

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)

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Refrigeration, Heating and Air Conditioning Standards Policy Committee (RHE/-) to Technical Committee RHE/10, upon which the following bodies were represented:

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
British Gas plc
Building Services Research and Information Association
Chartered Institution of Building Services Engineers
Department of Energy (Energy Efficiency Office)
Department of the Environment (Property Services Agency)
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

This British Standard, having been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 31 May 1990

© BSI 1990

The following BSI references relate to the work on this standard:
Committee reference RHE/10
Draft for comment 87/76507 DC
First published 1939
Second edition January 1952
Third edition September 1961
Fourth edition May 1976
Fifth edition May 1990

ISBN 0 580 17591 X

Amendments issued since publication

Amd. No.	Date	Text affected

Contents

	Page		Page
Committees responsible	Inside front cover	Section five. Mountings and fittings	
Foreword	4	5.1 Safety valves	32
		5.2 Vent pipes	33
		5.3 Emptying valves or cocks	33
Specification		5.4 Pressure gauges	33
Section one. General		5.5 Temperature gauges	33
1.1 Scope	5	5.6 Inspector's test gauge connection	33
1.2 Definitions	5	5.7 Water-level gauges	34
1.3 Performance	5	5.8 Water-level alarms, fuel cut-outs and fusible plugs	34
1.4 Design pressures and flow temperatures	5	5.9 Connection pipes for water-level fittings	34
		5.10 Feed-water valves	34
Section two. Materials and design stresses		5.11 Blowdown	35
2.1 Materials	7	5.12 Stop valves	35
2.2 Design stress	7		
		Section six. Combustion equipment	
Section three. Design		6.1 General	36
3.1 General	9	6.2 Solid fuel firing	36
3.2 Cylindrical shells subject to internal pressure	9	6.3 Liquid fuel firing	36
3.3 Dished and flanged ends	11	6.4 Gas firing	36
3.4 Standpipes and branches	13		
3.5 Manhole and sighthole openings	14	Section seven. Automatic controls and electrical installation	
3.6 Stays, stiffeners and supported surfaces	14	7.1 Automatic controls for steam and hot water boilers	37
3.7 Tubes and tube plates	19		
3.8 Cylindrical furnaces and combustion chambers subject to external pressure	21	Section eight. Inspection and marking	
3.9 Fireboxes	22	8.1 Inspection	40
		8.2 Hydraulic test	40
Section four. Manufacture and workmanship		8.3 Marking	40
4.1 Pressure parts	24		
4.2 Welding	28	Appendices	
4.3 Dampers, doors and observation ports	30	A Installation provisions	85
4.4 Ashpits	30	B Electrical installation	85
4.5 Inspection and cleaning holes	30	C Categories of boilers	87
4.6 Provisions for mountings, appliances and connections	30	D Information to be supplied by the manufacturer	88
4.7 Assembly of boiler	31		

E	Information to be supplied by the purchaser	Page 88	5	Fillet-welded studded connections	Page 45
Tables			6	Typical methods of welding manhole frame and compensating plates	46
1	Design pressures, flow temperatures and outputs	6	7	Typical dished ends	47
2	Design stress f	8	8	Shape factor	48
3	Minimum thickness of shells subject to internal pressure	9	9	Opening in ends	49
4	Values of z for welded longitudinal seams	9	10	Limits of reinforcement	49
5	Tapped openings: minimum thickness of plate	14	11	Flanges	50
6	Values of constant K_5	15	12	Angle rings	51
7	Weld attachments	18	13	Set-trough branches up to 150 mm o.d. branch	51
8	Number of bar stays in vertical boilers	18	14	Set-in branches: full penetration connections	52
9	Minimum thickness of plain tubes subject to internal or external pressure	20	15	Set-through branches	52
10	Minimum thickness of cylindrical shells subject to external pressure	21	16	Typical screwed connections	53
11	Dimensions of manholes and inspection holes	25	17	Welding details for compensated openings in flat end plates	55
12	Tapping sizes for safety valves	32	18	Typical arrangement of end plates on single furnace economic boilers	56
13	Sizes of safety valves (open vented systems only)	32	19	Access openings for wet-back boilers	57
14	Tapping sizes for vent pipes	33	20	Attachment of unflanged flat end plates to cylindrical shells	58
15	Minimum open vent pipe sizes	85	21	Attachment of dished or flat flanged end plates to cylindrical shells and furnaces	59
Figures			22	Typical arrangement of end plates on multitubular boilers	60
1	Maximum diameter of unreinforced openings	41	23	Bar stays	62
2	Compensation of welded branches or standpipes	42	24	Attachment of longitudinal bar stays	63
3	Compensated set-through branches	43	25	Plate stays	64
4	Typical method of attachment of ash drop-out tube	44	26	Plug-welded firebox or water-leg stays	65
			27	Detail of mild steel anchor stays	66
			28	Attachment of dished or flat flanged end plates to cylindrical shells	67
			29	Attachment of flanged end plates to shell: ends thicker than shell	68
			30	Attachment of flanged flat end plates to shell: shell thicker than ends	69

	Page
31 Attachment of end plates to reversal chamber or firebox wrapper plates	70
32 Typical details for all-welded gusset stays	71
33 Attachment between flat plates	72
34 Attachment of stay tubes to tube plates	73
35 Effective length L between centres of substantial support for fireboxes of vertical boilers	74
36 Stiffener for horizontal furnaces	75
37 Typical plate preparation for butt-welded longitudinal and circumferential seams	76
38 Attachment of plain tubes to tube plates	77
39 Fusion-welded oval manhole frames	78
40 Detail of furnace joints	79
41 Attachment of fireboxes to shells	79
42 Firehole mouthpieces and access openings	80
43 Welding of fluepipes	81
44 Fusion welds of cross tubes	82
45 Typical methods of fitting welded girders to welded combustion chambers and fireboxes	82
46 Butt-welded studded connections	82
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	83
48 Diagrammatic arrangement of water level and high steam pressure automatic controls and cuts-out for boilers fired with solid fuel complying with section six	83
49 Heating system categories	84

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.

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/mm² (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;

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.				
Steam	kW	kW	N/mm ²	°C	N/mm ²	N/mm ²
	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.

Table 2. Design stress 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
Plates	BS 1501 – 151 and BS 1501 – 161	400	mm	mm	N/mm ²	N/mm ²	N/mm ²	N/mm ²
			3	16	163	109	174	116
			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 BS 3602 : Part 1 HFS CFS }	410	–	–	163	109	–	–
		410	–	–	–	–	172	115
Sections and bars	BS 1502 – 151 and BS 1502 – 161	430	–	16	180	120	–	–
			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 $E_t/1.5$.

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:

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

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.

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):

$$K_1 = \frac{pD_o}{1.82ft} \quad (2)$$

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.

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:

$$t = \frac{pD_o K_2}{2f} + C \quad (6)$$

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).

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)

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

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.

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):

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

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):

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

where

p is the design pressure (in N/mm²);
 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/mm²) (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:

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

where

p is the design pressure (in N/mm²);
 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:

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

where

p is the design pressure (in N/mm²);
 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.

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
$> 20 \leq 20$	12
$> 20 \leq 32$	19
$> 32 \leq 38$	22
$> 38 \leq 50$	25
$> 50 \leq 75$	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 sight hole 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/mm².

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 mm²) 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):

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

where

t is the plate thickness (in mm);

p is the design pressure (in N/mm²);

$K_4 = 8.3$ for plates exposed to flame;

$K_4 = 8.9$ for plates not exposed to flame.

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)) (see figure 20(b)) and where it is impractical to effect a seal weld	0.4	0.36
	0.5	0.46
	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

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):

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

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:

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

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 %.

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,

$$K_5 = 0.47; \text{ or}$$

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).

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

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 $l s_1$, 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

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
	sealed	0.60
Double bevel butt welds (with or without superimposed fillets)	0.60	0.70
Double fillet welds	0.55	0.65

69 N/mm². 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/mm².

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 mm²) 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).

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):

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

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.

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):

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

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
$> 38 \leq 76.1$	3.2
$> 76.1 \leq 101.6$	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.	

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):

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

where

- p is the design pressure (in N/mm²);
- 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/mm²);
- 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):

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

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/mm²);
- 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

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

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

where

- p is the design pressure (in N/mm²);
- 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/mm²) 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/mm²) 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 mm⁴) about the neutral axis of the stiffener shall be not less than that calculated from equation (22):

$$I = \frac{D_o^3 p l}{1.33 \times 10^6} \quad (22)$$

where

- D_o is the external diameter of the furnace (in mm);
- p is the design pressure (in N/mm²);
- 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/mm².

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.

$$t = \sqrt{\left(\frac{p D_o (L + 610)}{1.03 \times 10^4} \right)} + 4 \quad (23)$$

$$t = \frac{p D_o}{110} + \frac{L}{320} + 4 \quad (24)$$

where

- p is the design pressure (in N/mm²);
- 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;

(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:

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

where

- p is the design pressure (in N/mm²);
- 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/mm²) 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/mm²) 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).

$$t = \sqrt{\left(\frac{p D_i (D_i - d_o)}{990} \right)} + C \quad (26)$$

where

- p is the design pressure (in N/mm²);
- 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/mm², shall be not less than that given by equation (27).

$$t = \frac{p l V}{193 (V - d_i)} \quad (27)$$

where

- p is the design pressure (in N/mm²);
- 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 plates 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)).

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**.

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/mm², 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/mm² to 494 N/mm². 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.