BRITISH STANDARD

BS 855 : 1990

UDC 621.772.1 : 621.18 : 697.326 : 669.14 : 621.791 : 006.3/.8

Specification for

Welded steel boilers for central heating and indirect hot water supply (rated output 44 kW to 3 MW)

Chaudières soudées en acier pour chauffage central et approvisionnement indirect en eau chaude (débit nominal de 44 kW à 3 MW)

Geschweisste Stahlkessel für Zentralheizungs - und indirekte Warmwasserversorgungssysteme (Nennleistung 44 kW bis 3 MW)

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British Standards

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Committees responsible for this British Standard

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Associated Offices Technical Committee
Association of British Solid Fuel Appliances Manufacturers
Association of Shell Boilermakers
Boiler and Radiator Manufacturers' Association Limited
British Coal Corporation
British Combustion Equipment Manufacturers' Association
British Foundry Association
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Domestic Solid Fuel Appliances Approval Scheme
Engineering Equipment and Materials Users' Association
Health and Safety Executive
Institute of Domestic Heating Engineers
Institution of Chemical Engineers
Society of British Gas Industries
Waterheater Manufacturers' Association

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Foreword

This British Standard has been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Policy Committee. It supersedes BS 855 : 1976, which is withdrawn. As well as re-editing and updating the information to comply with current practice the sections on automatic controls, inspection and testing and electrical wiring have been rewritten to accord with the latest Health and Safety Executive (HSE) requirements.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

This standard forms one of a series of standards used in boiler construction, the others being:

BS 779	Specification for cast iron boilers for central heating and indirect hot water supply (rated output 44 kW and above)
BS 1113	Specification for design and manufacture of water-tube steam generating plant (including superheaters, reheaters and steel tube economizers)
BS 1894	Specification for electrode boilers of riveted seamless, welded and cast iron construction for water heating and steam generating
BS 1971	Specification for corrugated furnaces for shell boilers
BS 2790	Specification for design and manufacture of shell boilers of welded construction

Appendix A includes information on those items which are essential inclusions on a boiler plant but which may not necessarily form part of the supply by the manufacturer.

Appendix B gives recommendations for electrical wiring of boiler installations, however reference should be made to the 15th Edition of Institution of Electrical Engineers (IEE) 'Regulations for Electrical Installations'[1] for electrical distribution in buildings and to the appropriate British Standards for the equipment cables, controls and components of an electrical installation.

Appendix C of this standard gives information on International and European categorization of boilers and identifies the classifications referred to in some European countries.

This standard is included in the list of 'Standards significant to health and safety at work'[2] published by the UK Health and Safety Executive (HSE) and is also referred to by HSE in giving guidance.

In order not to conflict with the work of CEN in the field of oil-fired boilers it has been necessary to restrict the scope of this standard. However, pending the publication of a European standard covering oil-fired boilers up to 300 kW rated heat output, users of this standard will find the information contained useful when determining specific requirements for such boilers.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

[1]Available from the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London WC2 0BL.

[2]Available from the HSE through any of its offices.

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Section one. General

1.1 Scope

1.1.1 This British Standard specifies requirements for the design and construction including materials, workmanship, inspection, testing and marking of welded steel boilers for central heating and indirect hot water supply for which the classification of design pressures, flow temperatures and outputs are given in table 1.

1.1.2 This standard applies to boilers for hot water or low pressure steam (see table 1), with rated heat output between 44 kW and 3 MW and for use with one or more of the following fuels:

(a) smokeless solid fuels, e.g. furnace coke, low temperature coke or anthracite;

(b) bituminous coal fired by means of mechanical stokers;

(c) gaseous fuels of the 2nd and 3rd families (see BS 4947);

and for rated heat output between 300 kW and 3 MW when used with liquid fuels of the classes specified in BS 2869.

This standard also applies to hot water boilers pressurized by steam.

NOTE. The titles of the publications referred to in this standard are listed on page 89.

1.2 Definitions

For the purposes of this British Standard, the definitions given in BS 499 : Part 1 apply, together with the following.

1.2.1 design pressure

The pressure used in the design calculations and also the maximum permissible setting of any safety valve fitted on the boiler.

1.2.2 operating pressure

The maximum pressure measured in the boiler under normal operating conditions.

NOTE. The pressure is dependent on static head pressurizing equipment (where fitted) and the effect of the circulating pump. The static head, and pressurizing equipment in the case of pressurized systems, determine the maximum water temperature permissible, at the point of lowest pressure, which is not to exceed a predetermined level below the saturated steam temperature for the lowest pressure.

1.2.3 design stress

The stress (f) used in the calculations, where applicable, to determine the minimum scantlings of pressure parts.

1.2.4 safety valve

A spring loaded automatic valve fitted to a boiler for relieving the build up of excess pressure by means of discharge to atmosphere.

1.2.5 inspecting authority

The body or association which checks the design, materials, and construction to ensure that they are in accordance with this standard.

1.3 Performance

The manufacturer shall declare the rated heat output in kilowatts and the efficiency of the boiler for the appropriate fuel or fuels under normal conditions of operation.

The declared values shall be based on values determined in accordance with BS 7190 or BS 845 : Part 1, when the boiler is fired with combustion equipment either supplied or recommended by the manufacturer (see appendix D). For combustion equipment giving cyclic variation in heat release rate due to periodic refuelling or de-ashing operations, the period for which the rated output is obtainable shall also be stated.

NOTE 1. The manufacturer should supply on request a copy of the boiler performance test report (see appendix D).

NOTE 2. The purchaser should disclose to the manufacturer at the time of enquiry the information listed in appendix E.

1.4 Design pressures and flow temperatures

1.4.1 There shall be a margin between the actual pressure at which the boiler operates and the lowest pressure at which any of the safety valves is set, to prevent the unnecessary lifting of the safety valves (see table 1).

1.4.2 For hot water central heating boilers for use in pressurized (medium pressure) systems designed to operate at a pressure in the boiler not exceeding 0.45 N/mm^2 (see table 1), the maximum permissible working temperature at or near the boiler flow outlet shall not exceed 132 °C and shall be 17 °C or more below the saturated steam temperature corresponding to the pressure of the highest point of the circulating system above the boiler.

1.4.3 In hot water boilers, if the difference between the water flow temperature (outlet) and the water return temperature (inlet) is greater than 25 K, internal and/or external mixing devices shall be used to limit the effective differential temperature within the boiler to 25 K.

1.4.4 Where solid fuel is used in connection with a pressurized system automatic stoking shall be used and in all cases provision shall be made for the positive dissipation of the heat generated. Automatic stoking equipment and all automatically controlled combustion equipment burning liquid or gaseous fuels shall be arranged to shut down in the event of:

(a) the boiler flow outlet temperature exceeding the maximum specified;

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Table 1. Design pressures, flow temperatures and outputs

Type	Output		Maximum operating pressure	Maximum working temperature	Maximum design pressure[1)]	Maximum safety valve setting
	min.	max.				
	kW	kW	N/mm²	°C	N/mm²	N/mm²
Steam	44	1500	0.20	132	0.23	0.23
Externally pressurized hot water	44	3000	0.45	132	0.52	0.52
Vented hot water	44	3000	0.69	100	0.76	0.76

[1)]See **3.1**.

(b) the pressure falling below the specified operating pressure of the boiler while the working temperature is maintained.

1.4.5 Provision shall be made in the design of forced circulation systems fired by solid fuel to ensure that in the event of circulation pump failure circulation is maintained either by gravity or by a stand-by pump in such a way that the design pressure and temperature will not be exceeded because of the residual heat in the firebox.

1.4.6 The provision of **1.4.4** shall also be made when liquid or gaseous fuel is to be used, or alternatively, if such a provision is not practicable, an arrangement is permissible in which the controls for item (a) of **1.4.4** shall be supplemented by an independent overriding control affording complete shutdown of the heat input to the boilers and actuated by the water temperature at or near the flow outlet of the boiler. This independent overriding control if fitted in the flow pipe, shall be within 300 mm of the boiler and with no intervening valve.

1.4.7 A welded steel hot water central heating boiler with a flow outlet temperature greater than 100 °C shall be used only in a system which is provided with safety devices in the pressurizing equipment:

(a) to relieve excess pressure;

(b) to maintain the system pressure at its design value;

(c) to maintain the water level in the pressurizing vessel.

NOTE 1. The provision of a relief valve in the pressurizing unit does not eliminate the need for the fitting on the boiler of a safety valve(s) of the size required by this standard.

NOTE 2. It is essential that externally fitted boiler units, such as water-cooled combustion chambers which are intended to operate in connection with hot water heating boilers, and which are subjected to the same static head as the boiler itself, should comply with the appropriate design requirements of this standard.

Section two. Materials and design stresses

2.1 Materials

2.1.1 General

Materials used in the construction of boilers to this standard shall comply with **2.1.2** to **2.1.5**.

2.1.2 Plates

The steels used for plates shall comply with any of the following specifications:

(a) BS 1501 – 151 and BS 1501 – 161, class A or B, but with minimum of grades 400A or 400B;

(b) a carbon or carbon manganese steel of equivalent strength, ductility, weldability, short term (and where relevant long term) mechanical properties at elevated temperatures to those given in (a).

NOTE. In the case of (b) the choice of materials should be subject to agreement between the purchaser and manufacturer and their general suitability proven to the satisfaction of the inspecting authority.

2.1.3 Sections and bars

The steels used for sections and bars shall comply with any of the following specifications:

BS 1502 – 151 and BS 1502 – 161, but with a minimum of grade 430.

2.1.4 Studs, bolts and nuts

The steels used for studs, bolts and nuts shall comply with the material specifications in tables 1 and 2 of BS 4882 : 1990. They shall be threaded in accordance with BS 1580 or BS 3643 : Part 1 and Part 2.

2.1.5 Tubes

2.1.5.1 *Plain tubes and stay tubes*

Plain tubes and stay tubes shall be seamless or electric resistance welded and made of a steel that complies with one of the following:

(a) BS 3059 : Part 1;

(b) a carbon or carbon manganese steel of equivalent strength, ductility, weldability, short term (and where relevant long term) mechanical properties at elevated temperatures to those given in (a).

NOTE. In the case of (b) the choice of materials should be subject to agreement between the purchaser and manufacturer and their general suitability proven to the satisfaction of the inspecting authority.

2.1.5.2 *Seamless steel cross tubes and uptakes*

The steel used in seamless steel cross tubes, uptakes, branches, standpipes and furnaces shall comply with one of the following:

(a) grade 430S of BS 3601;

(b) grade 410 HFS or CFS of BS 3602 : Part 1;

(c) a carbon or manganese steel of equivalent strength, ductility, weldability, short term (and where relevant long term) mechanical properties at elevated temperatures to those given in (a) or (b).

NOTE. In the case of (c) the choice of materials should be subject to agreement between the purchaser and manufacturer and their general suitability proven to the satisfaction of the inspecting authority.

2.1.5.3 *Tolerances on tubes*

Where minus tolerances are incorporated in the tube specifications these shall be taken into account in the design of the boiler.

2.2 Design stress

The design stress (f) based on metal design temperature not exceeding 250 °C shall not exceed the appropriate value given in table 2 for the material of construction.

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Table 2. Design stess f

Boiler parts	Material designation	Permissible grades	Nominal thickness		Material with no specified elevated temperature properties (for plates: class A)		Material with specified elevated temperature properties (for plates: class B)	
			Over	Up to and including	E_t	f	E_t	f
			mm	mm	N/mm^2	N/mm^2	N/mm^2	N/mm^2
Plates	BS 1501 – 151 and	400	3	16	163	109	174	116
	BS 1501 – 161		16	40	155	103	165	110
			40	63	152	101	162	108
		430	3	16	180	120	192	128
			16	40	170	113	181	121
			40	63	167	111	178	119
Tubes (furnaces, uptakes and cross tubes)	BS 3601 S	410	–	–	163	109	–	–
	BS 3602 : Part 1 HFS, CFS	410	–	–	–	–	172	115
Sections and bars	BS 1502 – 151 and	430	–	16	180	120	–	–
	BS 1502 – 161		16	40	170	113	–	–
			40	63	167	111	–	–
			63	100	161	107	–	–

NOTE 1. The mechanical properties given in this table relate to the most favourable conditions. Reference should be made to the appropriate sections of this standard to determine whether other limiting factors apply.

NOTE 2. E_t is the specified minimum yield or 0.2 % proof stress at a temperature of 250 °C. In the case of class A plates, E_t is derived from table 2.5 (3) of BS 2790 : 1986.

NOTE 3. The values of f for plates, in the as rolled and normalized conditions, tubes, sections and bars are based on $E_t/1.5$.

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Section three. Design

3.1 General

NOTE 1. The formulae in this standard dealing with rules for scantlings apply to boilers constructed throughout under the conditions prescribed in the standard, and which are to be operated under average conditions of draught, good feed-water and adequate supervision.

NOTE 2. Where working conditions are adverse by reason of abnormal rates of firing, bad feed-water, undue erosion, exposure to the elements, or other causes, it is recommended that the scantlings established by calculation from the given formulae should be given special consideration.

NOTE 3. Attention is drawn to BS 2486 for recommendations for treatment of water for boilers.

The design pressure as defined in **1.2.1** shall be not less than the highest pressure at which the safety valve is to be set to lift, but in no case less than 0.23 N/mm^2.

NOTE 4. It is recommended that the margin in pressure between the safety valve setting and that due to the head of water (in N/mm^2) should take into account the effect of circulators. See **5.1.4** for requirements for the safety valve setting.

3.2 Cylindrical shells subject to internal pressure

3.2.1 Shell thickness

The minimum thickness of a cylindrical shell t (in mm) shall be calculated using equation (1), but in no case shall the thickness be less than the minimum thickness given in table 3:

$$t = \frac{pR_i}{fz - 0.5p} + C \qquad (1)$$

where

- p is the design pressure (in N/mm^2);
- R_i is the internal radius of shell (in mm);
- f is the design stress (in N/mm^2) (see **2.2**);
- C is the corrosion allowance (in mm);
- z is the efficiency, expressed as a fraction, of the longitudinal welded seam.

C shall be not less than 0.75 mm.

NOTE 1. Special consideration should be given to boiler seating arrangements and other external loads to ensure that stresses remain within safety limits.

Table 3. Minimum thickness of shells subject to internal pressure

Maximum internal diameter of cylinder	Cylindrical shell minimum thickness (with internal pressure)
mm	mm
400	4
800	5
1200	6
1600	7
above 1600	8

The value for z shall be as given in table 4 for the appropriate weld form.

NOTE 2. The use of these values of z for other means of weld formation should be agreed between the manufacturer and the inspecting authority.

Table 4. Values of z for welded longitudinal seams

Values of Z	Conditions
0.65	For double sided butt welds in which the weld metal at the root of the first side weld is prepared by grinding or gouging down to sound metal in order to provide a clean metallic surface preparatory to welding from the second side
0.55	For sealed single sided butt welds in which after the main weld is completed and prior to the depositing of the sealing runs at the reverse side of the plate the seam is cleaned and dressed at that side, but the weld metal at the root of the main weld is not prepared

NOTE. Where access to the inside is not possible it should be ensured that the weld on the main side is fully penetrating.

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3.2.2 Openings in cylindrical shells

3.2.2.1 *Unreinforced openings*

The maximum diameter of unreinforced openings shall not exceed 200 mm. The maximum diameter *d* of any unreinforced opening below 200 mm shall be obtained from the curves in figure 1 using the appropriate value of the shape factor K_1 which is calculated using equation (2):

$$K_1 = \frac{pD_o}{1.82 f t} \qquad (2)$$

where

- p is the design pressure (in N/mm²);
- D_o is the outside diameter of shell (in mm);
- t is the actual thickness of shell (in mm);
- f is the design stress (in N/mm²) (see **2.2**).

For elliptical or oval holes *d* shall refer to the mean of the major and minor axes.

Where K_1 has a value of unity or greater, the maximum size of an unreinforced opening shall be 50 mm.

3.2.2.2 *Reinforced openings*

Openings larger than those permitted by **3.2.2.1** shall be reinforced. The effectiveness of reinforcement shall be calculated taking account of the cross-sectional area of locally disposed material, including the attachment weld(s), in excess of the minimum requirements for plate and branch thickness as shown in figure 2, the branch thickness being increased where required. Compensation shall be considered adequate when the compensating area *Y* (see figure 2) is equal to or greater than the area *X* requiring compensation.

Area *X* shall be calculated as the product of the inside radius (*d*/2) of the branch and the thickness *Z* which would be required for the shell if it were entirely unpierced by tube or other holes.

Area *Y* shall be measured in a plane through the axis of the branch parallel to the longitudinal axis of the shell and shall be calculated as the sum of (a), (b), (c) and (d).

(a) For that part of the branch which projects outside the shell calculate the full sectional area of the stem up to a distance *I* from the actual outer surface of the shell plate and deduct from it the sectional area which the stem would have if its thickness were calculated as indicated in figure 2.

(b) The full sectional area of that part of the stem which projects inside the shell up to a distance *I* from the inside surface of the shell.

(c) The sectional area of the fillet welds on both sides of the shell.

(d) The area obtained by multiplying the difference between the actual shell thickness and the unpierced shell thickness *Z* by a length *J*.

Where achievement of an adequate area *Y* is not practicable using the above method, additional reinforcement shall be provided.

NOTE 1. The additional reinforcement should follow any of the typical arrangements shown in figure 3 or use an alternative method mutually agreed between the purchaser, the manufacturer and the inspecting authority.

In cases where additional reinforcement is used the sectional area of the additional reinforcement and its attachment welds shall be taken into account within the confines of dimensions *I* and *J*, *J* being as shown in figure 2 and *I* being amended to equal the smaller of the two values $2.5t$ or $t_r + 2.5t_a$.

where

- t is the actual thickness of the shell plate (in mm);
- t_a is the actual thickness of the branch wall (in mm);
- t_r is the actual thickness of the added reinforcement (in mm) on the outside of the shell plate.

Where material having a lower design stress than that of the shell or end plate is taken as compensation its effective area shall be assumed to be reduced in the ratio of the allowable design stresses at the design temperature. No allowance shall be made for the additional strength of material having a higher design stress value than that of the shell or end plate.

Welds attaching branches and reinforcing plates shall be of sufficient size to transmit the full strength of the reinforcing area and all other loadings to which they may be subjected.

In the case of manholes, handholes or openings not fitted with branches attached by welding, the foregoing method shall apply, but the radius used to determine *X* shall be replaced by half the maximum width of the opening in the shell on the axis under consideration.

When welding ash drop-out tubes to furnaces and shells from one side, where the other side is inaccessible for welding, lack of root penetration or root concavity shall not exceed 3 mm and the opening in the shell shall be reinforced with pad-type compensation (see figures 3 and 4).

NOTE 2. Reinforcements designed to these rules will always be adequate but may sometimes be greater than necessary because of the simplified nature of the design calculations.

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3.2.2.3 *Fillet welds attaching pads and compensating plates to cylindrical shells*

The size of the outer peripheral fillet weld L_o by which pads (see figure 5) and compensating plates (see figures 6(a) and 6(b)) are attached to shell plates shall be calculated using equation (3), but shall in no case be less than the inner welds nor less than the minimum shell thickness specified in **3.2.1**:

$$L_o \frac{4X - D_i L_i}{D_o} \quad (3)$$

where

- L_i is the length of leg of fillet weld around inner periphery of pad or compensating plate (in mm);
- X is half the cross-sectional area of opening in shell (based on unpierced shell thickness) (in mm²) (see **3.2.2.2**);
- D_o is the diameter of outer periphery of circular pad or compensating plate (in mm);
- D_i is the diameter of inner periphery of circular pad or compensating plate (in mm).

For elliptical compensating plates:

$$D_o = \frac{a_o + b_o}{2} \quad (4)$$

$$D_i = \frac{a_i + b_i}{2} \quad (5)$$

where

- a_o is the outer major axis of compensating plate (in mm);
- b_o is the outer minor axis of compensating plate (in mm);
- a_i is the inner major axis of compensating plate (in mm);
- b_i is the inner minor axis of compensating plate (in mm).

3.3 Dished and flanged ends

3.3.1 Torispherical, semi-ellipsoidal and hemispherical unstayed drum ends

Torispherical and semi-ellipsoidal unstayed drum ends, dished from plate, having pressure on the concave side shall comply with the following.

(a) *Torispherical ends.* The internal radius R_i of dishing shall be not greater than D_o.

The internal corner radius r_i shall be not less than 10 % of the outside diameter D_o, nor less than $3t$.

The external height H shall be not less than $0.18D_o$.

(b) *Semi-ellipsoidal ends.* The external height H shall be not less than $0.2D_o$

where

- D_o is the outside diameter of the parallel portion of the end (in mm);
- t is the thickness of the end plate (in mm);
- H shall be measured from the commencement of curvature (see figure 7).

NOTE. There are no special requirements for hemispherical ends.

3.3.2 Thickness

Subject to the limitations given in **3.3.1** the minimum thickness t (in mm), after dishing, of any of the three forms of end shall be calculated using equation (6), and shall be not less than 6.0 mm:

$$t = \frac{pD_oK_2}{2f} + C \quad (6)$$

where

- p is the design pressure (in N/mm²);
- D_o is the outside diameter of the dished end (in mm);
- K_2 is a shape factor;
- f is the design stress (in N/mm²) (see **2.2**);
- C is the corrosion allowance (in mm).

C shall be not less than 0.75 mm.

NOTE 1. The shape factor K_2, used in equation (6) is obtained from a series of curves in figure 8 and depends on the ratio of height to diameter, H/D_o.

NOTE 2. The curve drawn with a full line in the series provides the factor K_2 for plain, i.e. unpierced, ends. Where the value of H/D_o is lower than 0.25 the value of K_2 depends on the ratio of thickness to diameter t/D_o as well as on the ratio H/D_o and a trial calculation may be necessary to arrive at the correct value of K_2.

3.3.3 Openings in dished ends

3.3.3.1 *Unreinforced openings*

Openings in dished ends shall be circular or nominally elliptical.

For ends with unreinforced openings the value of $d/(D_o t)$ shall be used to select the correct curve in figure 8 to provide appropriate values of K_2 for use in equation (6):

where

- d is the diameter of the largest opening in the end plate (in mm) (in the case of an elliptical opening, the major axis of the ellipse);
- t is the minimum thickness, after dishing (in mm);
- D_o is the outside diameter of dished end (in mm).

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Trial calculation is necessary in order to select the correct curve in figure 8; the following requirements shall be satisfied:

$\frac{t}{\sqrt{D_o}}$ shall be not greater than 0.1;

$\frac{d}{\sqrt{D_o}}$ shall be not greater than 0.5.

NOTE. It will be seen from figure 8 that for any selected ratio of H/D_o the curve for unpierced ends indicates a value for $d/\sqrt{(D_o t)}$ as well as value for K_2. Holes giving a value of $d/\sqrt{(D_o t)}$ not greater than the value so obtained may thus be cut in an end designed as unpierced without any increase in thickness.

3.3.3.2 ***End plate thickness***

The rules in **3.3.3.1** shall apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction shall be made in end plate thickness on account of flanging.

Where openings are flanged the radius r_m of the flanging shall be not less than 25 mm (see figures 7 and 9).

3.3.3.3 ***Unreinforced and flanged openings***

Unreinforced and flanged openings in dished ends shall be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in figure 9.

3.3.3.4 ***Reinforced openings***

Where it is desired to use a large opening on a dished end of less thickness than would be required by the application of **3.3.3.1**, reinforcement of the end shall be provided. Reinforcement shall consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or the inside of the end plate in the region of the hole (see figure 10), or a combination of both methods.

Account shall be taken of added reinforcing material as effective reinforcement within the following limits:

(a) the effective width l_1 (in mm) of reinforcement shall not exceed $\sqrt{(2R_i t)}$ or $d_o/2$ whichever is the less;

(b) the effective length l_2 (in mm) of a reinforcing ring shall not exceed $\sqrt{(d_o l_t)}$;

where

R_i is the internal radius of the spherical part of a torispherical end (in mm); or for an elliptical end, the internal radius (in mm) of the meridian of the ellipse at the centre of the opening;

t is the actual thickness of the end (in mm);

l_t is the actual thickness of the ring (in mm);

d_o is the external diameter of the ring (in mm).

The dimensions l_1 and l_2 are as shown in figure 10.

The shape factor K_2 for a dished end having a reinforced opening shall be read from figure 8 using the value obtained from:

$$\frac{d_o}{\sqrt{(D_o t)}} - \frac{A}{t} \text{ instead of from } \frac{d_o}{\sqrt{(D_o t)}}$$

where

A is the effective cross-sectional area of reinforcement and is twice the area shown shaded in figure 10.

The shaded area shown in figure 10 shall be calculated as follows:

(1) calculate the sectional area of reinforcement both inside and outside the end plate within the width l_1;

(2) add to it the full sectional area of that part of the stem of the nozzle which projects inside the end plate up to the distance l_2;

(3) add to it the full sectional area of that part of the stem of the nozzle which projects outside the internal surface of the end plate up to the distance l_2 and deduct from it the sectional area which the stem would have if its thickness were as calculated in accordance with equation (1), but taking C = 0.25 mm, and disregarding the minimum thicknesses required by **3.2.1**.

If the material of the ring or of the reinforcing plates has an allowable stress lower than that of the end plate then the effective cross-sectional area A shall be reduced, below that calculated, in proportion to the difference in the allowable stresses for the material. As in **3.3.3.1** trial calculation is necessary in order to select the correct curve.

3.3.4 Dished and flanged crowns for vertical boilers

3.3.4.1 The minimum thickness t (in mm) of dished and flanged crowns for vertical boilers which are subject to pressure on the concave side and are supported by central uptakes shall be calculated using equation (7)

$$t = \frac{pR_i}{2f_2} + C \qquad (7)$$

where

p is the design pressure in (N/mm²);

R_i is the internal radius of curvature of the end plate (in mm);

f_2 = 0.65f, where f is the design stress (in N/mm²) (see **2.2**);

C is the corrosion allowance (in mm).

C shall be not less than 0.75 mm.

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The inside radius to which a crown plate is dished shall be not greater than the external diameter of the cylinder to which it is attached.

The inside radius of the flange to the shell or firebox shall be not less than four times the thickness of the crown plate and in no case less than 64 mm.

The inside radius of curvature of flanges to the uptake shall be not less than twice the thickness of the crown plate and in no case less than 25 mm.

3.3.4.2 Where a dished crown has a manhole, compensation shall be obtained by flanging the edge of the opening, or by providing a stiffening ring. The total depth h (in mm) of the flange, measured from the outer surface of the plate on the minor axis, shall be not less than that calculated using equation (8):

$$h = \sqrt{(tw)} \qquad (8)$$

where

- t is the thickness of the end plate (in mm);
- w is the minor axis of the manhole (in mm).

3.3.4.3 The minimum thickness t (in mm) of dished and flanged crowns for vertical boiler fireboxes which are subject to pressure on the convex side and are supported by a central uptake shall be calculated using equation (9):

$$t = \frac{pR_i}{2f_3} + C \qquad (9)$$

where

- p is the design pressure (in N/mm^2);
- R_i is the internal radius of curvature of the end plate (in mm);
- f_3 = $0.5f$, where f is the design stress (in N/mm^2) (see **2.2**);
- C is the corrosion allowance (in mm).

C shall be not less than 0.75 mm.

The general shape and size of the corner radii shall be the same as that specified in **3.3.4.1.**

3.3.4.4 The thickness of a flanged firebox crown plate t (in mm) dished to partial spherical form and subject to pressure on the convex side shall be calculated using equation (10), but in no case shall the thickness be less than the thickness of the firebox:

$$t = \frac{pR_o}{66} + C \qquad (10)$$

where

- p is the design pressure (in N/mm^2);
- R_o is the outer design radius of curvature of crown plate (in mm);
- C is the corrosion allowance (in mm).

C shall be not less than 0.75 mm.

In no case shall R_o/t exceed 88.

3.3.4.5 Where a flange or an angle ring is used in conjunction with a full-face joint, the thickness t (in mm) of such a flange or ring shall be calculated using equation (11), but in no case shall the thickness after machining be less than 8 mm:

$$t = \sqrt{\left\{\frac{pD\,(D_1 - D)}{K_3}\right\}} \qquad (11)$$

where

- p is the design pressure (in N/mm^2);
- D is the external diameter of shell (in mm);
- D_1 is the pitch circle diameter of bolts (in mm);
- K_3 = 10.5 for flanges and angle rings welded as in figures 11 and 12.

3.4 Standpipes and branches

3.4.1 Thickness and bolting

The thickness and bolting of all flanges for mountings shall be not less than that required by tables 6/3, 6/5, 10/3 or 10/5 of BS 4504 : Part 1 : 1969 for the appropriate pressure, but in no case shall the thickness be less than 12 mm.

Flanges shall be secured by any of the methods shown in figure 11.

NOTE 1. The flange is not to be a tight fit on the pipe. The maximum clearance is to be 3 mm and the sum of the clearance diametrically opposite is not to exceed 4.5 mm.

The minimum thickness of standpipes fabricated from seamless tubes shall be half the thickness of the shell or 6 mm whichever is the greater.

NOTE 2. It may be necessary to increase the calculated thickness to allow for external loading.

3.4.2 Forms of connections

Standpipe and branch connections shall generally be in accordance with the forms given in figures 3, 13, 14 and 15.

NOTE. In selecting the appropriate detail to use from the several alternatives shown for each type of connection, consideration should be given to the service conditions under which it will be required to function.

Weld sizes, as shown in the various figures, are those which are used in good practice but it is necessary in each case to ascertain that these welds are adequate for strength and suitable for the welding process.

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Where compensating plates are fitted, tell-tale holes shall be made in the compensating rings.

3.4.3 Tapped openings

3.4.3.1 Openings for mountings and pipe connections with pipe thread sizes above R3 (see BS 21) shall be suitable for flanged connections.

NOTE. Mountings with male ends not exceeding R3 pipe thread size (in which the screwed portion is an integral part of the mounting) and screwed pipe connections not exceeding R3 pipe size thread may be screwed into bosses on the boiler (see figure 16).

3.4.3.2 The minimum thickness of the plate into which connections or fittings are screwed shall be as specified in table 5.

NOTE. Where necessary the plate should be reinforced to the required thickness by a suitable boss or seating securely fixed to the plate.

Table 5. Tapped openings: minimum thickness of plate

Nominal size	Minimum thickness of plate required
mm	mm
$>20 \le 20$	12
$>20 \le 32$	19
$>32 \le 38$	22
$>38 \le 50$	25
$>50 \le 75$	38

3.4.3.3 Where pads, blocks, or standpipes are fitted to openings for flanged pipe connections, they shall be designed to suit flange connections to table 6/3, 6/5, 10/3 or 10/5 of BS 4504 : Part 1 : 1969 for the appropriate pressure. The joint faces of such pads, blocks and standpipes shall be machined. The pads or blocks shall have sufficient thickness to allow the drilling of stud holes without the inner surface of the pad or block being pierced and the length of the screwed portion of the stud in the pad or block shall be not less than the diameter of the stud, measured over the thread. All bolt and stud holes in the pads, blocks and standpipes shall be drilled.

3.5 Manhole and sighthole openings

3.5.1 Raised circular manhole, access and inspection openings

The thickness of frames for raised circular manholes, access or inspection openings in the boiler shell not exceeding 400 mm diameter shall be not less than the thickness of the shell plate, and the diameter shall be not greater than one third of the diameter of the shell.

The openings on the shell shall be compensated in accordance with **3.2.2.**

Flanges shall be in accordance with tables 6/3, 6/5, 10/3 or 10/5 of BS 4504 : Part 1 : 1969, except that the stress in the bolts shall not exceed 34.5 N/mm^2.

The thickness of the cover plate shall be as given in table 6/8 or 10/8 of BS 4504 : Part 1 : 1969.

For the purpose of calculation, the pressure shall be assumed to act on the whole area within the pitch circle of the bolts and the bolt area shall be taken at the bottom of the screw thread.

3.5.2 Manholes or access openings in flat plates

3.5.2.1 Where manholes are located in flat plates, the openings shall be compensated by flanging the edge of the opening, or by the provision of a stiffening ring (see figure 17).

In all cases the depth of the flanging or ring shall be not less than that determined by equation (8) (see **3.3.4.2**).

3.5.2.2 Where openings over 75 mm diameter, other than manholes, are located in flat plates the methods of **3.2.2.2** shall apply, except that the area X (in mm^2) requiring compensation shall be $0.5\,rt$

where

r is the radius (in mm) of the opening, or for oval holes the mean of the major and minor semi-axes;

t is the minimum thickness (in mm) of the unpierced plate in the area being considered, as required by the appropriate equation in this standard.

3.6 Stays, stiffeners and supported surfaces

3.6.1 Flat plate margins

3.6.1.1 The width of margin b (in mm) giving support in relief of the stays which may be attributed to the shell, furnaces or flues to which flat plates are attached (see figure 18), shall not exceed that calculated using equation (12):

$$b = \frac{K_4\,(t - 0.75)}{\sqrt{p}} \qquad (12)$$

where

t is the plate thickness (in mm);

p is the design pressure (in N/mm^2);

K_4 = 8.3 for plates exposed to flame;

K_4 = 8.9 for plates not exposed to flame.

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Table 6. Values of constant K_5

Description of plate support	Values of K_5	
	Plates exposed to flame or comparable high temperature	Plates not exposed to flame
(1) Where stays are strength welded into the plates (see figures 23(a) and 23(b))	0.45	0.42
(2) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in figure 24(a)	0.42	0.39
(3) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in figure 24(b)	0.4	0.36
(4) Where plain bar stays pass through holes in the plate and are fillet welded as in figure 23(c)	0.45	0.42
(5) Where plate stays are used as in figure 25(a) the point of support being taken at a position 13 mm from the toe end of the stay (see figure 25(c))	0.44	0.41
(6) Where plate stays are used as in figure 25(b) the point of support being taken as 13 mm from the toe end of the stay (see figure 25(c))	0.47	0.44
(7) Where two flat plates are stayed together by a plug welded stay as shown in figure 26	0.47	0.44
(8) Where two flat plates are stayed together by a plug welded bridge stay as shown in figure 27	0.47	0.44
(9) Where a flat plate is flanged for attachment to the shell, flue, furnace or wrapper as shown in figures 21(b), 21(c), 28(a), 28(b), 29(a), 29(b), 29(c), 30(a), 30(b) and 31(a)	0.4	0.36
(10) Where the flat plate is welded directly to the shell, flue, furnace, wrapper or access opening frame (see **3.6.3.3** and figures 19, 20(a), 21(a), 31(b), 31(c) and 31(d))	0.4	0.36
(see figure 20(b))	0.5	0.46
and where it is impractical to effect a seal weld	0.53	0.48
(11) Where the support is a gusset (see figure 32)	0.47	0.43
(12) For the crown plates of combustion chambers supported by continuously welded on girders (see figure 45)	0.67	0.61
(13) Where a flat plate is welded direct to another flat plate substantially at right angles, as given in figures 33(a) to 33(h) inclusive, for the method of attachment and weld preparation adopted:		
Figure 33(a)	0.47	0.44
Figure 33(b)	0.59	0.55
Figure 33(c)	0.47	0.44
Figure 33(d)	0.47	0.44
Figure 33(e)	0.59	0.55
Figure 33(f)	0.76	0.71
Figure 33(g)	0.50	0.47
Figure 33(h)	0.62	0.58

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If it is not practicable to effect a seal weld when the flat plate is attached as shown in figures 19, 20 and 21(a) the constant K_4 used in equation (12) shall be:

K_4 = 6.4 for plates exposed to flame;
K_4 = 6.7 for plates not exposed to flame.

If the welds are stress-relieved the constant K_4 in equation (12) shall be increased by 10 %.

3.6.1.2 Where the plates are flanged, the margin shall be measured from the commencement of curvature of flanging, or from a line 3.5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange. Where the flat plate is not flanged for attachment to the shell or flue tubes and is welded as shown in figures 20(a), 20(b) and 21(a) the width of the margin shall be measured from the inside of the shell or the outside of the flue tube, whichever is applicable.

In no case, however, shall the diameter D (in mm) of the circle forming the boundary of the margin supported by the uptake of a vertical boiler be greater than that found by equation (13):

$$D = \sqrt{\left(\frac{34.4A}{p}\right) + d^2} \qquad (13)$$

where

- A is the cross-sectional area of the uptake tube (in mm²);
- p is the design pressure (in N/mm²);
- d is the external diameter of uptake (in mm).

3.6.2 Breathing space

Gusset stays shall be arranged to give breathing space around the furnace connections and tube nests (see figure 22).

NOTE. For gusset stays above tube nests, a breathing space of 200 mm from the centre line of the adjacent tubes to the toe of the gusset angle or plate, is recommended.

3.6.3 Stayed flat surfaces

3.6.3.1 *General*

Stayed flat surfaces, other than the crowns of vertical boilers, shall comply with the requirements of **3.6.3.2** to **3.6.4**.

3.6.3.2 *Radius of flange*

Where flat end plates are flanged for connection to the shell, the inside radius of flanging shall be not less than twice the thickness of the plate, with a minimum of 38 mm. Where combustion chamber or firebox plates are flanged for connection to the wrapper, the inside radius of flanging shall be equal to the thickness of the plate, with a minimum of 25 mm.

3.6.3.3 *Point of support*

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

3.6.3.4 *Thickness*

The thickness of those portions of flat plates t (in mm) supported by stays shall be calculated using equation (14) and shall be not less than 6 mm:

$$t = K_5\, d \sqrt{\left(\frac{p}{f_4}\right)} + C \qquad (14)$$

where

- p is the design pressure (in N/mm²);
- f_4 = $0.85f$ where f is the design stress (in N/mm²) (see **2.2**);
- C is the corrosion allowance (in mm);
- d = $\sqrt{(A^2 + B^2)}$ where the stays are regularly pitched;

  where

  - A is the horizontal distance between the stays;
  - B is the vertical pitch of the stays.

Where the stays are irregularly pitched, then:

- d is the diameter of the largest circle which can be drawn through three points of support without enclosing another point of support. Only two points of support may lie on one side of any diameter of the circle. Where a flange is taken as a point of support, the circumference of the circle shall be tangent to the line of flange curvature (see **3.6.3.3**);
- K_5 is the constant, dependent on the method of support as given in **3.6.3.5** and **3.6.4**. Where various forms of support are used the constant K_5 shall be the mean of the values for the respective methods adopted.

C shall be not less than 0.75 mm.

3.6.3.5 *Constant K_5*

The value of the constant K_5 in equation (14) shall be taken from table 6.

NOTE. All constants given in table 6 are dependent on the method of support given to the plates. If the boiler is stress-relieved after the completion of all welding, the constants may be reduced by 10 %.

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3.6.4 Stiffened flat surfaces

In boilers where an end plate is supported in the steam space by a single substantial tee bar or a deep bulb bar, which is continuously fillet welded, with not less than 9.5 mm fillet welds, to the plate, the thickness of the plate shall be calculated using equation (14).

The tee bar or deep bulb bar shall extend across the plate to the commencement of curvature of the flange or the toe of the fillet weld securing the end plate to the shell.

The values of d and K_5 to be used in equation (14) shall be as follows.

(a) For the portion of the plate above the stiffener:

d is the diameter (in mm) of the largest circle passing through the centre of the tee bar, or bulb bar and the commencement of flange curvature, or the inside of the shell, whichever is applicable,

$K_5 = 0.39$.

(b) For the portion of the plate below the stiffener either:

d is the diameter (in mm) of the circle passing through the centre of the tee bar, or bulb bar and two adjacent stays,

$K_5 = 0.47$; or

d is the diameter (in mm) of the circle passing through the centre of the tee bar or bulb bar and the centre line of the top row of tubes,

$K_5 = 0.60$.

3.6.5 Flat crown plates for vertical boilers

3.6.5.1 *Support*

Flat crown plates shall be supported by the uptake and/or bar stays.

3.6.5.2 *Radius of flange*

The inside radius of curvature of the flange to the shell or firebox shall be not less than twice the thickness of the plate, and in no case less than 38 mm. Where the plate is flanged for attachment to the uptake the inside radius of curvature of the flange shall be not less than the thickness of the plate and in no case less than 25 mm.

3.6.5.3 *Thickness*

The thickness of flat crown plates shall be calculated using equation (14) with d and K_3 defined as follows.

(a) For a crown plate supported by an uptake only:

d is the diameter (in mm) of the largest circle which can be drawn between the connections to the shell or firebox and uptake (see **3.6.3.3**);

$K_5 = 0.51$ for plates exposed to flame;

$K_5 = 0.47$ for plates not exposed to flame.

(b) For bar stays fitted in accordance with **3.6.3**:

d is the diameter (in mm) of the largest circle which can be drawn through three points of support, without enclosing another point of support;

K_5 is the mean of the values for the respective points of support through which the circle passes (see **3.6.3.4**).

3.6.6 Girders for firebox and combustion chamber crowns

3.6.6.1 The total thickness t (in mm) of girders for firebox and combustion chamber crowns shall be calculated from equation (15).

$$t = \frac{l^2 p s_1}{c d^2 f_{20}} \qquad (15)$$

where

- l is the length of the girder (in mm) between supports, measured between the inside of the tube plate and the firehole (or back) plate, or between the inside of the side plates, according to the method of support;
- p is the design pressure (in N/mm²);
- s_1 is the pitch of the girders (in mm);
- d is the effective depth of the girder (in mm), i.e. the total depth less depth of water way, where such is provided;
- f_{20} is the minimum specified tensile strength (in N/mm²) of the steel at room temperature;
- c is a constant with:
  - $c = 0.31$ for steel plates;
  - $c = 0.25$ for steel castings.

3.6.6.2 Where girders are welded to the crown plate, the dimensions of the welds shall be such that the stress, calculated on an area equal to the sum of the effective lengths (see **3.6.10.3**) of the welds attaching each girder multiplied by the effective throat thickness (see **3.6.10.3**) shall not exceed 52 N/mm² multiplied by the appropriate weld factor in table 7. The load on the welds shall be taken as that due to the design pressure acting on the area ls_1, where l and s_1 are defined in **3.6.6.1**.

3.6.7 Stays for fireboxes, circular furnaces and combustion chambers

3.6.7.1 *Stays for flat plates*

The permissible stress in the stays, calculated on the net sectional area, shall not exceed 62 N/mm². The diameter of any stay shall be not less than 19 mm. Where plain stays exceeding 38 mm diameter are used, the stress shall not exceed

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Table 7. Weld attachments

Form of weld	Weld factor	
	Not stress-relieved	Stress-relieved
Single bevel butt welds (with or without superimposed fillet):		
unsealed	0.35	0.45
sealed	0.60	0.70
Double bevel butt welds (with or without superimposed fillets)	0.60	0.70
Double fillet welds	0.55	0.65

69 N/mm^2. The stress, in a plate stay secured at either end to the plate by fillet welds in accordance with figure 25(b), or in an anchor stay secured by a fillet weld as shown in figure 27, or in a bar stay secured at either end to the plate by fillet welds in accordance with figure 23(c), shall not exceed 52 N/mm^2.

3.6.7.2 ***Circumferential stays for circular furnace and fireboxes***

The diameter of the stay shall be not less than 22 mm or twice the thickness of the firebox plate, whichever is the greater.

The pitch of the stays at the firebox shall not exceed 14 times the thickness of the firebox plate.

3.6.8 Longitudinal bar stays

3.6.8.1 The diameter of each bar stay shall be such that the stress calculated on the least sectional area shall not exceed the specified minimum tensile strength divided by 5.3. In no case shall the diameter of the stay at any part be less than 25 mm.

3.6.8.2 Where bar stays are fitted in vertical boilers, the number fitted shall be as given in table 8.

3.6.8.3 Supports shall be provided for longitudinal bar stays of length equal to or greater than 4900 mm.

3.6.9 Loads on stay tubes and bar stays

Stay tubes and bar stays shall be designed to carry the whole load due to the pressure on the area to be supported, the area being calculated as follows.

(a) For a stay tube within the tube nest the net area to be supported shall be the product of the horizontal and vertical pitches (in mm) of the stay tubes, less the area of the tube holes embraced. Where the pitch of the stay tubes is irregular the area shall be taken as the square of the mean pitch of the stay tubes, i.e. the square of one quarter of the sum of the four sides of any quadrilateral bounded by four adjacent stay tubes, less the area of the tube holes embraced within this area.

(b) For a stay tube in the boundary row, or for a bar stay, the net area to be supported shall be the area (in mm^2) enclosed by lines bisecting at right angles the lines joining the stay and the adjacent points of support and by the boundary margin (see **3.6.1**), less the area of any tubes or stays embraced within this area (see figures 22(a) and 22(b)).

(c) For a bar stay where there are no stay tubes in the tube nest the area to be supported shall extend to the tangential boundary of the tube nest.

Table 8. Number of bar stays in vertical boilers

Boiler diameter	Number of bar stays
mm	
≥ 1200 < 1500	4
≥ 1500 < 1800	5
≥ 1800	6

3.6.10 Gusset stays

3.6.10.1 ***Load on each stay***

Each gusset stay supporting a flat plate of a boiler shall be designed to carry the whole load due to the pressure on the area it supports. The area supported by any one stay shall be obtained by considering the total area to be supported, which lies within the limits of the flat plate margins, and dividing this area by boundary lines drawn between the stays. These boundary lines shall be at all points equidistant from the adjacent points of support in the area under consideration.

The effective uniformly distributed load on a triangular gusset plate shall be assumed to be equal to the perpendicular load on the portion of the plate to be supported (determined as above) multiplied by L/L_1 (see figure 32).

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3.6.10.2 ***Gusset plate***

Gusset plates shall be so proportioned that the angle V (see figure 32) is not less than 60°.

The thickness of the gusset plate shall be such that the stress in the plate to withstand the effective uniformly distributed load (as defined in **3.6.10.1**) calculated on the smallest cross section on line XX or YY (see figure 32) shall not exceed one-seventh of the minimum tensile strength of the plate used, but in no case shall the thickness be less than seven-eighths of the thickness of the thinnest adjoining plate, with a minimum of 6.0 mm.

Where all-welded gusset stays are used to support the end plate in a cylindrical shell a stiffening plate shall be welded at the toe of the gusset where it is secured to the end plate, i.e. where the maximum stress occurs (see figure 32).

3.6.10.3 ***Weld attachments***

Where gusset plates, or angles are welded to the shell and/or end plates, the attachment shall be by means of continuous fillet welds on each side or by full penetration welds. The welds shall be of such dimensions that the stress calculated on an area equal to the effective length of the weld multiplied by the effective throat thickness shall not exceed that permitted for the parent metal multiplied by the appropriate weld factor in table 7.

The effective length of a weld shall be taken as that length of weld which is of the specified size throughout. For open ended fillet welds the effective length shall be the overall length less twice the weld size.

For the purpose of stress calculation the effective throat thickness of a butt weld shall be taken as the thickness of the gusset, or anchor plate, and the effective throat thickness of a fillet weld shall be taken as 0.7 of the fillet size. For compound welds the effective throat thickness shall be the sum of the constituent parts.

3.7 Tubes and tube plates

3.7.1 Wide water spaces between and around tube nests

3.7.1.1 Except as specified in **3.7.2** stay tubes shall be fitted in the tube nests. The thickness t (in mm) of the tube plate in the wide water space between tube nests shall be calculated from equation (16):

$$t = K_6 d \sqrt{\left(\frac{p}{f_5}\right)} + C \qquad (16)$$

where

- p is the design pressure (in N/mm²);
- f_5 = $0.85f$, where f is the design stress (in N/mm²) (see **2.2**);
- C is the corrosion allowance (in mm);
- d = $\sqrt{(A^2 + B^2)}$

where

- A is the width (in mm) of the wide water space between the tube nests (measured at the centre line of the stay tubes);
- B is the pitch (in mm) of the stay tubes in the boundary rows of the wide water space;
- K_6 is a constant, for which values are given in figure 34.

C shall be not less than 0.75 mm.

Where the stays are irregularly pitched, d shall be taken as the diameter (in mm) of the largest circle which can be drawn through any three points of support without enclosing another point of support.

Where various forms of support are used, the value of K_6 shall be the mean of the values for the respective methods adopted.

For stay tubes welded to the tube plates in accordance with figures 34(a) to 34(d), with tubes having a clearance in the tube hole not exceeding 0.75 mm on the diameter, or expanded to give full contact with the tube plate and welded in accordance with figures 34(a) to 34(c) the value of the constant K_6 shall be as shown on those figures.

3.7.1.2 For the portions of the end plates between the top rows of tubes and the steam space stays, equation (16) shall apply, B being taken as the distance (in mm) between the centre line of the top rows of tubes and the centre of the bar stays or other point of supports, and A being taken as:

$$\frac{A_1 + A_2}{2}$$

where

- A_1 is the distance (in mm) between the centres of bar stays or other method of support; and
- A_2 is the horizontal distance (in mm) between the centre of one stay tube and the centre of the next stay tube in the top boundary row.

3.7.1.3 Where stay tubes are not fitted equation (16) shall apply, d being taken as the largest circle which can be drawn through the centre of two stays and the centre line of the top row of tubes. The appropriate constants for stays shall be taken from **3.6.3**, and the value of the constant K_6 for the top row of tubes shall be taken as:

K_6 = 0.88 for plates exposed to flame;
K_6 = 0.78 for plates not exposed to flame.

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Where no stay tubes are fitted the support afforded by the plain tubes shall be taken not to extend beyond the line enclosing the outer surfaces of the tubes except that, between the outside of the wing row of tubes and the attachment of the end plate to shell, an unsupported width equal to the flat plate margin as given by equation (12) is allowed.

3.7.2 Parts of flat tube plates within tube nests

3.7.2.1 Stay tubes shall be fitted in the following cases:

(a) in directly fired, multitubular boilers in which all the tubes are arranged in one nest, the area of which exceeds 0.65 m^2;

(b) in multitubular, and waste-heat boilers in which all the tubes are arranged in one nest, the area of which exceeds 1.95 m^2;

(c) in all cases where the tubes are arranged in more than one nest.

3.7.2.2 Where stay tubes are fitted and secured as shown in figures 34(a) to 34(d), the thickness t (in mm) of those parts of the tube plates within the tube nests shall be calculated from equation (17):

$$t = K_6 M\sqrt{\left(\frac{p}{f_5}\right)} + C \qquad (17)$$

where

p is the design pressure (in N/mm^2);

f_5 = $0.85f$, where f is the design stress (in N/mm^2) (see **2.2**);

M is the mean pitch of the stay tubes (in mm), being the sum of the four sides of any quadrilateral bounded by four adjacent stay tubes divided by four;

K_6 is the constant, as given in figures 34(a), 34(b) and 34(c);

C is the corrosion allowance (in mm).

C shall be not less than 0.75 mm.

3.7.2.3 Where stay tubes are not fitted and where the area of the tube nest does not exceed 0.65 m^2 in the case of directly-fired boilers, or 1.95 m^2 in the case of waste-heat boilers, the thickness of the tube plate shall be calculated by equation (17) where all the symbols have the same significance except that:

M is four times the mean pitch (in mm) of the plain tubes in the nest;

K_6 = 0.49 for plates exposed to flame;

K_6 = 0.45 for plates not exposed to flame.

Where stay tubes are not fitted, the ends of all tubes shall be expanded and seal-welded or expanded beaded at the inlet end, and expanded and seal-welded or expanded only at the outlet end.

3.7.2.4 In the case of expanded tubes only the minimum thickness of any tube plate in the tube area shall be 12.0 mm where the diameter of the tube hole does not exceed 52 mm, or 15 mm where the diameter of the tube hole is greater than 52 mm.

NOTE. In the case of strength welded tubes only, with or without expansion before welding, these thicknesses may be calculated in accordance with **3.7** subject to a minimum thickness of 6 mm.

3.7.3 Tubes subject to internal or external pressure

3.7.3.1 ***Stay tubes***

Each stay tube shall be designed to carry its proportion of the load on the plates which it supports. No stay tube shall be less than 4.8 mm nominal thickness, and the thickness of stay tubes welded into tube plates shall be such that the maximum stress on the thinnest part of the tube does not exceed 70 N/mm^2.

3.7.3.2 ***Pitch of tubes***

The spacing of tube holes shall be such that the minimum width W (in mm) of any ligament between the tube holes shall be not less than:

$$W = 0.125d + 12.5$$

where

d is the diameter of the tube hole (in mm) (see **3.7.2.4** for the minimum thickness of tube plate).

3.7.3.3 ***Plain tubes***

The thickness of plain tubes subject to internal or external pressure shall be that shown in table 9. In determining the thickness in table 9 the negative manufacturing tolerances have been taken into account (see **2.1.5.3**).

Table 9. Minimum thickness of plain tubes subject to internal or external pressure

Outside diameter	Minimum thickness
mm	mm
≤ 38	2.9
> 38 ≤76.1	3.2
> 76.1 ≤101.6	3.6

NOTE. This table is based upon materials complying with BS 3059 : Part 1, having a minimum tensile strength of 324 N/mm^2. Other materials may be used by agreement between the manufacturer and the inspecting authority.

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3.7.3.4 ***Bent tubes***

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

3.7.4 Horizontal tube nests in vertical boilers

Where vertical boilers have a nest or nests of horizontal tubes, so that there is direct tension on the tube plates due to the vertical load on the boiler ends or to tube plates acting as horizontal ties across the shell, each alternate tube in the outer vertical rows of tubes shall be a stay tube and the thickness of the tube plates t (in mm) shall be calculated from equation (18):

$$t = \frac{2pD}{Jf_{20}} + C \qquad (18)$$

where

- p is the design pressure (in N/mm^2);
- D is twice the radial distance of the centre of the outer row of tube holes from the axis of the shell (in mm);
- C is a corrosion allowance (in mm);
- f_{20} is the specified minimum tensile strength at room temperature (in N/mm^2);
- J is the efficiency of ligaments between tube holes expressed as a fraction $\frac{S - d}{S}$

where

- S is the pitch of the tubes in the outer vertical row (in mm);
- d is the diameter of the tube holes (in mm).

C shall be not less than 0.75 mm.

3.7.5 Horizontal shelves of tube plates forming part of the shell

3.7.5.1 To withstand the vertical load F due to pressure on the boiler ends, the horizontal shelves of the tube plates shall be supported by a number of gussets determined from consideration of F (in N/mm) which is calculated using equation(19):

$$F = \frac{AD_i p}{t} \qquad (19)$$

where

- A is the maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate (in mm);
- D_i is the inside diameter of the boiler (in mm);
- p is the design pressure (in N/mm^2);
- t is the thickness of the tube plate (in mm).

For the combustion chamber tube plates the minimum number of gussets shall be:

one gusset where F exceeds 25 000 (N/mm);

two gussets where F exceeds 35 000 (N/mm);

three gussets where F exceeds 42 000 (N/mm).

For the smoke box tube plate the minimum number of gussets shall be:

one gusset where F exceeds 25 000 (N/mm);

two gussets where F exceeds 47 000 (N/mm).

3.7.5.2 The shell plates to which the sides of the tube plates are connected shall be not less than 1.5 mm thicker than is required by the formula applicable to shell plates with continuous circularity (see equation (1)); and where gussets or other stays are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other, shall be sufficient to withstand the whole load on the boiler end, with a factor of safety of not less than 4.5 related to f_{20}.

3.8 Cylindrical furnaces and combustion chambers subject to external pressure

3.8.1 Plain furnace and flue sections

3.8.1.1 ***Thickness***

The thickness of plain furnaces and flue sections t (in mm) shall be the greater of those calculated by the use of equations (20) and (21), but the thickness shall not exceed 22 mm or be less than the minimum thickness indicated in table 10.

Table 10. Minimum thickness of cylindrical shells subject to external pressure

Maximum outside diameter of cylinder	Minimum thickness (with external pressure)
mm	mm
700	6
1000	8
1500 and above	9

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$$t = \sqrt{\left\{\frac{p\,D_o\,(L + 610)}{1.03 \times 10^4}\right\}} + C \qquad (20)$$

$$t = \frac{K_8 p D_o}{110} + \frac{L}{320} + C \qquad (21)$$

where

- p is the design pressure (in N/mm);
- C is the corrosion allowance (in mm);
- D_o is the external diameter of the furnace or flue (in mm);
- L is the length of the section (in mm) between the centres of points of substantial support (see figure 35);

$K_8 = \frac{E_{tx}}{E_t}$;

where

- E_{tx} is the minimum specified 0.2 % proof stress (in N/mm^2) for plates complying with BS 1501 – 151 or BS 1501 – 161, grade 400B (see table 2);
- E_t is the minimum specified 0.2 % proof stress (in N/mm^2) for the material to be used (see table 2).

C shall be not less than 0.75 mm.

3.8.1.2 ***Stiffeners***

Where stiffeners are used on furnaces as shown in figure 36 the second moment of area I (in mm^4) about the neutral axis of the stiffener shall be not less than that calculated from equation (22):

$$I = \frac{D_o^3\,pl}{1.33 \times 10^6} \qquad (22)$$

where

- D_o is the external diameter of the furnace (in mm);
- p is the design pressure (in N/mm^2);
- l is the length of the section (in mm) between centres of points of substantial support.

NOTE 1. Equation (22) includes the value of Young's modulus of elasticity which has been taken as 185 kN/mm^2.

NOTE 2. Where stiffeners are made in sections from bar or plate, the abutting ends should be so prepared as to ensure that full penetration welds are made.

The thickness of the stiffening rings shall be kept to the minimum required, but in no case shall it exceed twice the thickness of the furnace plate.

Full penetration welds shall be used to attach stiffeners to furnaces.

3.8.2 Corrugated furnaces

For corrugated furnaces refer to figures **3.10.1.9.2** and **3.10.1.9.3** of BS 2790 : 1986.

3.8.3 Circular combustion chambers or gas reversal chambers

The thickness of wrapper plates of circular combustion chambers of horizontal multitubular boilers shall be calculated in accordance with equations (20) and (21). The maximum thickness shall, in no case, exceed 35 mm.

3.9 Fireboxes

3.9.1 Fireboxes of vertical boilers

The thickness of fireboxes not exceeding 1700 mm in external diameter shall be the greater of those obtained by the use of equation (20) or (21), where all the symbols have the same significance except that:

- D_o is the external diameter of the firebox (in mm). Where the firebox is tapered the diameter taken shall be the mean of that at the top and at the bottom where it meets the substantial support from the flange or ring.
- L is the effective length (in mm) of the firebox as indicated in figure 35 (see also **3.6.7.2**).

In no case, however, shall the thickness be more than 22 mm.

NOTE. For minimum thickness see table 10.

3.9.2 Uptakes

The thickness of the uptake t (in mm) shall be the greater of those obtained from equations (23) and (24) but the thickness shall be not less than 8.0 mm.

$$t = \sqrt{\left\{\frac{pD_o\,(L + 610)}{1.03 \times 10^4}\right\}} + 4 \qquad (23)$$

$$t = \frac{pD_o}{110} + \frac{L}{320} + 4 \qquad (24)$$

where

- p is the design pressure (in N/mm^2);
- D_o is the external diameter of the uptake (in mm);
- L is the length of uptake (in mm), measured between the points of substantial support.

3.9.3 Cross water tubes

Cross water tubes shall not exceed 305 mm internal diameter. The thickness of the tubes in no case shall be less than:

(a) 6.35 mm for tubes of 102 mm nominal bore and smaller;

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(b) 8.0 mm for tubes above 102 mm nominal bore and up to and including 152 mm nominal bore;

(c) 9.5 mm for tubes above 152 mm nominal bore and up to and including 305 mm nominal bore.

Tubes of 102 mm nominal bore and smaller expanded in and renewable shall be not less than 4.75 mm thick.

3.9.4 Hemispherical fireboxes

The thickness t (in mm) of unsupported hemispherical fireboxes subject to pressure on the convex surface shall be not less in any part than that calculated from:

$$t = \frac{K_9 p R_o}{60.5} + C \qquad (25)$$

where

p is the design pressure (in N/mm^2);

R_o is the outer radius of curvature of the firebox (in mm);

C is the corrosion allowance (in mm);

$$K_9 = \frac{E_{tx}}{E_t} > 0.85;$$

where

E_{tx} is the minimum specified 0.2 % proof stress (in N/mm^2) for plates complying with BS 1501 – 151 or BS 1501 – 161, grade 400B (see table 2);

E_t is the minimum specified 0.2 % proof stress (in N/mm^2) for the material to be used (see table 2).

3.9.5 Ogee rings

The thickness t (in mm) of the ogee ring which connects the bottom of the firebox to the shell of a vertical boiler and sustains the whole vertical load on the firebox shall be calculated from equation (26).

$$t = \sqrt{\left\{\frac{pD_i\,(D_i - d_o)}{990}\right\}} + C \qquad (26)$$

where

p is the design pressure (in N/mm^2);

C is a corrosion allowance (in mm);

D_i is the inside diameter of the boiler shell (in mm);

d_o is the outside diameter of the lower part of the firebox where it joins the ogee ring (in mm).

C shall be not less than 0.75 mm.

3.9.6 Firebox plates under compression

The thickness t (in mm) of firebox tube plate under compression due to the pressure on the crown plate, based on a compressive stress of 97 N/mm^2, shall be not less than that given by equation (27).

$$t = \frac{plV}{193\,(V - d_i)} \qquad (27)$$

where

p is the design pressure (in N/mm^2);

l is the internal length of firebox (in mm), measured at the top between the tube plate and the back plate;

V is the pitch of tubes (in mm), measured horizontally where the tubes are chain pitched, or diagonally where the tubes are zig-zag pitched and the diagonal pitch is less than the horizontal pitch;

d_i is the internal diameter of the plain tubes (in mm).

Section four. Manufacture and workmanship

4.1 Pressure parts

4.1.1 Cylindrical shells

4.1.1.1 *General*

Except where the design incorporates flat tube plates in the shell, each ring shall be formed from not more than two plates, bent to cylindrical form to the extreme ends of the plate. The bending shall be done entirely by machine, and local heating or hammering shall not be used.

The seams in successive rings shall not fall in line.

NOTE. In the case of brick set boilers the seam or seams should be kept clear of the brickwork as far as practicable.

4.1.1.2 *Circularity*

The difference between the maximum and minimum internal diameters of the shell measured at any one cross section shall not exceed 1 % of the nominal internal diameter.

Irregularities in profile (checked by a 20° gauge) shall either:

(a) not exceed 3 mm plus 5 % of the nominal plate thickness; or

(b) not exceed the value of (a) by more than 25 % if the length of the irregularity does not exceed one quarter of the length of the shell part between two circumferential seams with a maximum of 1000 mm.

NOTE. There should not be flats at the welded seams, and any local departure from circularity should be gradual. Cold rolling of a welded shell to rectify a small departure from circularity is permitted provided that non-destructive testing takes place after the departure from circularity has been remedied.

4.1.1.3 *Compensating plates*

Compensating plates shall be fabricated from carbon steel.

NOTE. Before attachment, compensating places should bed closely to the plates to which they are to be connected.

Welds shall be on the transverse centre line (see **3.2.2** regarding the sizes of fillet welds). Tell-tale holes shall be drilled in compensating plates.

4.1.2 End plates, crown plates and tube plates

4.1.2.1 All end plates, crown plates and tube plates shall be of one piece and shall be made from one rolled plate.

4.1.2.2 The segments for hemispherical shell crown plates shall be pressed in one heat to correct curvature and shall be butt welded together in accordance with figure 37(a) or 37(b). The cylindrical portion of the crown shall be tangential to the hemispherical portion.

Where hemispherical shell crowns are pressed from one plate the provisions of **4.1.8.2** shall apply.

4.1.2.3 Flanging of plates shall be done by machine and such flanging shall be done hot.

NOTE 1. Flanging of plates should preferably be carried out in one operation, but where this is impracticable, creep machine flanging may be used provided that the plate is worked at a suitable temperature and heated for an adequate distance beyond this portion of the plate under immediate treatment.

NOTE 2. After completion of the flanging operation flanges should be of true peripheral contour (either circular or straight as necessary, to ensure accurate alignment with the connecting parts), and of good surface free from bulges, grooves or other local irregularities; flat portions of plate should be free from set or distortion.

4.1.2.4 Where flats are pressed in dished end plates for the attachment of mountings they shall be formed with a radius at the junction of the flat and curved surfaces.

NOTE. The flats should be free from sharp corners and tool marks and the plate should not be unduly thinned.

4.1.2.5 Plates which are flanged in accordance with **4.1.2.3** shall be welded to the parts to which they are to be connected as follows:

(a) to shells or cylindrical fireboxes as shown in figure 29(a), 29(b) or 29(c), or 30(a) or 30(b);

(b) to internal furnace flue tubes as shown in figure 21(b) or 21(c);

(c) to uptakes as shown in figure 29(a), 29(b) or 29(c);

(d) to combustion chamber or firebox wrapper plates as shown in figure 31(a).

4.1.2.6 Plates which are not flanged shall be welded to the parts to which they are to be connected as follows:

(a) to shells as shown in figures 20(a) and 20(b);

(b) to internal furnace flue tubes or uptakes as shown in figure 21;

(c) to reversal chamber or firebox wrapper plates as shown in figures 31(b), 31(c) and 31(d).

The form of attachment shown in figure 31(d) shall be used only when the back plate is fully supported by stays.

4.1.2.7 Where dished ends or crowns are used they shall be flanged for connection to the shell or the cylindrical portion of the firebox. Flat shell and firebox crown plates of vertical boilers shall also be flanged for connection to the cylindrical portions of the shell or firebox.

4.1.2.8 The opening in the firebox crown plate of a vertical boiler for the uptake shall be flanged and the connection to the uptake made by means of a circumferential butt weld (see figures 37(a) and 37(b)).

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4.1.3 Plain tubes and stay tubes

4.1.3.1 Plain tubes shall be secured by any of the methods required by **4.1.3.3** for stay tubes or by one of the following methods.

(a) Expanded to give full contact with the tube hole and seal welded at both ends as shown in figure 38(a).

(b) Where the gas temperature does not exceed 315 °C, seal welded only at both ends in tube holes having a clearance not exceeding 0.75 mm on the diameter as shown in figure 38(b).

(c) Fully expanded both ends as shown in figure 38(c) or 38(d).

(d) Expanded to give full contact with the tube hole and welded as shown in figure 38(a) at the inlet and full expanded as shown in figure 38(c) or 38(d) at the outlet end.

4.1.3.2 Where plain tubes are expanded only, the process shall be carried out with roller expanders, and the expanded portion of the tube shall be parallel through the full thickness of the tube plate.

NOTE. In addition to expanding, tubes may be bell-mouthed or beaded at the inlet end (see figure 38(d)).

4.1.3.3 Stay tubes shall be fitted in all cases where the tubes are arranged in more than one nest, and shall be secured by one of the following methods.

(a) Expanded to give full contact with the tube hole and welded at both ends as shown in figure 34(a) to 34(d).

(b) Where the gas temperature does not exceed 315 °C and the tube wall thickness is 6 mm or less, welded at both ends as shown in figure 34(a) to 34(c) in tube holes having a clearance not exceeding 0.75 mm on the diameter.

(c) Where the tube wall thickness is greater than 6 mm and the length of the unwelded land does not exceed four times the tube wall thickness, welded at both ends as shown in figure 34(a) to 34(c) in tube holes having a clearance not exceeding 0.75 mm on the diameter.

4.1.4 Access openings for steam boilers

4.1.4.1 At least one manhole or inspection hole shall be provided in the upper part of the boiler. The dimensions of manholes and inspection holes shall be not less than those given in table 11 for the given size of the boiler, except as allowed in **4.1.4.2.**

NOTE 1. Where possible a manhole or inspection hole should be provided in the lower part of front end plates in horizontal multitubular boilers.

NOTE 2. Section 30 of the Factories Act 1961 applies if there is a likelihood of dangerous fumes being present within a tank to such an extent as to involve risk of persons being overcome by them.

The relevant part of Section 30 of the Factories Act 1961 states:

'The confined space shall, unless there is other adequate means of egress, be provided with a manhole, which may be rectangular, oval or circular in shape, and shall be not less than 18 inches (460 mm) long and 16 inches (410 mm) wide or (if circular) not less than 18 inches (460 mm) diameter.'

Section 30 also applies to the lack of oxygen within a confined space. Reference may be made to subsections (9) and (10) of Section 30 for the full legal requirements.

Table 11. Dimensions of manholes and inspection holes

Diameter of boiler	Minimum size of holes
mm	mm
> 600 ≤750	230 × 180
> 750 ≤900	320 × 220
> 900 ≤1050	350 × 250
> 1050 ≤1500	380 × 280
> 1500	400 × 300

NOTE. Openings smaller than 400 mm by 300 mm are not suitable as a means of entry into the boiler.

As an alternative where raised circular manholes or inspection openings are used, the diameter shall be not less than the major axis listed in table 11 and shall be in accordance with **3.5.1.**

4.1.4.2 Where the size or construction of the boiler does not permit entry for cleaning or inspection of all internal surfaces, cleaning holes shall be provided for this purpose. The cleaning holes shall be not less than 90 mm by 65 mm.

4.1.4.3 One cleaning hole shall be provided opposite at least one end of each cross tube in a vertical cross tube boiler. Where the water tubes are arranged in banks across the firebox, an opening in the shell to permit their replacement shall be provided.

4.1.4.4 At the bottom of the narrow water space in vertical boilers, openings shall be provided for cleaning and inspection purposes. A minimum of three openings shall be provided in boilers of internal diameter up to and including 900 mm, and a minimum of four openings shall be provided for boilers exceeding 900 mm internal diameter.

The openings shall be spaced at equal distances around the circumference of the boiler.

4.1.5 Manhole frames, mouthpieces and doors

4.1.5.1 ***General***

Manhole frames, mouthpieces, doors and cover plates shall be of steel complying with **2.1.**

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4.1.5.2 ***Location***

Manhole and other openings in shells shall be placed as far as practicable from any seam. Wherever practicable, oval openings shall be arranged with the minor axis parallel with the longitudinal centre line of the boilers. In no case shall the circumferential length of any opening exceed twice the longitudinal width of the opening.

Where the manhole is located in or in between tube nests in multitubular boilers the stay tubes in the boundary rows, or gusset stays, as applicable, shall be arranged as close as practicable to the manhole.

4.1.5.3 ***Frames***

Oval frames of the flanged type shall be formed to bed closely to the shell and provide a flat jointing surface for the door. Wherever practicable, such frames shall be attached to the inside of the shell, with the shorter axis parallel with the longitudinal centre line of the boiler.

Oval frames and external raised circular mouthpieces shall be either formed in one piece without weld, or formed from a suitable rolled section fabricated by fusion welding.

Welds in fabricated manhole frames and mouthpieces shall be positioned so that they are in a plane at right-angles to the longitudinal axis of the boiler.

The joint face of manhole frames shall be not less than 17.5 mm wide.

NOTE. Typical forms of manhole frames and attachments are shown in figures 6(a), 6(b) and 6(c), figure 17 and figure 39.

4.1.5.4 ***Jointing flanges***

The jointing flanges of mouthpieces and covers shall be machined on their jointing faces and a satisfactory bearing surface of the nuts and bolts shall be provided. All edges shall be machined or thermal cut by machines.

4.1.5.5 ***Doors***

Doors shall be constructed in accordance with the following.

(a) Doors shall be formed to bed closely to the internal joint surface and shall be fitted with studs, nuts and cross bars.

(b) Doors for openings larger than 230 mm by 180 mm shall have two studs, but for openings of 230 mm by 180 mm or less, only one stud need be fitted.

NOTE. Doors for openings not larger than 125 mm by 90 mm may have the stud forged integrally with the door.

(c) Door studs shall be of steel having a minimum specified tensile strength of 432 N/mm^2, and those for manholes shall be not less than 30 mm diameter. They shall be:

(1) screwed through the plate with a lock nut on the inside; or

(2) screwed through the plate and fillet welded on the inside; or

(3) riveted on the inside of the door; or

(4) fillet welded each side of the plate with a leg length of not less than 9.5 mm.

(d) The spigot part, or recess of the manhole and sighthole doors shall be as neat a fit as practicable. In no case, however, shall the clearance all round exceed 1.5 mm.

(e) Nuts shall be to BS 3643, and shall be faced on the seating surface.

(f) Cross bars shall be of steel (see **2.1**) and shall be forged or cut from plate having a minimum specified tensile strength of 432 N/mm^2 to 494 N/mm^2. The seating surface shall be faced.

4.1.6 Seatings for mountings

4.1.6.1 ***General***

Mountings over 25 mm internal diameter, except flanged mountings up to and including 75 mm bore, shall not be attached directly to any boiler plate, but shall be carried on forged, cast or fabricated steel seatings.

NOTE 1. These seatings should take the form of short standpipes, forged pads or pads cut from plate or round bar as may be convenient.

NOTE 2. Water gauges and pressure gauge syphons may be attached directly to the plate without the intervention of a pad or standpipe, provided that they are flanged and secured by studs.

NOTE 3. It is important that flanges and pads in contact with the boiler should be formed to bed closely to the plate to which they are to be attached.

If studs are screwed through the boiler plate, nuts of full thickness complying with BS 3643 and BS 1580 shall be fitted on the inside of the boiler.

4.1.6.2 ***Standpipes***

Where standpipes are used, the flanges shall be machined or flame-cut by machine on the edges. The bolting flanges shall be machined on the jointing face.

NOTE. A satisfactory bearing surface for bolt heads and nuts should be provided.

4.1.6.3 ***Pads***

Where pads are used, the jointing surfaces shall be machined. Pad thickness shall be such as to allow the drilling of the stud holes for mountings without the inner surface being pierced and the length of the screwed portion of the stud in the pad shall be not less than the diameter of the stud.

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4.1.6.4 ***Methods of attachment***

Seatings shall be attached to the shell or end plates by one of the following methods:

(a) welding in accordance with **4.2**;

(b) where the internal diameter of a standpipe does not exceed 32 mm, by screwing the standpipe through the plate and fitting with a nut on the water side, or seal welding.

Where mountings with screwed ends up to and including 25 mm diameter are used they shall be attached by one of the following methods:

(c) screwed into a seating;

(d) screwed directly into the shell or end plate with nuts being fitted on the water side;

(e) screwed into steel distance pieces, the length of the thread engaged being, in no case, less than the bore of the mountings plus 6.5 mm;

(f) any method of attachment of equivalent efficiency to those given in items (a) to (e).

NOTE. In the case of (f), the use of attachments of equivalent efficiency, these should be subject to agreement between the inspecting authority and the manufacturer.

The distance pieces shall be made from solid steel in accordance with **2.1**. They shall be screwed into the plate and fitted with nuts on the water side. The walls of the distance pieces shall be not less than 6.5 mm thick at the bottom of the thread.

All bolt and stud holes shall be drilled.

4.1.7 Cylindrical furnaces (or flues)

4.1.7.1 Cylindrical furnaces shall be made either in sections each being made from one plate, bent while cold to circular form and the longitudinal seam fusion butt welded by the metal arc process, in accordance with **4.2** or alternatively, made from hot finished seamless carbon steel pipes to grades 410 HFS or 410 CFS of BS 3602 : Part 1, or from grade 430S of BS 3601, the tensile strength and minus tolerances on thickness being taken into account.

4.1.7.2 The maximum permissible variation in diameter of any cross section shall not exceed 6.5 mm or half the thickness of the plate, whichever is the greater.

4.1.7.3 The longitudinal welds shall be placed at the lower part of the furnace and shall break joint in successive sections by at least 150 mm.

4.1.7.4 Where the furnace sections are flanged for circumferential joints the flanging shall be carried out at one heat by appropriate machinery.

4.1.7.5 Edges of all furnace flanges shall be machined or thermal cut by machine.

4.1.7.6 Where longitudinal dimensional flexibility is provided, it shall be permissible for the cylindrical sections to be connected to each other by fusion butt-welded circumferential seams.

4.1.7.7 Where stiffeners are used these shall have a second moment of area not less than that required by **3.8.1.2** and shall be attached externally by means of continuous full penetration welds on each side (see figure 36).

4.1.7.8 Where a complete furnace is constructed of short plain sections, and where flexibility is not already provided, the ends of each adjoining section shall be swaged out to a radius, to provide a point of support and longitudinal flexibility, and butt welded together.

The dimensions shall comply with figure 40.

NOTE 1. Forms of furnace connections to end plates are shown in figure 21(a), 21(b) and 21(c).

NOTE 2. Where the furnace is inserted into a hole in the end plate it should be a good fit around the whole periphery.

4.1.8 Fireboxes

4.1.8.1 ***Plain circular fireboxes***

The cylindrical portion of fireboxes shall be formed from one plate in a similar manner to the furnace plates (see **4.1.7**). The maximum permissible variation in diameter at any cross section shall not exceed 6.5 mm for fireboxes up to 900 mm diameter, or 9.5 mm for fireboxes over 900 mm diameter, or half the thickness of the plate whichever is the greater.

NOTE 1. Vertical fireboxes should preferably be tapered, a taper of 1 in 8 on diameter being recommended.

The water space at the bottom between the firebox and the shell shall be not less than 50 mm for boilers up to and including 750 mm diameter, and not less than 63 mm for boilers over 750 mm diameter.

The method of welding shall be in accordance with **4.2**.

Flats formed in the firebox for the insertion of water tubes shall have a radius at the junction of the flat and the curved surfaces and shall be free from sharp corners or tool marks.

NOTE 2. The plate should not be unduly thinned.

NOTE 3. Ogee flanging, whether integral with the firebox or made as a separate ring, should preferably be formed at one heat by suitable machinery and should be allowed to cool gradually to avoid internal stresses.

Rings for firehole mouthpieces or foundation rings shall be made of steel in accordance with **2.1**. 'Z' sections shall not be used for foundation rings.

Attachment of fireboxes to cylindrical shells shall be in accordance with figure 41.

NOTE 4. Typical methods of attachment of firehole mouthpieces are shown in figure 42(a) or 42(b).

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4.1.8.2 ***Hemispherical fireboxes***

Hemispherical fireboxes shall be pressed to form by machine in progressive stages without thinning and shall be normalized on completion.

Methods of attachment of firebox to the shell shall be in accordance with figure 41.

NOTE. Typical methods of attachment of firehole mouthpieces are shown in figure 42 and for flue pipes in figure 43.

4.1.8.3 ***Water-cooled reversal chambers***

The attachment of the combustion chamber tube plates and back plates to the wrapper plate shall be in accordance with figures 31(a), 31(b) and 31(c) and where the tube plate or back plate is flanged for connection to the wrapper plate the weld shall be located between the commencement of curvature of the flange and the first row of stays.

Weld detail in figure 31(d) shall only be used where the back plate is fully supported by stays.

NOTE. Typical methods of attachment of furnaces and access opening frames are shown in figure 21(a), 21(c) or 19 as appropriate.

4.1.8.4 ***Uptakes***

Uptakes shall be formed from seamless tube, or fusion butt-welded plate, and shall be fusion welded to the upward flange of the opening in the firebox crown plate.

The depth of the flange of the firebox crown plate opening, from the commencement of the curvature of the flange, shall be not less than twice the plate thickness, with a minimum of 25 mm.

NOTE 1. The uptake may be attached to the shell crown as indicated in figures 21(a) to 21(c) or by a method agreed between the inspecting authority and the manufacturer.

Where the vertical seam of the uptake is fusion welded the welding shall comply with **4.2** and the weld shall be arranged so that it is directly facing the manhole.

NOTE 2. It is desirable in the case of steam boilers that the uptake should be fitted with an internal cast iron liner extending below the low water level.

4.1.9 Cross tubes and stays

4.1.9.1 ***Cross tubes***

Cross tubes shall be made from seamless steel tubes (see **2.1.5**). The tubes shall be of sufficient length to project through the firebox plate not less than 6 mm, nor more than 16 mm, at any part of the circumference of the tube. The tube shall be fusion welded in position.

NOTE. The holes in the firebox plate should be suitably chamfered, and care should be taken to ensure good penetration (see figure 44).

4.1.9.2 ***Stays***

All bar stays or firebox stays shall be made from a solid rolled bar without weld in its length, except those welds attaching them to the plates they support.

NOTE. It is recommended that when a stay is in position in the boiler, its axis is normal to the plate it supports.

4.1.9.3 ***Bar stays***

Bar stays shall be secured to the plates they support by one of the following methods.

(a) Plain bars passing through clearance holes in the plates and welded thereto (see figures 23(a), 23(b), and 23(c)).

(b) Plain bars passing through clearance holes in the plates and fitted with washers on the outside, the stay and washers being welded to the plates in accordance with any one of the methods shown in figures 24(a) or 24(b).

4.1.9.4 ***Firebox stays***

Firebox stays shall be secured to the plates which they support by welding (see figures 23(a), 23(b) and 23(c)).

4.1.9.5 ***Gusset stays***

Gusset stays shall be flat and perpendicular to the end plates. Gusset plates shall not be subjected to cranking or setting.

4.1.9.6 ***Girder stays***

The attachment of girder stays welded directly to the crown plates shall be by means of double fillet or full penetration welds, and shall comply with figure 45.

NOTE. Each girder should be of sufficient strength to support its due proportion of the load on the crown plate independently of the crown plate, and the weld attachments have sufficient cross-sectional area to carry the applied load (see **3.6.10.3**).

4.2 Welding

NOTE. This clause does not specify individual processes or procedures. The manufacturer should be prepared to prove to the satisfaction of the purchaser or the inspecting authority, the suitability of the weldings and the ability of his organization to produce satisfactory welds.

4.2.1 General

Before commencing construction, the manufacturer shall supply to the inspecting authority, if any, on request, fully dimensioned sectional drawings, showing in full detail the construction of the pressure parts to be welded. Drawings of the proposed weld preparations of the main seams shall be dimensioned and shall be drawn to a scale which clearly shows the relevant details. Sketches shall also show details of the weld preparations for the attachment of standpipes, branches and seatings and their location relative to the longitudinal and circumferential seams and to other openings.

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NOTE 1. The welding terms used in this standard are defined in BS 499 : Part 1.

NOTE 2. It is important that care is taken when designing branches and similar components that the characteristics of the material of the main pressure part will not be adversely affected by the welds such as to render the component unfit for the duty intended.

4.2.2 Approval of welding procedures

Welds in boilers shall be made using any fusion welding process in accordance with BS 4870 : Part 1 or Part 4 by welders or welding operators whose competence has been established.

Routine tests of competence of welders or welding operators shall be made and recorded in accordance with the requirements of BS 4871 : Part 1 or BS 4870 : Part 4, respectively.

4.2.3 Materials

The welding consumables to be used shall comply with the relevant British Standard for the consumables where available.

NOTE. In the absence of a relevant British Standard agreement should be reached between the manufacturer, purchaser and/or inspecting authority, if any.

4.2.4 Preparation for welding

4.2.4.1 Weld preparations and openings of the required shapes shall be formed by either of the following methods:

(a) machining, chipping or grinding; chipped surfaces which will not be covered with weld metal shall be ground smooth after chipping; or

(b) thermal cutting and gouging.

NOTE. Plate edge weld preparations for butt-welded seams may be either of the single-V or double-V type, with the exception that, for machining welding, plates may have square edges.

4.2.4.2 Any material damaged in the process of cutting to size and preparation of edges shall be removed by machining, grinding or chipping back to undamaged metal. Surfaces which have been thermally cut shall be machine dressed or ground to remove severe notches, slag and scale. Slight oxidation of machine thermal-cut edges on mild steel shall not be regarded as detrimental.

4.2.4.3 After the edges of the plates have been prepared for welding they shall be given a thorough examination for flaws, cracks, laminations, slag inclusions or other defects by an appropriate method. When plates are thermal cut the edges shall be examined before further work is carried out. The profile of the weld preparation shall be as specified in the approved weld procedure (see **4.2.2**).

4.2.5 Assembly of components for welding

4.2.5.1 The parts to be welded shall be assembled and securely held in position by mechanical means, welded bridge pieces or tack welding. Tack welds, where used, shall be removed so that they do not become part of the seam. Correction of irregularities shall not be carried out by hammering.

4.2.5.2 Where a root gap is specified the edges of butt welds shall be held so that the correct gap is maintained during welding. The surfaces of plates at the longitudinal and circumferential seams shall not be out of alignment with each other at any point by more than 10 % of the plate thickness, but in no case shall the misalignment exceed 3 mm for longitudinal seams or 4 mm for circumferential seams (see also **4.2.5.4**).

4.2.5.3 Where welded bridge pieces are used, care shall be taken to ensure that the surfaces of material are not left in a damaged condition after the attachment has been removed.

4.2.5.4 Where plate edges of unequal thickness are abutted and the difference between the surfaces exceeds that mentioned in **4.2.5.2**, on either side, the thicker plate shall be trimmed to a taper for a distance not less than four times the offset.

4.2.5.5 Plates subject to forming shall be made from one piece.

4.2.6 Welds of main seams

NOTE 1. Reference should be made to figure 37 for typical welding details. Other welding preparation, approved by an inspecting authority, may be used.

NOTE 2. Butt welds of main seams may be welded from both sides of the plate, or from one side of the plate only with a backing strip.

4.2.6.1 Where multirun welding is employed each deposited run shall be free from slag and when required by the welding procedure, scale shall be removed before further runs of weld are deposited.

4.2.6.2 There shall be no undercutting present at the edges of completed welds. The positions of welds, where not apparent, shall be permanently marked at their extremities to facilitate location.

4.2.6.3 At no point should more than two welded seams meet.

NOTE. Openings in or near welded seams should be avoided, but if they cannot be avoided they may be accepted if the welds are proved to be sound by means satisfactory to the inspecting authority.

4.2.7 Attachment by welding

NOTE 1. Attachment of parts by welds which cross or which are in the immediate vicinity of existing main welds in pressure parts should be avoided. If such welds cannot be avoided, they should cross the main weld completely rather than stop abruptly near the main weld, in order to avoid stress concentrations in these areas.

NOTE 2. Reference should be made to figures 3, 5, 13 to 15 and 46. Other welding procedures approved by an inspecting authority may be used (see **4.2.1**).

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4.2.7.1 ***Attachment by welding of pressure parts to shells***

Not less than two runs of metal shall be deposited at each weld. Each run of weld metal shall be clean and free from slag before the next run is deposited. When one side of a full penetration double groove weld has been completed the under surface of the original run shall be removed by chipping, grinding, thermal cutting or gouging to give a clean metallic surface before welding from the other side is commenced.

The complete weld shall be free from crevices between weld runs and the final finish of all welds shall be such that the change of section between parts is gradual and free from sharp notches and significant undercutting.

4.2.7.2 ***Attachment by welding of non-pressure parts to shells***

The attachment of non-pressure parts, e.g. brackets, lugs and flats, to shells by welding shall be permitted.

NOTE. Non-pressure parts connected to the shell by welding should be of the same nominal chemical composition as that of the steel immediately adjacent.

4.2.7.3 ***Temperature***

No welding or tack-welding shall be carried out when the temperature of the parent material within 150 mm of the joint is less than 5 °C.

4.3 Dampers, doors and observation ports

4.3.1 Solid fuel boilers

4.3.1.1 ***Air control damper***

In order to control the combustion of the fuel in the boiler at varying rates of burning, boilers which are to be hand fired shall be provided with an adjustable air inlet below the grate.

4.3.1.2 ***Secondary air***

Provision shall be made for the admission of secondary air above the fuel bed for hand-fired boilers.

4.3.1.3 ***Doors at front and above grate level***

The clearance between doors when fitted, and the surface against which they close shall not exceed 1 mm or alternatively in the case of firing doors for hand-fired boilers shall not exceed 2 mm.

4.3.1.4 ***Flue or chimney damper***

Hand-fired boilers shall be fitted with a sliding or butterfly damper at the outlet. Sliding dampers shall be clearly graduated to facilitate accurate setting. Butterfly dampers shall have a handle, indicating clearly the position of the blade, which is to be capable of being held in position to prevent movement. Dampers of either type shall be so shaped that, when in the fully closed position, the free area to permit the passage of flue gases is not less than 12 % of the area of the flue in the plane of the damper.

In the case of boilers supplied for automatic stoking where a damper is fitted, provision shall be made for it to be locked in the correct position.

4.3.2 Boilers for gaseous and/or liquid fuels

4.3.2.1 A boiler using gaseous or liquid fuels shall not be fitted with a manually operated damper. In the case of a solid fuel boiler being converted to use gaseous or liquid fuel, any damper shall be removed or adequately secured in the open position.

4.3.2.2 Any automatic flue or combustion air dampers fitted on a boiler using gaseous fuel shall comply with BS 5978 and BS 5885 as applicable.

4.3.2.3 Automatic flue or combustion air dampers fitted on a boiler using liquid fuel, shall be provided with interlocking equipment to prevent the combustion equipment operating if the damper is not in the correct position.

NOTE. In the case of combustion equipment supplied or recommended by the boiler manufacturer, provision should be made for flame observation during the commissioning operation.

4.4 Ashpits

The capacity of the ashpit for hand-fired boilers shall be not less than 25 % of the fuel capacity of the boiler.

4.5 Inspection and cleaning holes

In steam boilers, inspection and cleaning holes shall be provided to permit thorough cleaning and inspection.

NOTE. It is recommended that means of cleaning and inspection also be provided on hot water boilers.

4.6 Provisions for mountings, appliances and connections

All boilers shall have openings for flow and return connections and for mountings and appliances as specified in the relevant clauses in sections five and six.

The position of flow openings in hot water boilers shall be such that air will not be retained in the boiler shell or waterway.

The openings in steam boilers for the feed-water connection shall be located above the lowest permissible water level in the boiler. Any internal distribution pipes shall also terminate above this level to safeguard against accidental loss of water from the boiler.

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Where face to face joints are embodied in the design of boilers, they shall be provided with counter flanges or flanged connections.

NOTE. The type of flange or flanged connection may be agreed between the purchaser and the manufacturer.

The screw thread of the studs or bolts shall comply with BS 1580 : Parts 1 & 2.

4.7 Assembly of boiler

For sectional boilers, sufficient jointing materials to seal all the joints, and assembly instructions shall be provided.

Section five. Mountings and fittings

5.1 Safety valves

5.1.1 Tappings for safety valves

Where the safety valve is not supplied by the manufacturer, a tapping for a safety valve shall be provided on the boiler of a size not less than that specified in table 12. For a sectional boiler, the tapping size shall be that appropriate to the maximum number of sections offered by the manufacturer.

Table 12. Tapping sizes for safety valves

Rated output	Nominal tapping size
kW	
44 to 264	R ¾
265 to 352	R 1
353 to 440	R 1¼
441 to 528	R 1½
529 to 732	R 2
733 to 1142	R 2½
1143 to 1640	R 3
1641 to 3000	2 × R 3

5.1.2 Provision of safety valves

5.1.2.1 Where the safety valve (or valves) is supplied or fitted by the boiler manufacturer it shall be in accordance with BS 6759 : Part 1, sized and fitted in accordance with **5.1.2.2** and **5.1.3** and set to lift at a pressure not higher than the boiler design pressure (see **1.2.1**).

NOTE 1. Attention is drawn to the provisions of the Factories Act 1961, Section 32 with regard to construction and attachments to steam boilers.

NOTE 2. It is important that, when safety valves are fitted by other than the boiler manufacturer, the safety valves meet the requirements of **5.1.2**.

NOTE 3. For recommendations regarding the installation provisions for safety valves see **A.1**.

5.1.2.2 The safety valve (or valves) shall be fitted vertically and attached directly to the boiler or, if this is impracticable, by means of the shortest possible straight length of pipe, arranged vertically and having an internal diameter not less than the bore of the valve, or an internal cross-sectional area not less than the aggregate area of all valves mounted upon it, and used solely for the purpose without any intervening valve or cock.

5.1.3 Sizing

5.1.3.1 The nominal bore of the safety valve shall be not less than 20 mm.

5.1.3.2 For open vented hot water systems, the sizes of safety valves shall be not less than those given in table 13 or for valve sizes not covered by table 13, the minimum flow area A shall be determined from equation (28).

Table 13. Sizes of safety valves (open vented systems only)

Valve rating	Nominal size	Minimum flow area (A)
kW	mm	mm²
44 to 263	20	314
265 to 352	25	491
353 to 440	32	802
441 to 528	40	1135
529 to 732	50	2050
733 to 1142	65	3210
1143 to 1640	80	4540
1641 to 3000	2 × 80	8180

$$Q_V = 2(0.329 P_a A K_{dr}) \qquad (28)$$

where

Q_V is the rating of the safety valve (in kW);

P_a is the maximum absolute relieving pressure {(design pressure × 1.10) + 1} (in bar[1]);

A is the flow area (in mm²);

K_{dr} is the derated coefficient of discharge.

NOTE. This equation is based on equation (18) of BS 6759 : Part 1 : 1984, but includes 100% vent allowance for vent sizes in accordance wilth table 14.

5.1.3.3 For unvented hot water systems, the maximum flow area, A, of the safety valves shall be determined using equation (29):

$$Q_V = 0.329 P_a A K_{dr} \qquad (29)$$

where

Q_V is the rating of the safety valve (in kW);

P_a is the maximum absolute relieving pressure {(design pressure × 1.10) + 1} (in bar);

A is the minimum flow area (in mm²);

K_{dr} is the derated coefficient of discharge.

[1] 1 bar = 10^5 N/m² = 10^5 Pa.

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5.1.3.4 For steam boilers, the certified discharge capacity W of dry saturated steam of the safety valve shall be determined using equation (30).

$$W = 0.525 P_a A K_{dr} \quad (30)$$

where

W is the certified discharge capacity (in kg/h);

P_a is the maximum absolute relieving pressure {(design pressure × 1.1) + 1.0} (in bar);

A is the flow area (in mm^2);

K_{dr} is the derated coefficient of discharge.

5.1.4 Setting of safety valves

For steam boilers the safety valves shall be set at the boiler operating pressure + 0.3 bar gauge.

For hot water boilers the safety valves shall be set at the boiler operating pressure + 0.7 bar gauge.

In no case shall the safety valve be set higher than the design pressure of the boiler.

5.2 Vent pipes

Low temperature open vented hot water boilers shall be provided with a tapping for a vent pipe unless the flow pipe connection is located in a position at the top of the boiler that permits satisfactory venting (see **A.2**).

Any tapping for a vent pipe shall be of a size not less than that specified in table 14.

Table 14. Tapping sizes for vent pipes

Rated output	Designated tapping size
kW	
44 to 60	R 1
60 to 150	R 1¼
151 to 300	R 1½
301 to 600	R 2

For rated outputs above 600 kW the designated tapping sizes for vent pipes (to the nearest R size) shall be calculated as follows:

$$\text{R size} = 0.083 \sqrt{Q} \quad (31)$$

where

Q is the boiler rated heat output (in kW).

NOTE. For recommendations regarding the installation provisions for vent pipes see **A.2**.

5.3 Emptying valves or cocks

The boiler shall be provided with a tapping, connected to the lowest water space, for the fitting of an emptying valve or cock.

NOTE. The size of the tapping should be chosen having regard to the water content of the boiler. The time required to empty the boiler should not exceed 30 min.

5.4 Pressure gauges

5.4.1 The boiler shall be provided with a tapping for the fitting of a pressure gauge.

5.4.2 Where the pressure gauge is supplied or fitted by the boiler manufacturer it shall meet the requirements given in **5.4.3** to **5.4.7**.

NOTE 1. It is important that, when a pressure gauge is fitted by other than the boiler manufacturer it meets the requirements of **5.4.3** to **5.4.7**.

NOTE 2. Attention is drawn to the provisions of the Factories Act 1961 Section 32 with regard to construction and attachments to steam boilers.

5.4.3 A pressure gauge shall be fitted, so sited that it is clearly visible at a distance of 2 m from the front of the boiler and can be replaced without draining the boiler or system.

5.4.4 Each steam boiler shall be fitted with a pressure gauge complete with syphon and cock.

5.4.5 The pressure gauge shall conform in all relevant particulars to the industrial concentric scale gauges as specified in BS 1780.

NOTE. Use of a Bourdon type gauge is recommended.

5.4.6 The dial shall be graduated in bars or metres head and a stop pin shall be provided at the zero position.

5.4.7 When the gauge is compensated for a head of water between the gauge and the boiler connection the amount of such compensation shall be marked on the dial.

5.5 Temperature gauges

The boiler shall be provided with a tapping for a temperature gauge.

NOTE. Where a temperature gauge is provided it should be fitted at or near the boiler outlet and should indicate the temperature of the boiler flow in degrees Celsius. The temperature gauge should be so sited that it is clearly visible and can be replaced without draining the boiler system.

5.6 Inspector's test gauge connection

Steam boilers shall be provided with a tapping fitted with a valve or cock carrying in a vertical position a connection for the attachment of the inspector's pressure gauge. This connection shall be tapped G 3/8 in accordance with BS 2779 and be fitted with a removable sealing plug.

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5.7 Water-level gauges

NOTE. Attention is drawn to the provisions of the Factories Act 1961 Section 32 with regard to construction and attachments to steam boilers.

5.7.1 Each steam boiler shall have at least two independent means of indicating the water level, each capable of being isolated from the boiler and both of which shall be water-level gauges in which the water level can be observed, or alternatively:

(a) for boilers of less than 145 kg/h evaporative capacity, at least one water-level gauge shall be provided;

(b) devices used in place of water-level gauges in which the water level can be observed shall have been specifically approved by the UK Chief Inspector of Factories.

Where two water-level gauges are required, it shall be permissible to mount them on a column or to attach them independently to the boiler shell. If water-level gauges are attached to other items of equipment, e.g. water-level control chambers, at least one gauge shall be attached directly to the boiler shell.

Water-level gauges and, where fitted, water-level gauge columns shall comply with BS 759 : Part 1.

5.7.2 The required water level gauge in which the water level can be observed shall be mounted so that the water level is visible in the gauge glass at the lowest alarm level, i.e. at the ultimate low level referred to in **7.1.2.3**.

The lowest alarm level shall be at a height above the level of the highest heated surface within the boiler shell which is the greater of either:

(a) 100 mm; or

(b) a height which will give a water volume above the level of the highest heated surface to allow sinking time, i.e. the time for the water to fall from the lowest alarm level to the level of the highest heated surface, of not less than 5 min or, in the case of solid fuel fired boilers, not less than 7 min, at a steam generation rate equal to the maximum capacity of the boiler.

5.7.3 At least one water-level gauge with its isolating valves or cocks shall be connected directly to the boiler, and other than a drain, no device shall be fitted to the gauge that could cause incorrect indication of the water level in the gauge.

5.7.4 In the case of horizontal return tube boilers, where the water-level gauge connections are taken from the sides of the boilers, the lower or water end at least shall be arranged with a tee or cross connection so as to permit cleaning and proving of the pipes.

5.8 Water-level alarms, fuel cut-outs and fusible plugs

NOTE. Attention is drawn to the provisions of the Factories Act 1961 Section 32 with regard to construction and attachments to steam boilers.

5.8.1 Each steam boiler shall be provided with a low water alarm/control.

NOTE. The low water alarm may be supplemented, where requested by the purchaser, by the fitting of fusible plugs complying with BS 759 : Part 1.

Fully flooded hot water boilers shall have provision for fuel cut-out such that the boiler cannot be fired without being flooded.

5.8.2 Water-level alarms, whether of low water or high and low water type, shall be so fitted that the alarm is actuated whilst the water level is still visible or indicated in the water-level gauges.

5.8.3 Fusible plugs where fitted shall, wherever practicable, be screwed into the boiler plates from the water-side.

Threads shall comply with BS 21 and shall have a pitch of not less than 2.309 mm.

Any fusible plug shall be so positioned as to give an early warning in the event of shortage of water to all parts of the boiler liable to damage by the direct application of furnace heat.

NOTE. In the case of oil-fired and gas-fired boilers, it is recommended that low water-level alarms should be fitted in preference to fusible plugs.

5.9 Connection pipes for water-level fittings

Where water-level gauges, safety control or alarm devices are connected to the boiler by pipes, the nominal bore of such pipes shall be not less than 25 mm.

NOTE 1. The ends of pipes local to the fittings may be reduced to not less than 20 mm bore for water-level gauges and to 25 mm bore for separate safety control and alarm devices.

NOTE 2. In order that the true level of the water in the boiler at the point of connection is indicated accurately in the water level of gauges and water-level control chambers, the water connection of these fittings should be mounted as close as is practicable to the boiler shell or drum. The water connections should be on the same horizontal plane and connecting pipes should be as short as practicable.

5.10 Feed-water valves

The boiler shall be provided with tappings for feed-water valves.

NOTE. For recommendations regarding feed-water valves see **A.3**.

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5.11 Blowdown

5.11.1 Steam boilers shall be provided with tappings for blowdown drain valves or cocks.

5.11.2 Where blowdown drain valves or cocks are supplied by the boiler manufacturer they shall meet the requirements given in **5.11.3** to **5.11.6**.

NOTE 1. It is important that, when blowdown drain valves or cocks are fitted by other than the boiler manufacturer they meet the requirements of **5.11.3** to **5.11.6**.

NOTE 2. Attention is drawn to the provisions of the Factories Act 1961 Section 32 with regard to construction and attachments to steam boilers.

5.11.3 Each steam boiler shall be fitted with blowdown and drain valves or cocks complying with BS 759 : Part 1.

5.11.4 Boiler blowdown and drain valves shall be attached to the boiler by pipes that are as short as practicable.

5.11.5 Blowdown valves or cocks shall be placed as near as practicable to the lowest point of the boiler.

NOTE. When continuous or automatic blowdown is requested by the purchaser, valves, cocks and mountings required to control the water conditions should be fitted at appropriate positions.

5.11.6 All blowdown mountings and drain valves connected directly to the boiler and discharging into the boiler blowdown system shall either be capable of being locked in the closed position or be protected by a second valve at their discharge which is capable of being locked in the closed position.

NOTE 1. The expression 'connected directly to the boiler' covers any valve that cannot itself be isolated from the boiler.

Where manually operated blowdown valves or cocks from more than one boiler deliver into a common discharge, a common handle or operating/interlocking device shall be provided which is capable of being removed only when such valves or cocks are fully closed; no other arrangement is permissible.

When at least two boilers are equipped with a continuous and/or automatic boiler blowdown system leading to a common main, this common main shall be separate from and independent of any main to which manually operated valves are connected. The discharges from the two mains shall be led to separate disposal points such that inadvertent pressurization of the manual blowdown main cannot occur. All such systems shall be either fitted with a stop valve, capable of being locked in the closed position, and a check valve, in addition to any regulating valves or devices required to control the blowdown flow or, alternatively, a globe stop and check valve, capable of being locked in the closed position, substituted for the stop valve and the check valve.

NOTE 2. Attention is directed to the Factories Act 1961 Section 34 which states 'No person shall enter or be in any steam boiler which is one of a range of two or more steam boilers unless:

(a) all inlets through which steam or hot water might otherwise enter the boiler from any other part of the range are disconnected from that part; or

(b) all valves or taps controlling the entry of steam or hot water are closed and securely locked, and, where the boiler has a blow-off pipe in common with one or more other boilers or delivering into a common blow-off vessel or sump, the blow-off valve or tap on each such boiler is so constructed that it can only be opened by a key which cannot be removed until the valve or tap is closed and is the only key in use for that set of blow-off valves or taps'.

5.12 Stop valves

5.12.1 Steam boilers shall have provision for the fitting of a stop valve.

5.12.2 Where stop valves are supplied by the boiler manufacturer they shall meet the requirements of **5.12.3**.

NOTE 1. It is important that, when stop valves are fitted by other than the boiler manufacturer they meet the requirements of **5.12.3**.

NOTE 2. Attention is drawn to the provisions of the Factories Act 1961 Section 32 with regard to construction and attachments to steam boilers.

5.12.3 Each steam boiler shall be fitted with a stop valve which shall comply with BS 759 : Part 1. The stop valve connecting the boiler to the steam pipe shall be attached directly to the boiler or shall be as near as practicable to it.

Where two or more boilers are connected to a common header or steam manifold, the steam connection from each boiler shall be provided with one stop valve, and either one globe stop and check valve capable of being locked in the closed position, or with a stop valve capable of being locked in the closed position and one separate check valve.

NOTE. An isolating valve is necessary as the Factories Act 1961 requires periodic thorough examination of boiler fittings and attachments and this includes the boiler stop valve. This is not possible unless the boiler under examination can be isolated from a common header or manifold.

Section six. Combustion equipment

6.1 General

When the boiler combustion equipment is supplied by the boiler manufacturer it shall comply with **6.2**, **6.3** or **6.4** as appropriate.

NOTE. It is important that, when the combustion equipment is supplied by other than the boiler manufacturer, it is in line with the boiler manufacturer's recommendations and complies with the appropriate standards.

6.2 Solid fuel firing

Solid fuel firing equipment shall comply with BS 749.

6.3 Liquid fuel firing

Liquid fuel firing equipment shall comply with BS 799 : Parts 3 and 4.

NOTE. For recommendations regarding oil-firing installations reference should be made to BS 5410 : Part 2.

6.4 Gas firing

Gas firing equipment shall comply with BS 5978 and BS 5885, as appropriate.

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Section seven. Automatic controls and electrical installation

NOTE. The installation of electrical wiring for electrical equipment on boilers complying with this standard, and associated electrical equipment, e.g. motors, mains voltage operated controls and components, should be in accordance with the recommendations of appendix B.

7.1 Automatic controls for steam and hot water boilers

7.1.1 General

Boiler automatic controls when supplied by the boiler manufacturer either separately or as an integral part of the boiler shall comply with **7.1**.

NOTE 1. It is important that, when supplied by other than the boiler manufacturer the automatic controls meet the requirements of **7.1**.

NOTE 2. Unless close manual supervision can be guaranteed at all times that steam and hot water boilers are in service, it is essential for safety reasons that, at least, the automatic controls described in this clause are fitted on boilers or as part of the firing equipment or on systems as appropriate.

Automatic controls may be of two basic types:

(a) controls intended to assist the boiler attendant who constantly supervises the boiler; and

(b) controls intended to replace continuous supervision with occasional supervision.

NOTE 3. Attention is drawn to the recommendations, in particular those concerned with the testing of controls, contained in guidance note PM 5 entitled 'Automatically controlled steam and hot water boilers', issued by the Health and Safety Executive.

The requirements for automatic controls for steam or hot water boilers not continuously supervised shall be as in (a) to (e) as follows, supplemented by the requirements of either **7.1.2** or **7.1.3** as appropriate.

(a) In the event of failure of the automatic controls, the boiler shall be capable of being brought safely under manual control. Use under manual control shall be in accordance with a clearly defined written emergency procedure.

(b) All electrical equipment and circuits for water level and firing controls shall be designed to fail safe, i.e. faults in circuits shall cause the fuel and air supply to the boiler to be shut off automatically. All electrical conductors and equipment in connection with water level and firing controls shall be sized for the duty and shall be insulated and protected to prevent damage. Where necessary, protection against the ingress of moisture and the effects of abnormal temperature shall be provided.

(c) Means shall be provided to test the controls with the boiler in operation. Where float or electrode type controls are housed in chambers external to the boiler, a blowdown valve, which blows through steam and water in sequence, shall be fitted to the water-side of the chamber. Where an isolating valve is fitted in the steam balance pipe, it shall either be locked in the open position or it shall be of a type which cannot accidentally be left closed. Where a locked valve is used, a duplicate key shall be kept in a glass-fronted cabinet in the boiler house for use in emergency.

(d) Where controls are of the internal type, i.e. where the floats or the electrode are mounted inside the boiler, means shall be provided to test the operation of these controls.

(e) The blowdown lines from the chambers shall be piped separately to a blowdown tank, tundish or sump. They shall not be piped into the main boiler blowdown line.

7.1.2 Automatic controls for steam boilers

NOTE. See figures 47 and 48.

7.1.2.1 *Automatic water-level controls*

Automatic water-level controls shall be so arranged that they positively control the boiler feed pumps or regulate the water supply to the boilers and maintain the level of water between predetermined limits.

Automatic water-level controls shall be operated by one of the following means:

(a) float or displacer;

(b) electrical probe;

(c) a method approved by the inspecting authority.

7.1.2.2 *Automatic firing controls*

Automatic firing controls shall, at all times, control the supply of fuel and air to the firing equipment. In the event of one or more of the following circumstances arising automatic controls shall shut off the fuel supply to boilers using gaseous or liquid fuels and shut off the air supply, and if necessary, the fuel supply to firing equipment using solid fuels:

(a) failure of the main flame or pilot flame on boilers using gaseous or liquid fuels;

(b) failure to ignite the fuel within a predetermined time on boilers using gaseous or liquid fuels;

(c) when a predetermined high pressure at or below the safety valve set pressure is reached;

(d) when the boiler water level falls to a predetermined level below the normal operating level;

(e) failure of forced or induced draft fan or of an automatic flue damper.

In the case of (a) and (b) the control provided shall be of the lock-out type requiring manual resetting.

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In (d) the control provided shall cause an audible alarm to sound.

7.1.2.3 ***Independent overriding controls***

In addition to the water level and firing controls specified in **7.1.2.1** and **7.1.2.2** an entirely independent and separately operated overriding control shall be fitted. This control shall shut off the fuel supply to boilers using gaseous or liquid fuels and shut off the air supply and, if necessary, the fuel supply to firing equipment using solid fuels when the water level falls to a predetermined low level in the boiler, below that indicated in item (d) of **7.1.2.2**.

NOTE. In the case of firing equipment using solid fuels, the heat should be dissipated from the fuel bed as quickly as possible. Means of achieving this will depend upon the type of installation concerned.

Water shall be visible in the water-level gauge when the independent overriding control operates. The independent overriding control shall also cause an audible alarm to sound and be of the lock-out type requiring manual resetting.

Where mounted externally to the boiler, the overriding control shall be provided with its own chamber and independent connections to the boiler and shall comply with **7.1** where applicable.

7.1.3 Automatic controls for hot water boilers

7.1.3.1 ***General***

For convenience in detailing the requirements for automatic controls, hot water boiler systems shall be classified into four categories (see figure 49):

(a) *category A:* static head systems open to atmosphere;

(b) *category B:* closed pressurized system with separate gas cushioning pressurizing vessels and provision for make-up water;

(c) *category C:* sealed pressurized systems with separate diaphragm or bladder type pressurizing vessels and provision for make-up water;

(d) *category D:* continuously pumped pressurized systems with provision for make-up water.

Boilers pressurized by steam are classified as steam boilers and shall comply, where applicable, with the requirements for steam boilers.

7.1.3.2 ***Basic controls***

In the event of one or more of the following circumstances arising, automatic controls shall shut off the fuel supply to boilers using gaseous or liquid fuels, and shut off the air supply and, if necessary, the fuel supply to firing equipment using solid fuels:

(a) failure of the main flame or pilot flame on boilers using gaseous or liquid fuels;

(b) failure to ignite the fuel within a predetermined time on boilers using gaseous or liquid fuels;

(c) failure of a forced or induced draught fan or of an automatic flue damper;

(d) when the temperature of the water at or near the boiler flow outlet rises to a preset value at least 17 °C below the temperature of saturated steam, which corresponds to the pressure at the highest point in the circulating system above the boiler;

(e) when the water level in the pressurizing equipment in a category B system falls to a preset value below the normal operating level;

(f) when the pressure in a category B, C or D system falls to a predetermined pressure below the specified operating pressure;

(g) when the pressure in a category C system increases to within 0.35 bar of the safety valve set pressure.

In the case of (a) and (b) the control provided shall be of the lock-out type requiring manual resetting.

NOTE. In the case of (e), this should also cause an audible alarm to sound.

In (f) the predetermined pressure shall be at a level which will ensure that the water does not reach boiling point in any part of the system whilst the working temperature is maintained.

In (g) the safety valve set pressure shall be such that it will not allow the design pressure of any part of the boiler to be exceeded.

7.1.3.3 ***Independent overriding controls***

Automatic controls for all categories of boilers shall include independent overriding controls which cut off the fuel supply to oil or gas burners or cut off the air supply and, where required, the fuel supply to solid-fuel firing equipment in the event of one or more of the following circumstances arising:

(a) when the temperature of the water at or near the boiler flow outlet rises to a predetermined temperature providing a margin below the temperature of saturated steam corresponding with the pressure at the highest point of the circulating system above the boiler;

(b) when the water level in the pressurizing equipment of a category B system falls to a predetermined level, below the normal operating level, lower than that indicated in item (e) of **7.1.3.2**.

The controls in the case of (a) and (b) shall lock out the firing equipment and be of a type which requires manual resetting.

In the case of (a) for oil-fired or gas-fired boilers the margin shall be at least 6 °C and for solid-fuel fired boilers be at least 10 °C.

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NOTE. In the case of solid-fuel firing boilers, the heat should be dissipated from the fuel bed as quickly as possible. The means of achieving this will depend upon the type of installation concerned.

7.1.3.4 *Boilers using mixing valves*

Where mixing valves are used to blend return water with flow water, solid-fuel fired boilers shall serve at least one circuit which is independent of the mixing valve and which is capable of dissipating residual heat in the fuel bed when the mixing valve closes against the boiler, e.g. during mild weather, otherwise a heat dissipation thermostat which will override the mixing valve control in the event of excessive temperature rise, shall be fitted in the boiler flow line.

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Section eight. Inspection and marking

8.1 Inspection

Before despatch from the works, each assembled boiler or boiler section shall be hydraulically tested (see **8.2**) in the presence of a responsible representative of the manufacturer or the inspecting authority. The manufacturer shall furnish a certificate of test and thorough examination for steam boilers, and a certificate of test, if requested, for hot water boilers (see appendix D).

NOTE. The choice of representative at the boiler testing should be the subject of agreement between the manufacturer and purchaser.

8.2 Hydraulic test

8.2.1 Each boiler, on completion of all welding, shall be subjected to a hydraulic test pressure of 1½ times the design pressure, but in no case to less than 0.414 N/mm^2.

8.2.2 The test pressure shall be maintained for sufficient time to enable a full visual inspection to be made, and in any case for not less than 5 min.

The boiler, during testing, shall show no signs of leakage or weakness.

8.3 Marking

Each boiler complying with this standard shall be durably and clearly marked with the following particulars:

(a) the manufacturer's identification mark;

(b) the number and date of this British Standard, i.e. BS 855 : 1990[1)];

(c) the rated continuous output, with the number of sections to which the output refers, where appropriate;

(d) the name and address in the UK of the manufacturer or of his agent, where applicable;

(e) the boiler type, name and/or serial number, with identification of more detailed variations or modifications by, for example, suffix or prefix, serial number, batch number or date of manufacture, etc.;

(f) the hydraulic test pressure and date of test;

(g) the design and/or operating pressure;

(h) whether boiler combustion equipment is supplied.

[1)]Marking BS 855 : 1990 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is therefore solely the responsibility of the person making the claim. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

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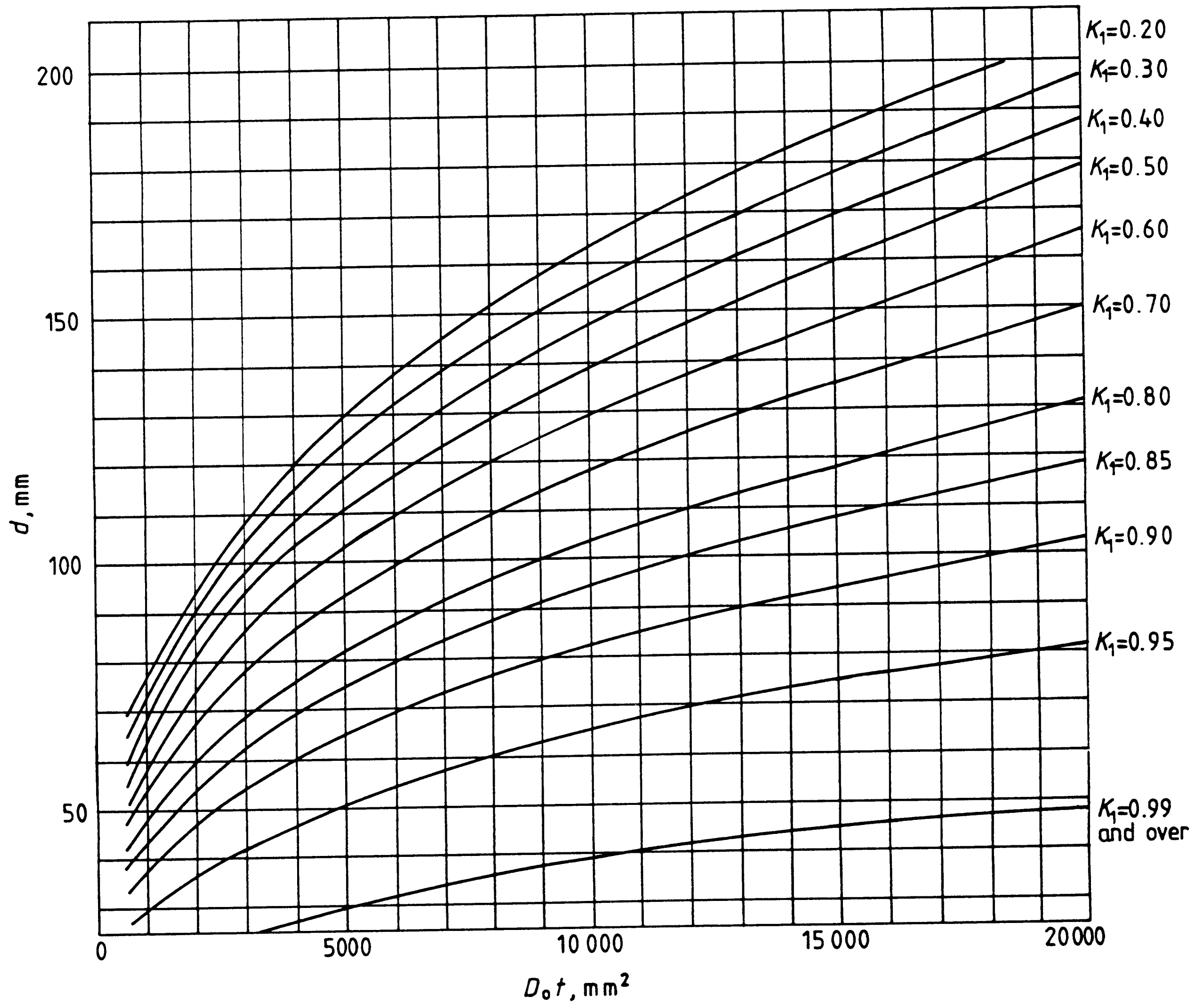

Figure 1. Maximum diameter of unreinforced openings

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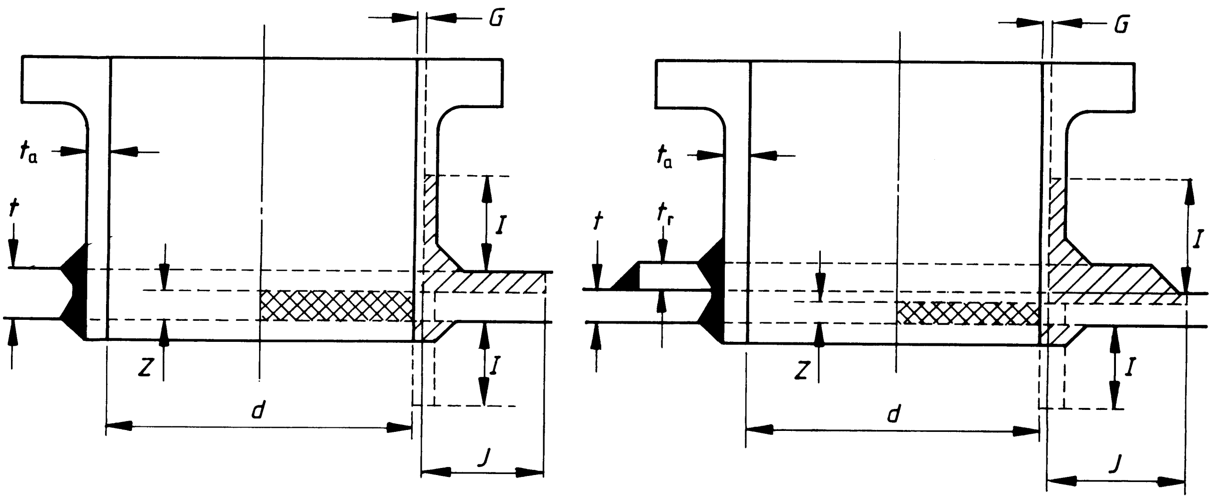

(a) Welded nozzle

(b) Welded nozzle with compensating plate

Limits of reinforcement: the area Y should be not less than the area X

Z is the thickness calculated in accordance with equation (1) disregarding the minimum thickness required in **3.2.1**

G is the thickness calculated in accordance with equation (1), but taking C = 0.25 mm, and disregarding the minimum thickness required by **3.2.1**

I is the smaller of the two valves: $2.5t$ or $(2.5t_a + t_r)$

J is the greater of the two values: $(t + 75\text{ mm})$ or $\frac{d}{2}$

NOTE. t_r will be equal to zero when there is no compensating plate on the side of the shell under consideration.

Figure 2. Compensation of welded branches or standpipes

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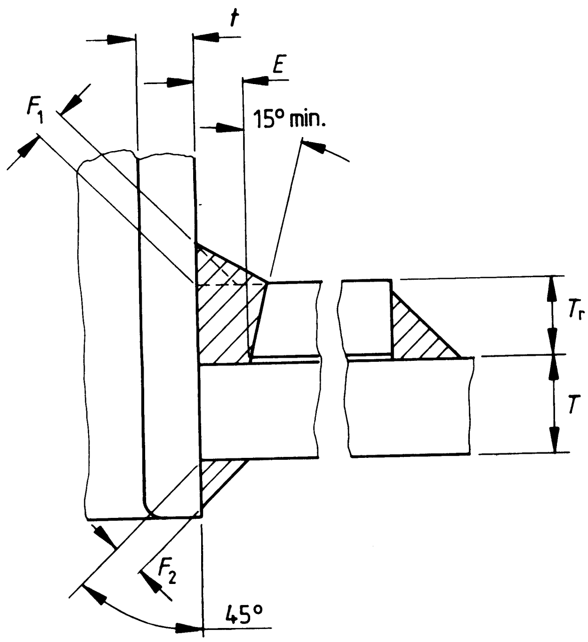
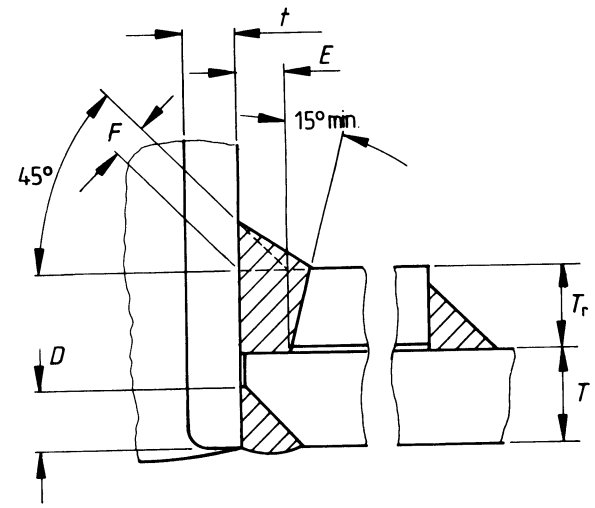


f_1 = $T/10$ mm min., but not less than 6 mm

F_2 = $T/5$ mm min., but not less than 6 mm

E = 10 mm min.

(a)

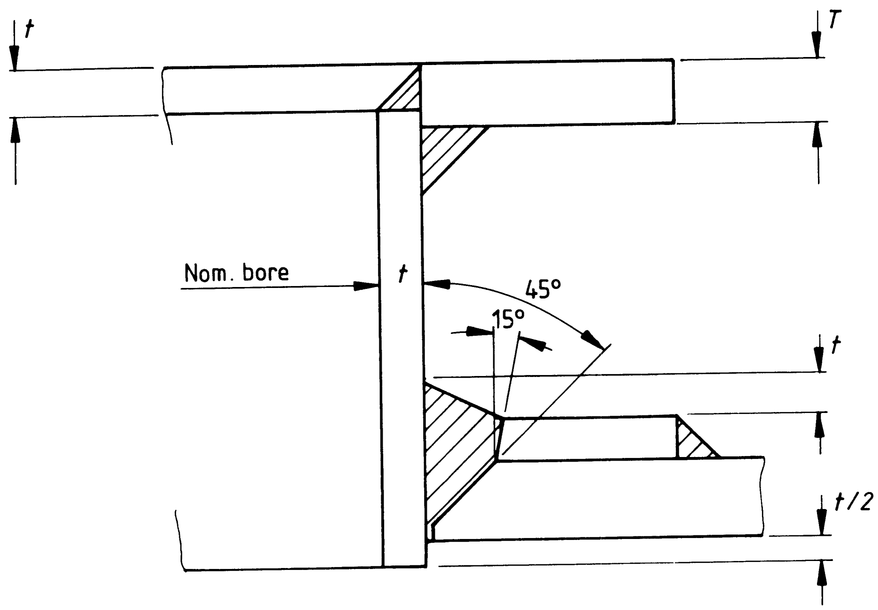


F = $T/10$ mm min., but not less than 6 mm

D = t

E = 10 mm min.

(b)



Detail of compensated flanged connection welded from one side only.

(c)

NOTE. Where a single side weld is used, the technique and electrodes used are to be demonstrated to the inspecting authority on separately prepared test specimens to prove full penetration with sound weld metal at the root.

Figure 3. Compensated set-through branches

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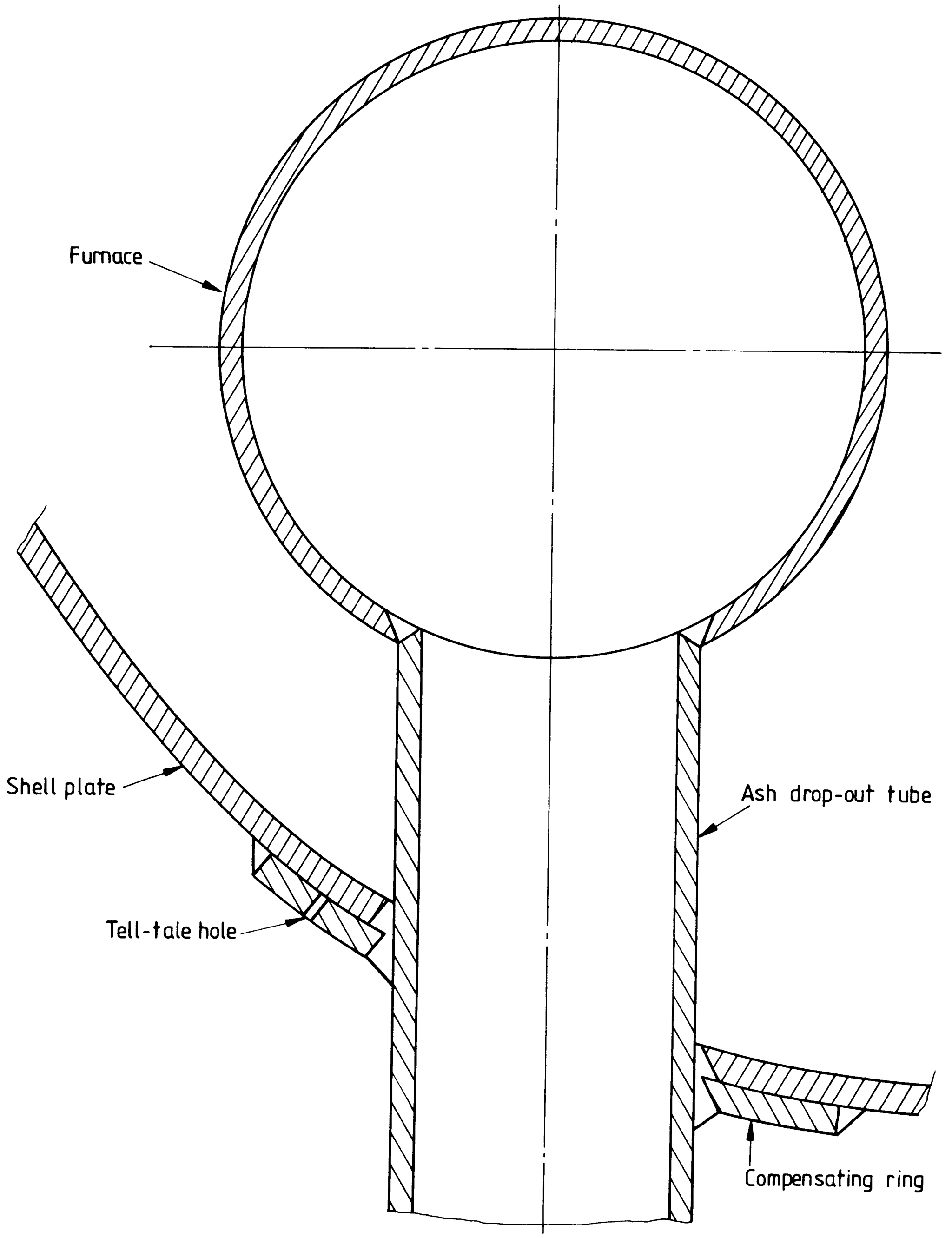

Figure 4. Typical method of attachment of ash drop-out tube

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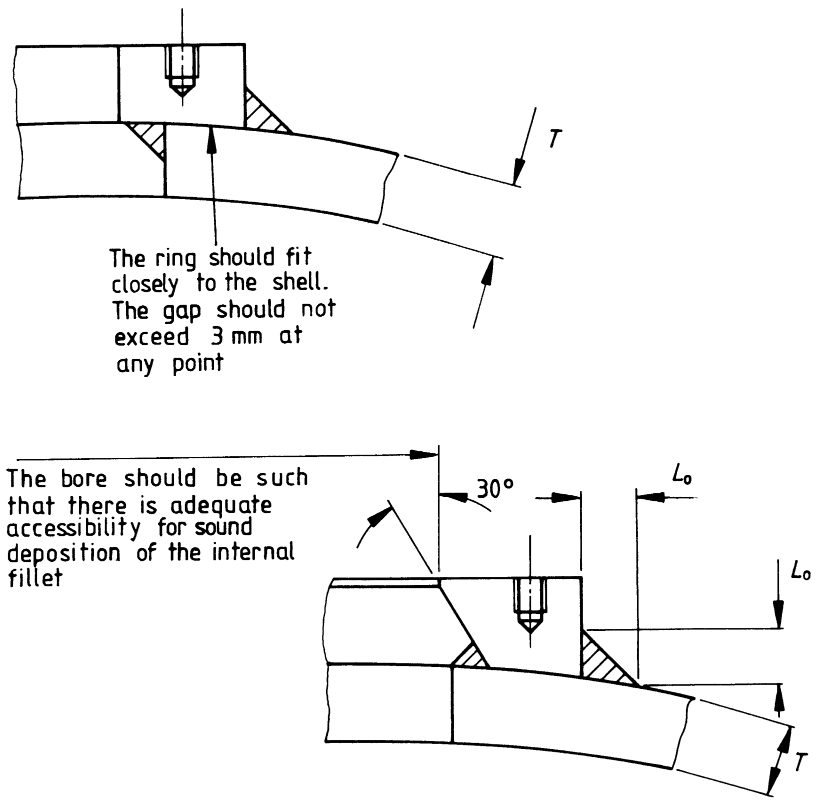
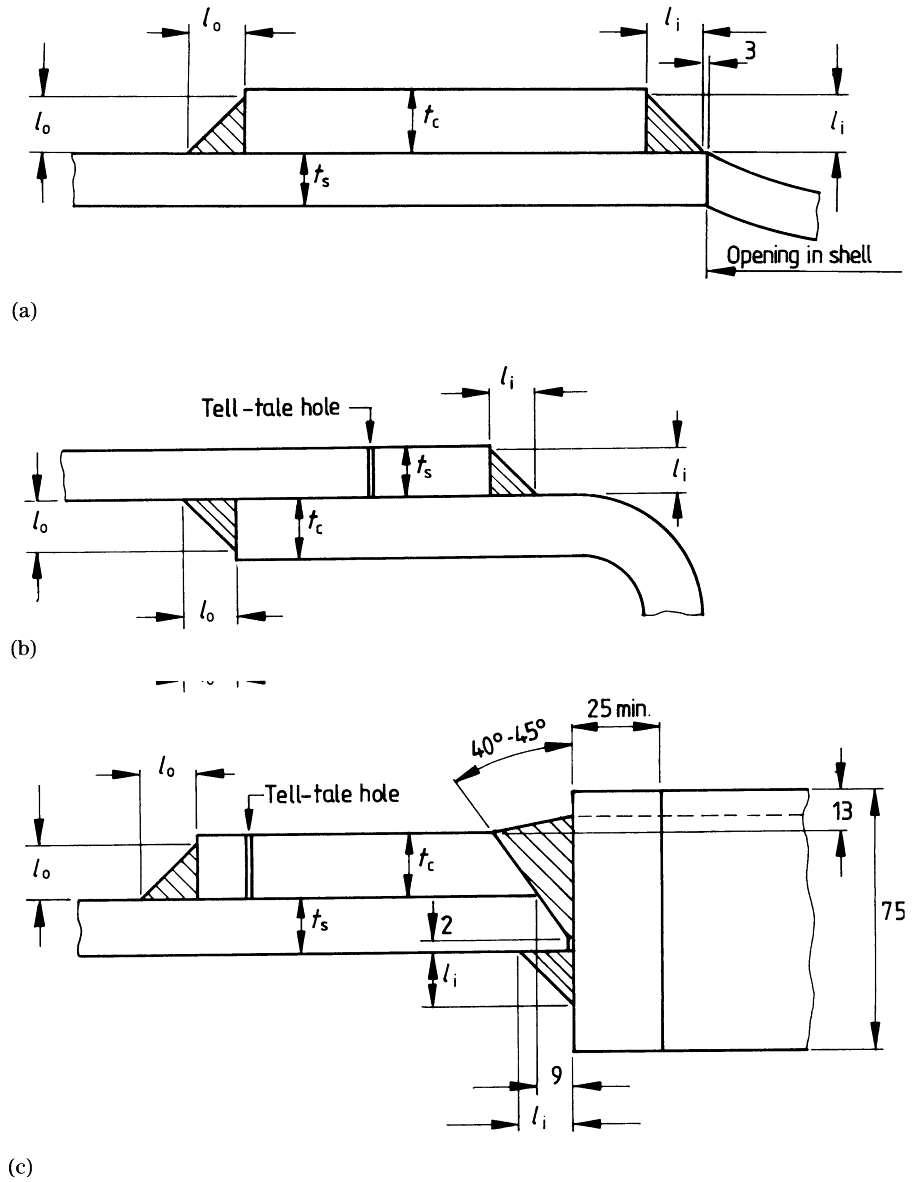


NOTE. The sizes of the fillet welds should be based on the loads transmitted, paying due regard to all fabrications and service requirements, but in any case should not be less than 6 mm.

Figure 5. Fillet-welded studded connections



All dimensions are in millimetres.

Figure 6. Typical methods of welding manhole frame and compensating plates

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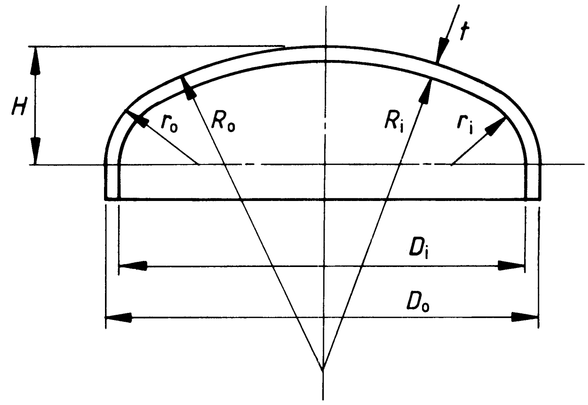
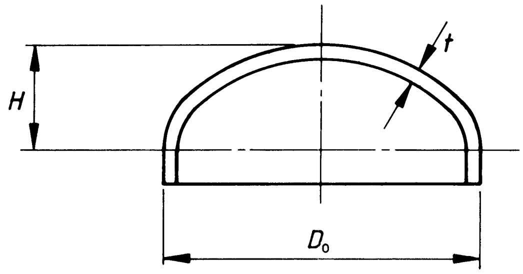
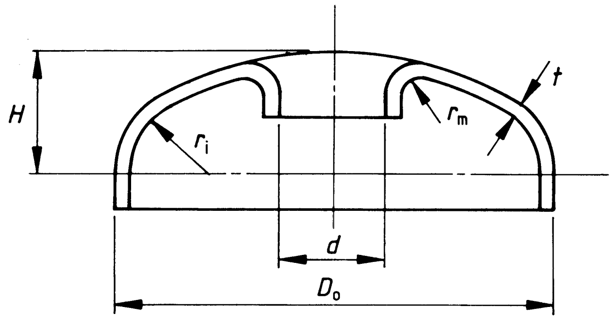


(a) Torispherical end



(b) Semi-ellipsoidal end



(c) End with manhole (semi-ellipsoidal or torispherical)

Figure 7. Typical dished ends

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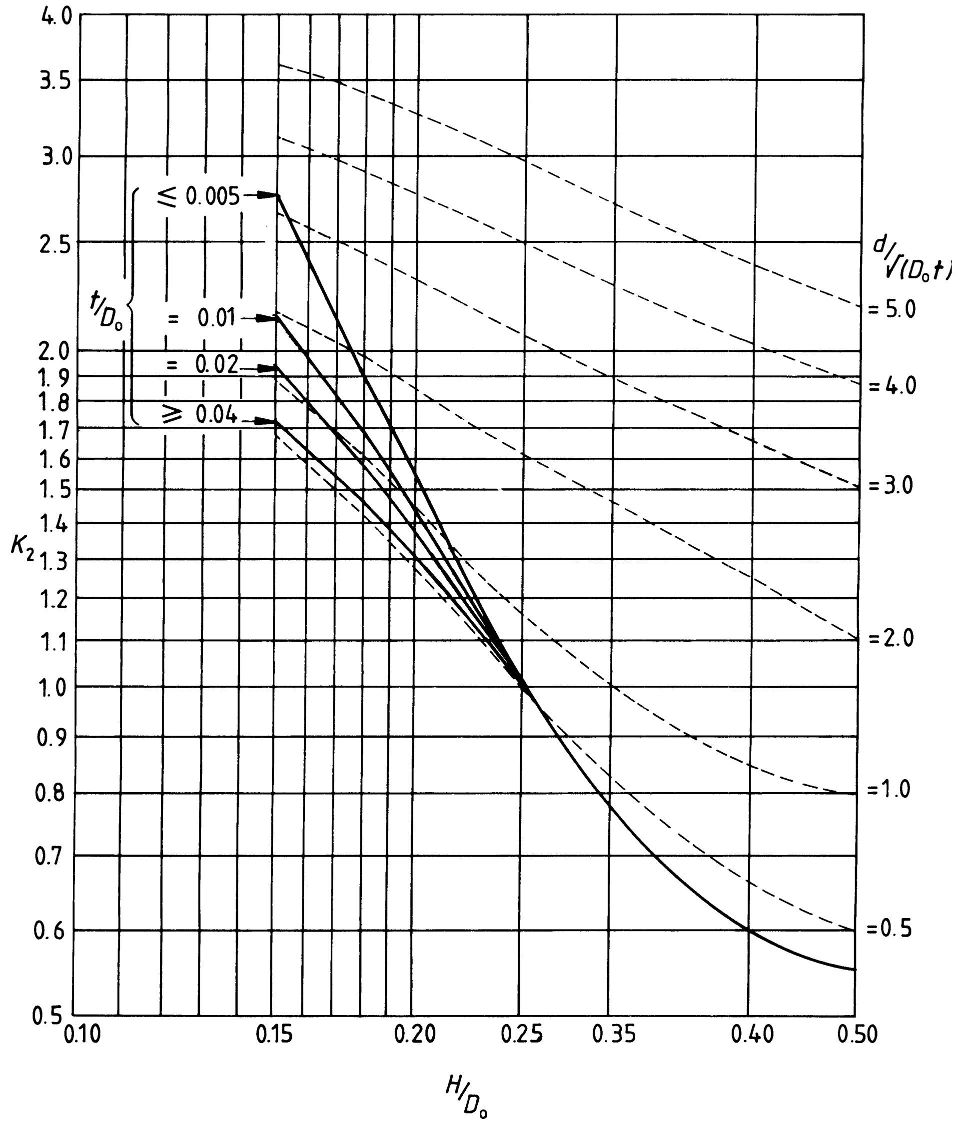

Figure 8. Shape factor

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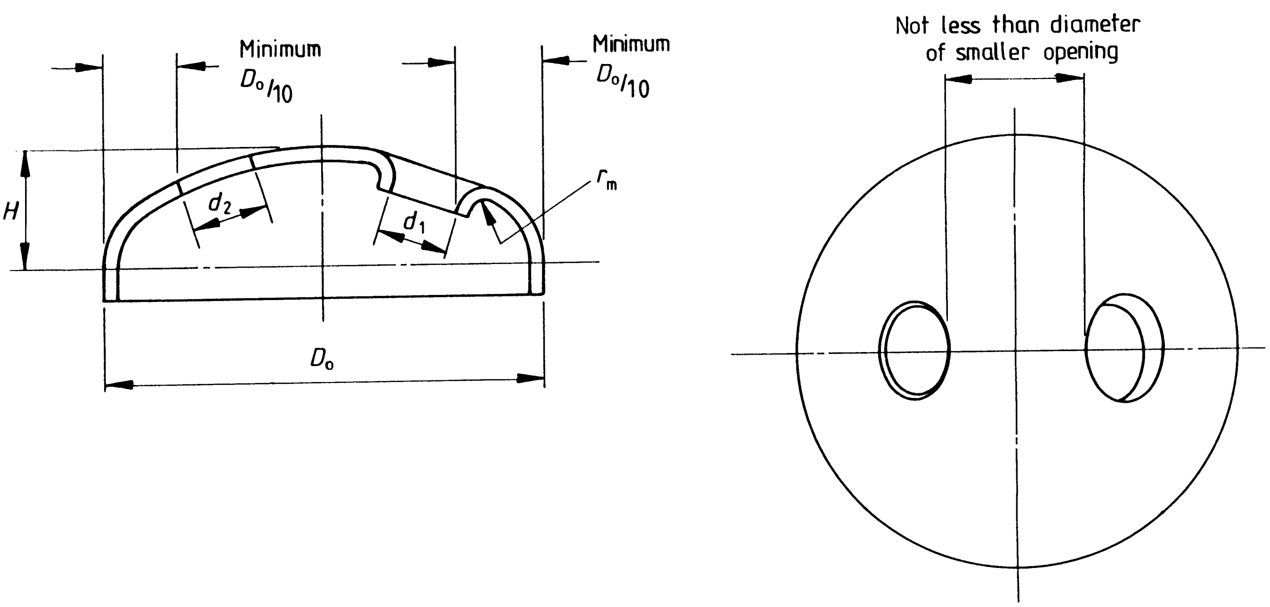
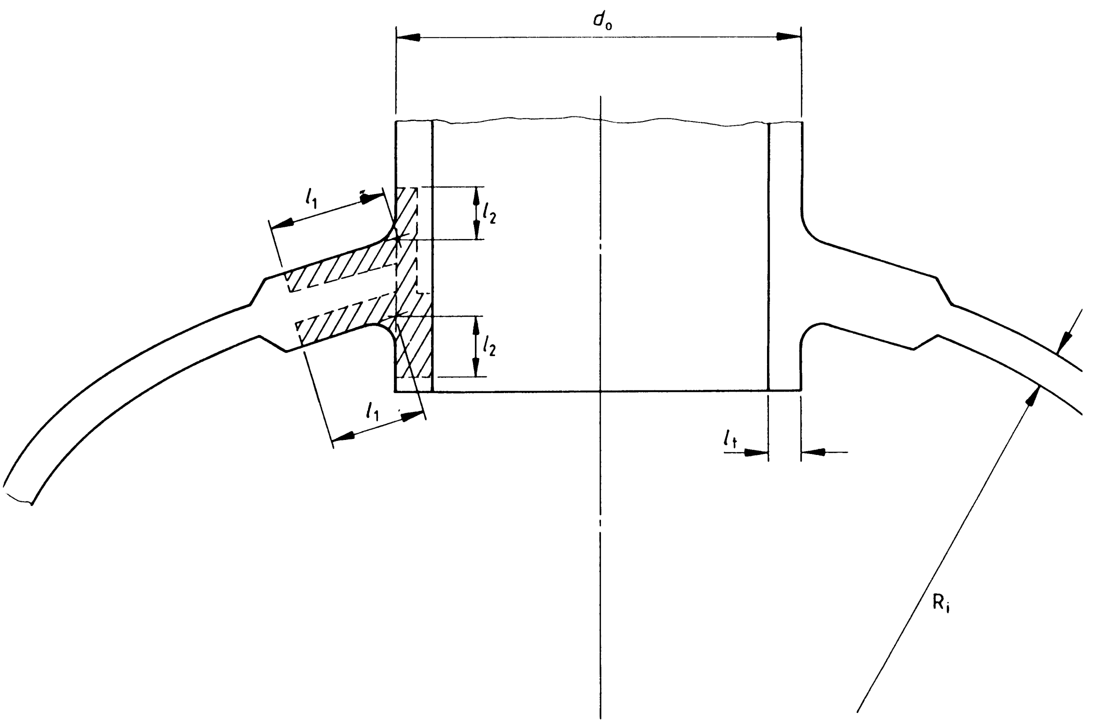


NOTE. d_2 is the diameter of the smaller opening.

Figure 9. Opening in ends



NOTE. The limits for l_1 and l_2 are given in **3.3.3.4**.

Figure 10. Limits of reinforcement

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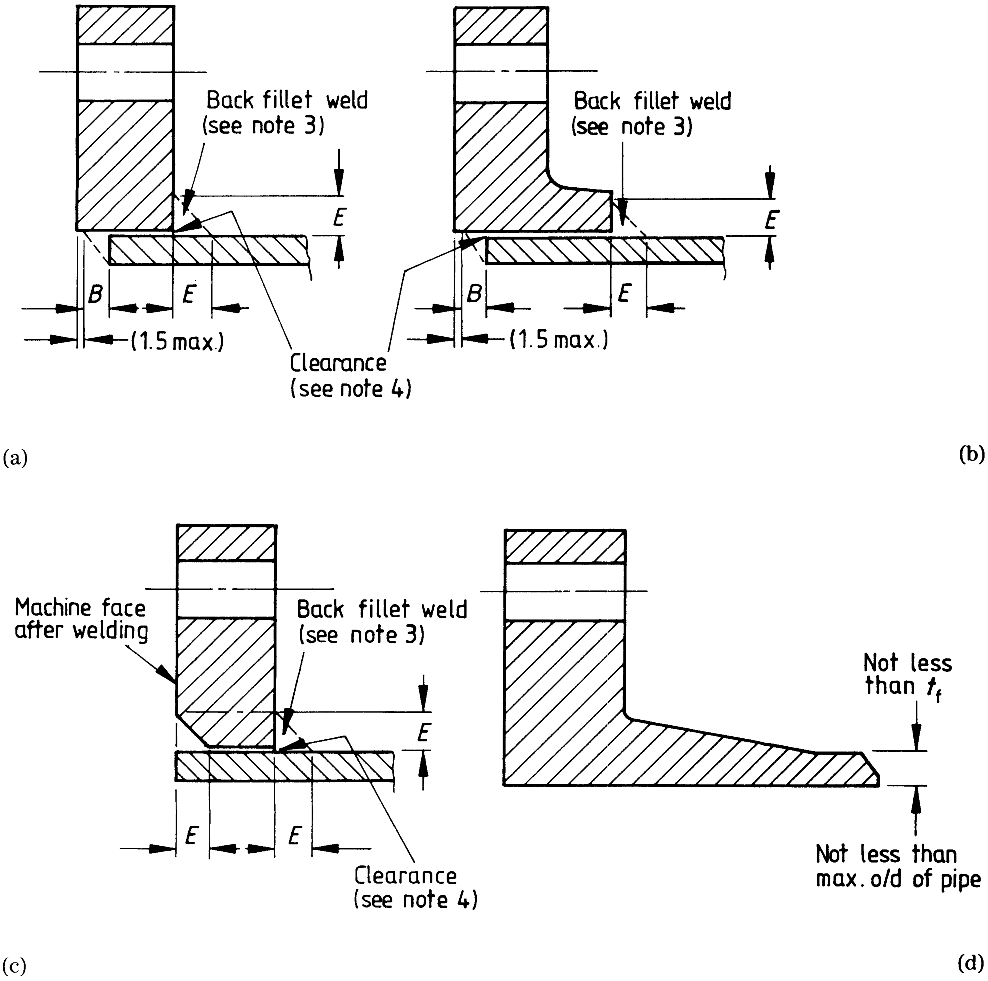


All dimensions are in millimetres.

NOTE 1. Dimensions are finished sizes.

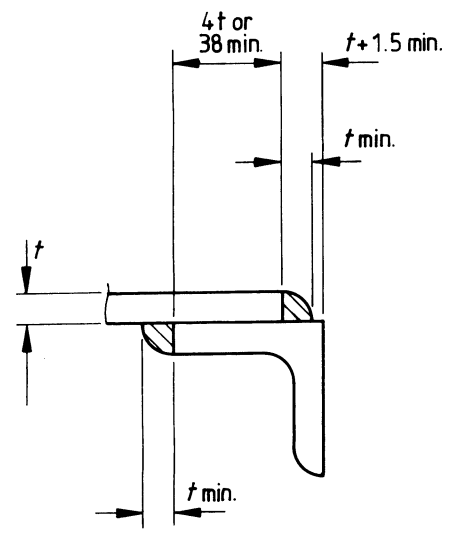
NOTE 2. t_f is the calculated pipe thickness (see **2.2** of BS 806 : 1986).

NOTE 3. The outer surface of the weld should lie wholly outside the position indicated by the dotted line.

NOTE 4. These flanges are suitable for all conditions covered by this standard (see also BS 4504).

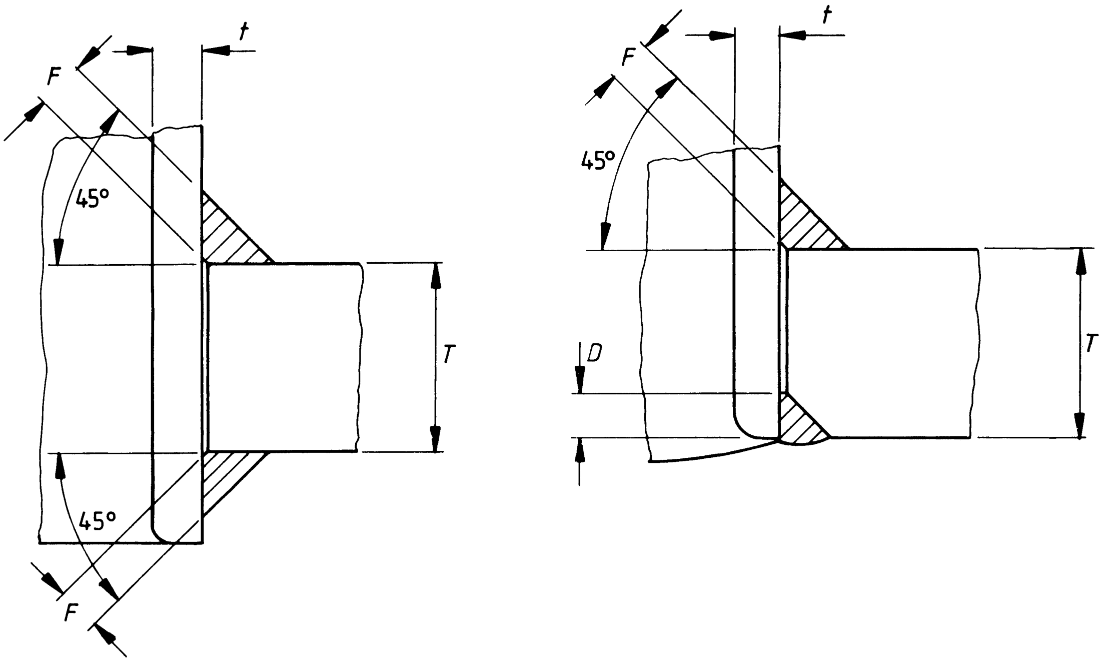
Dimension	**Design basis**
B	t_f
E	$1.5t_f$ but not less than 6.5

Figure 11. Flanges



All dimensions are in millimetres.

Figure 12. Angle rings



(a)

(b)

$F = t_1$ but not less than 6 mm
$D = t$
T not to exceed 19 mm
Fillet-welded connections. Recommended when $t < 13$ mm

Figure 13. Set-through branches up to 150 mm o.d. branch

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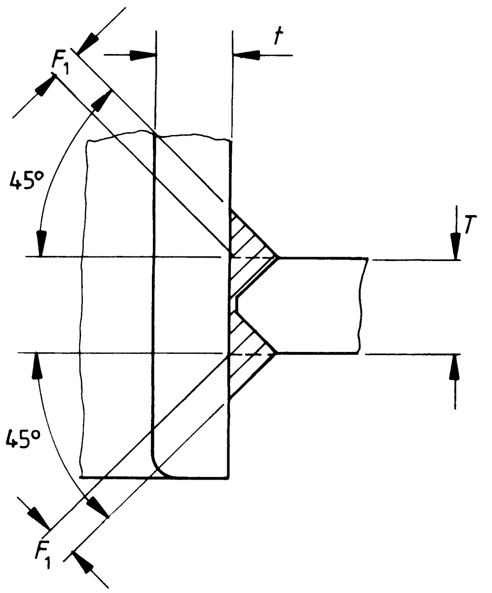
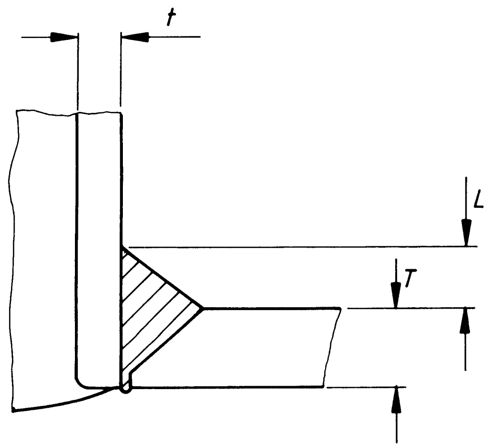


(a)

(b)

F_1 = T/10 mm min. but not less than 6 mm
F_2 = T/5 mm min. but not less than 6 mm

Figure 14. Set-in branches : full penetration connections



Full penetration connections welded from one side only
t = 16 mm max.
T = 25 mm max.
L = T/3 mm min., but not less than 6 mm

NOTE. As a general recommendation all set-in branches should be welded on the inside of the shell as shown in figures 13(a) to 14(b) when accessible for the purpose. The connections shown above in this figure are only permitted when they are inaccessible for internal welding and only if assurance can be provided that the welding procedure employed will ensure sound and consistent root conditions with uniform penetration.

Figure 15. Set-through branches

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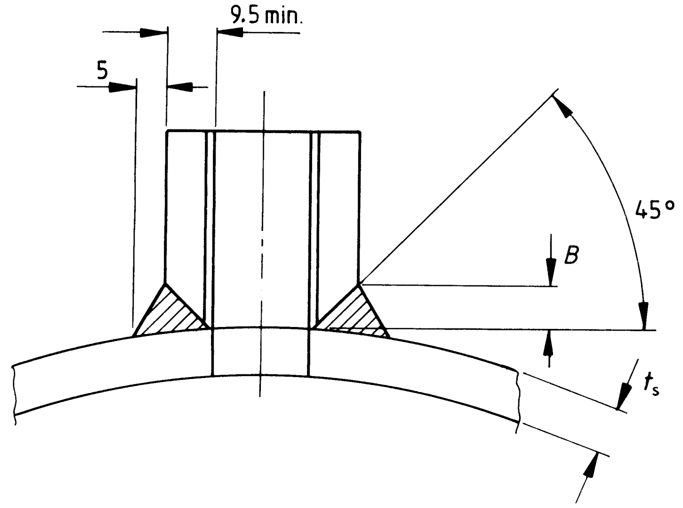
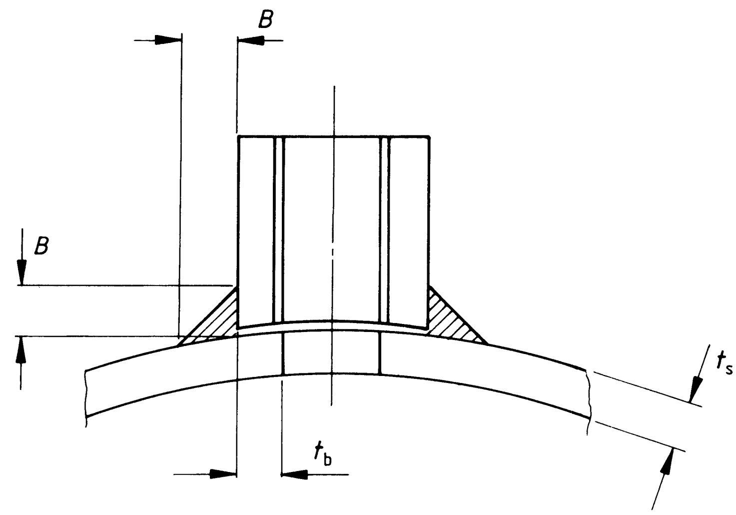
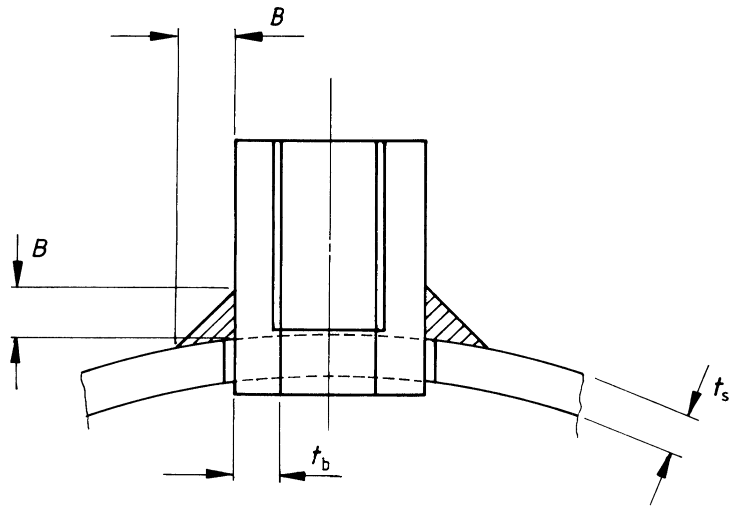


NOTE. Full penetration weld.
(a) Maximum connection size R3

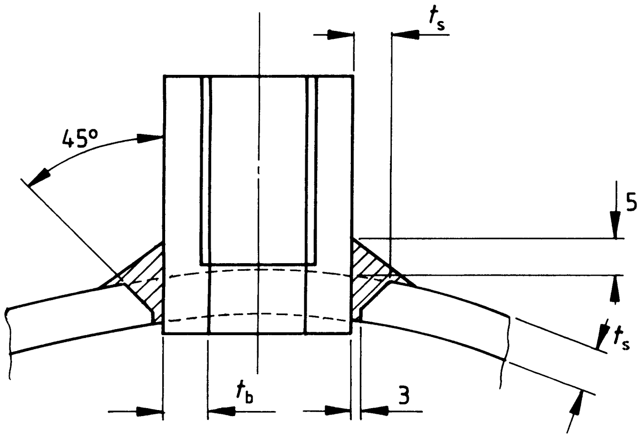


(b) Maximum connection size R1

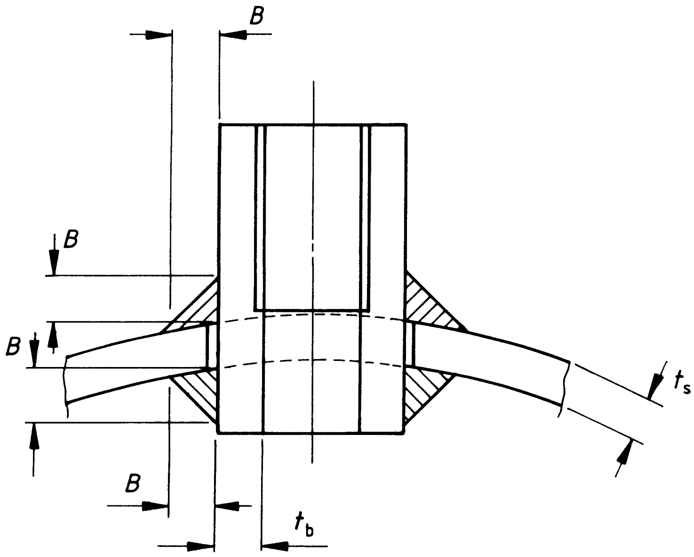


NOTE. Connection (c) is not recommended where the inside of the vessel is accessible for welding.
(c) Maximum connection size R1

Figure 16. Typical screwed connections



(d) Maximum connection size R3



(e) Maximum connection size R3

All dimensions are in millimetres.
NOTE 1. *T* is the thickness of socket (t_b) or vessel (t_s), whichever is the smaller.
NOTE 2. Weld dimensions are minima.

T	*B*
mm	mm
5	8
6.5	9.5
8	12.5
9.5	14.5
≥11	≥16

Figure 16 (*concluded*)

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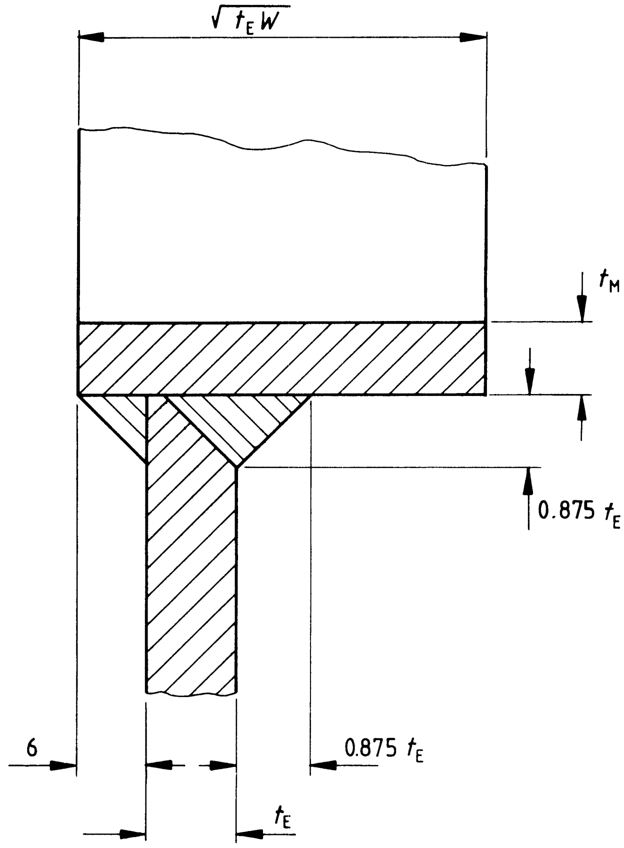

All dimensions are in millimetres.

NOTE. t_M is a minimum of 19 mm, and W is the width of opening (in mm) measured on minor axis.

Figure 17. Welding details for compensated openings in flat end plates

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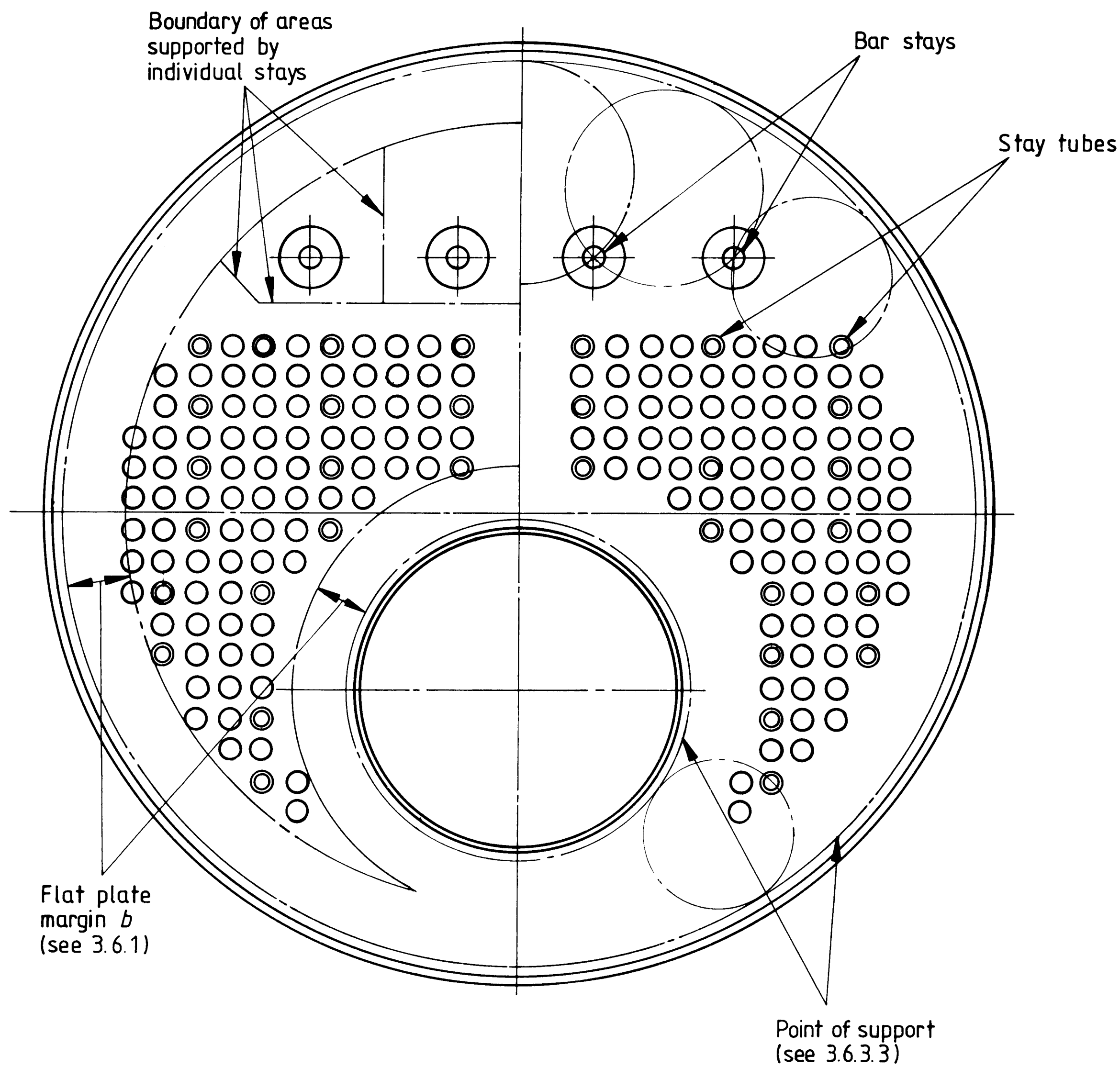

NOTE. See **4.1.2** for methods of attachment of end plates to shell and furnaces.

Figure 18. Typical arrangement of end plates on single furnace economic boilers

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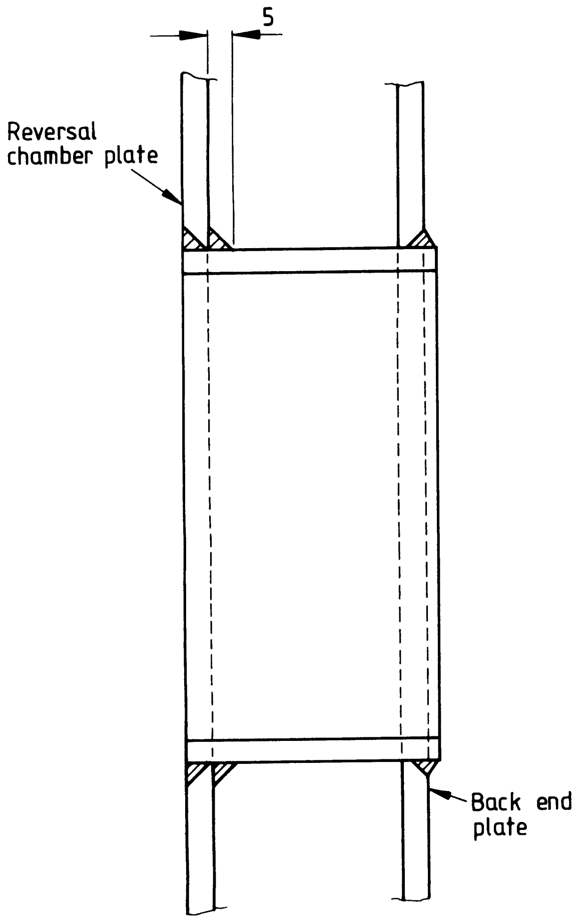

The dimension is in millimetres.

NOTE. All welds are to be full penetration welds.

Figure 19. Access openings for wet-back boilers

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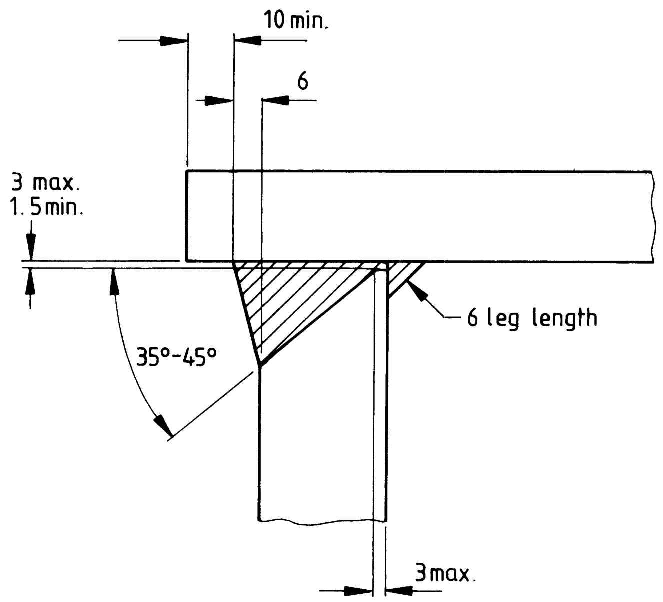
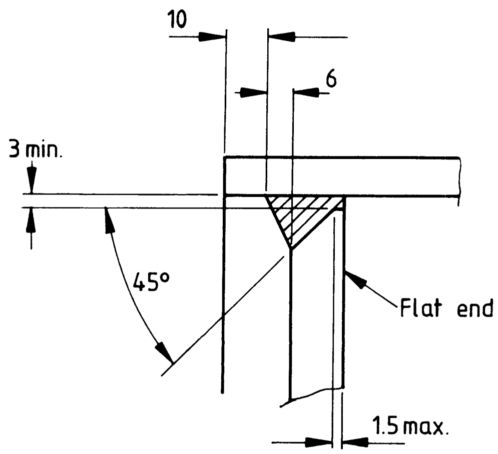


(a)



(b)

All dimensions are in millimetres.

NOTE 1. This form of attachment may be used only where access does not permit the making of an internal fillet weld.

NOTE 2. All welds are to be full penetration welds.

Figure 20. Attachment of unflanged flat end plates to cylindrical shells

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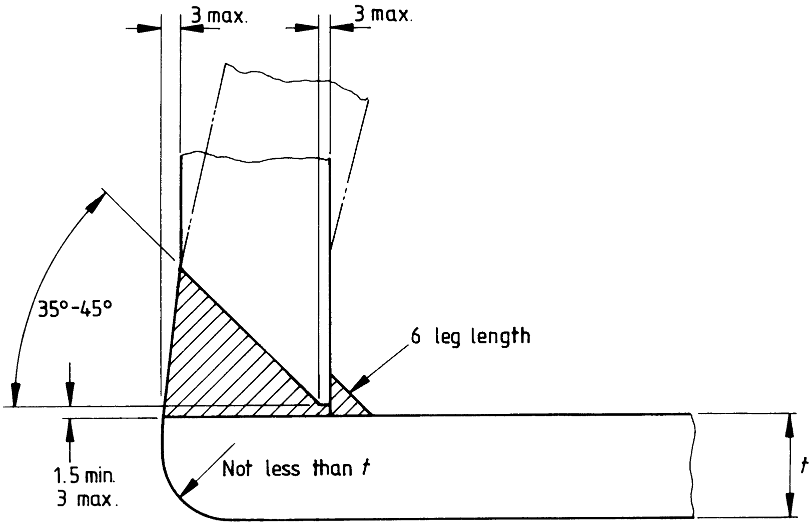
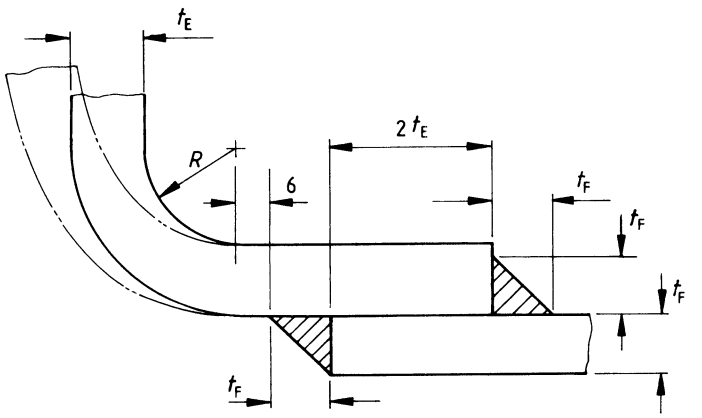
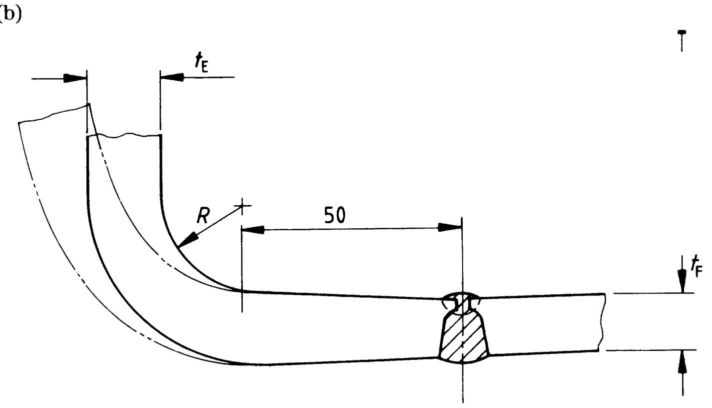


NOTE. The plate edge radius of not less than 0.5 t is only required when the furnace end is exposed to a flame or comparatively high temperature, e.g. at the entry to the reversal chamber.
All welds are to be full penetration welds.
The front end of the furnace can protrude beyond the weld provided that the protrusion and the weld are adequately insulated to prevent overheating.
(a)



NOTE. The furnace to end plate attachment is suitable for front ends only, or in cases where there is no impingement of flame or hot gases.
(b)



(c)
All dimensions are in millimetres.

Figure 21. Attachment of dished or flat flanged end plates to cylindrical shells and furnaces

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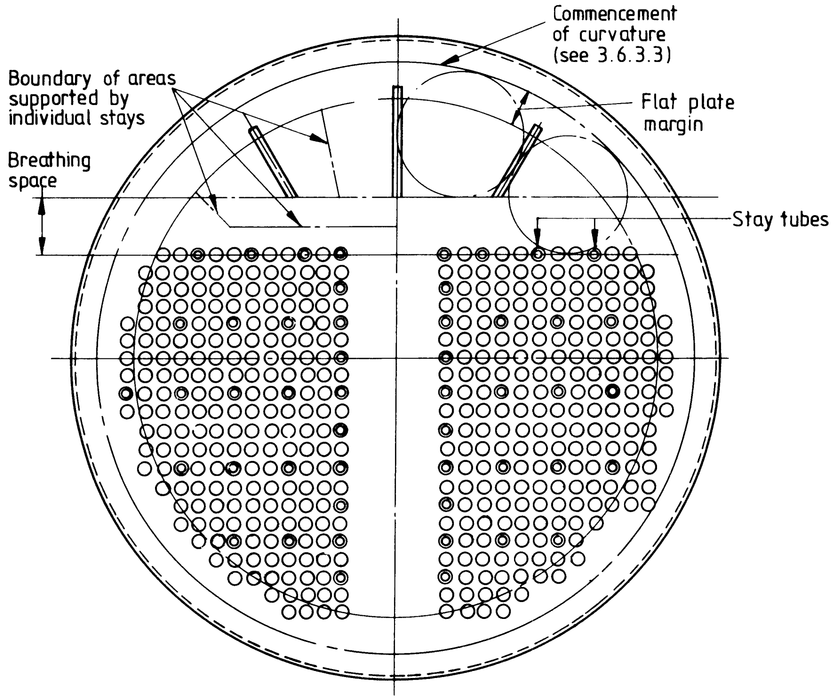
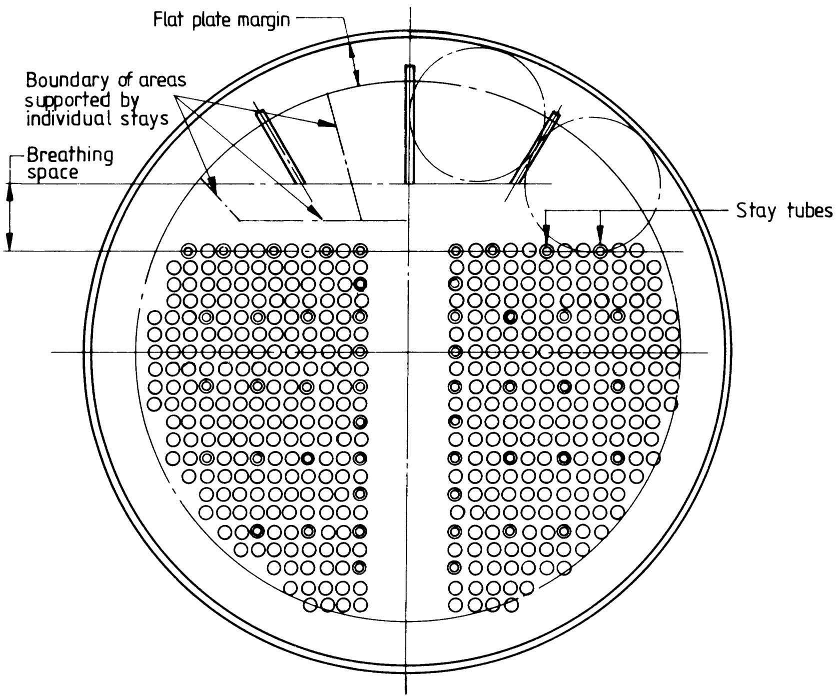


NOTE. See **4.1.2** for methods of attachment of end plates to shell.

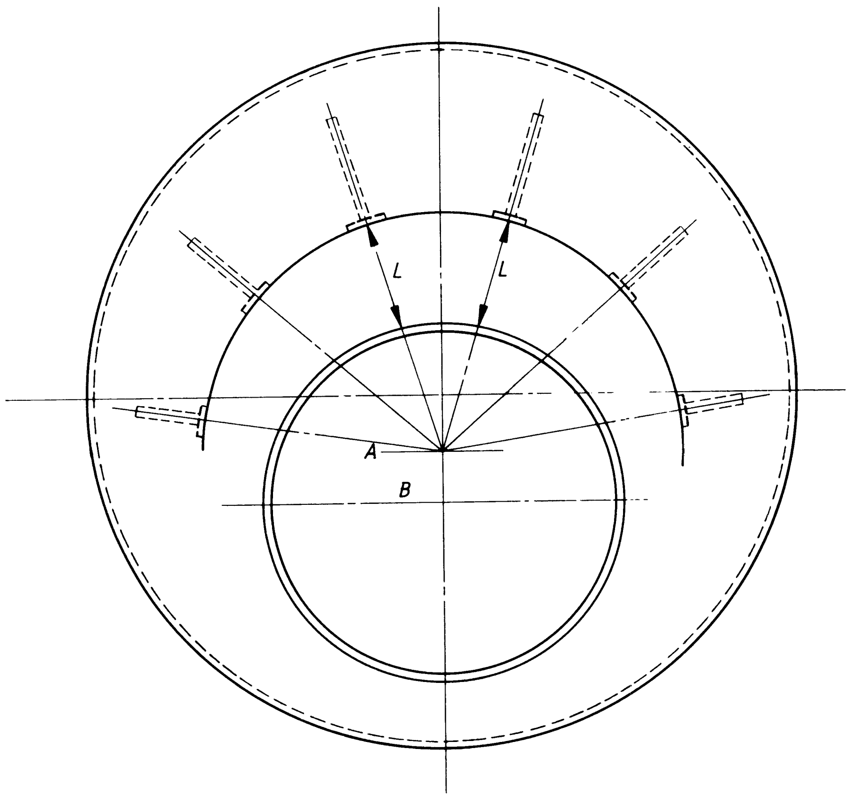
(a) Boiler with flanged end plate



NOTE. See **4.1.2** for methods of attachment of end plates to shell.

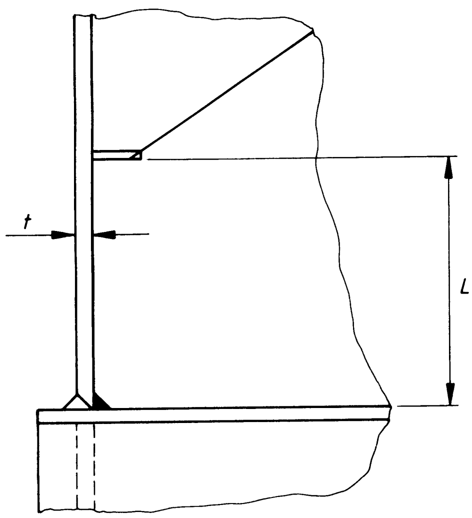
(b) Boiler with directly welded end plate

Figure 22. Typical arrangement of end plates on multitubular boilers



NOTE. The distance A - B between the centre of the stay circle and centre of furnace is not to be less than $3t + 63$, where t is the thickness of the end plate (in mm).

(c) Typical arrangement of end plates on a single furnace boiler



t	L
mm	mm
13	255
14	280
16	305
18	330
20	330
>20	340

(d) Breathing space

Figure 22 (*concluded*)

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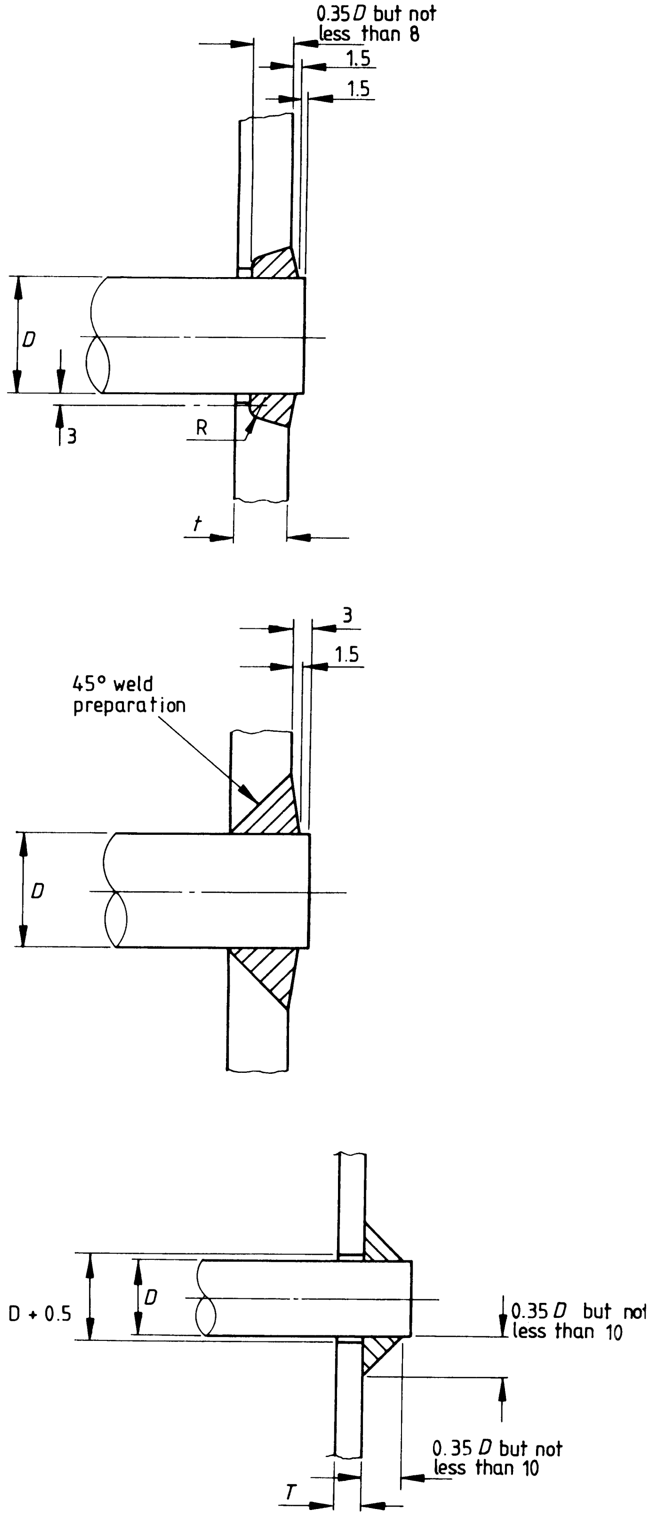

NOTE. This form of attachment is also suitable for longitudinal bar stays.
(a)

(b)

NOTE. Where these bar stays are exposed to flame or comparably high temperature, the stress on the stay is to be limited to 52 N/mm^2 and the stay is not to project beyond the fillet weld.
(c)

All dimensions are in millimetres.

Figure 23. Bar stays

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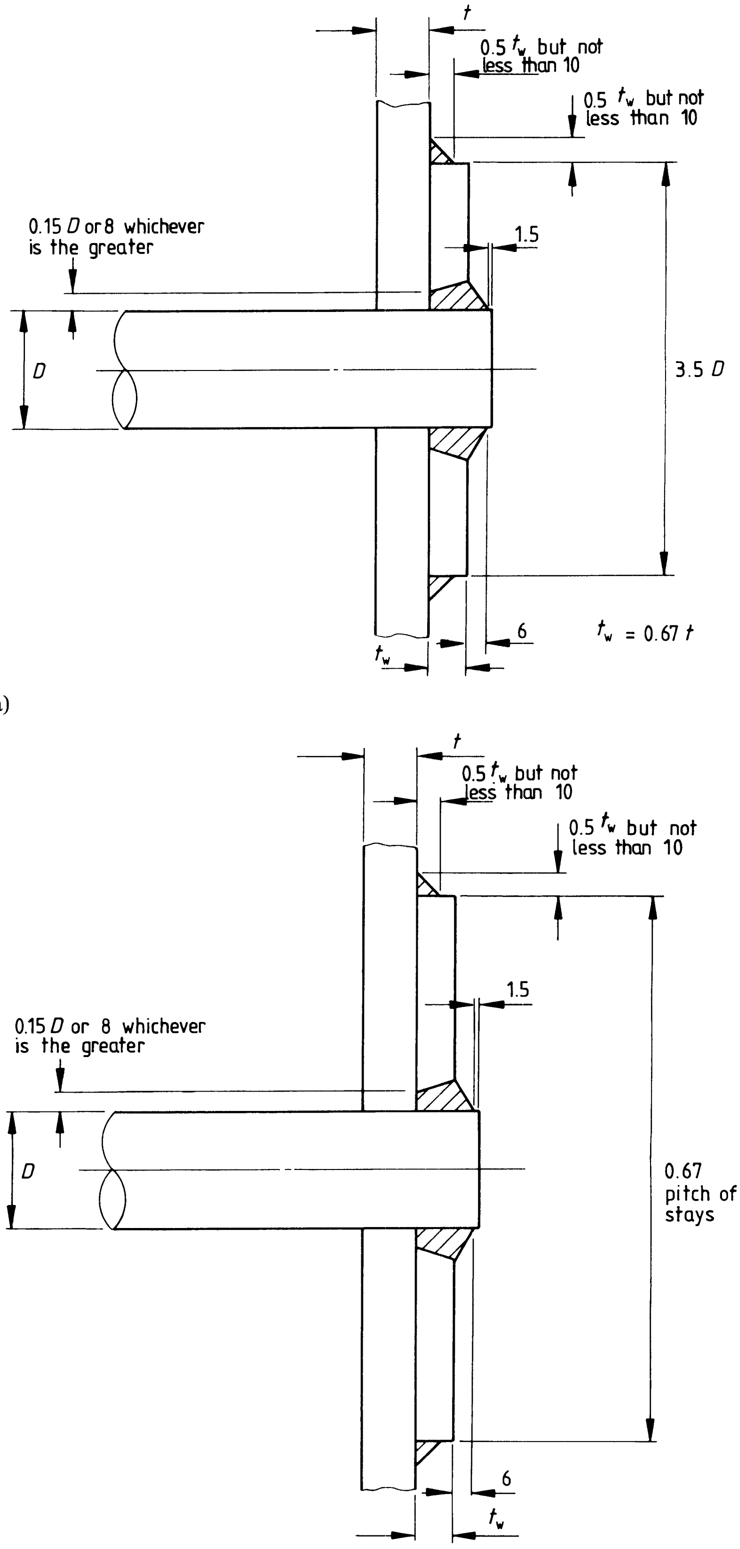

All dimensions are in millimetres.

Figure 24. Attachment of longitudinal bar stays

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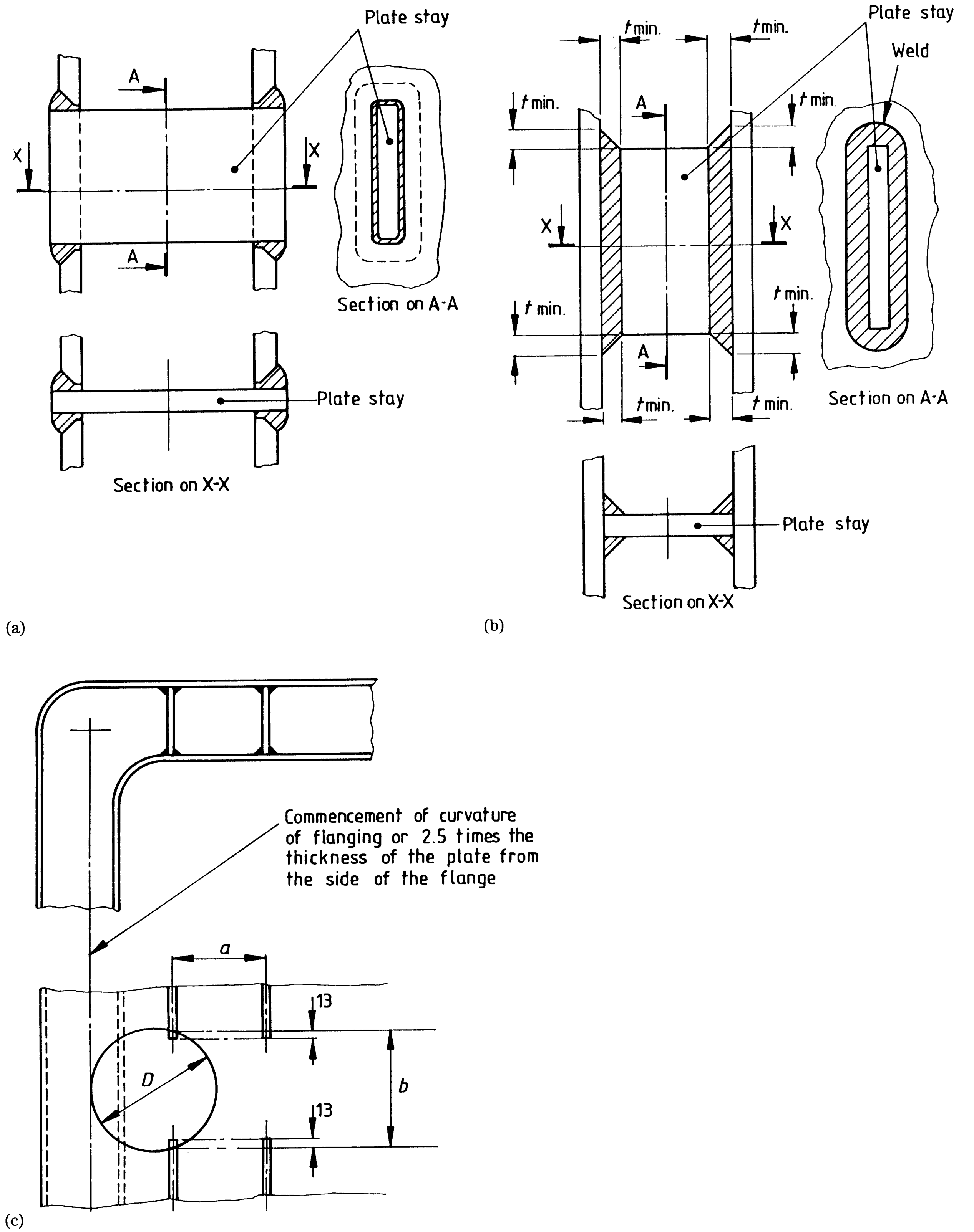

All dimensions are in millimetres.

Figure 25. Plate stays

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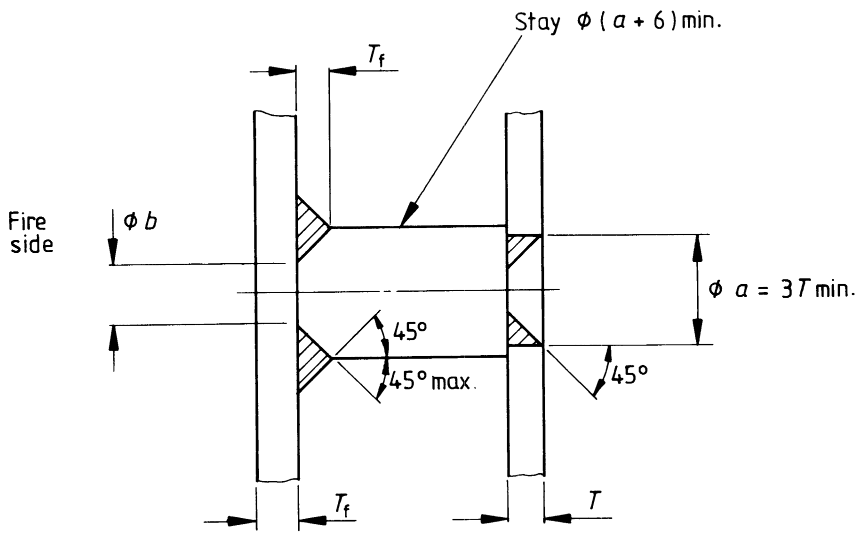

The linear dimension is in millimetres.

$b = 2T_r$ max. but in not case greater than 25 mm.

NOTE. The load (in N) on the stay is not to exceed 114 $T(a - 0.5T)$, a and T being in millimetres.

Figure 26. Plug-welded firebox or water-leg stays

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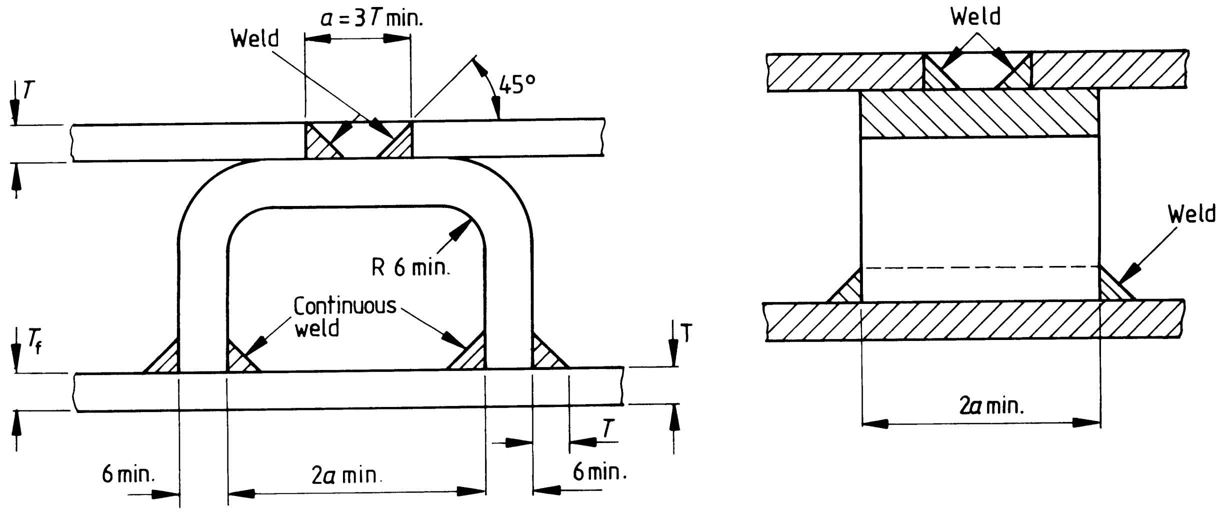
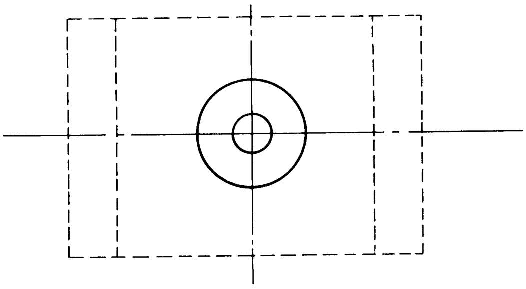


Side section

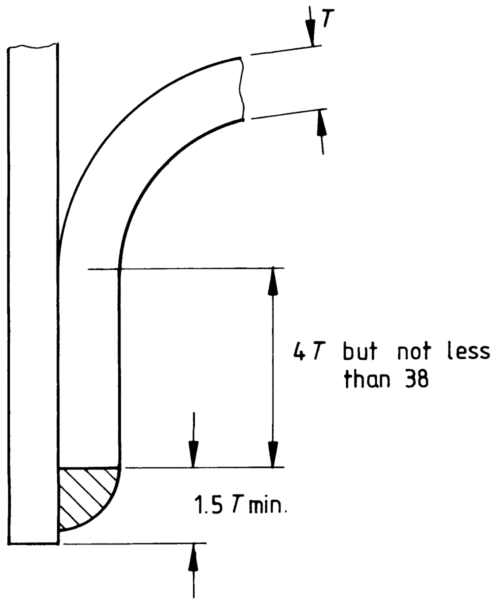


Plan

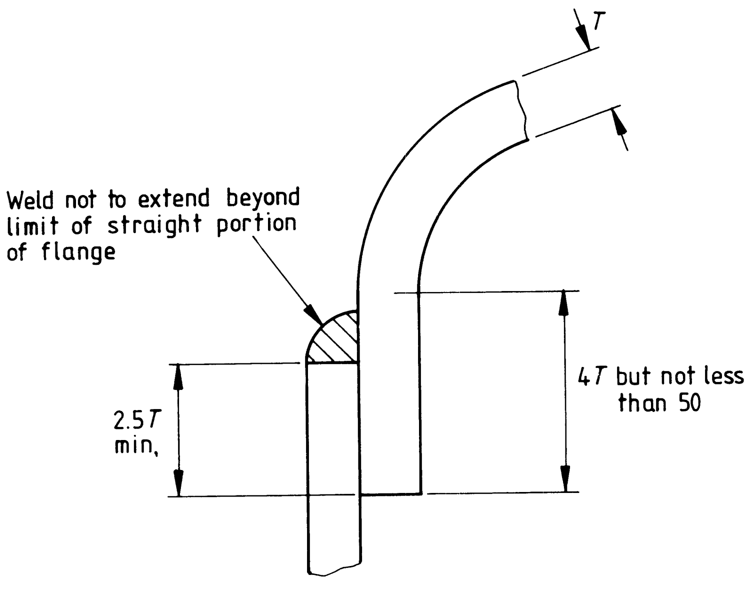
All dimensions are in millimetres.

NOTE. The load (in N) on the stay is not to exceed 114 $T(a - 0.5T)$, a and T being in millimetres.

Figure 27. Detail of mild steel anchor stays



(a)



(b)

All dimensions are in millimetres.

NOTE. These two attachments are to be used only where the diameter of the vessel does not permit welding of the vessel internally, but in no case are they acceptable when the diameter exceeds 610 mm and the maximum design pressure exceeds 450 kN/m^2.

Figure 28. Attachment of dished or flat flanged end plates to cylindrical shells

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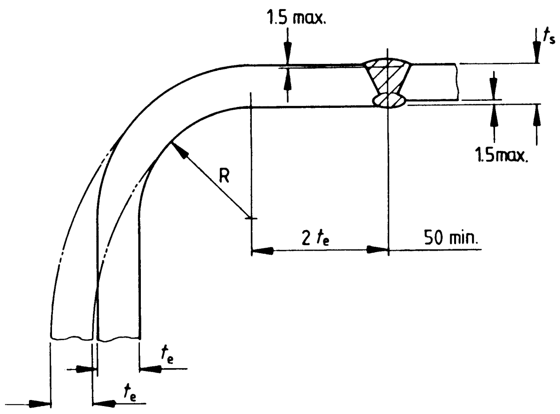
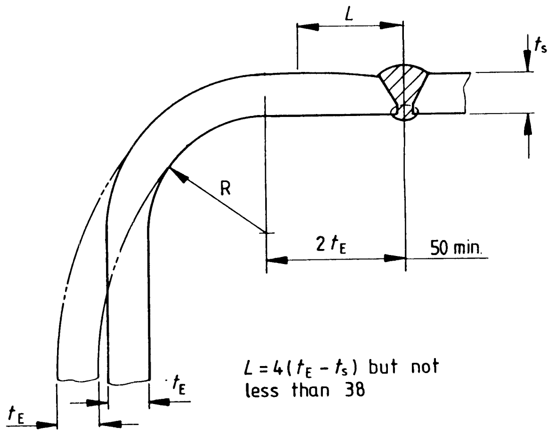
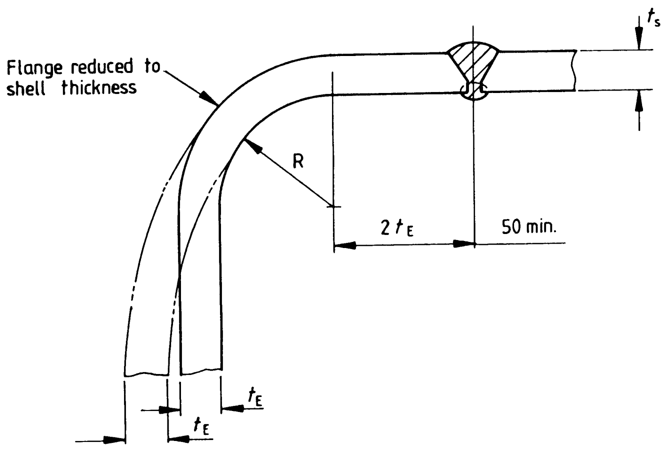


(a)



(b)

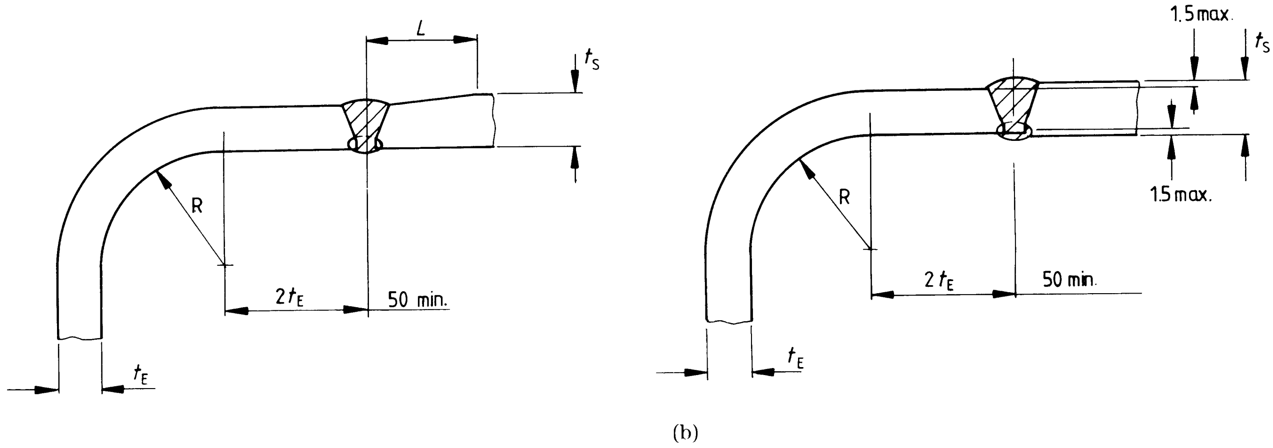
NOTE. Inside or outside of the end plate. If the tapering is carried out on the end plate, the length of the cylindrical flange is to be not less than L.



(c)

All dimensions are in millimetres.

Figure 29. Attachment of flanged end plates to shell: ends thicker than shell



(b)

$L = 4(t_S - t_E)$ but not less than 38 mm.

(a)

All dimensions are in millimetres.

NOTE. Difference $(t_S - t_E)$ is not to exceed 20% of t_S.

Figure 30. Attachment of flanged flat end plates to shell: shell thicker than ends

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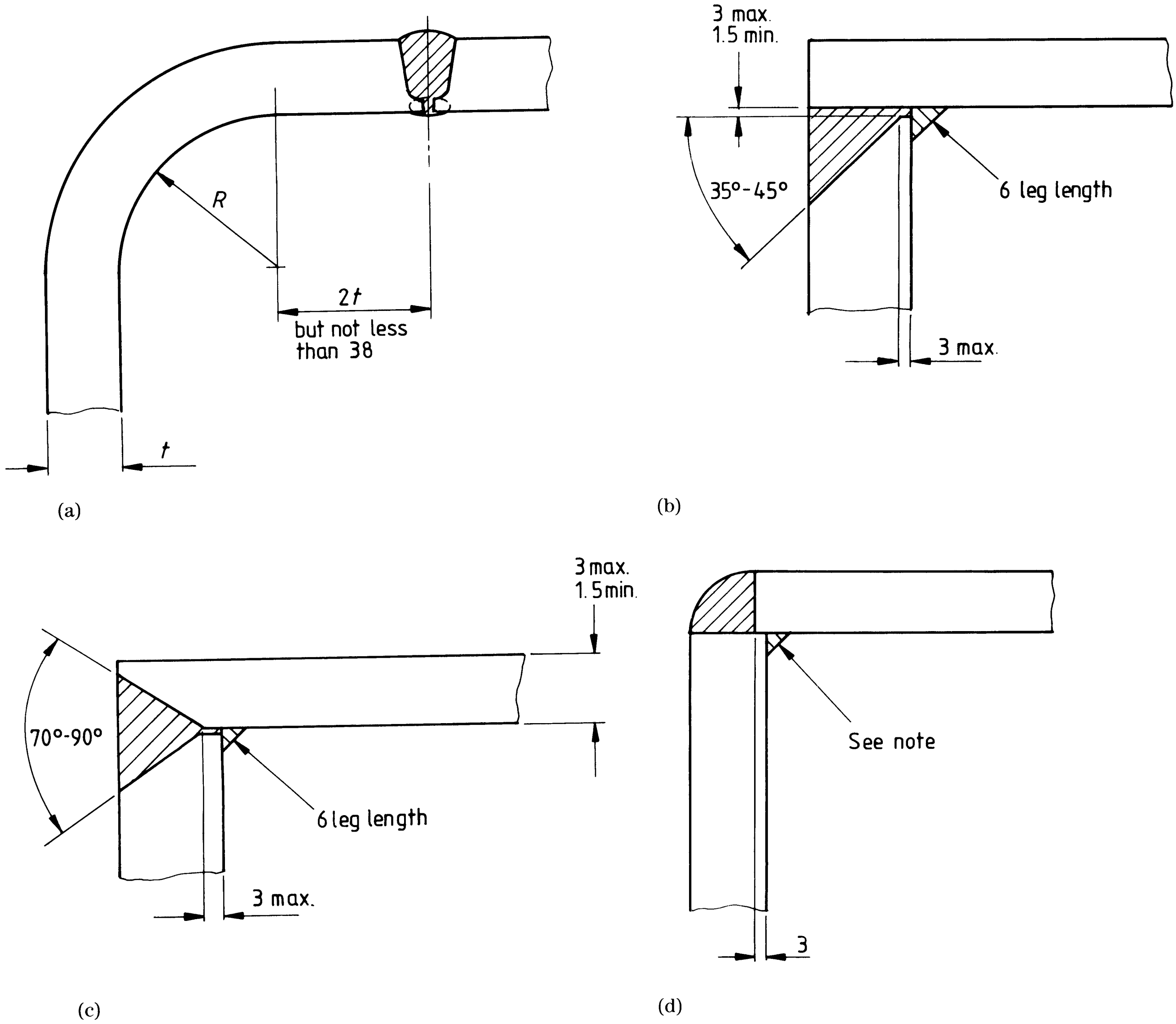

All dimensions are in millimetres.

NOTE. There is a minimum leg length of weld of 5 mm for end plates up to and including 19 mm thick and a minimum leg length of weld of 6 mm for end plates above 19 mm up to and including 32 mm thick.

Figure 31. Attachment of end plates to reversal chamber or firebox wrapper plates

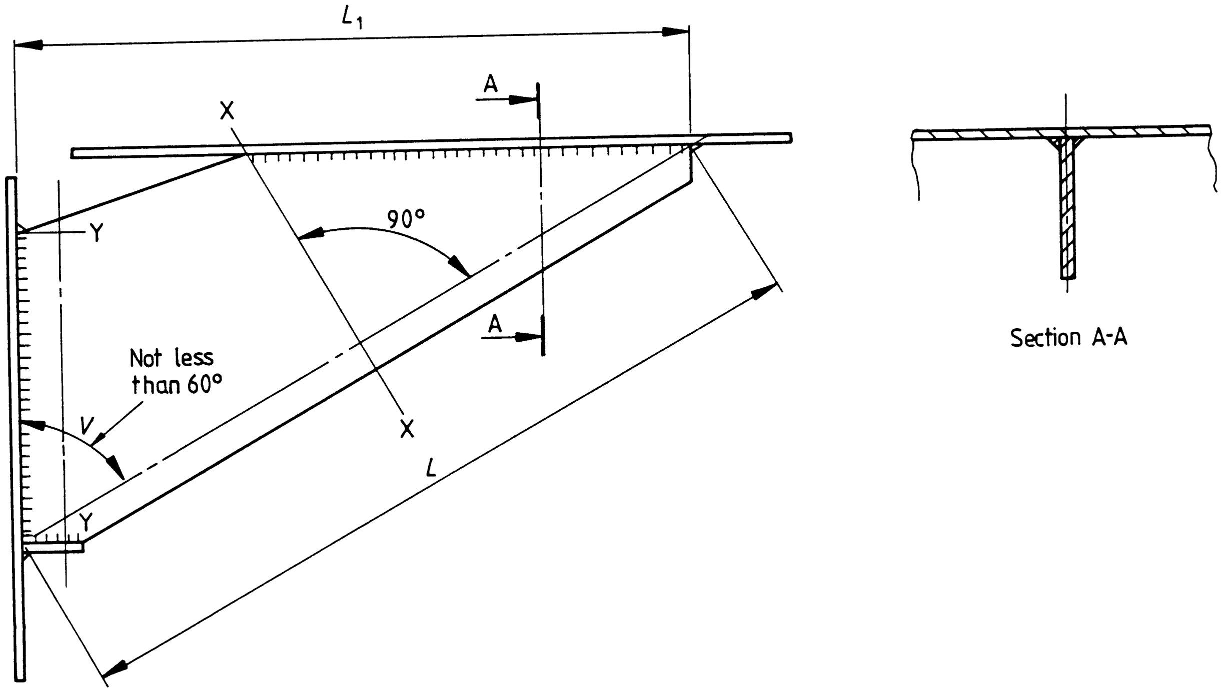

Figure 32. Typical details for all-welded gusset stays

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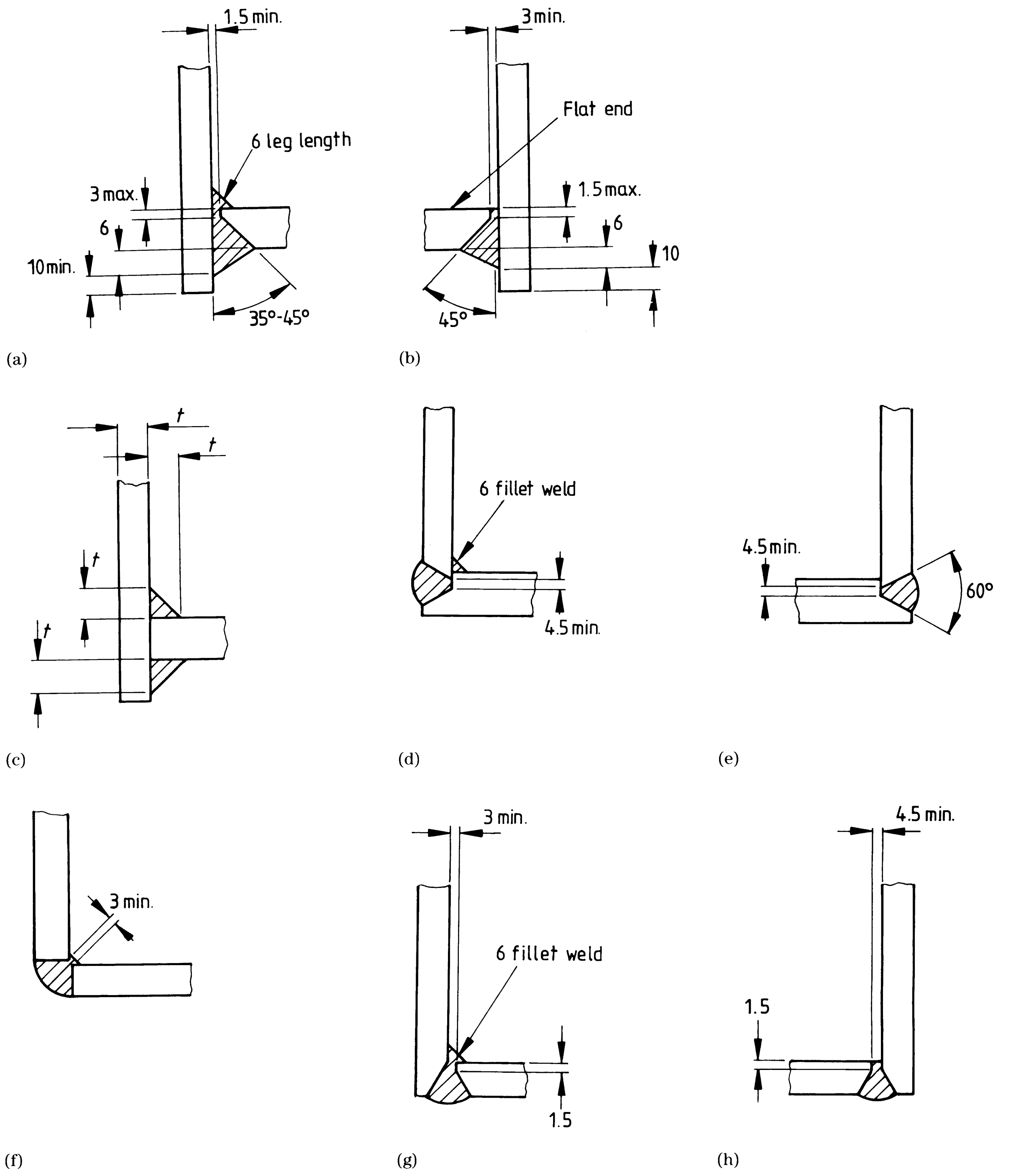

All dimensions are in millimetres.

Figure 33. Attachment between flat plates

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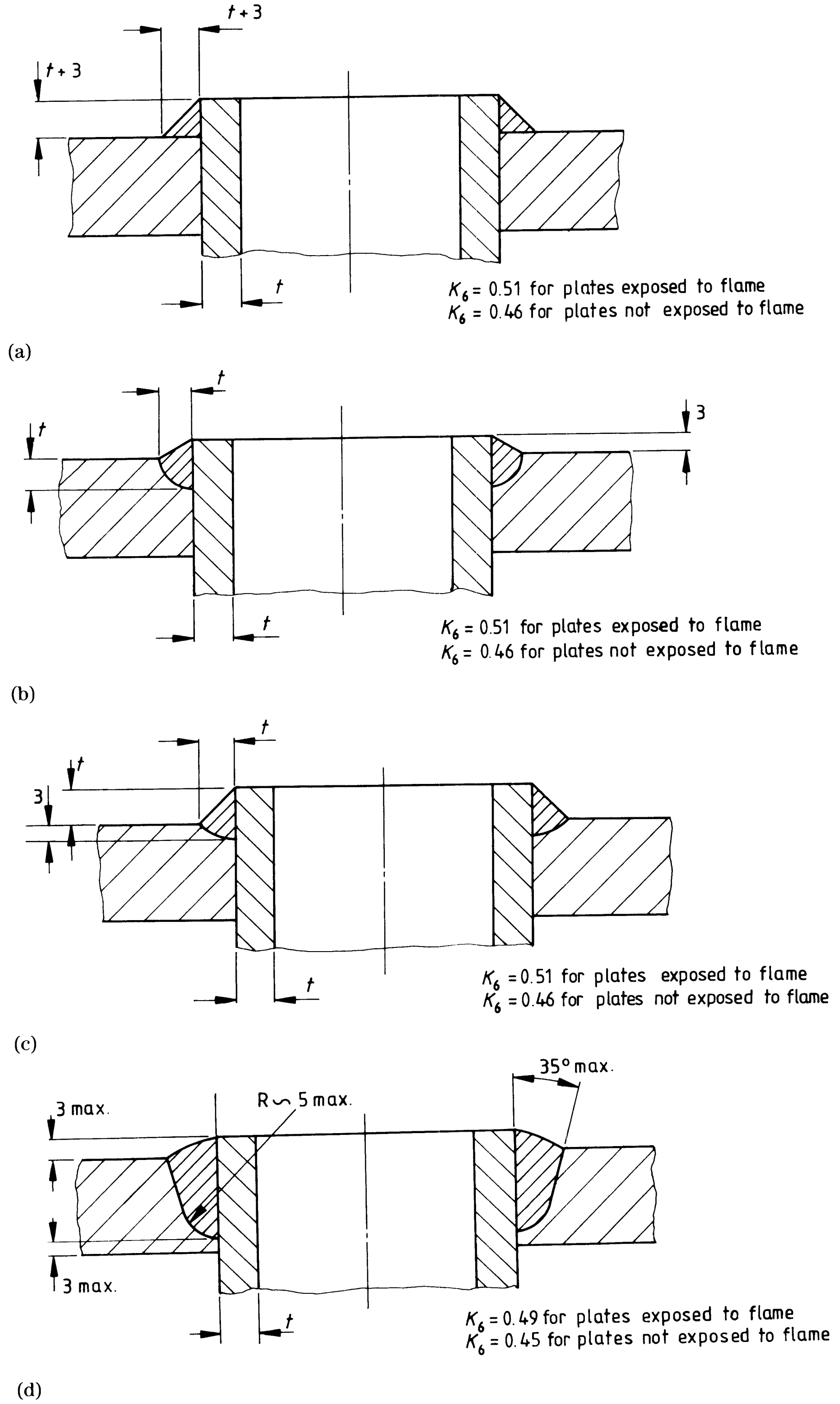

All dimensions are in millimetres.

NOTE 1. The ends of the tubes are to be dressed flush with the welds when exposed to flame or gas temperatures exceeding 600 °C; where not so exposed, the ends of the tubes may extend a maximum of 10 mm beyond the weld.

NOTE 2. See **4.1.3.3** with reference to the use of clearance holes.

Figure 34. Attachment of stay tubes to tube plates

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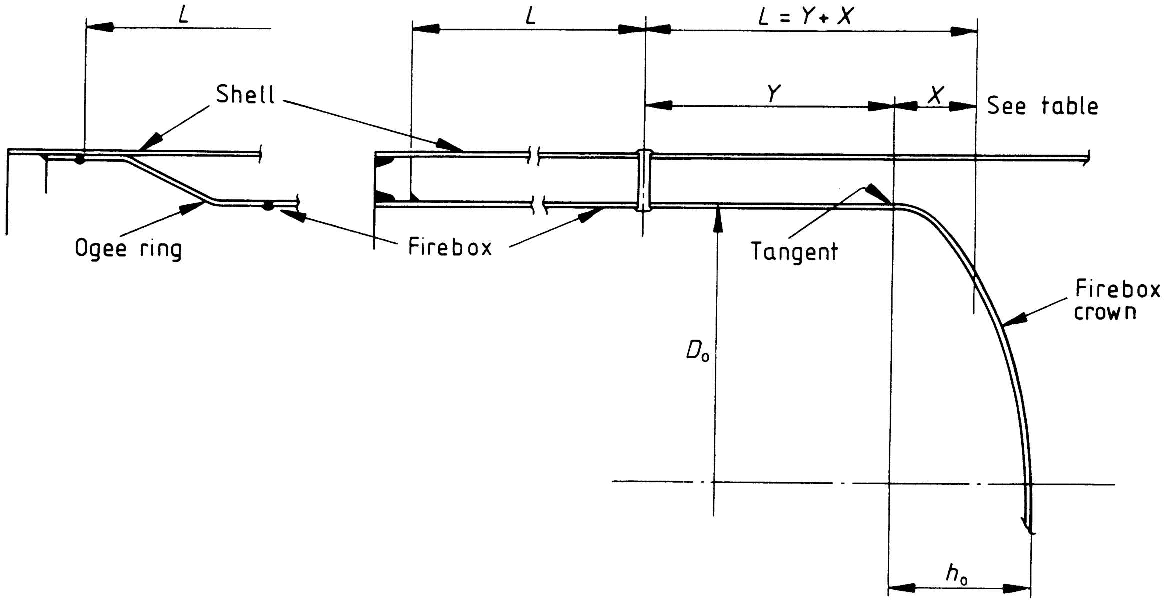

h_O/D_O	X/D_O
0.169	0.07
0.2	0.08
0.25	0.10
0.3	0.12
0.4	0.16
0.5	0.20

Figure 35. Effective length L between centres of substantial support for fireboxes of vertical boilers

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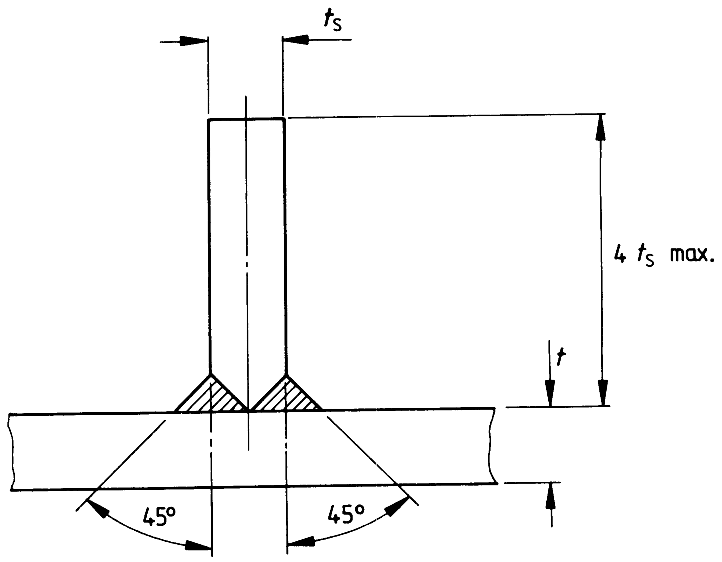

NOTE. t_S is to be equal to or greater than t, but not greater than $2t$ and in no case to exceed 20 mm.

Figure 36. Stiffener for horizontal furnaces

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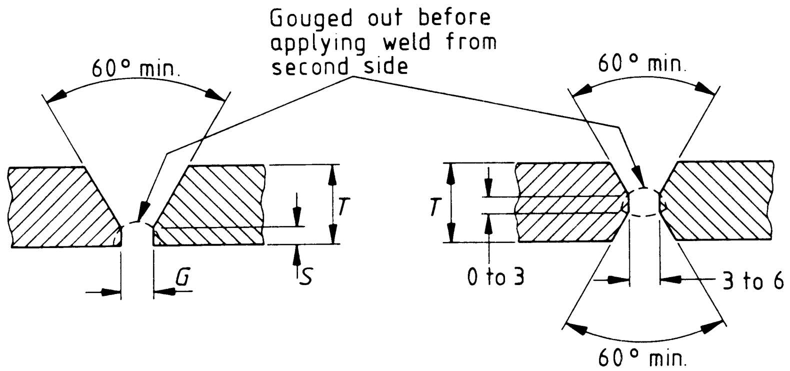

(a) (b)

All dimensions are in millimetres.

Thickness T	Gap G	Minimum angle	Root face S
mm	mm		mm
5 to 10	1.5 to 5	60°	0 to 1.5
Over 10	3 to 6	60°	0 to 3

Figure 37. Typical plate preparation for butt-welded longitudinal and circumferential seams

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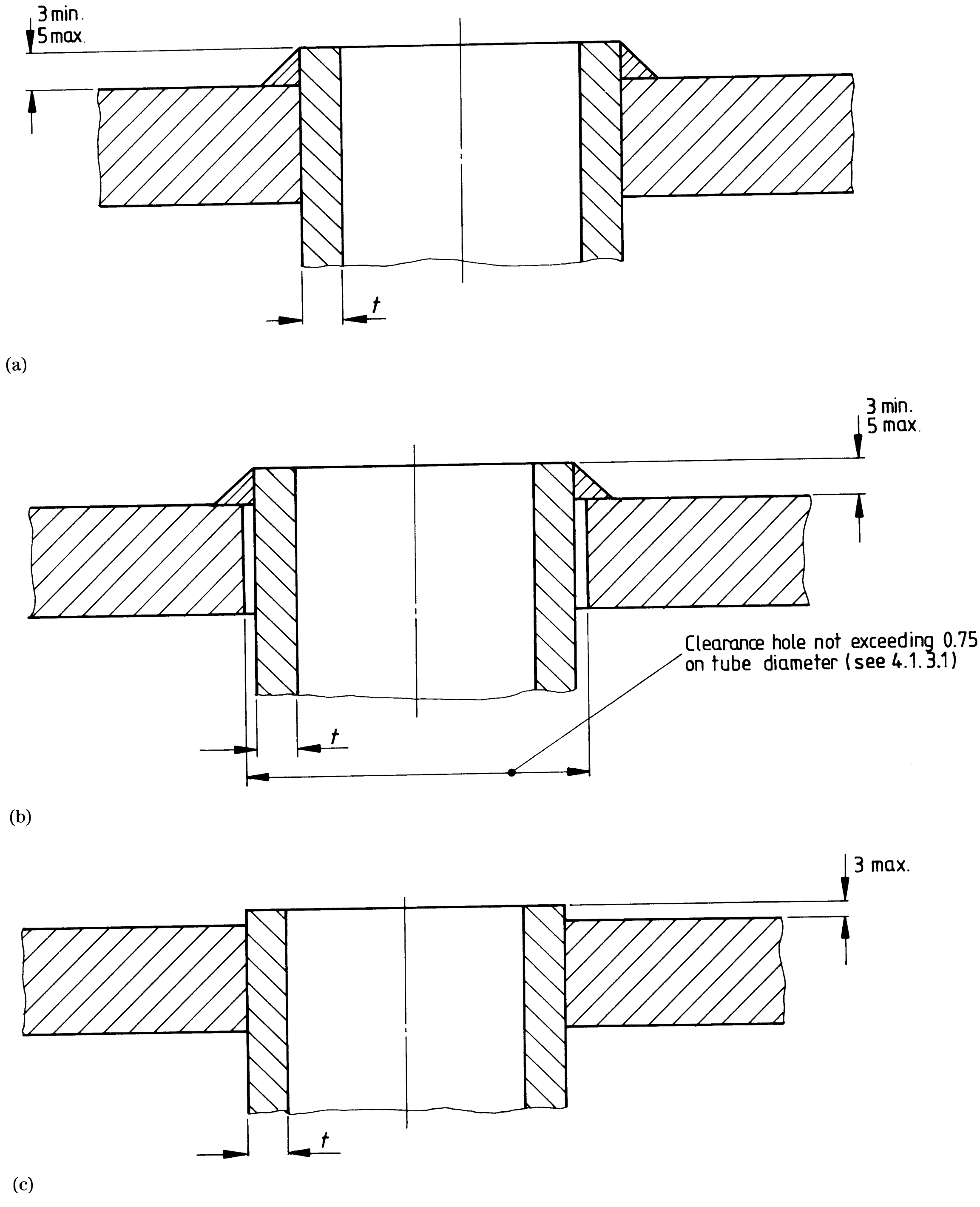

All dimensions are in millimetres.

Figure 38. Attachment of plain tubes to tube plates

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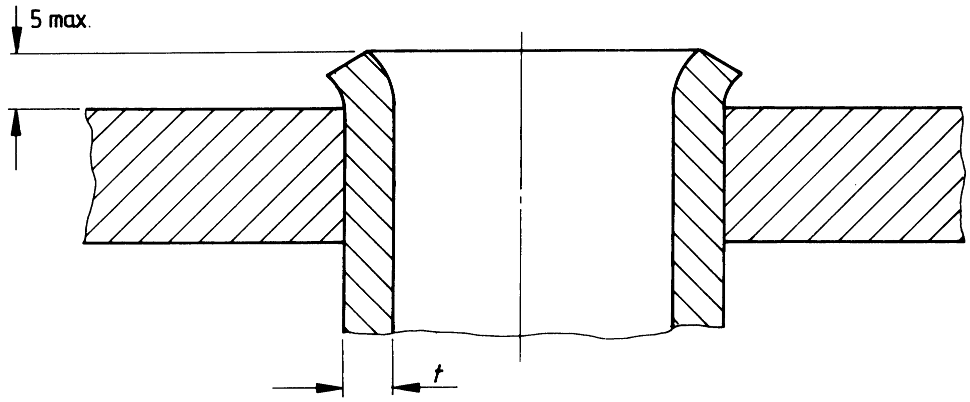
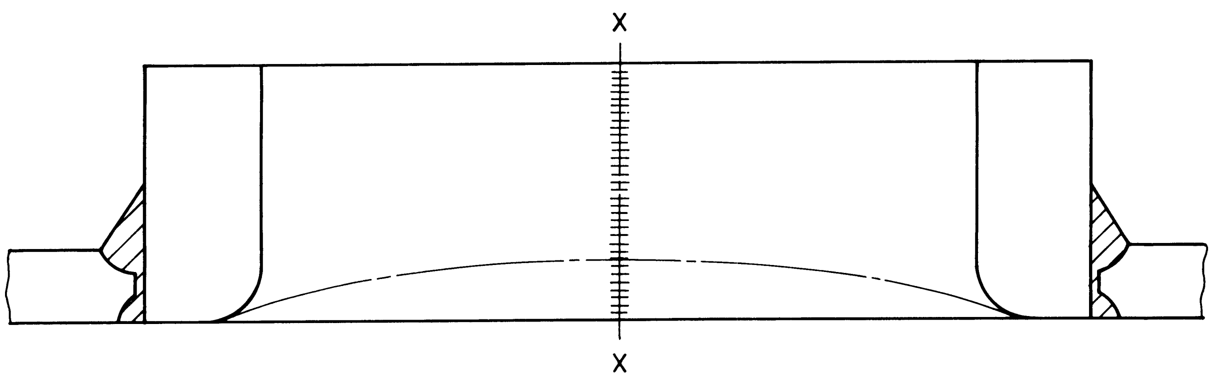


(d)

All dimensions are in millimetres.

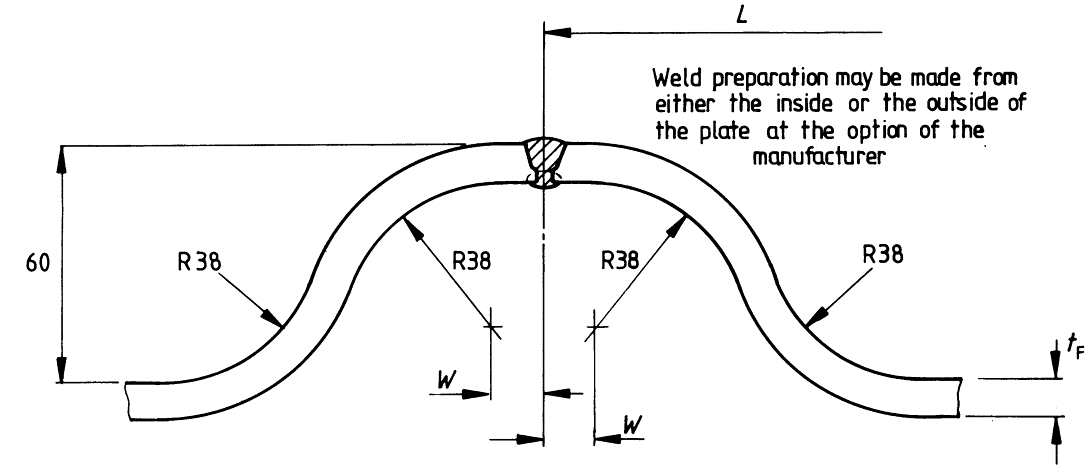
NOTE. The ends of tubes in figure (a) are to be flush with welds where exposed to flame or gas temperatures exceeding 600 °C; where not so exposed they may project up to 10 mm beyond the weld. The ends of tubes in figures (c) and (d) are to be as shown where exposed to flame or gas temperatures exceeding 600 °C; where not so exposed they may project up to 10 mm beyond the tube plate.

Figure 38. (*concluded*)



Alternative forging made in halves and fusion-welded along XX.

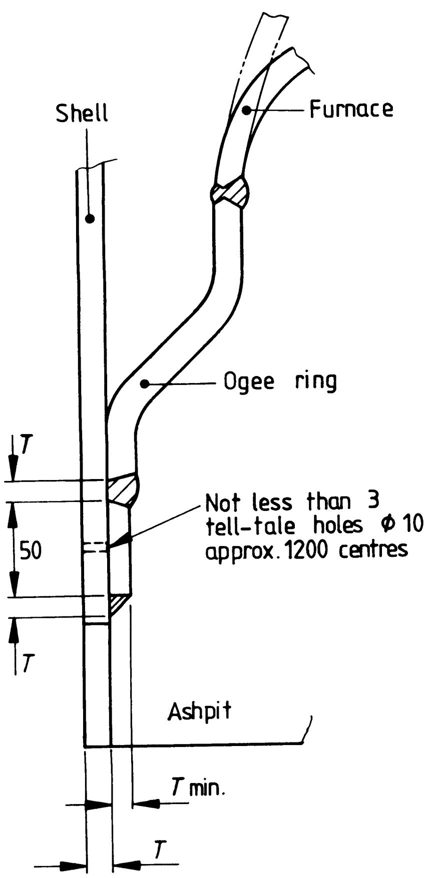
Figure 39. Fusion-welded oval manhole frames



$W = (t_F - 3)$ but not less than 13

All dimensions are in millimetres.

Figure 40. Detail of furnace joints



All dimensions are in millimetres.

Figure 41. Attachment of fireboxes to shells

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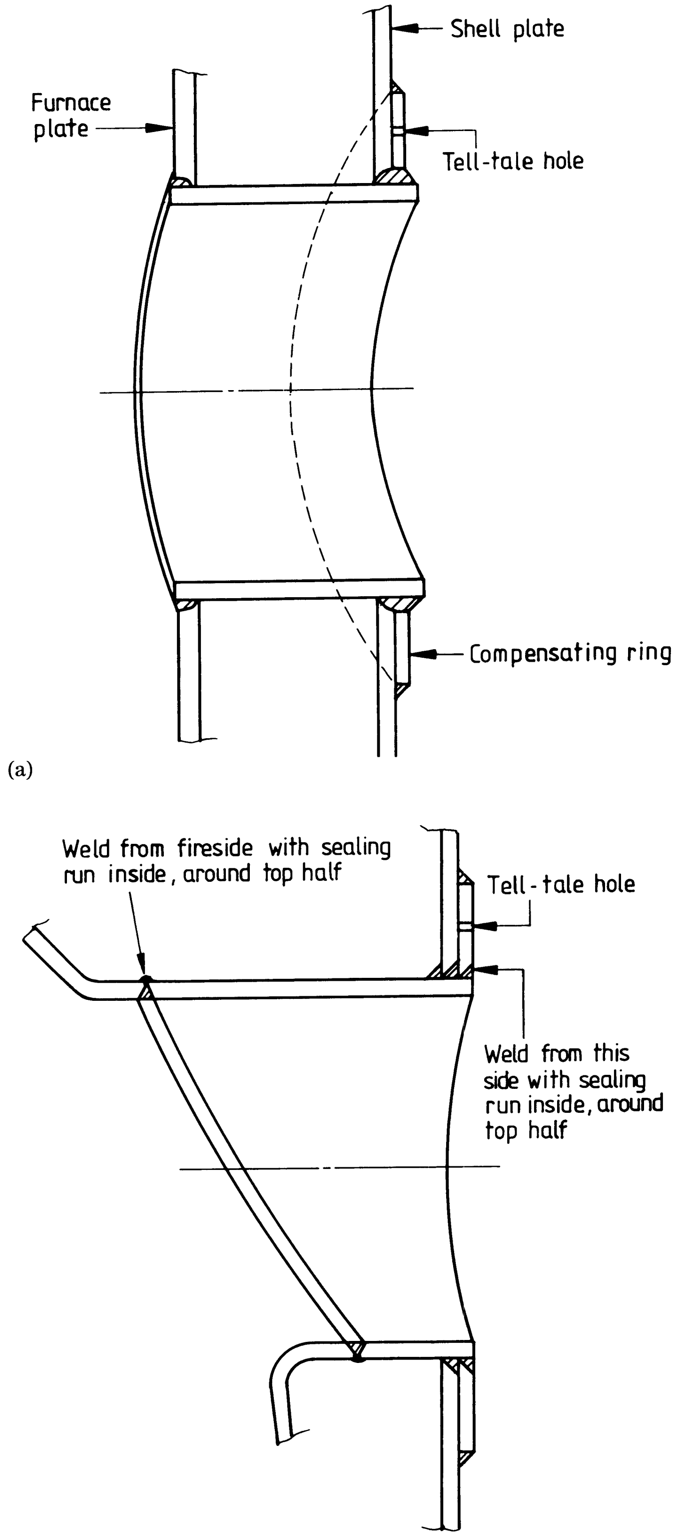

NOTE. The compensating ring may be fitted either inside or outside.

Figure 42. Firehole mouthpieces and access openings

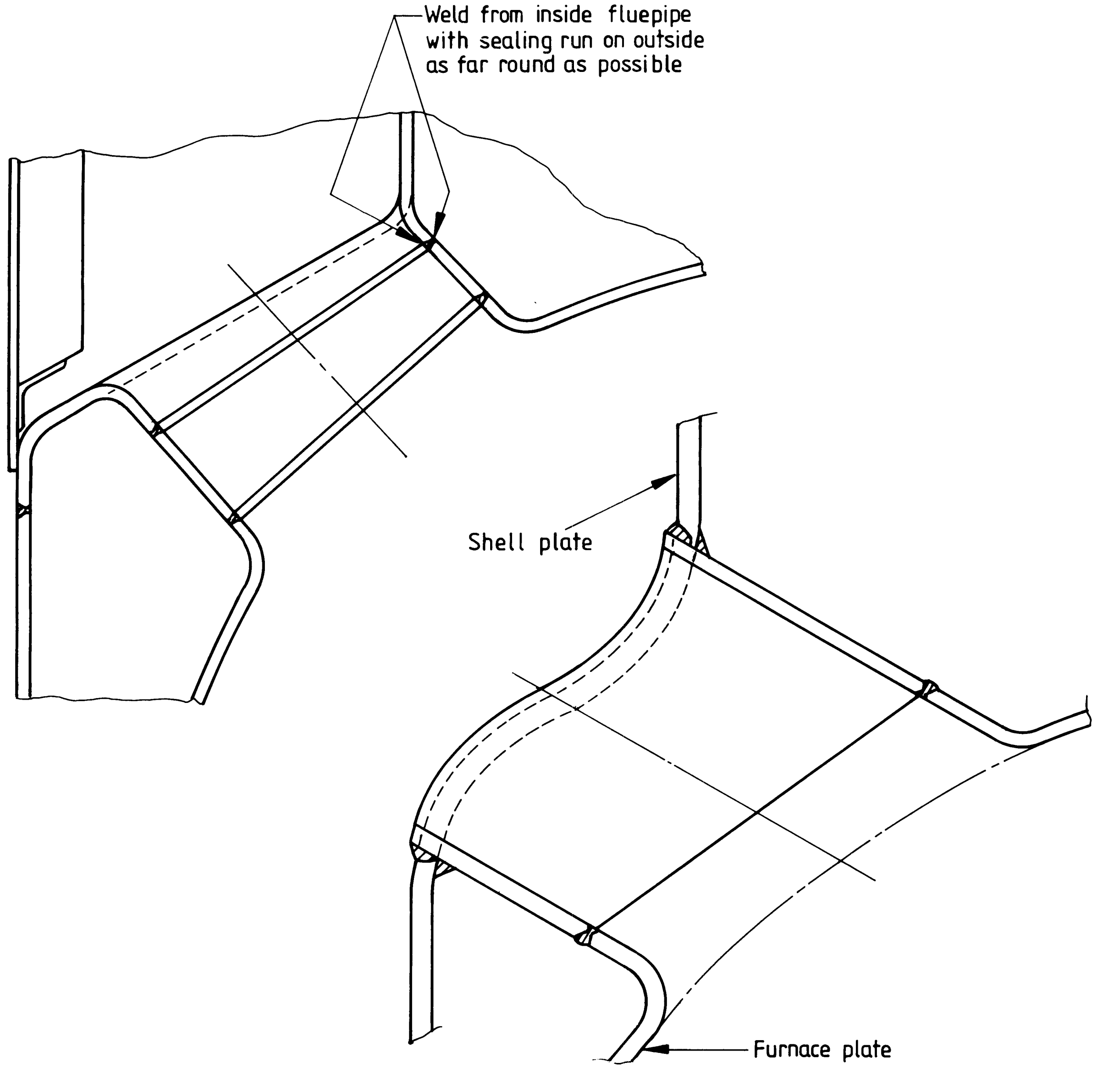

Figure 43. Welding of fluepipes

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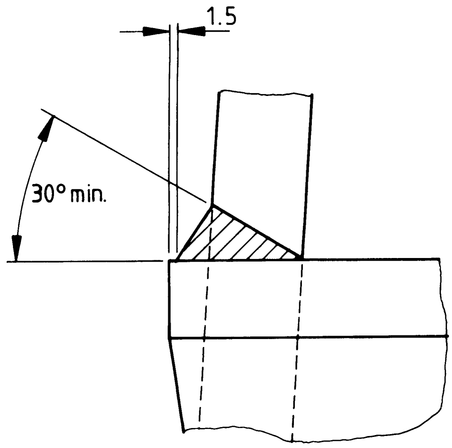
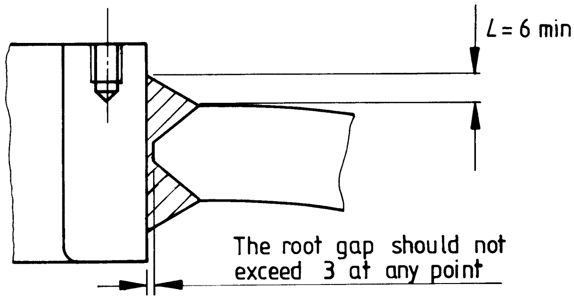


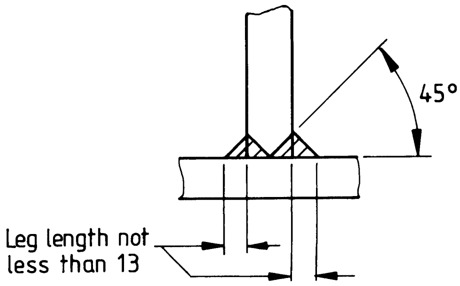
The linear dimension is in millimetres.

Figure 44. Fusion welds of cross tubes

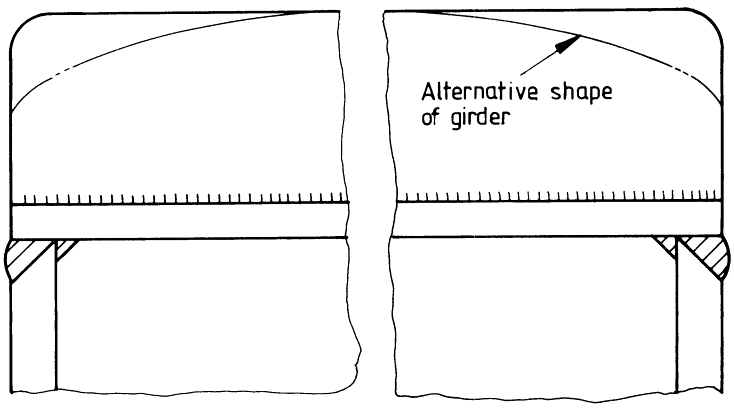


All dimensions are in millimetres.

Figure 46. Butt-welded studded connections



(a) Method of welding girders to reversal chamber top



(b) Welded-on girder to reversal chamber having square corners

All dimensions are in millimetres.

Figure 45. Typical methods of fitting welded girders to welded combustion chambers and fireboxes

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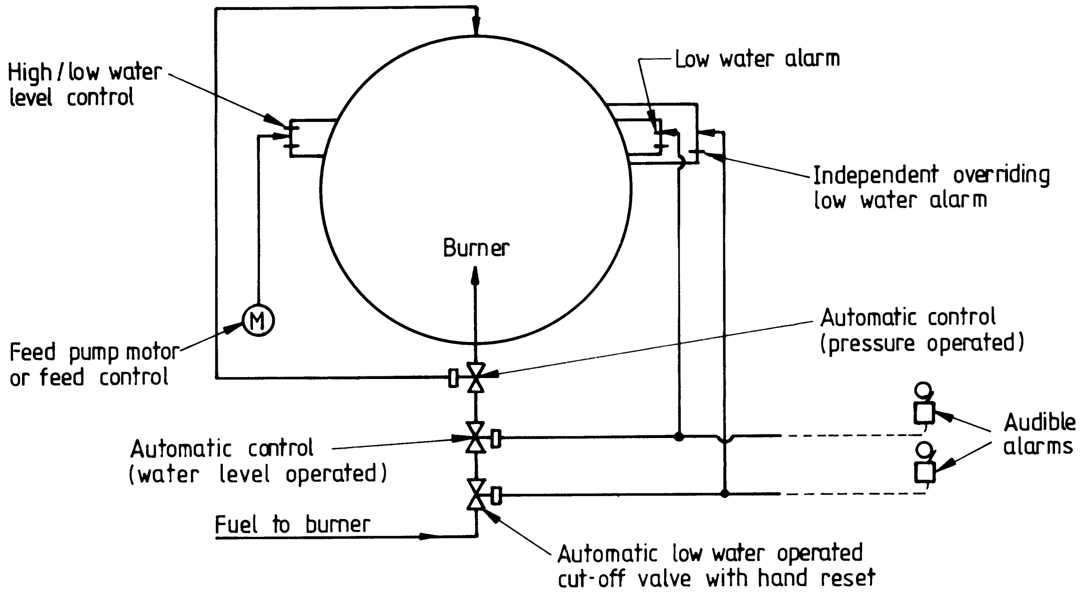

Figure 47. Diagrammatic arrangement of water level and high steam pressure automatic controls and cut-outs for boilers fired with oil or gas complying with section six

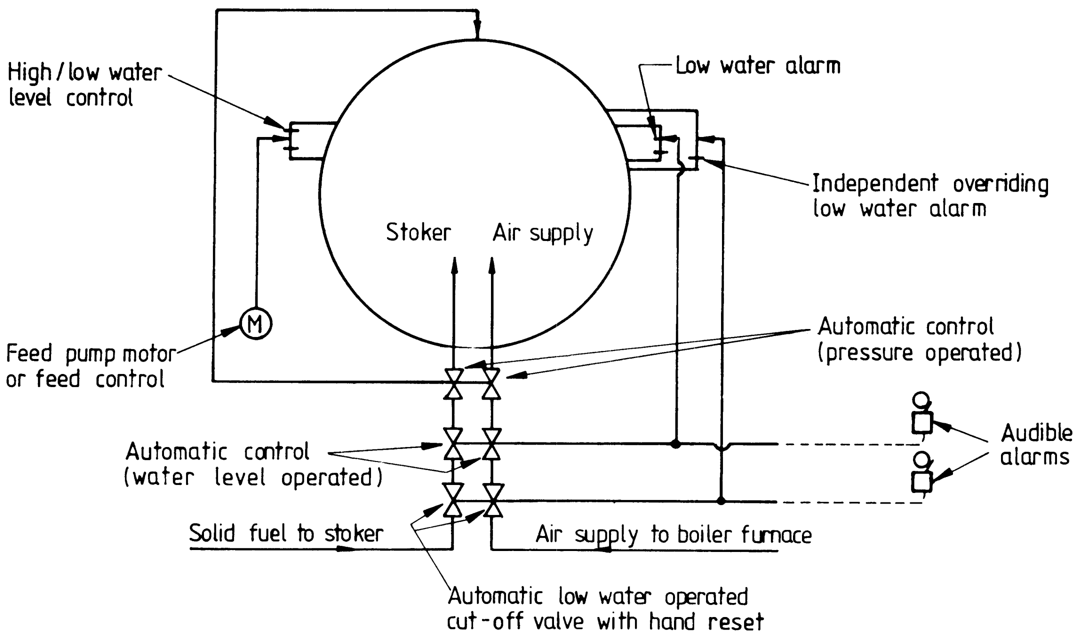

Figure 48. Diagrammatic arrangement of water level and high steam pressure automatic controls and cut-outs for boilers fired with solid fuel complying with section six

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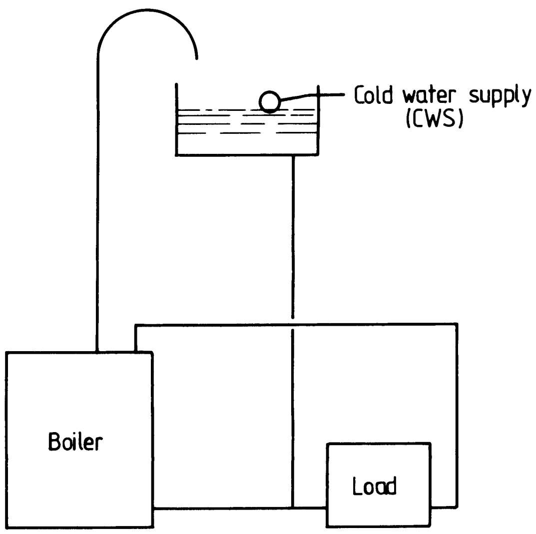
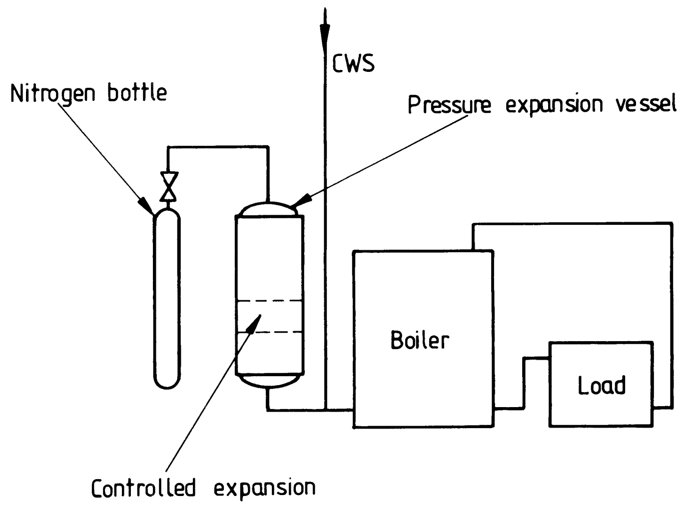
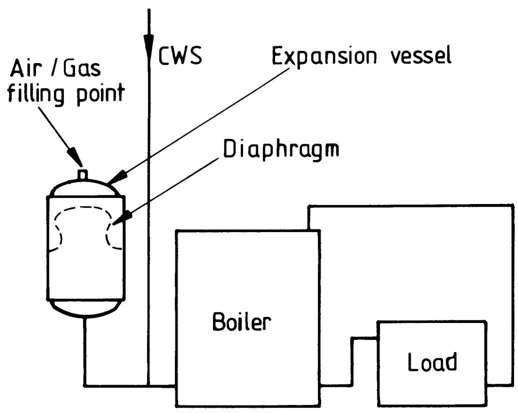


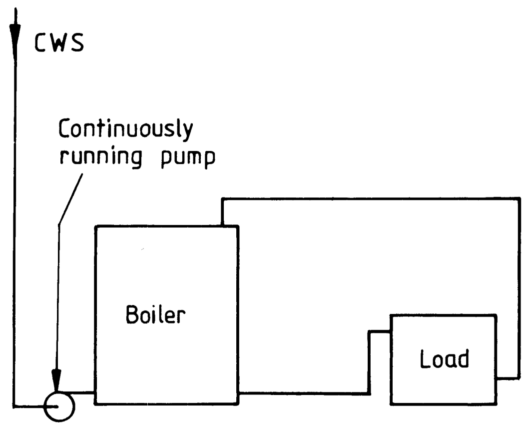
Category A



Category B



Category C



Category D

NOTE. The figures show the basic elements which classify the system. Details of pumps, valves and tanks in the make-up supply will vary according to the system design and are not shown.

Figure 49. Heating system categories

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B.7.4 Where the purchaser/user of the boiler is responsible for carrying out the electrical installation, the boiler manufacturer should provide detailed instructions as to how the installation is to be made and provide a detailed test procedure in order to prove the completed installation.

Appendix C. Categories of boilers

NOTE. The following information is typical of the European and international categorization of boilers.

C.1 According to the combustion arrangement

C.1.1 Boilers in which combustion equipment is specified by the boiler manufacturer.

C.1.2 Boilers suitable for use with a range of unspecified combustion equipment by the user.

C.2 According to usage

C.2.1 Boilers in which only the heat transmitted to the heat carrier is regarded as useful. (Some European countries refer to these as class I.)

C.2.2 Heat generators which, in addition to the heat transmitted to the heat carrier, are designed specifically to give additional useful heat directly to the room in which they are installed. (Some European countries refer to these as class II.)

The heat transferred to the heat carrier and the heat output directly to the room has to be indicated separately, and their sum will be the rated output.

C.3 According to the type of heat carrier used and its circulation within the boiler

C.3.1 Hot water boilers

C.3.1.1 Boilers having water as the heat carrier in which the designed heat output can be achieved without mechanical circulation.

C.3.1.2 Boilers having water as the heat carrier in which the designed heat output can be achieved only with mechanical circulation.

C.3.2 Steam boilers

Boilers having steam as the heat carrier with either natural condensate return or automatic feed.

C.4 According to the type of fuel or fuels to be used

C.4.1 Single fuel boilers

Boilers designed for operation on one fuel category only: solid, liquid or gaseous.

There is a further classification of solid fuel boilers (see **C.5**).

C.4.2 Multi-fuel boilers

These are boilers which can operate on fuels of more than one fuel category.

C.4.3 Convertible boilers

Boilers in which the conversion from one fuel category to another makes it necessary to dismantle parts of the boiler and/or combustion arrangement and to fit the parts and/or components required for the fuel in question.

The conversion can only be carried out by a qualified fitter. The rated output with each fuel has to be specified by the manufacturer.

Conversions cover:

(a) boilers convertible from solid to liquid or gaseous fuels, or vice versa;

(b) boilers convertible from liquid to gaseous fuels, or vice versa.

C.4.4 Changeable boilers

Boilers in which the change from one fuel category to another can be made without dismantling parts of the boiler and/or combustion arrangement.

Boilers in which this conversion is achieved by swivelling the oil or gas burner, in or out, are included in this classification. The rated output with each fuel has to be specified by the manufacturer.

Changes cover:

(a) boilers changeable from solid to liquid or gaseous fuels, or vice versa;

(b) boilers changeable from liquid to gaseous fuels, or vice versa.

C.5 Solid fuel boilers

These are categorized according to the method of firing.

(a) Boilers in which the fuel is fed to the firebed automatically, but in which the ash and clinker are removed manually.

(b) Boilers in which there is automatic fuel feed to the firebed and automatic removal of ash from the firebed.

(c) Boilers in which fuel feed, de-ashing of the firebed and fuel and air modulation are carried out automatically.

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C.6 According to method of air input and fuel gas removal

C.6.1 Open combustion circuit (type B)

C.6.1.1 ***General***

In this classification the air inlet to the boiler is taken from the room in which the boiler is installed and the flue gases are removed through a flue gas duct.

C.6.1.2 ***Natural draught (type B1)***

A boiler in which the products of combustion are removed by natural draught.

C.6.1.3 ***Induced draught (type B2)***

A boiler in which the products of combustion are removed mechanically by means of a fan in the flue gas duct.

C.6.1.4 ***Forced draught (type B3)***

A boiler in which the whole of the boiler system is maintained at above atmospheric pressure.

C.6.2 Closed combustion circuit (type C)

C.6.2.1 ***Room sealed of the type C1***

Boilers joined to a special device applied to the external face of a wall by two ducts, one bringing in the air for combustion and one expelling the products of combustion.

C.6.2.2 ***Room sealed of the type C2***

Boiler connected to a common duct for bringing in the air for combustion and expelling the products of combustion.

C.6.2.3 ***Room sealed of type C3***

Boiler having air intake and flue gas removal through ducting, with natural or induced draught.

Appendix D. Information to be supplied by the manufacturer

D.1 The manufacturer shall supply a certificate of hydraulic test for steam boilers (see **8.1**).

D.2 The manufacturer shall supply assembly instructions for sectional boilers (see **4.7**).

D.3 The following information is to be supplied on request, by the manufacturer:

(a) a copy of the report of the boiler performance test (see **1.3**);

(b) for boilers supplied without combustion equipment, any relevant details or recommendations regarding suitable combustion arrangements (see section six);

(c) those leading dimensions associated with the location, installation and fixing of the boiler (see section four);

(d) a copy of the certificate of hydraulic test for hot water boilers (see **8.1**).

Appendix E. Information to be supplied by the purchaser

The following information is to be supplied by the purchaser at the time of enquiry:

(a) the required boiler output (in kW);

(b) the type of fuel;

(c) the operating pressure and temperatures, i.e. flow and return;

(d) electrical supply details;

(e) type of system;

(f) any special specification requirements.

NOTE. If the purchaser requires that the boiler is independently inspected, the purchaser should indicate to the inspecting authority any special statutory or other regulations with which the boiler is required to comply.

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Publications referred to

BS 21 Specification for pipe threads for tubes and fittings where pressure-tight joints are made on the threads (metric dimensions)

BS 499 Welding terms and symbols
Part 1 Glossary for welding brazing and thermal cutting

BS 749 Specification for underfeed stokers

BS 759 Valves, gauges and other safety fittings for application to boilers and to piping installations for and in connection with boilers
Part 1 Specification for valves, mountings and fittings

BS 779 Specification for cast iron boilers for central heating and indirect hot water supply (rate output 44 kW and above)

BS 799 Oil burning equipment
Part 3 Automatic and semi-automatic atomizing burners up to 36 litres per hour
Part 4 Atomizing burners over 36 litres per hour and associated equipment for single and multiburner installations

BS 806 Specification for design and construction of ferrous piping installations for and in connection with land boilers

BS 845 Methods for assessing thermal performance of boilers for steam, hot water and high temperature heat transfer fluids
Part 1 Concise procedure

BS 1113[1)] Specification for design and manufacture of water-tube steam generating plant (including superheaters, reheaters and steel tube economizers)

BS 1387 Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads

BS 1501 Steels for pressure purposes: plates

BS 1502 Specification for steels for fired and unfired pressure vessels: sections and bars

BS 1580 Specification for Unified screw threads
Parts 1 & 2 Diameters ¼ in and larger

BS 1780 Specification for bourdon tube pressure and vacuum gauges

BS 1894 Specification for electrode boilers of riveted, seamless, welded and cast iron construction for water heating and steam generating

BS 1971[1)] Specification for corrugated furnaces for shell boilers

BS 2486 Recommendations for treatment of water for land boilers

BS 2779 Specification for pipe threads for tubes and fittings where pressure-tight joints are not made on the threads (metric dimensions)

BS 2790 Specification for design and manufacture of shell boilers of welded construction

BS 2869 Fuel oils for non-marine use

BS 3059 Specification for steel boiler and superheater tubes
Part 1 Specification for low tensile carbon steel tubes without specified elevated temperature properties

BS 3601 Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes

BS 3602 Specification for steel pipes and tubes for pressure purposes: carbon and carbon manganese steel with specified elevated temperature properties
Part 1 Specification for seamless and electric resistance welded including induction welded tubes

BS 3643 ISO metric screw threads
Part 1 Principles and basic data
Part 2 Specification for selected limits of size

[1)]Referred to in the foreword only.

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BS 4504	Specification for flanges and bolting for pipes, valves and fittings. Metric series Part 1 Ferrous
BS 4870	Specification for approval testing of welding procedures Part 1 Fusion welding of steel Part 4 Specification for automatic fusion welding of metallic materials, including welding operator approval
BS 4871	Specification for approval testing of welders working to approved welding procedures Part 1 Fusion welding of steel
BS 4882	Specification for bolting for flanges and pressure containing purposes
BS 4947	Specification for test gases for gas appliances
BS 5410	Code of practice for oil firing Part 2 Installations of 44 kW and above output capacity for space heating, hot water and steam supply purposes
BS 5885	Automatic gas burners Part 1 Specification for burners with input rating 60 kW and above Part 2 Specification for packaged burners with input rating 7.5 kW up to but excluding 60 kW
BS 5978	Safety and performance of gas-fired hot water boilers (60 kW to 2 MW input) Part 1 Specification for general requirements Part 2 Specification for additional requirements for boilers with atmospheric burners Part 3 Specification for additional requirements for boilers with forced or induced draught burners
BS 6759	Safety valves Part 1 Specification for safety valves for steam and hot water
BS 7190	Methods for assessing thermal performance of low temperature hot water boilers using a test rig

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