.5.2.4\text{-}2)$$

$$l_s = 1{,}25 \sqrt{(d + s_s - c)(s_s - c)} \,, \qquad (2.5.2.4\text{-}3)$$

$$l_s' \leq 0{,}5 \; l_s \,, \qquad (2.5.2.4\text{-}4)$$

D_u – inside diameter of the spherical section, [mm]

Cutouts exert a mutual effect if the ligament:

$$l \leq 2 \sqrt{(D_u + s_A - c)(s_A - c)} \,, \qquad (2.5.2.4\text{-}5)$$

The compensation area is according to Fig. 2.5.2.4-2.

Where materials for the branch or reinforcing plate with lower mechanical strengths than that of the parent component are used, the effective supporting cross sectional area should be reduced in the ratio of the relevant mechanical strengths.

In the calculation, the allowable stress in the reinforcement may not be greater than that for the parent material.

In the calculation, the thickness of disc-shaped reinforcements may not be made greater than the wall thickness of the parent material.

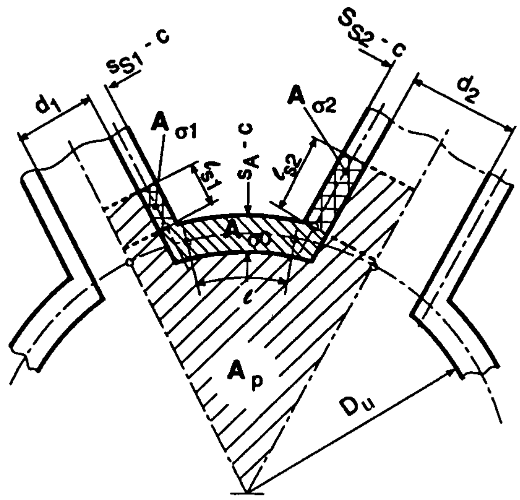


Fig. 2.5.2.4-2

The edge of the disc may not extend beyond 0,8 D_v.

In the case of tubular reinforcements, the following wall thickness ratio is applicable:

$$\frac{s_s - c}{s_A - c} \leq 2 \,, \qquad (2.5.2.4\text{-}6)$$

2.5.2.5 Design calculation for dished ends subjected to external pressure

The same formulae are to be applied to as for dished ends subjected to internal pressure, only the allowable stress is to be reduced by 17%.

A check of the spherical section for the safety against elastic buckling is according to the following relationship:

$$p \leq 0{,}366 \; \frac{E_t}{S_k} \left(\frac{s - c}{R_u} \right)^2 \,, \qquad (2.5.2.5)$$

where:

E_t – modulus of elasticity for steel at design temperature according to table 2.5.2.5-1.

The safety coefficient, S_k, against elastic buckling is taken from Table 2.5.2.5-2.

Table 2.5.2.5-1

Design temperature t, [°C]	20	250	300	400	500
1	**2**	**3**	**4**	**5**	**6**
Modulus of elasticity for steel, E_t, [N/mm^2]	206.000	186.000	181.000	172.000	162.000

Table 2.5.2.5-2

$\frac{s-c}{R_u}$	S_k [1)]
0,001	5,5
0,003	4,0
0,005	3,7
0,01	3,5
0,1	3,0

1) Intermediate values should be interpolated.

2.5.2.6 Weakening factor

The weakening factor for welded dished ends is taken according to 2.1.5. The weakening factor for welded dished ends, except for hemispherical ends, is taken $\varphi = 1$, if the welded seam impinges on the area within the apex defined by 0,6 D_v (see fig. 2.5.2.6).

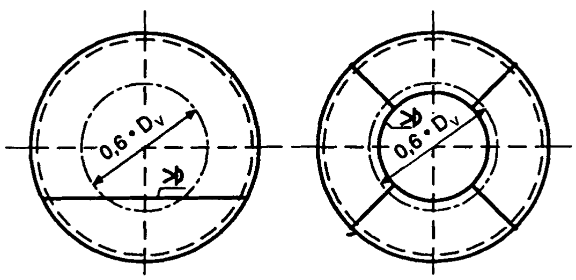


Fig. 2.5.2.6

2.5.2.7 The minimum wall thickness of steel dished ends shall not be less than 5 mm. For ends manufactured from non-ferrous alloys or stainless steel, the minimum wall thickness may be reduced. Wall thickness shall not be smaller than 3 mm for dished ends made of non-ferrous metals, and 2 mm for dished ends made of stainless steels.

2.5.3 Dished ends subjected to internal and external pressure, supported by central uptakes, for vertical boilers

2.5.3.1 The minimum thickness of dished and flanged ends which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:

$$s = \frac{p \cdot R_u}{1{,}3\ \sigma_d} + c, \quad [\text{mm}] \quad (2.5.3.1)$$

The inside radius of flanging to uptake is not to be less than twice the thickness of the end plate and in no case less than 25 mm.

2.5.3.2 The minimum thickness of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are supported by central uptakes is to be determined by the following formula:

$$s = \frac{p\ (R_u + s)}{\sigma_d} + c\,, \quad [\text{mm}] \quad (2.5.3.2)$$

2.6 HEADERS

2.6.1 The wall thickness of the rectangular header is to be calculated for the centre of the side, for the ligaments between the holes, and at the corners. The maximum calculated value governs the wall thickness of the entire rectangular header.

The wall thickness of rectangular headers (fig.2.6.1-1) subjected to internal pressure shall not be less than that determined from the formula:

$$s = \frac{p \cdot n}{2 \cdot \sigma_d \cdot \varphi} + \sqrt{\frac{4{,}5 \cdot p \cdot k}{\sigma_d \cdot \varphi'}} \quad [\text{mm}], (2.6.1\text{-}1)$$

where:

- p – design pressure, MPa (2.1.2),
- n – half clear width of header side normal to that being calculated, [mm],
- σ_d – allowable stress, [N/mm^2], (2.1.4),
- φ, φ' – efficiency factors of headers, weakened by holes, determined as follows:
- φ – by formula 2.1.5.2.1,
- φ' – by formula 2.1.5.2.1 with d < 0,6 m,
- φ' = $(t - 0{,}6\ m)/t$, where $d \geq 0{,}6$ m; (2.6.1.2)
  - Where the holes are arranged in a staggered pattern, t_s (fig.2.6.1.2) shall be substituted for t in formula 2.6.1.2 and 2.1.5.2.1.
  - Where the rectangular headers have longitudinal welded joints (fig. 2.6.1.-1) the efficiency factors φ and φ' are assumed to be equal respectively to the efficiency factor of welded joints selected as per 2.1.5.1. Longitudinal welded joints shall be arranged at a distance a from the centre line of the side wall, for which k=0;
  - Where the header wall is weakened in several different ways, the calculations shall be based on the lowest efficiency factor value;

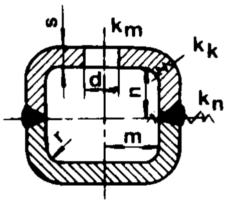


Fig. 2.6.1-1

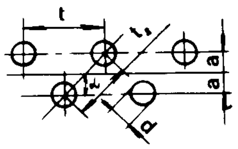


Fig. 2.6.1-2

k – Design factor, [mm^2], calculated from the formulae:

– for centre line of header wall:

$$k = \frac{1}{3} \cdot \frac{m^3 + n^3}{m + n} - \frac{m^2}{2}, \quad (2.6.1.3)$$

– for rows of holes or for longitudinal welded joints:

$$k = \frac{1}{3} \cdot \frac{m^3 + n^3}{m + n} - \frac{m^2 - a^2}{2} \quad (2.6.1.4)$$

– at the corners:

$$k = \frac{1}{3} \cdot \frac{m^3 + n^3}{m + n}, \quad (2.6.1\text{-}5)$$

If the above formulae yield negative values, the absolute numerical values shall be used;
For oblique ligaments, the value of k is to be determined by applying formula (2.6.1.3) multiplied by cos α;

where is:

m – half of the clear width of the header side parallel to that being calculated, mm,

α – angle of diagonal pitch to the longitudinal axis, deg.;

a – distance between row of holes under consideration and centre line of header wall (fig.2.6.1-2);

d – diameter of hole, mm. For oval holes d shall be taken equal to the size of holes on the longitudinal axis. However, in the expressions $d < 0,6$ m and $d \geq 0,6$ m, the size on the axis normal to the header centre line shall be taken as d for oval holes.

2.6.2 The radius of curvature of rectangular header sides shall not be less than 1/2 of the wall thickness but not less than 3 mm for rectangular tubes with clear width of up to 50 mm, and 8 mm for rectangular tubes with clear width of 80 mm and over. Intermediate values are to be interpolated linearly. The minimum thickness of header walls designed to accommodate expanded tubes shall not be less than 14 mm. The width of ligament between holes shall not be less than 0,25 times the pitch between hole centres. The wall thickness in the area of curvature shall not be less than that determined from the formulae 2.6.1-1.

2.6.3 Minimum thickness of a toroidal header forming the lower end of a waterwall furnace and supporting the weight of the boiler and water is to be determined by the following formula:

$$s = \frac{pr}{3\varphi\sigma_d} + \sqrt{\left(\frac{pr}{3\varphi\sigma_d}\right)^2 + \frac{4M}{(t-d)\sigma_d}} + c \quad , \text{[mm]} \ (2.6.3.1)$$

where:

r – inside radius of toroid circular cross-section [mm]

$$M = \frac{Wr}{3} - \frac{pd^2 r}{4}, \ \text{[Nmm]} \quad (2.6.3.2)$$

W - imposed loading on each water wall tube due to the weight of the boiler and water [N]

Other symbols are the same as in 2.1.5.2 and 2.2.1.2.

2.7 STAYS

2.7.1 Scantlings of stays

2.7.1.1 The cross-sectional area of long and short stays, corner stay and stay tubes subject to tensile or compressive stresses shall not be less than that calculated from the formula:

$$A' = \frac{p \cdot A}{\sigma_d}, \quad \text{[mm}^2\text{]} \ (2.7.1.1)$$

where:

p – design pressure, [N/mm^2] (2.1.2),

σ_d – allowable stress, [N/mm^2] (2.1.4),

A – surface area per stay of the wall to be reinforced, bounded by lines passing at right angles through the centres of the lines joining the centre of the stay with the adjacent points of support (stays), [mm^2].

The cross-sectional area of the stays and tubes within this area may be deducted from the surface area per stay.

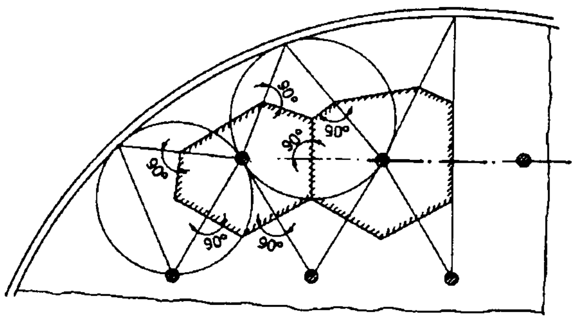


Fig. 2.7.1.1

2.7.2 Attachment of stays

2.7.2.1 The cross-sectional area of welded joints of welded-on stays shall be calculated from the following formula:

$$\frac{\pi \cdot d \cdot e}{A'} \geq 1{,}25, \qquad (2.7.2.1)$$

where:

- d – stay diameter, for stay tubes outside diameter [mm];
- e – weld height in direction of load [mm];
- A' – cross-sectional area of the stay (2.7.1.1), [mm²].

2.7.2.2 Expansion joints shall be checked to secure seating of the tubes in the tube plates by axial testing loads. The tubes may be considered securely seated if the value obtained from the formula:

$$\frac{p \cdot A}{20 \cdot s \cdot l} \qquad (2.7.2.2)$$

shall not exceed:

- 15 – for joints of plain holes,
- 30 – for joints with sealing grooves,
- 40 – for joints with flanging of tubes,

where:

- s – thickness of tube wall, [mm],
- l – length of expansion belt, [mm].

The length of the expansion belt for tubes, l, shall be taken as not more than 40 mm.

Other symbols used are the same as in 2.7.1.1.

2.8 TOP GIRDERS

2.8.1 This item apply to steel girders welded continuously to the top combustion chamber plate by means of a full penetration weld. The section modulus of top girders of rectangular section shall not be less than that determined from the formulae:

$$W = \frac{1000\ M}{1{,}3 \cdot \sigma_d \cdot z} \leq \frac{B \cdot H^2}{6} \quad [\text{mm}^3],\ (2.8.1\text{-}1)$$

where:

- σ_d – allowable stress, [N/mm²] (2.1.4),
- z – coefficient which takes account of the increase in the section modulus due to the combustion chamber crown plate. In general it may be taken as $z = 5/3$;
- M – bending moment of girder, [Nm]. For a rectangular section

$$M = \frac{p \cdot b \cdot l^2}{8000},\ (2.8.1\text{-}2)$$

where:

- H – height of girder (which is not to be more than 8 B) [mm] (fig.2.8.1);
- l – design length of girder, [mm],
- p – design pressure , [MPa] (2.1.2);
- b – spacing of girders, [mm] (fig. 2.8.1).
- B – thickness of girders, [mm].

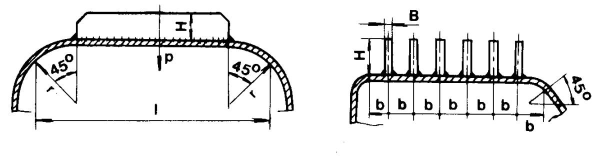


Fig. 2.8.1

2.9 TUBES AND BRANCH PIPES

2.9.1 This chapter applies to boiler tubes subject to internal pressure and to boiler tubes subject to external pressure with an outside diameter up to 200 mm.

2.9.2 The minimum wall thickness of tube is to be determined by the following formula:

$$s = \frac{D_V \cdot p}{2\sigma_d \varphi + p} + c, \qquad [\text{mm}] \qquad (2.9.2)$$

Symbols are the same as in 2.2.1.2.

The wall thickness of tubes should not be less than the values shown in Tables 2.9.2.1 and 2.9.2.2.

Table 2.9.2-1
Minimum thickness of tubes

Nominal outside diameter of tube [mm]	**Minimum wall thickness [mm]**
≤ 38	1,75
> 38 ≤ 50	2,16
> 50 ≤ 70	2,40
> 70 ≤ 75	2,67
> 75 ≤ 95	3,05
> 95 ≤ 100	3,28
> 100 ≤ 125	3,50

2.9.3 The wall thickness of boiler tubes heated by heating gases with temperature above 800°C is to be not greater than 6,3 mm.

2.9.4 The minimum wall thickness of standpipes and branches is determined according to 2.9.2. The wall thickness is to be not less than:

$$s = 0{,}04\ D_V + 2{,}5 \quad [\text{mm}] \quad (2.9.4\text{-}1)$$

This wall thickness is to be maintained for a length not less than L, from the outside surface of the vessel, or to the first connection, flange or butt weld:

$$L = 3{,}5\ \sqrt{D_V \cdot s}, \quad [\text{mm}] \quad (2.9.4\text{-}2)$$

Table 2.9.2-2
Thickness of plain tubes under external pressure

Design pressure, [bar]											Wall thickness, [mm]
Outside diameter, [mm]											
38	44,5	51	57	63,5	70	76	82,5	89	95	102	
–	–	–	–	–	–	–	–	–	26,9	25,2	5,89
–	–	–	–	–	–	–	26,2	24,1	22,8	21,4	5,38
–	–	–	–	–	–	24,1	22,1	20,7	19,3	17,9	4,88
–	–	–	27,6	24,8	22,8	20,7	19,3	17,9	16,6	15,9	4,47
–	29,3	25,5	22,8	20,7	18,9	17,3	15,9	14,8	13,7	12,7	4,06
26,6	22,8	20,7	17,9	15,9	14,8	13,1	12,4	11,4	10,3	9,6	3,66
20,3	16,9	14,8	13,1	12,1	11,0	9,6	8,9	8,2	7,6	6,9	3,25
14,8	12,4	10,7	9,6	8,6	7,6	–	–	–	–	–	2,95

3 BOILERS

3.1 GENERAL PROVISIONS

3.1.1 The general provisions concerning the supervision, technical documentation, manufacture, materials and general requirements for boilers and also strength calculations standards for boiler elements are set forth in Sections 1 and 2.

3.1.2 The boilers shall remain operative under the environmental conditions specified in the *Rules, Part 7. - Machinery Installations*, 1.6.

3.2 CONSTRUCTION REQUIREMENTS

3.2.1 The thickness of tube walls thinned in the process of bending shall not be less than the design value after process of bending.

3.2.2 The use of long and short stays and also that of stay tubes exposed to bending or shearing stresses should be avoided. Stays, strength walls, reinforcements etc. shall not have abrupt changes in cross-sections.

Control driller holes shall be provided for at short-stay ends as shown in fig. 5.2 and 5.3 of the Appendix. Boiler walls into which longitudinal stays are welded are to be relieved by reinforcing plates.

3.2.3 For flat walls reinforced by short stays and exposed to flame and high-temperature gases, the distance between the stay centres shall not be greater than 200 mm. The thickness of flat end plates exposed to heating gases with high temperatures should not exceed 30 mm.

3.2.4 Corner stays of fire tube boilers shall be arranged at a distance of not less than 200 mm from the furnaces. Where flat walls are reinforced with welded-on girders, this should be done so that the load involved is transferred directly to the boiler shell or its other most rigid parts.

The angle made by gusset stays and the longitudinal axis of the boiler shall not exceed 30^o (see Fig. 2.4.2.1-3). Welds of gusset stays are to be executed as full strength welds, and the stress concentrations at the welds are to be minimised by suitable component geometry.

3.2.5 The distance between furnaces and boiler shell shall not be less than 100 mm. The distance between any two furnaces shall not be less than 120 mm.

3.2.6 Branches and nozzles shall be of rigid construction and minimum length sufficient for fixing and dismantling boiler mountings and fittings without removing the insulation.

Branch pieces shall not be subjected to excessive bending stresses and shall be reinforced by stiffening ribs, if so required.

Branches must be protected against the radiant heat effect.

3.2.7 Pads intended for installation of mountings, fittings and pipes as well as branches, sleeves and nozzles passing through the entire thickness of the boiler wall shall generally be attached by welding from both sides. Branches and nozzles may also be welded by a fillet joint, with single-edge preparation, using removable backing strip or by some other method that ensures penetration throughout the thickness of the part being attached.

3.2.8 For drums and headers with a working pressure of more than 25 bar, thermal stress analysis shall be made. The thermal stress analysis may be waived, if gas temperatures at the location of boiler drums do not exceed 1000^{o}C, the wall thickness of drums is up to 30 mm, and the drums and headers are protected from the radiant heat in accordance with 2.1.3.3.

It is recommended that in vertical fire-tube boilers the gas uptake pipe passing through the steam space of the boiler are protected from direct exposure to hot gases.

3.2.9 Where use is made of non-metal sealing gasket, throat and handhole closures shall be so designed as to prevent the possibility of gasket being forced out.

This can be achieved with a rim or spigot on external side of a cover plate. The height of the rim or spigot must be at least 5 mm greater than the thickness of the packing. The gap between rim or spigot and the edge of the opening is to be not more than 1,5 mm.

3.2.10 A name-plate indicating all principal particulars of boilers shall be provided in a conspicuous place.

- manufacturer's name and address;
- serial number and year of manufacture;
- maximum allowable working pressure [bar];
- steam output [kg/h];
- allowable superheated steam temperature [^{o}C].

3.2.11 The fastening elements of the boiler, apart from those which are not stressed, shall not be attached by welding directly to boiler walls (shell, ends, headers, drums, etc.), but shall be attached by means of welded-on plates.

3.3 MOUNTINGS, FITTINGS AND GAUGES

3.3.1 General requirements

3.3.1.1 All boiler mountings shall be fitted on special welded on branches, nozzles and pads and be secured on those, as a rule, by studs or bolts. The studs shall have a full thread holding in the pad for a length of at least one external diameter. The bore of threaded nozzle fitted mountings is allowed to be not greater than 15 mm, special pads being used for attaching them to the boiler.

3.3.1.2 The valve covers shall be secured to valve cases by studs or bolts. Valves with bore diameters of 32 mm and less may have screwed covers provided that they are fitted with reliable stops.

3.3.1.3 The valves and cocks shall be fitted with open and shut position indicators. Position indicators are not required where the design allows to see without difficulty whether the fittings are open or shut.

Valves are to be arranged to be shut with a clockwise motion of the hand wheels.

3.3.2 Feed valves

3.3.2.1 Each main boiler and each auxiliary boiler for essential services shall be equipped with at least two feed valves. The common inlet pipe for main and auxiliary feed systems is allowed. Auxiliary boilers for other services and also waste - heat boilers may have one feed valve each.

3.3.2.2 Feed valves shall be of a non-return type (check valves). A shut-off valve shall be installed between the check valve and the boiler. Check and shut-off valves may be connected to a single stand pipe at the shell. The shut-off valve shall be fitted directly on the boiler or to an economizer which forms an integral part of the boiler.

3.3.2.3 The requirements concerning the feed water system are given in Chapter 12, of the *Rules, Part 8 - Piping*.

3.3.2.4 The feedwater is to be introduced into the boiler in such a manner that it does not impinge directly on surfaces exposed to hot gases.

3.3.3 Water level indicators

3.3.3.1 Each natural - circulation boiler with free water evaporating surface shall be provided with at least two independent water level indicators with transparent faces (3.3.3.3). In agreement with the *Register*, one of these indicators may not be installed when provision is made on boiler for the lowest water level protective devices, as well as the lowest and highest water level alarms (the transducers of protective and signalling systems shall be independent and shall have different measuring points) or for remote water level indicator of an approved type with separate measuring points.

Natural-circulation boilers with a steaming capacity of 750 kg/h, steam generators, waste-heat boilers with free water evaporating surface and steam accumulators of waste-heat boilers may be provided with one water level indicator having a transparent face.

3.3.3.2 Forced circulation boilers shall be provided, instead of the water level indicators, with two independent alarms to signal a shortage of water supply to the boiler. A second alarm is not required, if the oil burning installation is in compliance with *Rules, Part 13, Automation*, item 4.7.2.1.

This requirement is not applicable to the waste-heat boilers.

3.3.3.3 Flat prismatic glass shall be used in water level indicators having a working pressure of less than 3,2 MPa. Protective devices against splinters and escaping steam are to be fitted to safeguard in the event of breakage. For boilers having a working pressure of 3,2 MPa and upwards, sets of mica sheets shall be used instead of flat glass, or flat glass with mica sheets protecting the glass from water and steam effects or other materials resistant to destructive action of the boiler water.

3.3.3.4 Cylindrical boilers are to be fitted with one water level gauge in the boiler centre line and with one water level gauge at one of the sides. Where this is not possible, the water level gauges are to be fitted one on each side of the boiler.

Where a steam and water drum, for water tube boilers, exceeds 4 m in length, two water level gauges are to be fitted one on each side of the drum.

Water level gauges are to be fitted so that the lower end of the glass is at the same height as the top of the uppermost tubes.

3.3.3.5 All water level indicators shall be provided with shut-off devices both on the water and steam sides.

Shut-off devices shall have safe drives for disconnection of the devices in case of glass breakage.

3.3.3.6 Water level indicators shall have the possibility of separately blowing off the water and steam spaces. Blow-down ducts shall have an inside diameter of not less than 8 mm. The design of water level indicators shall prevent the gasket materials from being forced into the ducts and to allow cleaning of the blow-down ducts as well as replacing of glasses while boiler is in operation.

3.3.3.7 Water level indicators shall be so installed that the lower edge of the gauge slot is positioned below the lowest water level in boiler by not less than 30 mm. However, the lowest water level shall not be above the centre line of the visible portion of water level indicator. Water level indicators must enable reading of the water level despite the movements and inclinations of the ship.

3.3.3.8 Water level indicators shall be connected to the boiler by means of independent branch pieces. The branches shall be protected from exposure to hot gases, radiant heat and intense cooling.

Water gauges and connecting pipes shall not be allowed to carry nozzles or branch pieces to be used for other purposes.

3.3.3.9 The connecting lines between boiler and water level indicator must have an inside diameter of at least 20 mm. They must be installed without sharp bends, avoiding water and steam pockets.

3.3.3.10 The design dimensions, number, location and lighting of water level indicator shall provide an adequate visibility and reliable control of boiler water level. Where water level visibility is inadequate, irrespective of the height of water level indicator location or where the boilers are remotely controlled, provisions shall be made for highly reliable remote water level indicators, or other types of water gauges approved by the *Register* and installed in the boiler control stations. These requirements are not applicable to waste-heat boilers and their steam accumulations.

3.3.4 Lowest water level and highest heating-surface point

3.3.4.1 Each natural-circulation boiler with a free water evaporating surface shall have its lowest water level marked on the boiler water level indicator with a reference line drawn on the gauge frame or body. Additionally, the lowest water level shall be marked on a plate with a reference line and the inscription “lowest level”.

This plate shall be attached to the boiler shell close to the water level indicators.

The reference line and plate shall not be covered over with boiler insulation.

3.3.4.2 The lowest water level in the boiler in all cases shall be not less than 150 mm above the highest heating surface point. This distance shall also be maintained when the ship is lifted up to 5^{o} on either side and in all possible service trim conditions.

In case of boilers with design steaming capacities less than 750 kg/h, the said minimum distance between the lowest water level and the highest heating-surface point may be reduced to 125 mm.

3.3.4.3 The highest heating surface point is the highest point on a heated surface, which is in contact with water and which is exposed to radiant heat or which is heated with gases whose temperature exceeds 400^{o}C at a maximum continuous rating. The position of the upper ends of the upper most downcomers is assumed to be the highest point of water-tube boiler.

In addition, the lowest water level is to be fixed in such a way that the dropping time (time needed for the water level, under conditions of interrupted feed and allowable steam output, to drop from the lowest water level to the highest heating surface point) is not less than 7 minutes.

For boilers with automatic regulation according to 4.2 dropping time of 5 minutes is required.

3.3.4.4 Fire tube boilers shall be fitted with a position indicator for the highest heating surface point which is to be securely attached to the boiler wall close to the lowest water level plate and to have the inscription "highest heating surface point".

3.3.4.5 The requirements for position of the highest heating surface point and the relevant position indicator do not apply to waste heat boilers, forced circulation boilers, economizers and steam superheaters.

3.3.5 Pressure gauges and thermometres

3.3.5.1 Each boiler shall have at least two pressure gauges connected with steam space by separate pipes fitted with stop valves or stop cocks.Three-way valves or cocks shall be provided between the pressure gauge and the pipe, thus making it possible to shut off the pressure gauge from the boiler, connect it to the atmosphere, blow off the connecting pipe and install the control pressure gauge.

3.3.5.2 One of the pressure gauges shall be installed on the front of the boiler, the other at the main engine control station.

3.3.5.3 Boilers with design steaming capacities below 750 kg/h and waste-heat boilers are allowed to have one pressure gauge.

3.3.5.4 A pressure gauge shall be provided at the water outlet from the economizer.

3.3.5.5 Pressure gauges shall have a scale sufficient to allow boiler hydraulic testing. The pressure gauge scale shall have a red line to mark the working pressure in the boiler.

3.3.5.6 Pressure gauges fitted on boilers shall be protected from the heat emitted by the hot boiler surfaces.

3.3.5.7 The pressure gauges shall be duly tested and marked with the date of testing carried out by the competent authorities recognized by the *Register*.

3.3.5.8 Steam superheaters and economizers shall be equipped with thermometers. Remote temperature control does not obviate the need for providing local thermometers even in its direct vicinity.

3.3.5.9 Temperature gauge is to be fitted at inlet and outlet of exhaust gases in wasteheat boilers.

3.3.6 Safety valves

3.3.6.1 Each boiler shall not have less than two spring-loaded safety valves of identical construction and equal size, to be installed on drums, as a rule, on a common branch piece and one valve to be fitted on the superheater outlet header.

Safety valve superheater is to be adjusted to open before safety valves on drum.

Safety valves of the impulsive action type are recommended for steam boilers having a working pressure of 4,0 MPa and more.

One safety valve is sufficient for steam boilers with design steaming capacities below 750 kg/h.

3.3.6.2 The aggregate cross-sectional area of safety valves shall be not less than that determined from the formulae:

– for saturated steam:

$$A = k \cdot \frac{G}{10{,}2 \cdot p + 1}, \qquad [\text{mm}^2] \quad (3.3.6.2.1)$$

– for superheated steam:

$$A = k \cdot \frac{G}{10{,}2 \cdot p + 1} \cdot \sqrt{\frac{v_p}{v_z}}, \quad [\text{mm}^2] \quad (3.3.6.2.2)$$

where:

A – aggregate cross-sectional area of safety valves, [mm^2],
G – design steam capacity, [kg/h],
p – working pressure, [MPa],
v_p – specific volume of superheated steam at the appropriate working pressure and temperature, [m^3/kg],
v_z – specific volume of saturated steam at the appropriate pressure, [m^3/kg],
k = factor as per Table 3.3.6.2

Table 3.3.6.2

Valve lift h, [mm]	Factor k
$\frac{d}{20} \le h < \frac{d}{16}$	22
$\frac{d}{16} \le h < \frac{d}{12}$	14
$\frac{d}{12} \le h < \frac{d}{4}$	10,5
$\frac{d}{4} \le h < \frac{d}{3}$	5,25
$\frac{d}{3} \le h$	3,3
d – internal diameter of valve seat, [mm]. h – valve lift, [mm].	

Safety valves shall not be less than 25 mm and where only one safety valve is sufficient not less than 50 mm in diameter.

If specially approved by the *Register*, the use of valves with smaller cross-sectional areas than required by formulae 3.3.6.2.1 and 3.3.6.2.2 may be allowed, provided it is proved experimentally (according to ISO 4126-1) in the presence of *Register*, that each of these valves has a discharge capacity not lower than the design steam capacity of the boiler.

3.3.6.3 The cross-sectional area of the safety valve installed on the non-disconnectable superheater may be included in the aggregate cross-sectional area of the valves to be determined from formulae 3.3.6.2.1 and 3.3.6.2.2. This area shall not amount to more than 25 percent of the aggregate area of the valves.

3.3.6.4 The safety valves shall be adjusted to operate at the pressure of 3 to 5 percent exceeding the working pressure value. When setting the safety valves on a superheater, the pressure drop in superheater is to be taken into account.

When lifted, the safety valves of main and auxiliary boilers for essential services, shall fully interrupt the outgoing steam flow, in case of the pressure drop in the boiler, not below 0,85 of the working pressure.

3.3.6.5 Economizers shall be provided with spring loaded safety valves with not less than 15 mm in diameter.

The safety valve must open when the maximum allowable working pressure of the economiser is reached. The safety valve is to be designed that, even if shut-off devices between the economiser and the boiler are closed, the maximum allowable working pressure of the economiser is not exceeded by more than 10%.

3.3.6.6 Where safety valves are fitted on a common branch, the cross-sectional area of the branch shall not be less than the aggregate cross-sectional area of valves for valves with a lift greater than d/4, and for other valves shall not be less than 1/2 of the aggregate cross sectional area of valves.

3.3.6.7 Waste steam pipes are to be led to the atmosphere. They must not impose additonal load to the safety valve connections. The cross-sectional area of the waste steam branch of safety valve and of the pipe connected thereto, shall not be less than twice the aggregate area of the valve opening, for valves with a lift greater than d/4, and for other valves shall not be less than 1,1 of the aggregate cross sectional area of the valve.

Where more valves are connected to a common waste steam pipe, its cross sectional area is not to be less than the combined cross sectional areas of waste steam pipes leading thereto.

The safety valves of waste heat boilers should have separate waste steam pipes.

3.3.6.8 To remove the condensation water, a drain pipe without any stopping device, which leads into bilge well, shall be provided on the valve body or on the waste steam pipe, if the latter is located below the valve.

3.3.6.9 Safety valves shall be connected directly to the boiler steam space without any stopping device. Supply pipes leading to the safety valves are not allowed to be installed inside the boiler. No provision is to be made on safety valve bodies or their connections for steam extraction devices for other purposes.

3.3.6.10 Valves shall be so arranged that they can be lifted by a special hand-operated easing gear. Easing gear of one of the valves shall be operated from the boiler room and that of the other valve from other readily accessible place outside the boiler room.

Remote control gear for safety valves of the steam superheaters, waste heat boilers and their steam accumulators (separators) can be operated only from the boiler room.

3.3.6.11 Safety valves shall be so designed that they could be sealed or provided with an equivalent safeguard to prevent the valves from being adjusted without knowledge of the operating personnel.

Springs of the safety valves shall be protected from direct exposure to steam and shall be manufactured from heat and corrosion resistant materials, as well as the sealing surfaces of seats and valves.

Safety valves are to be made with working parts having adequate clearances to ensure complete freedom of movement. Valves are to be so designed that in the event of fracture of springs they cannot lift out of their seats.

3.3.6.12 The capacity of safety valve is checked by an accumulation test. During a test of 15 minutes, or of 7 minutes for watertube boilers, with the stop valves closed and under full firing conditions, the accumulation of pressure is not to exceed 10 per cent of the design pressure. During this test no more feed water is to be supplied than is necessary to maintain a safe working water level.

3.3.7 Shut-off valves

3.3.7.1 Each boiler shall be separated from all pipelines leading to it by means of shut-off valves secured directly to the boiler.

3.3.7.2 In addition to local control, the shut-off-valves of the main and auxiliary steam lines shall be provided with remote control gears for the operation from the upper deck or from other readily accessible position outside the boiler room.

3.3.7.3 Where there is one main boiler or an auxiliary boiler for essential services installed on board the ship complete with a superheater or economizer, the superheater and economizer shall be so arranged as to be shut-off from the boiler.

3.3.7.4 The requirement for steam lines and boiler blow-down pipes are set forth in the *Rules Part 8 - Piping*, Chapter 13.

3.3.8 Blow-down valves and drain valves

3.3.8.1 Boilers, their steam superheaters, economizers and steam accumulators shall be fitted with blow-down valve and with drain valves.

Blow-down and drain valves shall be fitted directly to the boiler shell. At working pressure below 1,6 MPa these valves may be installed on welded-on profiled branch pieces.

3.3.8.2 Inside diameter of blow-down valves and pipes shall not be less than 20 mm and not more than 40 mm.

For boilers with design steam capacity below 750 kg/h, diameter of valves and pipes shall not be less than 15 mm.

3.3.8.3 In boilers with free water evaporating surface the scum arrangements shall ensure scum and sludge removal from the entire evaporating surface.

3.3.9 Salinometer valves

Each boiler shall be provided with at least one salinometer valve or cock. The fitting of such valves or cocks on pipes and branches intended for other purposes is not allowed.

3.3.10 Valves for deaeration

Boilers, steam superheaters and economizers shall be equipped with sufficient number of valves or cocks for deaeration.

3.3.11 Openings for internal inspection

3.3.11.1 Boilers, heat exchangers and pressure vessels, shall be provided with manholes for inspection, cleaning and maintenance of all internal surfaces. Welds exposed to high stresses and parts exposed to radiant heat must be accesible for inspection. Where the provision of manholes is not possible, arrangements shall be made for sight holes.

3.3.11.2 Manhole openings shall have dimensions in the clear not less than:

- 300x400 mm – for oval openings,
- 400 mm – for round openings.

Inspection openings are required to have the following minimum dimensions:

- Holes for the head – 220x320 mm or Φ 320 mm;
- Handholes-87x103 mm;
- Sight holes – Φ 50 mm.

Oval manholes in cylindrical shells shall be so positioned that the minor axis of manhole is arranged longitudinally.

3.3.11.3 Vertical fire-tube boilers shall have at least two sight holes arranged in the shell opposite to each other in the area of the working water level.

3.3.11.4 All boiler parts such as may prevent or hinder free access to and inspection of, internal surfaces shall be of a removable type.

3.3.11.5 Doors of the internal type for the openings not larger than 180x230 mm need to be fitted with one stud which may be forged integral with the door. Doors for larger openings are to be fitted with two studs.

3.3.11.6 Vessels over 2 m long must have inspection openings at each end.

3.3.11.7 Inspection and access openings on pressure vessels and heat exchangers are not required where internal inspection can be carried out by removing or dismantling parts, or where experience has proved the unlikelihood of corrosion or deposits, or where the construction of vessels excludes the possibility of inspection through such openings.

3.4 EXHAUST GAS ECONOMISERS

3.4.1 Suitable equipment is to be fitted to prevent steam from being generated in the economiser. This may take the form of a circulating line from the economiser to a feed water tank to enable the economiser to be cooled, or of a by-pass enabling the economiser to be completely isolated from the flow of exhaust gas.

3.4.2 Soot deposits on economiser tubes which can cause fire hazard must be removed with a soot cleaning equipment.

3.4.3 Shell type exhaust gas heated economizers that may be isolated from the steam plant system

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

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

3.4.3.2 Where a shell type economizer is capable of being isolated from the steam plant system, it is to be provided with at least one safety valve, and when it has a total heating surface of 50 m^2 or more, it is to be provided with at least two safety valves in accordance with 3.3.6.5.

3.4.3.3 Safety valves for shell type exhaust gas heated economizers are to incorporate features that will ensure pressure relief even with solid matter deposits on the valve and guide, or features that will prevent the accumulation of solid matter in way of the valve and in the clearance between the valve spindle and guide.

3.4.3.4 Where no safety valves incorporating the features described in 3.4.3.3 are fitted, a bursting disc discharging to suitable waste steam pipe is to be fitted in addition to the valve.

The alternative arrangements for ensuring pressure relief in the event of solid matter on the valve and guide are to function at a pressure not exceeding 1.25 times the economizer approved design pressure and are to have sufficient capacity to prevent damage to the economizer when operating at its design heat input level.

3.4.3.5 To avoid the accumulation of solid matter deposits on the outlet side of safety valves and bursting discs, the discharge pipes and safety valve/bursting disc housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economizer where it will not pose threats to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements.

3.4.3.6 Every shell type economizer is to be provided with a means of indicating the internal pressure in accordance with 3.3.5.4.

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

3.4.3.8 The manufacturer is to provide operating instructions for economizer which are to include reference to:

- feed water treatment and sampling arrangements,
- operating temperatures and operating pressure,
- inspection, maintenance and cleaning procedures,
- the need to maintain adequate water flow through the economizer under all operating conditions,
- procedure for using the economizer in the dry condition,
- procedures for operational checks, maintenance and overhaul of safety devices.

3.5 THERMAL FLUID BOILERS

3.5.1 The requirements of the present chapter apply to thermal fluid boilers in which organic liquids (thermal oils) are heated by firing, exhaust gases or electricity to temperatures below their initial boiling point at atmopheric pressure.

3.5.2 Definitions:

- The maximum allowable working pressure is the maximum pressure which may occur in the individual parts of the equipment under service conditions.
- The thermal oil temperature is the temperature of the thermal oil at the centre of the flow cross-section.
- The discharge temperature is the temperature of the thermal oil immediately at the heater outlet.
- The return temperature is the temperature of the thermal oil immediately at the heater inlet.
- The film temperature is the wall temperature on the thermal oil side.

3.5.3 The following documentation is to be submitted to *Register* for approval:

- a description of the system (the discharge and return temperature, the maximum film temperature, the total volume of the system, physical and chemical characteristics of the thermal oil);
- drawings of the heaters, the expansion vessel and the drainage and storage tanks;
- piping flow chart with fittings;
- circuit diagrams of the electrical control system.

3.5.4 The requirements for material, manufacture and strength calculation of heaters and expansion vessels are set forth in chapters 1,2,3 and 6.

The surfaces which come into contact with the thermal oil are to be designed for the maximum allowable working pressure subject to a minimum gauge pressure of 10 bar.

The requirements which apply to oil burning installations are set forth in chapter 5.

The piping and fittings in thermal oil systems must comply with *Rules, Part 8-Piping*, chapter 16.

3.5.5 Heaters are to be designed thermodynamically that neither the surfaces nor the thermal oil become excessively heated at any point.

3.5.6 Heaters heated by exhaust gas are to be provided with inspection openings at the exhaust gas inlet and outlet.

Oil fired heaters are to be provided with inspection openings for examination of the combustion chamber.

3.5.7 Each boiler shall be equipped with shut-off device at the thermal fluid inlet and outlet. The devices shall be arranged in readily accessible position safe for maintenance and shall be remote controlled.

Heaters are to be equipped with safety valves having a blow-off capacity at least equal to the increase in volume of the thermal oil at the maximum heating power, without the maximum allowable working pressure being exceeded by over 10%.

Heaters are to be capable of being completely drained.

3.5.8 If the permitted discharge temperature (about 50°C lower than the maximum allowable film temperature) is exceeded, for oil fired heaters the heat supply must be switched off, and for heaters heated by exhaust gases an alarm is to be activated.

The flow of the thermal oil must be indicated and monitored by a flow monitor. If the flow rate falls below a minimum value, the heating must be cut out in case of oil fired heaters, while in case of heaters heated by exhaust gases an alarm must be activated.

3.5.9 The discharge temperature of heaters heated by exhaust gas must be controlled independently of the control of the engine output by automatic regulation of the heat input or in accordance with *Rules, Part 8-Piping*, item 16.7.1.

3.5.10 Measures must be taken to ensure that the maximum allowable film temperature is not exceeded in case of failure of the circulating pump.

3.5.11 If the circulating pump is stationary, an alarm is to be provided in case the diesel engine is started, and start up of the burner must be prevented by interlocks in case of oil fired heaters.

3.5.12 The heaters must be equipped with a leakage detector which, when actuated, trips an alarm and shuts down the circulating pump as well as the heating system in case of oil fired heaters. When a leakage detector is actuated, the start up of the burner must be prevented.

3.5.13 Heaters heated by exhaust gases are to be fitted with a permanent system for extinguishing and cooling in the event of fire approved by *Register*. Heaters must be fitted with a fire alarm.

The exhaust gas feed must be arranged that the water cannot penetrate the engine.

3.5.14 If the specified smoke gas temperature or exhaust gas temperature is exceeded, an alarm must be ensured and for oil fired heaters the heating must be switched off.

3.5.15 Each boiler shall be fitted with pressure gauges according to 3.3.5, unless the boiler working pressure is equal to the atmospheric pressure.

3.5.16 Thermometers shall be provided at thermal fluid inlet and outlet. The thermometer measuring range shall be at least by 10 per cent more than the thermal fluid service temperature.

Temperature measuring devices are to be fitted at the heaters outlet in the flue gas or exhaust gas stream.

3.5.17 Waste-heat boilers shall be provided with a shut-off device to stop gas supply in case of operation of protective devices.

3.5.18 For electrically heated heaters, the same requirements as for oil fired heaters apply.

3.5.19 A name plate with the following information must be attached to the heater:

- manufacturer's name and address;
- serial number;
- year of manufacture;
- maximum allowable heating power;
- maximum allowable operating pressure;
- maximum allowable discharge temperature;
- minimum flow rate;
- liquid capacity.

3.5.20 The equipment must be capable of being manually operated. In this case control of flow and temperature of the thermal oil must function.

3.5.21 Testing of thermal oil system

After completion of installation on board, the system including associated monitoring equipment is to be subjected to pressure, tightness and operational tests in the presence of the *Register*.

4 CONTROLS, PROTECTIVE DEVICES, GOVERNORS AND ALARMS FOR BOILERS

4.1 GENERAL PROVISIONS

4.1.1 Requirements of the present part apply to boilers for which continuous attendance is necessary.

Requirements for controls, governors, protective devices and alarms for unattended boilers are specified in the *Rules, Part 13 - Automation*, 4.7.

4.1.2 Control and monitoring systems and their elements shall comply with the requirements of *the Rules, Part 13 - Automation*, Chapters 2 and 3.

4.2 GOVERNORS AND CONTROLS

4.2.1 Main watertube boilers and auxiliary watertube boilers for essential services shall be equipped with feed water governors and combustion controls. For other types of boilers these governors and controls are recommended.

4.2.2 Governors and controls shall be capable of maintening the water level and other variable parameters (for example steam pressure) within predetermined limits over the entire steam load range and shall ensure a quick change-over from one state of operation to another one.

4.2.3 In boilers with superheaters, the superheated steam temperature must be automatically controlled.

In continuous flow boilers, the feed water supply may be automatically controlled as a function of the fuel supply.

In exhaust gas boilers, the steam pressure must be automatically controlled by regulating the heat input or by means of a by-pass system.

4.3 PROTECTIVE DEVICES

4.3.1 Boilers shall be equipped with protective device which cuts out and interlocks the firing system when the maximum allowable working pressure is exceeded and when the water falls below the specified minimum water level. This protective device shall not be able to be swiched off during the boiler service.

4.3.2 In boilers with superheaters, protective device which cuts out the heating is case of superheated steam temperature rise above allowable limit.

In continuous flow boilers, protective device which cuts out the heating in case of unallowable decrease in water flow is to be fitted.

4.3.3 Boilers with automatic combustion controls shall be protected according to requirements in 5.5 of the present Rules.

4.4 ALARMS

4.4.1 Boilers with automatic feed water governors and combustion controls shall be equipped with visual and audible alarms.

4.4.2 Light and sound alarms shall function in cases of:

- water level reaching its lowest limit,
- water level reaching its highest limit,
- working pressure reaching its highest limit, for exhaust gas boilers,
- failures in the automatic control systems or protective devices,
- failures in the boiler oil burning system, (5.5.2),
- feed water salinity rise above the permissible value (see *Rules, Part 8 - Piping*, 12.2.4 and the *Rules, Part 13 - Automation*, Table 4.1).

4.4.3 The lowest level limit alarms of the main and auxiliary boilers for essential services shall function prior to the operation of the protective devices.

4.4.4 Provision shall be made for manual disconnection of the audible alarm after its operation.

5 OIL BURNING INSTALLATIONS OF BOILERS

5.1 GENERAL PROVISIONS

5.1.1 General provisions concerning the supervision,technical documentation, manufacture and general requirements for oil burning installations are set forth in Chapter 1.

5.1.2 All equipment to be used in oil burning installations such as pumps, fan, quick-closing valves, electric drives shall be approved by the *Register* and shall be manufactured and tested under supervision of the *Register* or of the other competent authority recognized by the *Register*. Control, protective, interlocking and signalling devices shall comply with the requirements of *Part 13 - Automation*.

5.1.3 Electrical equipment for oil burning installations shall comply with the requirements of the *Rules, Part 12 - Electrical equipment*.

5.1.4 Oil fuel used for boilers shall have a flash point in accordance with the *Rules, Part 7 - Machinery installations*, 1.1.2.

5.1.5 This part of Rules applies to automatic, semi automatic and manually operated oil firing equipment for boilers and thermal fluid boilers.

The requirements for oil burners burning waste oil are subject to special consideration by the *Register*.

5.2 PIPES AND FITTINGS

5.2.1 The pipes and fittings of burning installations shall comply with the requirements specified in *Rules, Part 8-Piping*.

5.2.2 Flexible pipes of a type approved by the *Register* may be used for the fuel supply line only directly in front of the burner.

5.2.3 Where fuel oil is preheated in tanks at atmospheric pressure, the requirements *in Rules, Part 8-Piping*, item 8.3 are to be complied with.

The design and construction of pressurised fuel oil heaters are subject to the requirements in chapter 6.

5.2.4 Temperature or viscosity control must be in accordance with *Rules, Part 13-Automation*, Table 4.1.

5.2.5 Where oil fuel is preheated, it is necessary to take structural measures to prevent overheating of the fuel in the heaters when the steaming capacity of the boiler is reduced or the burners are shut off, or when change is made from heavy to light oil. If only steam preheaters are present, fuel which does not require preheating must be available to start up the boilers.

5.3 OIL BURNING INSTALLATIONS

5.3.1 The burners shall be so designed as to ensure the possibility of controlling the size and shape of the flame jet.

Boiler parts which might suffer damage from flames are to be adequately protected.

5.3.2 In case of a variable - delivery burners provision shall be made for controlling the amount of combustion air.

5.3.3 Structural measures shall be taken to prevent the burners from being turned and removed from the working position until fuel supply to them is stopped. The high voltage ignition system must be automatically disconnected when this occurs.

5.3.4 Where pneumatic or steam-atomizing burners are used, structural measures shall be taken to prevent penetration of air or steam into fuel and vice versa.

5.3.5 Observation openings shall be provided for watching the combustion process in the boiler furnace. They are to be arranged and designed in such a way that any danger from flame blowbacks is avoided.

5.3.6 The firing system shall be arranged as to allow unburnt fuel to be safely drained. Where burners are blown through after shut-down, provision must be made for the safe ignition of the residual oil ejected.

5.3.7 Every burner must be equipped with an igniter. The ignition is to be initiated immediately after purging.

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

5.3.9 The inlets of the boiler fans are recommended to be protected against penetration of moisture and solids. The protection from moving parts if the burners is to be provided.

5.4 PURGING OF COMBUSTION CHAMBER

5.4.1 The combustion chamber and flues are to be adequately purged with air prior to every burner start up.

A threefold renewal of the total air volume of the combustion chamber and the flue gas ducts up to the funnel inlet is considered sufficient. Purging shall be performed with the total flow of combustion air needed for the maximum heating power of the firing system for at least 15 seconds.

5.5 SAFETY EQUIPMENT

5.5.1 Oil burning installation is to be equipped with two automatic quick-closing devices. They must not release the oil supply to the burners on start up and must interrupt the oil supply during operation if one of the following faults occurs:

- burner retracted or pivoted out of position;
- failure of the required pressure of the atomising medium (steam or compressed-air atomisers);
  failure of the oil pressure needed for atomisation (pressure atomisers);
  insufficient rotary speed of spinning cup (rotary atomisers);

- failure of combustion air supply or insufficient air pressure;
- actuation of limit switches (e.g. for water level or temperature);
- actuation of flame monitor (flame extinguished);
- failure of control power supply;
- failure of induced-draught fan or insufficient opening of exhaust gas register (dampers insufficiently opened).

One automatic quick closing device is required for oil supply line to igniter if the fuel oil pump is switched off after burner ignition.

5.5.2 Each installation is to be shut down automatically and secured by the oil burner control box if:

- a flame does not develop within the safety period following start up;
- a flame is extinguished during operation and an attempt to restart the burner within the safety period is unsuccessful;
- limit switches are actuated.

5.5.3 Burning installations shall be equipped with a burner flame-jet monitor. Such a monitor shall respond only to the flame - jet of the burner under control.

This appliance must comply with the following safety periods (the maximum permitted time during which fuel oil may be supplied to the combustion space in the absence of a flame):

- on burner start up 5 seconds;
- in operation 1 second.

5.5.4 The capacity of pilot burner is to be such that the burner itself could not maintain the boiler under pressure with the steam consumption completely stopped.

Where the pilot and main burners are simultaneously in operation and the protective devices are caused to function under conditions specified in 5.5.2, the pilot burner shall cease operation at the same time as the main burner.

5.5.5 The return line of burners with return lines must also be provided with an automatic shut off device. This requirement 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.

5.5.6 Burning installation of main and auxiliary boilers for essential services shall be capable of being manually controlled in case of emergence. Manual controls shall be provided directly at the boiler. In this case flame monitoring specified in 5.5.3 must remain operative.

5.5.7 Provision shall be made for the burning installation to be shut off from two stations, one of which shall be located outside of the boiler room.

5.6 TESTING OF OIL FIRING EQUIPMENT AFTER INSTALLATION

5.6.1 The reliable operation of the safety equipment and satisfactory combustion at all load settings is to be checked.

Purging time required prior to burner start up is to be determined.

5.6.2 The pressurised fuel oil system is to be subjected to a pressure and tightness test in accordance with *Rules, Part 8-Piping*, chapter 15

6 HEAT EXCHANGERS AND PRESSURE VESSELS

6.1 GENERAL PROVISIONS

6.1.1 General provisions concerning the supervision, technical documentation, manufacture and materials for heat exchangers and pressure vessels as well as strength calculation standards are set forth in Chapters 1 and 2.

6.1.2 The elements of heat exchangers and pressure vessels which come in contact with the sea water or other aggresive media shall be manufactured from the corrosion resistant materials. Where other materials are used, their protection against corrosion shall be subject to special consideration by the *Register* in each case.

6.2 CONSTRUCTION REQUIREMENTS

6.2.1 The requirements specified in 3.2.1, 3.2.2, 3.2.6, 3.2.7, 3.2.9 and 3.3.11 also apply to heat exchangers and pressure vessels.

6.2.2 Where necessary, the construction shall provide for thermal elongation of the shells and various parts of heat exchangers and pressure vessels.

6.2.3 The shells of heat exchangers and pressure vessels shall be provided with suitable lugs for reliable attachment to the foundations. Overhead attachments shall be provided, where necessary.

6.2.4 Every heat exchanger and pressure vessel must have a name plate which contains basic data about equipment.

6.3 FITTINGS AND GAUGES

6.3.1 Each heat exchanger, pressure vessel or their banks in permanent communication shall be fitted with safety valves directly connected to the vessel or to the branch without stopping devices. Where there are several non-communicating spaces, safety valves shall be provided for each space.Hydrophores shall be fitted with a safety valve to be installed on the water side.

In separate cases, in agreement with the *Register*, the departure from the present requirements may be permitted.

6.3.2 Safety valves shall generally be of a spring loaded type. In fuel and oil heaters it is allowed to use safety diaphragms of a type approved by the *Register* and installed on the fuel and oil side.

6.3.3 The discharge capacity of safety valves shall be such that under no conditions the working pressure is exceeded by more than 10 per cent. Safety valves are to be adjusted to a pressure 3-5 % exceeding the working pressure.

6.3.4 The safety valves shall be so designed as to allow their being sealed or fitted with an equivalent safeguard to prevent valve adjustment without the knowledge of the operating personnel. Materials used for springs and sealing surfaces of valves shall be capable of withstanding the corroding effect of the medium.

6.3.5 Round sight glasses may be installed on heat exchangers and pressure vessels only if this is necessary. Level indicators must be fitted on heat exchangers and pressure vessels which are heated and in which a fall of the liquid level can result in unacceptably high temperatures in the vessel walls. Level indicators and sight glasses shall be of a reliable design and shall have an adequate protection. Flat glass plates shall be used for level indication containing steam, fuel or oil. In deaerators cylindrical glasses may be used.

6.3.6 Heat exchangers and pressure vessels shall be fitted with shut-off valves, which are, generally, to be secured directly to the shell on welded plates and on short stiffened flanged pipes. Attachment with threads may be allowed on hydrophores.

6.3.7 Heat exchangers and pressure vessels shall be equipped with blow-through and drainage devices. Means of drainage which cannot be shut off are to be provided at the lowest point on the discharge side of the safety valves.

6.3.8 Each heat exchanger, pressure vessel or their banks in permanent communication shall be equipped with pressure gauges or compaund gauges. Where heat exchangers have several non-communicating spaces, pressure gauges shall be provided for each space.

Pressure gauges shall comply with the requirements set forth in 3.3.5.1, 3.3.5.5 and 3.3.5.7

6.3.9 Oil heaters where oil temperature may exceed 220°C shall be provided with signalling devices indicating the temperature in excess or the break of fuel flow, in addition to temperature control.

6.4 SPECIAL REQUIREMENTS FOR HEAT¸EXCHANGERS AND PRESSURE VESSELS

6.4.1 Air receivers

6.4.1.1 When lifted, the safety valves on air receivers of the main and auxiliary engines and of fire extinguishing systems shall fully stop the fluid bleeding in case of the pressure drop in the receiver to 85 per cent of the working pressure.

6.4.1.2 Where compressors, reduction valves or pipelines intended for air supply to air receivers are provided with safety valves which are so installed that the air supply to the air receivers under pressure exceeding the working pressure is excluded, the installation of safety valves on the air receivers is not obligatory. In this case, the air receivers shall be equipped with fusible plugs instead of safety valves.

6.4.1.3 The fussible plug shall have a fusion temperature of 100-130°C. The fusion temperature shall be punched out on the fusible plug. Air receivers having a capacity over 700 l shall be fitted with plugs not less than 10 mm in diameter.

6.4.1.4 Each air receiver shall be equipped with a device for moisture removal. In case of air receivers arranged horizontally, the moisture removed devices are to be provided at both ends of the receiver.

6.4.2 Condensers

6.4.2.1 The construction of condenser and their location on board ship shall be such as to enable tube replacement.

The shell of the main condenser shall generally be of steel welded structure.

The construction of condenser must fulfill the requirements specified in 6.2.2.

Baffles shall be provided inside the condenser, at excess pressure steam inlets, to protect the tubes from direct steam impact.

The tube attachments shall be so designed at to prevent sagging and hazardous vibration of tubes.

6.4.2.2 Covers of condenser water chambers shall be fitted with manholes in number and position as may be required for ensuring access to the tubes in any part of the tube nest for the purpose of expansion, packing replacement or plugging.

Cathodic protection is to be provided for water chambers, tube plates and tubes for prevention of electrolytic corrosion.

6.4.2.3 Main condenser shall ensure the operation under emergency conditions with any casing of the turbine set being disconnected.

6.4.2.4 Condenser shall be so designed as to enable the instrumentation specified in the *Rules, Part 9 - Piping*, 14.4 to be connected to it.

6.4.3 Heat exchangers and pressure vessels of refrigerating and fire fighting installations

Heat exchangers and pressure vessels of refrigerating and fire fighting installations shall comply with the requirements of the *Rules Part 11 - Refrigerating plants* and *Part 17-Fire protection*, respectively.

6.4.4 Pressure vessels of processing equipment for sea products

6.4.4.1 Pressure vessel covers which are periodically opened shall be provided with devices preventing their incomplete closing or spontaneous opening. It is also necessary to safeguard against the cover opening in case of excessive pressure or vaccum in the pressure vessel, as well as against pressurisation of the vessel in case of incomplete closing of the cover.

6.4.4.2 Inside arrangements of pressure vessels (mixers, coils, disks, diaphragms etc.) which interfere with the internal examination shall be of a removable type.

6.4.4.3 Light glasses not more than 150 mm in diameter intended for observation of the mixer working space may be fitted on the pressure vessels having pressure not exceeding 0,25 MPa

6.4.4.4 For pressure vessels having the pressure in excess of 0,25 MPa closing appliances of the loading holes shall be so constructed that in case of loss of cover sealing, steam is removed in direction safe for operating personnel.

6.4.4.5 Pressure vessels operating under vacuum and heated by steam or hot water of more than 115°C in temperature shall be fitted with safety valves to prevent, in case of the heating system leakage, an excessive pressure in the space operating under vacuum which is over 0,85 times the test pressure. In strength calculations of these vessels the design pressure, equal to that of the safety valve opening shall be taken.In this case, the design stresses in the pressure vesel walls shall not exceed 0,8 times the yield stress of material at the design temperature.

6.4.4.6 Strength of flanges, bolts or studs of covers which are periodically opened shall be confirmed by calculations. In this case, the design stresses in them shall not exceed 0,4 times the yield stress of material at the design temperature. The diameter of bolts or studs shall not be less than 16 mm.

6.4.4.7 For mixers heated by steam or water and also for walls of pressure vessel mixing chambers which are in contact with the processed sea products, allowance, c, to the design wall thickness, shall be taken as not less than 2 mm.

6.4.5 Testing of pressure vessels after installation on board

After installation on board, a check is carried out on the fittings of vessels and on the arrangement and setting of safety appliances, and operating tests are performed.

6.4.6 Compressed gas cylinders

6.4.6.1 Compressed gas cylinders are considered to be portable pressure vessels, specially manufactured for storage of compressed gas, refrigerant or CO_2 and are installed on board ship during navigation and can not be filled with existing means on the ship. Capacity of bottles is not more than 150 *l*, outside diameter ≤ 420 mm and a length ≤ 2000 mm.

6.4.6.2 The strength calculation shall be made in accordance with Chapter 2 and with the following requirements:

.1 for design pressure, *p*, specified test pressure according to current standards can be taken, which is subject to special consideration by the *Register* in each case.
For CO_2 bottles with filling factor of 0,67, specified test pressure is 250 bar.

.2 for mechanical characteristics of materials the following symbols are used:
- R_m - guaranteed minimum tensile strength, [N/mm^2];
- $\sigma_{0,2}$ – guaranteed 0,2% proof stress, [N/mm^2],
- R_{eH} - guaranteed yield point, [N/mm^2];

For allowable stress the smaller of the following two values is taken:

$$\sigma_d = \frac{R_{eH}\ (\sigma_{0,2})}{4/3} \qquad (6.4.6.2.2\text{-}1)$$

$$\sigma_d = \frac{0{,}75\ R_m}{4/3}$$ for normalized cylinders;

(6.4.6.2.2-2)

$$\sigma_d = \frac{0{,}9\ R_m}{4/3}$$ for quenched and tempered cylinders;

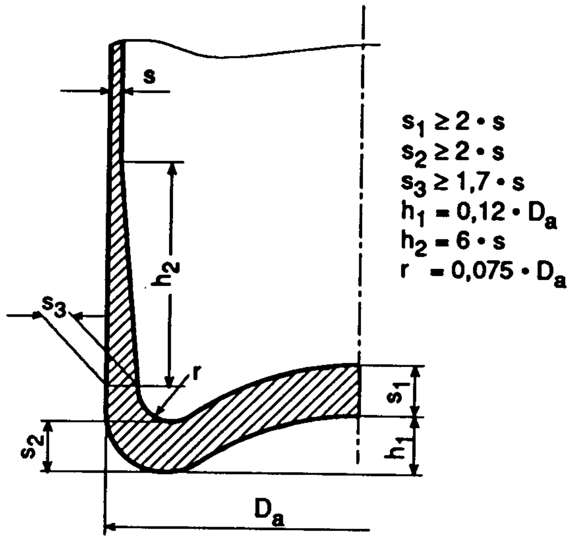


Fig. 6.4.6.2

6.4.6.3 Gas cylinders must be manufactured by methods approved by *Register*, using suitable materials.

The following documentation is to be submitted to *Register* for approval:

– a description of manufacturing process;
– specification of materials and heat treatment;
– drawings of cylinders and of fittings;
– strength calculation;
– test pressure [MPa];
– capacity [*l*] and empty weight [kg].

6.4.6.4 Testing of gas cylinders

.1 Two bottles-samples from each 200 originating from one melt and one heat treatment are to be taken.

.2 One longitudinal tensile test specimen, three transverse bending test specimens and a set of ISO V-type notched bar impact test specimens at – 20°C are to be taken from the sample cylinder.
On other sample cylinder the bursting test is to be carried out. Curve of pressure as a function of time at a room temperature is to be recorded.

.3 The cylindrical wall thickness of all sample cylinders is to be measured in transverse planes at three levels (neck, middle, base), and also the thickness of end plate.

.4 Examination of the inner surface of the neck and bottom portions of the sample cylinders is to be carried out in order to detect possible manufacturing defects.

.5 Hydrostatic testing of all cylinders and hardness testing of all quenched and tempered cylinders is to be carried out.

.6 Final visual inspection of cylinders, and a check of weight and volumetric capacity of about 10% of the cylinders. Manufacturer must establish the volumetric capacity and weight of each cylinder.

6.4.6.5 The following particulars shall be specified on the bottles:

.1 manufacturer;
.2 number of bottle;
.3 date of test;
.4 kind of gas;
.5 volume (capacity);
.6 test pressure;
.7 empty weight;
.8 stamp

7 APPENDIX

7.1 TYPICAL EXAMPLES OF ALLOWABLE WELDED JOINTS FOR BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

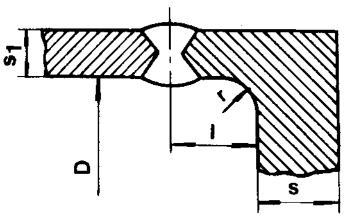
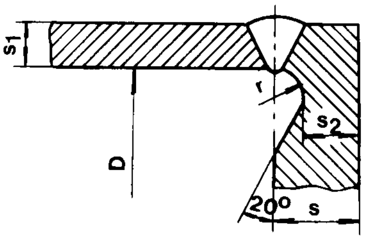
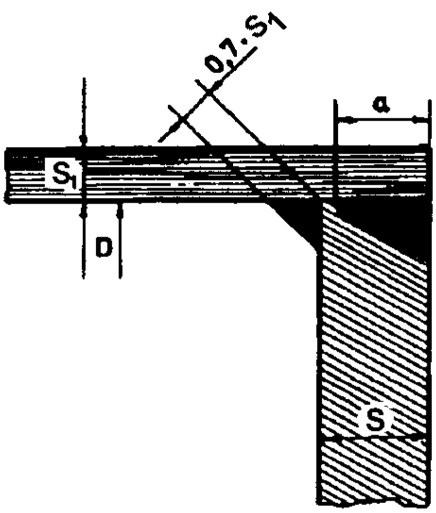
7.1.1 Dimensions of structural elements of the prepared edges of welded parts and dimensions of welds shall be taken according to national standards and with regards to the welding method used.

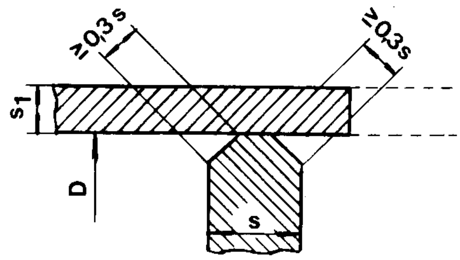
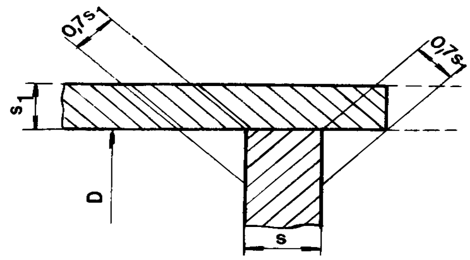
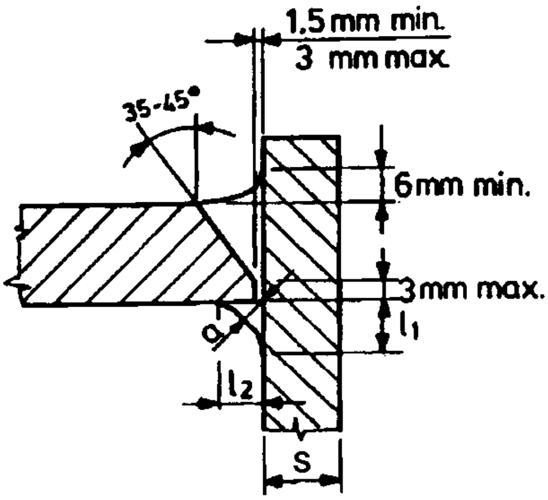
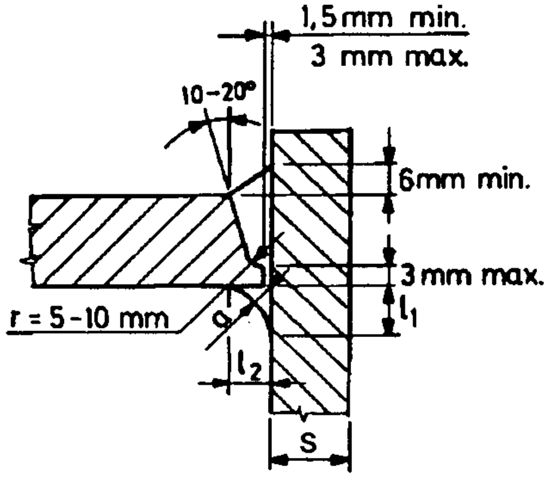
7.1.2 The typical examples of allowable welded joints are given in Table 7.1.2. Different types of welded joints shall not be considered as equivalents.

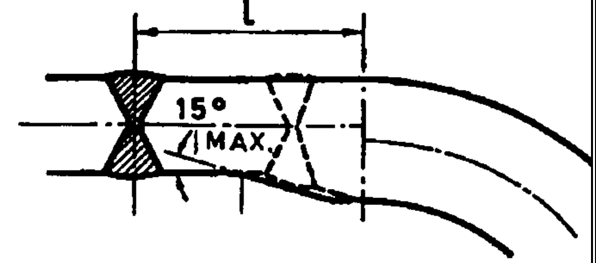
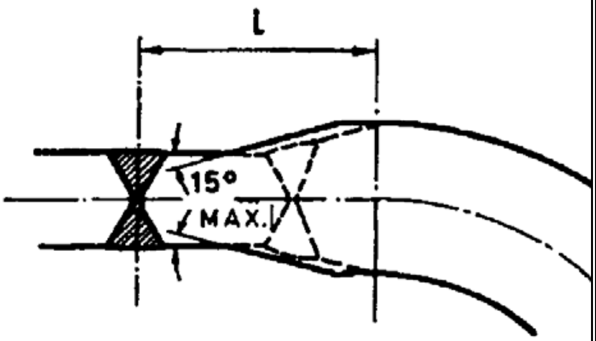
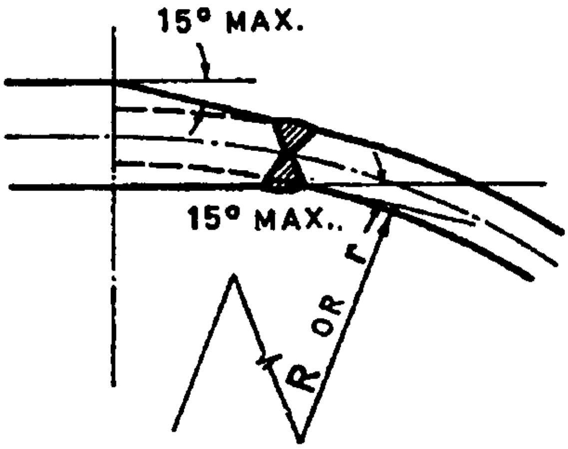
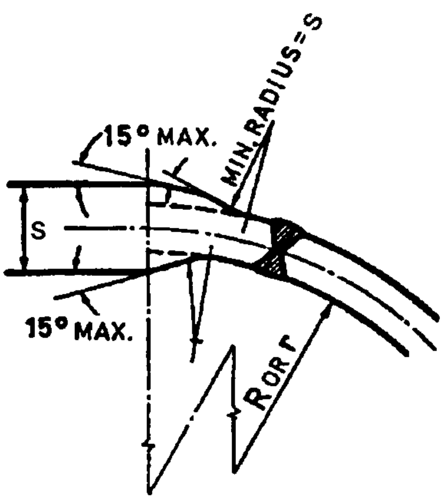
7.1.3 The shown types of welded joints for the elements shall be used in order that adequate strength of the structure is ensured.

7.1.4 Depending on the characteristics of the materials used and also on further improvement of the welding procedure, other types of welded joints may be also allowed. In that case and also in case the typical examples of the welded joints cannot be used in the whole, the type of the welded joint shall be agreed with the *Register*.

Table 7.1.2
Allowable welded joints

1. Flat ends, covers and tube plates		
1.1		$r \geq s/3$, but not less than 8 mm $l \geq s$ where impossible to weld from the inside,care is to be taken to ensure full penetration
1.2		$r \geq 0{,}2 \cdot s$, but not less than 5 mm. $s_2 \geq 5$ mm. See note 1.
1.3		$a = 2\ s_1$ or $s - 1{,}5$ mm whichever is smaller

1.4		See note 1.
1.5		See note 1.
1.6		$l_1/l_2 = 4/3$ shell thickness mm | a, mm $s < 12$ | 4,5 $12 \le s \le 16$ | 5 $16 < s$ | 6
1.7		$l_1/l_2 = 4/3$ shell thickness mm | a, mm $s < 12$ | 4,5 $12 \le s \le 16$ | 5 $16 < s$ | 6 The use of minimum angle is associated with a maximum radius r.

<table>
<tr><th colspan="3">2. Dished ends</th></tr>
<tr><td>2.1</td><td>
</td><td>It is permitted for boilers and pressure vessels of classes I, II and III. See note 2. and 10.</td></tr>
<tr><td>2.2</td><td>
</td><td>It is permitted for boilers and pressure vessels of classes I, II and III. See note 10.</td></tr>
<tr><td>2.3</td><td>
</td><td>Attachment of hemispherical end to cylindrical shell.</td></tr>
<tr><td>2.4</td><td>
</td><td>Attachment of hemispherical end to cylindrical shell.</td></tr>
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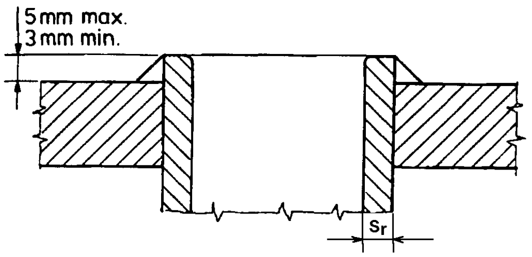
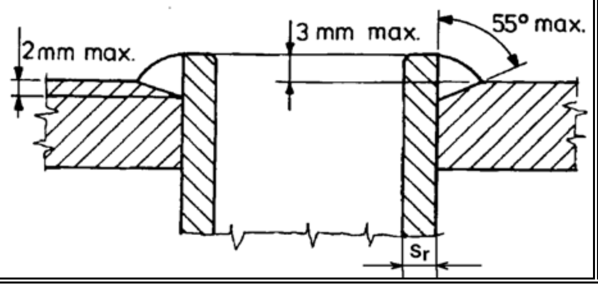
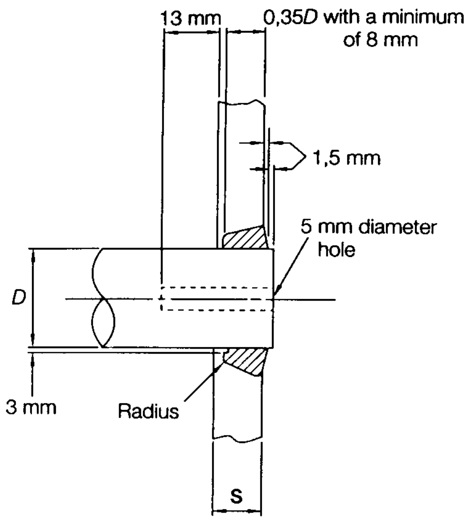
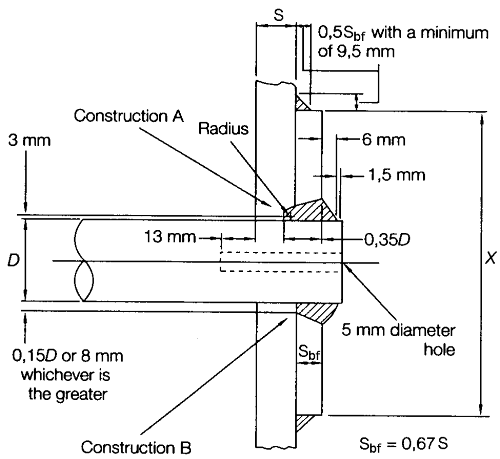
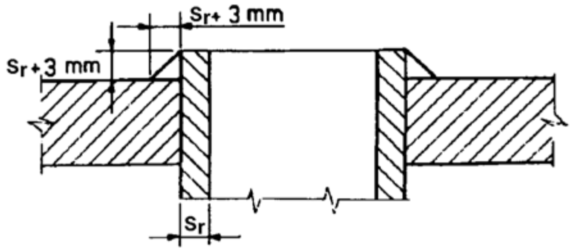
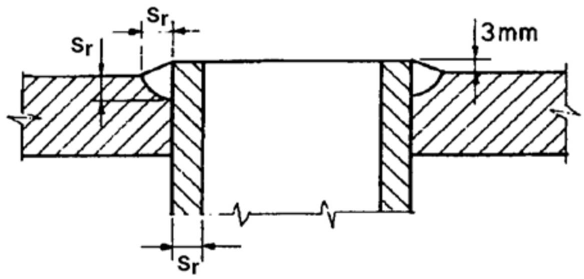
<table>
<tr><th colspan="3">3. Tubes</th></tr>
<tr><td>3.1</td><td>
</td><td>See note 3, 4 and 5.
Tubes are to be lightly expanded before and after welding.</td></tr>
<tr><td>3.2</td><td>
</td><td>See note 3, 4 and 5.
Tubes are to be lightly expanded before and after welding.</td></tr>
<tr><th colspan="3">4. Stays and stay tubes</th></tr>
<tr><td>4.1</td><td>
</td><td></td></tr>
<tr><td>4.2</td><td>
</td><td>Method of construction B is to be used only where $s_{bf} \geq 0,35$ D
X = 3,5 D or
0,67 x pitch of stays</td></tr>
</table>

<table>
<tr><td>4.3</td><td>
</td><td rowspan="4">See note 3.
Tubes are to be lightly expanded before and after welding.</td></tr>
<tr><td>4.4</td><td>
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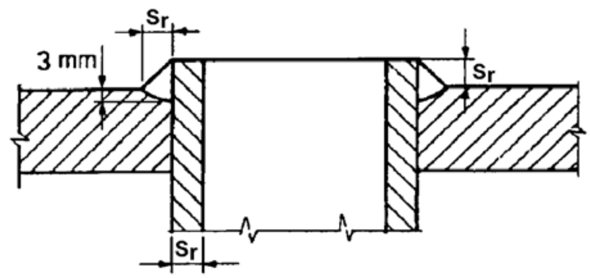
<tr><td>4.5</td><td>
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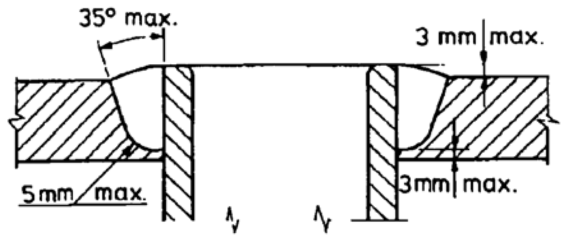
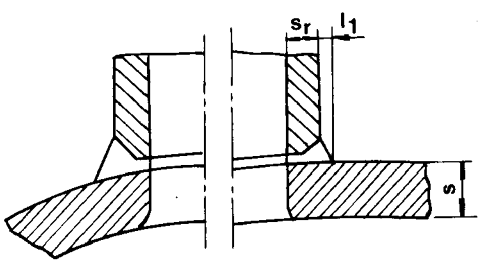
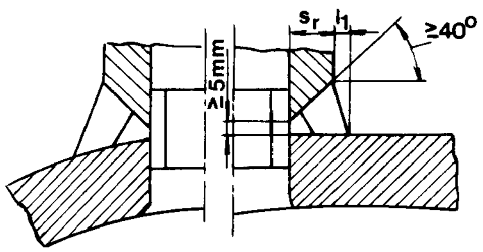
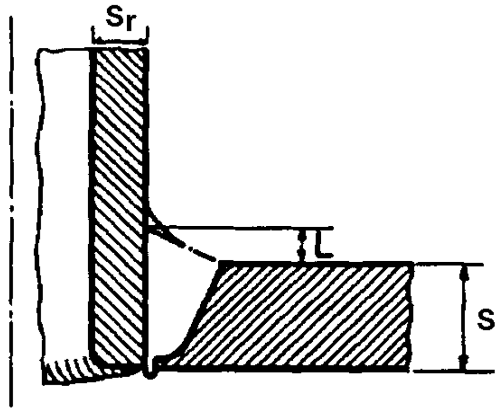
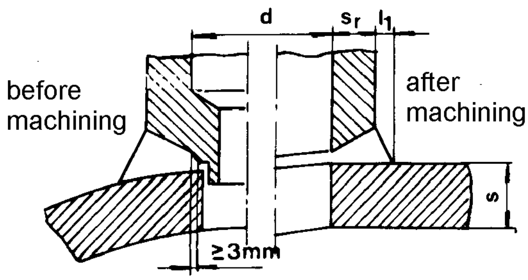
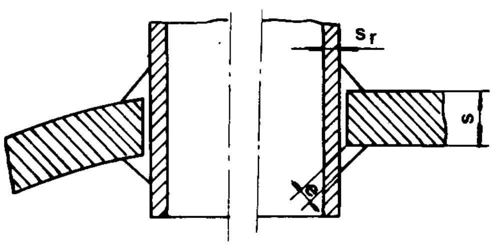
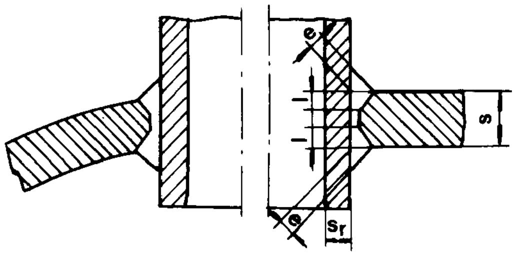
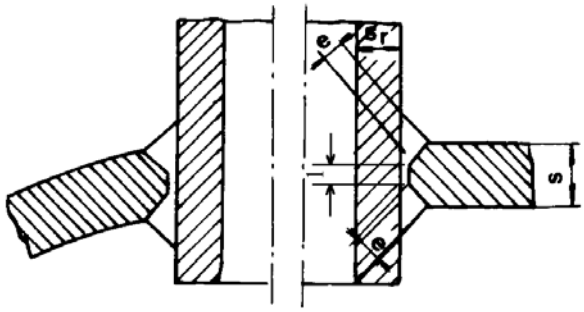
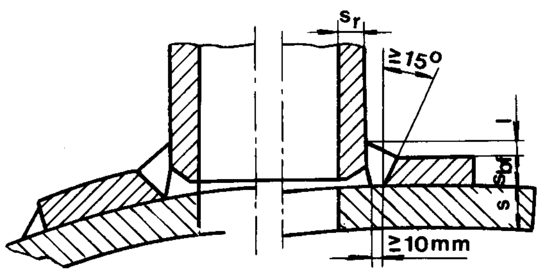
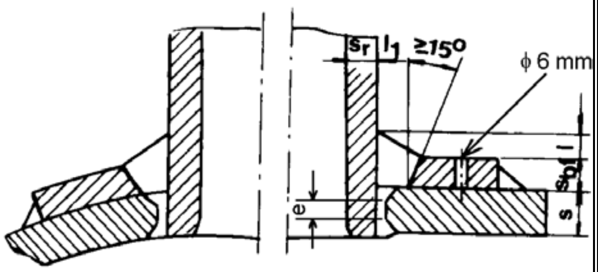
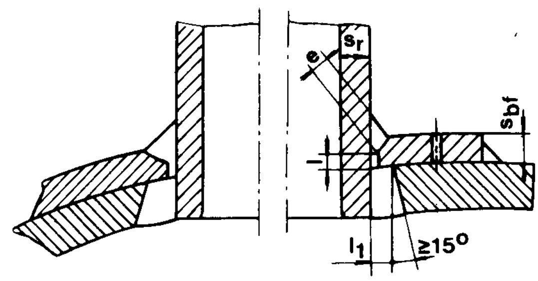
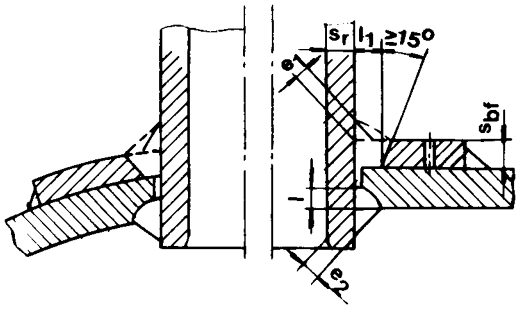
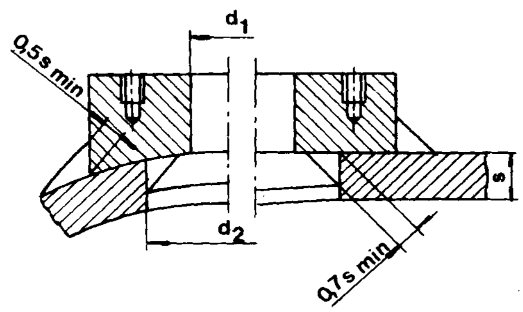
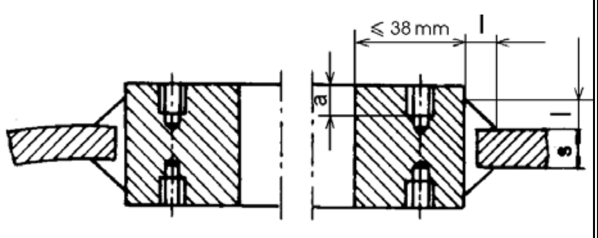
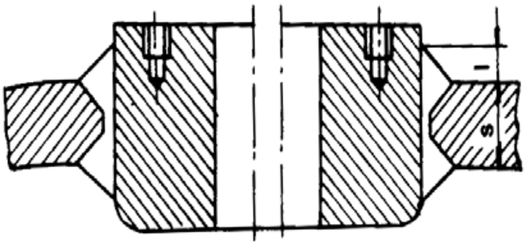
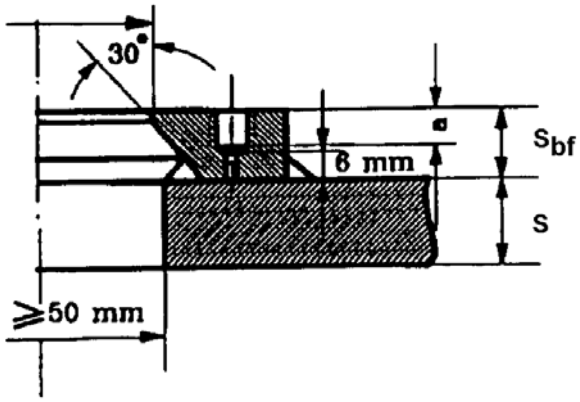
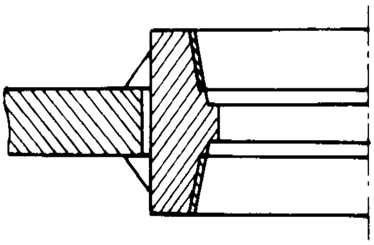
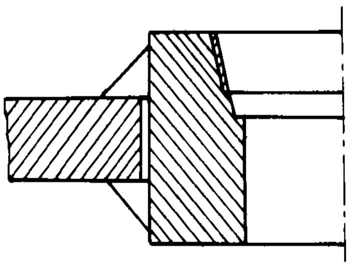
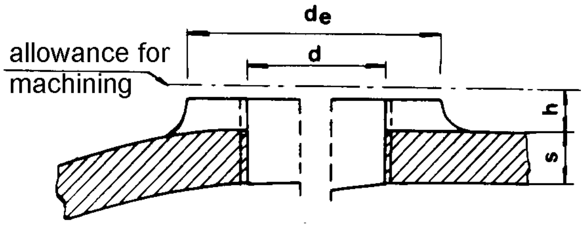
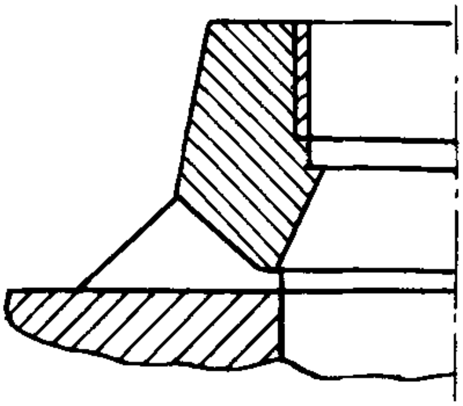
<tr><td>4.6</td><td>
</td></tr>
<tr><td colspan="3">5. Branches, nozzles, pads</td></tr>
<tr><td colspan="3">5.1 Welded on branches - non through</td></tr>
<tr><td>5.1.1</td><td>
</td><td>$s_r \leq 16$ mm
$l_1 \geq \frac{1}{3} \cdot s_r$, but not less than 6 mm.</td></tr>
</table>

5.1.2		$l_1 \geq \frac{1}{3} \cdot s_r$, but not less than 6 mm. See note 6. and 7.
5.1.3		L ≥ $s_r/3$, but not less than 6 mm. $s \leq 25$ mm.
5.1.4		$l_1 \geq \frac{1}{3} \cdot s_r$, but not less than 6 mm. See note 8. and 9. No weld root gap.
5.2 Welded – on branches - through		
5.2.1		Joint is mainly used at: $s_r < \frac{1}{2} \cdot s$ $e = s_r$

5.2.2		Joint is mainly used at: $s_r = \frac{1}{2} \cdot s$ $e = 6 \div 13$ mm $e + l = s_r$
5.2.3		Joint is mainly used at: $s_r > \frac{1}{2} \cdot s$ $e \geq \frac{1}{10} \cdot s$, but not less than 6 mm. $l = 1{,}5 - 3$ mm
5.3 Branches with disc – shaped reinforcing plates		
5.3.1		$l \geq \frac{1}{3} \cdot s_r$, but not less than 6 mm.

5.3.2		$l \geq \frac{1}{3} \cdot s_r$, but not less than 6 mm. $l_1 \geq 10$ mm. $e = 1{,}5 - 3$ mm Excess weld material to be removed before fitting of reinforcing plate.
5.3.3		$e + l = s_r$ or s_{bf} whichever is less. $l_1 \geq 10$ mm.
5.3.4		$e_2 + l \geq s_r$ $l_1 \geq 10$ mm $2\, s_r \leq (e_2 + l)$ + smaller of the values $(s_{bf} + e_1)$ or l_1 Also valid for $e_2 = 0$.
5.4 Pads and nozzles for studs		
5.4.1		$d_2 \leq d_1 + 2 \cdot s$ min. See note 11, 15, 16, 17, 18. $s \leq 16$ mm
5.4.2		$l = s$, but not less than 6 mm $s \leq 10$ mm See note 12, 13, 15, 16, 17, 18.

5.4.3		$l = s$, but not less than 6 mm $s \leq 20$ mm See note 15 and 16.
5.4.4		The bore should be such that there is adequate accessability for sound deposition of the internal fillet. $l = s$ or s_{bf}, smaller value is to be taken, but not less than 6 mm. $s \leq 16$ mm See note 15, 16, 17, 18.
5.5 Pads and nozzles for threaded joints		
5.5.1		
5.5.2		

5.5.3		$d \geq s$, $d_e = 2\ d$ $h \leq 10$ mm, $h \leq 0{,}5 \cdot s$ See note 14.
5.5.4		

Notes:

1. Welded joints are applicable to boilers having a shell diameter up to 610 mm.
   For pressure vessels they may be used without restrictions in case $Rm \leq 460$ N/mm^2 or $R_{eH} \leq 365$ N/mm^2.
2. Reduction in thickness of the shell or flange part of the end may be effected either on the inside or on the outside.
3. Ends of tube protruding outside the weld seam are removed by milling or grinding.
4. Distance between tubes shall not be less than 2,5 s_r, but never below 8 mm.
5. In case of manual electric arc welding it is necessary that s_r is $s_r \geq 2{,}5$ mm.
6. Material of the backing ring shall be the same as that of the shell to which the branch is attached by welding.
7. Backing ring shall be tightly fitted and removed after welding.
8. It is used for branches of small sizes as compared to those of pressure vessels.
9. After welding the branch is machined to the final size, *d*.
10. Dimensions of cylindrical portion shall be such that the radiography could be carried out, if necessary.
11. Clearance between the pads and pressure vessel shall not exceed 3 mm.
12. Clearance between the opening and the outside nozzle diameter shall be minimum and in no case exceeding 3 mm.
13. Upper holes for studs shall be displayed in relation to the lower ones.
14. Total thickness of the pressure vessel shell and the weld metal shall be sufficient for provision of the required number of threads.
15. The threaded depth is not to be less than diameter of screw.
16. Connection is acceptable for use only on class II and III vessels.
17. Required reinforcement for the opening is to be integrated in the shell plate.
18. Connection is acceptable only for shell in carbon managenese steels with specified minimum tensile strength ≤ 430 N/mm^2 and when design temperature $\leq 120^oC$.