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Specification

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 l'approvisionnement
indirect d'eau chaude (débit nominal de 44 kW à 3 MW)

Geschweißte Stahlkessel für Zentralheizungs- und indirekte Heißwasserver-
sorgungssysteme (Nennleistung 44 kW bis 3 MW)

BS 855 : 1976

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Foreword

This revised British Standard supersedes BS 855 : 1961 and has been prepared under the authority of the Refrigeration, Heating and Air Conditioning Standards Committee. The scope of this standard has generally been extended to cater for new trends in the Heating Industry but excludes boilers for direct hot water supply.

The rating of boilers on performance and method of testing are also omitted, and these will be the subject of a separate new standard (currently being prepared).

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

- BS 779 Cast iron boilers for central heating (of 44 kW rating and above)
- BS 1113 Water tube steam generating plant

- BS 1894 Electrode boilers
- BS 2790 Shell boilers of welded construction (other than water-tube boilers)
 - Part 1 Class I welded construction
 - Part 2 Class II and Class III welded construction
- BS 1971 Corrugated furnaces for shell boilers

The standards in this series have been formulated with the object of providing adequate protection of life and property, a reasonably long safe period of usefulness and a proper margin for deterioration in service.

To facilitate calculations, both pressure and stress are expressed in N/mm^2 .*

*1 $\text{N/mm}^2 = 1 \text{ MN/m}^2 = 1 \text{ MPa} = 10 \text{ bar}$

British Standard Specification

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

Section one. General

1. Scope

This standard applies to welded steel boilers (other than boilers with cylindrical shells over 2 m diameter) for central heating and indirect hot water supply, for which the classification and the design pressures and flow temperatures are as given in table 1. It also covers mountings and appliances and automatic controls, where applicable, necessary for safe operation which are not necessarily to be supplied by the boiler manufacturer. Steam boilers are included but hot water boilers pressurized by steam are not covered by this standard.

2. References

The titles of the British Standards referred to in this standard are listed on the inside back cover.

3. Information to be supplied by the purchaser and the manufacturer

3.1 Information to be supplied by the purchaser. The purchaser shall disclose to the manufacturer at the time of enquiry

- (a) The name, if any, of the inspecting authority representing the purchaser.
- (b) Conditions under which the boiler will be required to operate. (See clause 8, table 1 and 18.1).
- (c) Details of equipment mountings and controls required to be supplied.
- (d) Any special statutory or other regulations with which the boiler is required to comply. (e.g. boiler laws in countries other than Great Britain).
- (e) Type of fuel.

3.2 Information to be supplied by the manufacturer. The manufacturer shall supply, on request, the purchaser and or the inspecting authority with fully dimensioned sectional drawings showing in full detail the construction of all the pressure parts of the boiler, including weld details (see 28.2.2).

4. Interpretation

If any ambiguity be found or doubt arise as to the meaning or effect of any part of this standard or as to whether anything ought to be done or omitted to be done in order that this standard should be complied with in full, the question shall be referred to the relevant technical committee of the British Standards Institution whose interpretation of the requirements of this standard upon the matter at issue shall be final and conclusive.

Parties adopting this standard for the purposes of any contract shall be deemed to have accepted this provision unless by their contract they either expressly exclude it or else import an arbitration provision in terms of extending to the interpretation of this standard. But this provision is limited to questions of interpretation and does not confer on the committee any power or jurisdiction to adjudicate upon the contractual rights or duties of any person under a contract except so far as they may necessarily be affected by the interpretations arrived at by the committee.

Findings or rulings of the committee upon matters of interpretation may be incorporated as addenda to the standard and if so incorporated shall be treated as amendments thereto.

5. Conditions for compliance with this standard

Use of the provisions of this standard for design and construction is only valid when the relevant requirements of the other standards listed are completely satisfied. Boilers and their ancillary pressure parts may only be marked and certified in accordance with section 9 of this standard when all the relevant requirements of the appropriate standards in that list have been fulfilled.

6. Performance

6.1 The manufacturer shall declare the continuous rating of the boiler for any particular fuel or fuels in kW under normal conditions of installation, as described in BS . . . * and to the levels of performance laid down in that standard.

NOTE. This standard does not call for the retesting of boilers for which acceptable test data are already available nor does it, in itself, entitle the purchaser to require an individual test on any boiler.

6.2 The manufacturer shall supply on request, information regarding the following physical features of the boiler.

- (a) The area in square metres of the primary and secondary heating surfaces; the primary heating surface being defined as that surface which receives heat by radiation from burning fuel and from which heat is conducted directly from the boiler heating surface to the water; the secondary heating surface being defined as that surface which receives heat by convection only from hot flue gases and from which heat is conducted direct from the boiler heating surface to the water.
- (b) The area of the grate in square metres.
- (c) The capacity of the combustion chamber in cubic metres.
- (d) A copy of the certificate of the boiler performance test.

*BS . . . 'Method of performance testing' (in course of preparation)

7. Definitions

For the purposes of this British Standard, the definitions in BS 499 relating to welding, together with the following, apply.

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

7.2 operating pressure. The maximum pressure measured in the boiler under normal operating conditions. The pressure will be dependent on static head, pressurizing equipment (where fitted) and effect of 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 must not exceed a pre-determined level below the saturated steam temperature for that lowest pressure.

7.3 safety valve. A spring or weight loaded automatic valve fitted to a boiler for relieving the build up of excess pressure by means of discharge to atmosphere. Includes valves previously referred to as relief valves.

7.4 combustion space. The space provided for combustion including that taken up by the refractory materials or other components connected with combustion arrangements.

7.5 volume of gas passages. The term gas volume refers to the volume available in the combustion space and the boiler flue ways up to the boiler outlet. This must be known to determine the purging time.

7.6 inspecting authority, if any, shall be, the body or association acting on behalf of the purchaser which ensures that the design, materials, and construction are in accordance with this standard.

8. Design pressures and flow temperatures

8.1 The classification and the design pressures and flow temperatures of welded steel boilers for central heating and indirect hot water supply are given in table 1.

8.1.1 Such boilers shall not be used on installations where any of the steam or condensate is drawn off the system.

8.1.2 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.)

8.1.3 Hot water central heating boilers for use in pressurized (medium pressure) systems designed to operate at a pressure in the boiler not exceeding 450 kN/m^2 and for which 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.

8.1.4 Where solid fuel is used in connection with a pressurized system, preference should be given to the use of automatic stoking equipment but in all cases provision must be made for the positive dissipation of the heat generated under normal and abnormal working conditions. Automatic stoking equipment and all automatically controlled combustion equipment burning liquid or gaseous fuels must be arranged to shut down in the event of

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

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

Table 1. Design pressures and flow temperatures

Type	Output kW	Max operating pressure N/mm^2	Max working temperature $^\circ\text{C}$	Max design pressure N/mm^2 *	References	Maximum safety valve setting N/mm^2
	Min. Max.					
Steam	45 1500	0.20	132	0.23	8.1.1 8.1.2	0.23
Externally pressurized hot water	45 3000	0.45	132	0.52	8.1.3	0.52
Vented hot water	45 3000	0.45	100	0.52	8.1.2	0.52

*Design pressure shall in no case be less than 0.23 N/mm^2 . See 18.2.

8.1.5 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 an adequate circulation is maintained either by gravity or by alternative means in such a way that the design pressure and temperature will not be exceeded because of the residual heat in the firebox.

8.1.6 This foregoing provision should also be made when liquid or gaseous fuel is to be used, except that if such a provision is not practicable an arrangement is permissible in which the controls for item 8.1.4 (a) shall be supplemented by an independent overriding control affording complete shut-down of the heat input to the boilers and actuated by the water temperature at or near the flow outlet of the boiler. If fitted in the flow pipe it must be within 300 mm of the boiler and with no intervening valve.

8.1.7 A welded steel hot water central heating boiler shall not be used with a flow outlet temperature greater than 100 °C in a system which is not provided with adequate 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.

8.1.8 It is the responsibility of the installer to ensure that the correct mountings appropriate to the system are fitted. 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.

8.1.9 Welded steel boilers which embody cylindrical shells having diameters larger than 2 m and boilers for operating pressures and temperatures higher than those stated in table 1 shall comply with BS 2709 : Part 1 or 2.

NOTE 1. 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 for this standard. The manufacturer should consult with the purchaser and/or inspecting authority on these matters before production commences.

NOTE 2. Gas or oil burning equipment, automatic stokers, and forced or induced draught equipment which may be required by the purchaser are extraneous to this standard and are subjects for mutual agreement between the purchaser and the manufacturer. Where such accessories are required or contemplated it is recommended that all particulars which would affect the boiler or boilers should be disclosed by the purchaser to the manufacturer at the time of the enquiry. It is strongly recommended that matched units be selected.

9. Dampers and doors

9.1 Boilers for solid fuel

9.1.1 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 a well-fitting, finely adjustable air inlet below the grate.

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

9.1.3 Doors at front and above grate level. The clearance between any door when properly fitted and the surface against which it closes shall not exceed 1 mm except in the case of firing doors for hand fired boilers for which the clearance shall not exceed 2 mm.

9.1.4 Flue or chimney damper. A sliding or butterfly damper shall be fitted on the boiler at the outlet. Sliding dampers shall be clearly graduated to facilitate accurate

setting. Butterfly dampers shall have an extended handle indicating clearly the position of the blade, which should be capable of being held in position to prevent movement. Dampers of either type should be so shaped that, when in the fully closed position, the free area to permit the passage of flue gases shall be 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 the damper to be locked in the correct open position.

9.2 Boilers for gaseous and liquid fuels

(a) A boiler using such 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. Automatically controlled dampers shall be provided with interlocking equipment to prevent the combustion equipment operating if the damper is not in the correct open position.

(b) In the case of combustion equipment supplied or recommended by the boiler manufacturer, provision should be made for flame observation.

(c) Care must be taken in the selection of draught control equipment in order to avoid the cooling of flue gases below their dew point.

9.3 Boilers for gaseous fuels

9.3.1 In the case of boilers supplied for gaseous fuel firing, no damper shall be fitted without the prior approval of the appropriate gas authority.

10. Ashpits

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

11. Openings

Mountings with male ends not exceeding 3 in BS pipe size (in which the screwed portion is an integral part of the mounting) and screwed pipe connections not exceeding 3 in BS pipe size may be screwed into tapped bosses on the boiler. Openings for mountings and pipe connections above this size shall be suitable for flanged connections (see clause 21).

12. Inspection and cleaning holes

In steam boilers, sufficient inspection and cleaning holes of adequate size shall be provided to permit thorough cleaning and inspection. (see 21.4). It is recommended that means of cleaning and inspection be provided on hot water boilers.

13. Provisions for mountings, appliances and connections

All boilers shall have suitable 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.

In the case of steam boilers the openings for the condensate return 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.

Where face-to-face joints are embodied in the design of boilers, they shall be provided with suitable counter flanges or flanged connections as may be agreed between the purchaser and the manufacturer.

The screw thread of the studs or bolts shall comply with BS 1580.

14. Assembly of boiler

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

15. Handles and knobs

Due regard to surface temperature should be taken into account when designing handles and knobs, in order to minimize the risk of skin burns.

Section two. Materials and design stresses

16. Materials

Materials used in the construction of boilers to this standard shall comply with the following requirements.

16.1 Plates. Plates shall comply with any of the following specifications.

BS 1501 – 151 – 161 Class A or B, but with minimum of grades 26A or B.

16.2 Sections and bars. Sections and bars shall comply with any of the following specifications:

BS 1502 – 151 – 161

16.3 Bolts and nuts. Bolts, nuts and set screws shall be of steel having a minimum tensile strength of 430 N/mm^2 , and in which neither the sulphur nor the phosphorous contents exceeds 0.05 %. They shall be screwed to the requirements of BS 1580, or BS 3643 : Parts 1 and 2.

16.4 Tubes

(a) *Plain tubes and stay tubes.* Plain tubes and stay tubes shall be seamless or electric-resistance-welded and shall comply with the requirements of BS 3059 Part 1.

(b) *Seamless steel cross tubes and uptake tubes.* Seamless steel cross tubes uptake, branches standpipes and furnaces shall comply with the requirements of BS 3601 and BS 3602 grade 27 HFS or CDS.

16.5 Tolerances on tubes. Where minus tolerances are incorporated in the tube specifications these shall be taken into account in the design of the boiler. This applies to all tubes dealt with in 16.4.

16.6 Subject to agreement between the purchaser and the manufacturer, carbon or carbon manganese steels other than those listed in 16.1 to 16.4, may be used provided that they are of the required type and tensile strength as indicated, and that their general suitability with regard to ductility, weldability, short term and, where relevant long term, mechanical properties at elevated temperatures have been proved to the satisfaction of the inspecting authority.

17. Design stresses

17.1 Allowable stress

17.1.1 The term 'allowable stress' designated by the symbol f in the following clauses means the stress to be used where applicable, to determine the minimum scantlings of pressure parts.

17.1.2 The allowable stress f based on a maximum temperature T of 250°C shall be as table 2, and E_t = specified minimum values of yield or 0.2 % proof stress at temperature T . In the case of class A plates E_t is derived from table 1 of BS 2790 : Part 2.

Table 2. Design stresses

British Standard	Tensile range	Thickness	Class A plates No specified elevated temperature properties		Class B plates Specified elevated temperature properties	
	kgf/mm ²	mm over up to and including	N/mm ²		N/mm ²	
Plate material			E_t	f	E_t	f
1501 – 151 and 161	40.9 – 49.6	0 32	161	101	167	111
" " "	" "	32 64	161	101	161	107
1501 – 151 and 161	44.1 – 52.7	0 32	173	108	179	120
1501 – 151 only	" "	32 64	173	108	173	115
British Standard	Tensile range	Thickness	No specified elevated temperature properties		Specified elevated temperature properties	
Tube material (furnaces, cross tubes, uptakes)	kgf/mm ²		N/mm ²		N/mm ²	
			E_t	f	E_t	f
3601 HFS and CDS (Steel 27)	42.6 – 55.2	—	167	104	—	—
3602 HFS and CDS (Steel 27)	42.6 – 55.2	—	167	104	179	120
Specimens and bars 1502 – 151	44.1 – 52.7	—	173	108	—	—

NOTE 1. It should be noted that the foregoing mechanical properties are those for the most favourable conditions. Reference should however be made to the appropriate sections of this text to determine if any other limiting factors apply.

NOTE 2. The stress values for class A plates in the as rolled and in normalized condition are based on $E_t/1.6$.

Section three. Design

18. General

18.1 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. 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. Attention is drawn to BS 2486.

18.2 The design pressure as defined in clause 7 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/mm².

NOTE. 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 are set to lift, to prevent the unnecessary operation of the safety valves. It is recommended that the margin in pressure between the safety valve setting and that due to the head of water in kN/m² should take into account the effect of circulators. The setting must in no case exceed the design pressure.

19. Cylindrical shells subject to internal pressure

19.1 Shell thickness. The minimum thickness of a cylindrical shell shall be determined by the following formula but in no case shall the thickness be less than the minimum thickness given in 19.2.

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

where

t is the minimum thickness of shell in millimetres;

p is the design pressure in N/mm²;

R_i is the internal radius of shell in millimetres;

f is the allowable stress at working metal temperature in N/mm²; (see 17.1).

C is a corrosion allowance. This shall be taken as 0.75 mm, unless a higher figure is agreed to take account of adverse conditions;

z is the efficiency, expressed as a fraction, of the longitudinal welded seam, as given in table 4.

Minimum thickness of shells subject to internal pressure shall not be less than the thickness given in table 3. Special consideration must be given to boiler seating arrangements and other external loads to ensure that stresses remain within safe limits.

Table 3. Minimum thickness of shells subject to internal pressure

Maximum internal diameter of cylinder	Cylindrical shell minimum thickness (with Internal pressure)
Up to and including 400 mm 2000 mm	4 mm 8 mm

NOTE. Intermediate values may be interpolated.

Table 4. Values of Z for welded longitudinal seams

Value of Z	Conditions
0.65	For double sided butt welds in which the weld metal at the root of the first side weld is gouged out 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 gouged out in the manner indicated above.

19.2 Openings in cylindrical shells

19.2.1 Unreinforced openings. The maximum diameter d of any unreinforced opening shall be obtained from the curves in figure 1. In figure 1 the value K to be used is calculated from the following formula.

$$K = \frac{pD_o}{1.82 f t} \quad \text{Equation 2}$$

where

- p is the design pressure in N/mm^2 ;
- D_o is the outside diameter of shell in millimetres;
- t is the actual thickness of shell in millimetres;
- f is the allowable stress (as used in equation 1) in N/mm^2 .

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

Notwithstanding the diameter d obtained from the use of figure 1, no unreinforced opening shall exceed 200 mm diameter, and where K has a value of unity or greater the maximum size of an unreinforced opening shall be 50 mm.

Openings in a definite pattern such as tube holes may be designed in accordance with the rules for ligaments given in BS 1113 provided that the diameter of the largest hole in the group does not exceed that permitted by 19.2.1.

19.2.2 Reinforced openings. Openings larger than those permitted by 19.2.1 shall be reinforced. Wherever practicable, reinforcement shall be achieved by taking account of the cross-sectional area of locally disposed material, including the attachment weld(s), in excess of the minimal 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 of the branch and the thickness A 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 follows.

(a) For that part of the branch which projects outside the shell calculate the full sectional area of the stem up to a distance C 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) Add to it the full sectional area of that part of the stem which projects inside the shell up to a distance C from the inside surface of the shell.

(c) Add to it the sectional area of the fillet welds on both sides of the shell.

(d) Add to it the area obtained by multiplying the difference between the actual shell thickness and the unpierced shell thickness A by a length D .

Where achievement of an adequate area Y is not practicable using the above method, additional reinforcement shall be provided in accordance with any of the typical arrangements shown in figure 45 or by using an alternative method mutually agreed between the purchaser, the manufacturer and the inspecting authority. In this case the sectional area of the additional reinforcement and its attachment welds shall be taken into account within the confines of dimensions C and D , D being as shown in figure 2 and C 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 millimetres;
- t_a is the actual thickness of the branch wall in millimetres;
- t_r is the actual thickness of the added reinforcement in millimetres on the outside of the shell plate.

Where material having a lower design stress than that of the shell or end 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 credit shall be taken for the additional strength of material having a higher stress value than that in shell or endplate.

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.

NOTE. 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. In special cases, an alternative design method based on more detailed analyses may be employed by agreement between manufacturer, purchaser and inspection authority.

19.3 Fillet welds attaching pads and compensating plates to cylindrical shells. The sizes of outer peripheral fillet welds by which pads (see appendix A) and compensating plates (see figures 3 (a) and 3 (b)) are attached to shell plates shall be determined by equation 3, but shall in no case be less than the inner welds nor less than the minimum plate thickness specified in 19.1.

$$L_o = \frac{4X - D_i L_i}{D_o} \quad \text{Equation 3}$$

where

L_o is the length in millimetres of leg of fillet weld around outer periphery of pad or compensating plate;
 L_i is the length in millimetres of leg of fillet weld around inner periphery of pad or compensating plate;
 X is half the cross-sectional area of opening in shell (based on unpierced shell thickness) in square millimetres (see 19.2.2);
 D_o is the diameter in millimetres of outer periphery of circular pad or compensating plate;
 D_i is the diameter in millimetres of inner periphery of circular pad or compensating plate.
 For elliptical compensating plates

$$D_o = \frac{a_o + b_o}{2} \quad \text{Equation 4}$$

$$D_i = \frac{a_i + b_i}{2} \quad \text{Equation 5}$$

where

a_o is the outer major axis of compensating plate in millimetres;
 b_o is the outer minor axis of compensating plate in millimetres;
 a_i is the inner major axis of compensating plate in millimetres;
 b_i is the inner minor axis of compensating plate in millimetres.

20. Dished and flanged ends

20.1 Torispherical, semi-ellipsoidal and hemispherical 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 not be greater than D_o .

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

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

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

where

D_o is the outside diameter of the parallel portion of the end in millimetres;

t is the thickness of the end plate in millimetres;
 H shall be measured from the commencement of curvature (see figure 4).

(c) *Hemispherical ends.* No special requirements.

20.2 Thickness

20.2.1 Subject to the limitations given in 20.1 the thickness of any of the three forms of end shall be calculated from the following formula.

$$t = \frac{pD_o K}{2f} + C \quad \text{Equation 6}$$

where

t is the minimum thickness, after dishing, in millimetres;

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

D_o is the outside diameter of the domed end in millimetres;

K is a shape factor (see 20.2.2);

f is the allowable stress at working metal temperature of 250°C in N/mm^2 (see 17.1);

C is a corrosion allowance of 0.75 mm.

The minimum thickness t shall in no circumstances be less than 6.0 mm.

20.2.2 The shape factor K used in equation 6 is obtained from the series of curves in figure 5 and depends on the ratio of height to diameter H/D_o .

The curve drawn with a full line in the series provides the factor K for plain (i.e. unpierced) ends. Where the value of H/D_o is lower than 0.25 the value of K 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 .

20.3 Openings in dished ends

20.3.1 Unreinforced openings. Openings in dished ends may be circular or approximately elliptical. The curves drawn with broken lines in figure 5 provide values of K to be used in equation 6 for ends with unreinforced openings (e.g. manholes or tube holes). The selection of the correct curve depends on the value of

$$\sqrt{\frac{d}{D_o t}}$$

where

d is the diameter of the largest opening in the end plate in millimetres (in the case of an elliptical opening, the major axis of the ellipse).

t is the minimum thickness, after dishing, in millimetres;

D_o is the outside diameter of dished end in millimetres.

Trial calculation is necessary in order to select the correct curve.

The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \text{ shall not exceed } 0.1;$$

$$\frac{d}{D_o} \text{ shall not exceed } 0.5.$$

NOTE. It will be seen from figure 5 that for any selected ratio of H/D_o the curve for unpierced ends indicates a value for $\sqrt{\frac{d}{D_o t}}$ as well as value for K .

Holes giving a value of $\sqrt{\frac{d}{D_o t}}$ not greater than the value so obtained may thus be cut in an end designed as unpierced without any increase in thickness.

20.3.2 End plate thickness. The rules in 20.3.1 apply equally to flanged openings and to unflanged openings simply cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

Where openings are flanged the radius r_m of the flanging shall not be less than 25 mm (see figures 4 and 6).

20.3.3 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 6. In figure 6, d_2 is equal to the diameter of the smaller hole.

20.3.4 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 20.3.1 reinforcement of the end shall be provided. Reinforcement may 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 7), or a combination of both methods.

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

(a) the effective width l_1 of reinforcement shall not exceed $\sqrt{2R_1t}$ or $d_o/2$ whichever is the less;

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

where

R_1 is the internal radius in millimetres of the spherical part of a torispherical end;

or

for an elliptical end, the internal radius in millimetres of the meridian of the ellipse at the centre of the opening.

t is the actual thickness of the end in millimetres;

l_t is the actual thickness of the ring in millimetres;

d_o is the external diameter of ring in millimetres;

The dimensions l_1 and l_2 are shown in figure 7.

The shape factor K for a dished end having a reinforced opening can be read from figure 5 using the value obtained from

$$\frac{d_o}{\sqrt{D_o t}} - \frac{A}{t} \quad \text{instead of from} \quad \sqrt{\frac{d}{D_o t}}$$

where

A is the effective cross-sectional area of reinforcement and shall be twice the area shown shaded in figure 7.

The shaded area shown in figure 7 shall be calculated as follows.

(c) Calculate the sectional area of reinforcement both inside and outside the end plate within the length l_1 .

(d) 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 .

(e) 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 $C = 0.25$, and disregarding the minimum thicknesses required by 19.1.

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 section A must be reduced below that calculated in proportion to the difference in the allowable stresses for the material. As in 20.3.1 trial calculation is necessary in order to select the correct curve.

20.4 Dished and flanged crowns for vertical boilers

20.4.1 The minimum thickness 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 determined from the following formula.

$$t = \frac{pR_1}{2f_2} + C \quad \text{Equation 7}$$

where

t is the thickness of the end plate in millimetres;

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

R_1 is the internal radius of curvature of the end plate in millimetres;

$f_2 = 0.65f$, where f is the allowable stress in N/mm^2 (see 17.1);

C is a corrosion allowance of 0.75 mm.

The inside radius to which a crown plate is dished shall not be 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 not be 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 not be less than twice the thickness of the crown plate and in no case less than 25 mm.

20.4.2 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 of the flange, measured from the outer surface of the plate on the minor axis, shall be not less than that determined by

$$H = \sqrt{tw} \quad \text{Equation 8}$$

where

H is the overall depth of flange in millimetres;

t is the thickness of the end plate in millimetres;

w is the minor axis of the manhole in millimetres.

20.4.3 The minimum thickness 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 determined from the following formula.

$$t = \frac{pR_1}{2f_3} + C \quad \text{Equation 9}$$

where

t is the thickness of the end plate in millimetres;

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

R_1 is the internal radius of curvature of the end plate in millimetres;

$f_3 = 0.5f$, where f is the allowable stress in N/mm^2 (see 17.1);

C is a corrosion allowance of 0.75 mm.

The general shape and size of the corner radii shall be the same as specified in 20.1.

20.4.4 The thickness of a flanged firebox crown plate dished to partial spherical form and subject to pressure on the convex side shall be determined by the following formula, but in no case shall the thickness be less than the thickness of the firebox:

$$t = \frac{pR_o}{66} + C \quad \text{Equation 10}$$

where

t is the thickness of crown plate in millimetres;

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

R_o is the outer radius of curvature of crown plate in millimetres;

C is a corrosion allowance of 0.75 mm;

In no case shall R/t exceed 88.

20.4.5 Thickness of jointing flanges. Where a flange or an angle ring is used in conjunction with a full-face joint, the thickness of such a flange or ring shall be determined by equation 11, but in no case shall the thickness after machining be less than 8 mm.

$$T = \sqrt{\frac{pD(D_1 - D)}{C}} \quad \text{Equation 11}$$

where

T is the minimum thickness in mm;

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;

$C = 10.5$ for flanges and angle rings welded as in figures 8 and 9.

21. Standpipes and branches

21.1 Thickness and bolting. The thickness and bolting of all flanges for mountings shall be not less than that required by Part 2, table D of BS 10 : 1962 or tables 6/3 or 6/5 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 types shown in figure 8.

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. It may be necessary to increase the calculated thicknesses to allow for external loading.

21.2 Tapped openings

21.2.1 Mountings with male ends not exceeding 3 in BS pipe size (in which the screwed portion is an integral part of the mounting) and screwed pipe connections not exceeding 3 in BS pipe size may be screwed into bosses on the boiler (see figure 10). Openings for mountings and pipe connections above this size shall be suitable for flanged connections.

21.2.2 The minimum thickness of the plate into which connections or fittings are screwed shall be as specified in table 5. Where necessary the plate shall 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 metal required
mm	mm
Up to and including 20	12
Over 19 up to and including 32	19
Over 32 up to and including 38	22
Over 38 up to and including 50	25
Over 50 up to and including 75	38

21.3 Openings for flanged pipe connections. Where pads, blocks, or standpipes are fitted, they shall be designed to suit British Standard flange connections to tables 6/3 and 6/5 of BS 4504 : Part 1 : 1969 or table D of BS 10 : 1962 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.

22. Manhole and sighthole openings

22.1 Raised circular manhole, access and inspection openings. Frames for raised circular manhole, access or inspection openings in the boiler shell, not exceeding 400 mm diameter shall be made at least the thickness of the shell plate, and the diameter shall not be greater than one third of the diameter of the shell.

The openings on the shell shall be compensated in accordance with 19.2.

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

The thickness of the cover plate shall be taken as being equal to table 6/8 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.

22.2 Manholes or access openings in flat plates

22.2.1 Where manholes are located in flat plates, the openings shall be suitably compensated. Compensation shall be obtained by flanging the edge of the opening, or by the provision of a stiffening ring (see figure 11).

In all cases the depth of the flanging or ring shall not be less than that determined by equation 8 (see 20.4.2).

22.2.2 Where openings over 75 mm diameter, other than manholes are located in flat plates the general methods of 19.2.2 shall apply, except that the area X requiring compensation shall be 0.5 rt .

where

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

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

22.2.3 For the dimensions of access openings see 27.4.

23. Stays, stiffeners and supported surfaces

23.1 Flat plate margins

23.1.1 The width of margin b , giving support in relief of the stays which may be attributed to the shell, furnaces or flues to which flat plates are attached, shall not exceed that determined by

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

where

b is the width of margin in millimetres;

t is the plate thickness in millimetres;

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

$C = 8.3$ for plates exposed to flame;

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

If it is not practicable to effect a seal weld when the flat plate is attached as shown in figures 12, 13 and 14(a) the constants C used in equation 12 shall be

$C = 6.4$ for plates exposed to flame;

$C = 6.7$ for plates not exposed to flame;

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

23.1.2 Where the plates are flanged, the margin shall be measured from the commencement of curvature of flanging, or from a line $3\frac{1}{2}$ 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 13 (a), 13 (b), and 14 (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 of the circle forming the boundary of the margin supported by the uptake of a vertical boiler be greater than that found by

$$D = \sqrt{\frac{34.4A}{p}} + d^2 \quad \text{Equation 13}$$

where

A is the cross-sectional area of the uptake tube in square millimetres;

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

d is the external diameter of uptake in millimetres.

23.2 Breathing space

23.2.1 Gusset stays shall be arranged to give sufficient breathing space around the furnace connections and tube nests (see figure 16).

23.2.2 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.

23.3 Stayed flat surfaces

23.3.1 Requirements. Stayed flat surfaces, other than the crowns of vertical boilers, shall comply with the requirements of 23.3.2 to 23.3.6.

23.3.2 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.

23.3.3 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 $3\frac{1}{2}$ 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.

23.3.4 Thickness. The thickness of those portions of flat plates supported by stays shall be determined from the following formula.

$$t = Cd \sqrt{\frac{p}{f_4}} + 0.75 \quad \text{Equation 14}$$

where

t is the thickness of the plate in millimetres;

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

$f_4 = 0.85 f$ where f is the allowable stress in N/mm^2 (see 17.1);

$d = \sqrt{A^2 + B^2}$ where the stays are regularly pitched, A being the horizontal distance between the stays, and B 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 23.3.3).

C is the constant, dependent on the method of support as given in 23.3.5 and 23.3.6. Where various forms of support are used the constant C shall be the mean of the values for the respective methods adopted.

Minimum thickness of flat plates supported by stays to be 6 mm.

23.3.5 All constants given below 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 %.

The value of the constant C in equation 14 shall be taken from table 6.

* $1\text{N/mm}^2 = 1\text{ MPa}$.

Table 6. Constant $C =$

Description	Exposed to flame or comparable high temperature	Not exposed to flame	Description	Exposed to flame or comparable high temperature	Not exposed to flame
(1) Where stays are strength welded into the plates (see figures 18 (a) and 18 (b))	$C =$ 0.47	$C =$ 0.43	(9) Where a flat plate is flanged for attachment to the shell, flue, furnace or wrapper as shown in figures 14 (b), (c); 15 (a), (b); 31 (a), (b), (c); 32 (a), (b) and 33 (a).	$C =$ 0.4	$C =$ 0.36
(2) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in figure 19 (a).	0.42	0.39	(10) Where the flat plate is welded directly to the shell, flue, furnace, wrapper or access opening frame (see 23.3.3 and figures 12, 13 (a), 14 (a), 33 (b), (c) and (d).	0.4	0.36
(3) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in figure 19 (b).	0.4	0.36	(see figure 13 (b))	0.5	0.46
(4) Where plain bar stays pass through holes in the plate and are fillet welded as in figure 18 (c).	0.45	0.42	and where it is impractical to affect a seal weld.	0.53	0.48
(5) Where plate stays are used as in figure 21 (a) the point of support being taken at a position 13 mm from the toe end of the stay (see figure 21 (c)).	0.44	0.41	(11) Where the support is a gusset (see figure 25).	0.47	0.43
(6) Where plate stays are used as in figure 21 (b) the point of support being taken as 13 mm from the toe end of the stay (see figure 21 (c)).	0.47	0.44	(12) For the crown plates of combustion chambers supported by continuously welded on girders (see figure 23).	0.67	0.61
(7) Where two flat plates are stayed together by a plug welded stay as shown in figure 22.	0.47	0.44	(13) Where a flat plate is welded direct to another flat plate substantially at right angles, the value of C shall be as given in figures 20 (a) to 20 (h) inclusive for the method of attachment and weld preparation adopted.	*	*
(8) Where two flat plates are stayed together by plug welded bridge stay as shown in figure 23.	0.47	0.44			

* The C factors indicated on the figures 20 (a) to 20 (h) will be as follows:

Figure No. 20	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Exposed to flame	0.47	0.59	0.47	0.47	0.59	0.76	0.50	0.62
Not exposed to flame	0.44	0.55	0.44	0.44	0.55	0.71	0.47	0.58

23.3.6 In boilers where the end plates are supported in the steam space by a single substantial tee bar continuously fillet welded to the plate with not less than 9.5 mm fillet welds extending 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, or where such plates are supported with a deep bulb extending across the plates as described above, the thickness of the plate shall be determined by equation 14, the values d and C being as follows.

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

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

$C = 0.39$;

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

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

$C = 0.47$;

or

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

$C = 0.60$

23.4. Flat crown plates for vertical boilers

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

23.4.2 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.

23.4.3 Thickness. The thickness of flat crown plates shall be determined by equation 14, d being substituted for $\sqrt{A^2 + B^2}$ with d and C defined as follows.

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

d is the diameter in millimetres of the largest circle which can be drawn between the connections to the shell or firebox and uptake (see 23.3.3);

$C = 0.51$ for plates exposed to flame;

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

(b) For bar stays fitted in accordance with 23.3.

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

C is the mean of the values for the respective points of support through which the circle passes (see 23.3.4).

23.5 Girders for firebox and combustion chamber crowns

23.5.1 The proportions for girders shall be calculated from

$$t = \frac{l^2 p s_1}{c d^2 R_{20}} \quad \text{Equation 15}$$

where

t is the total thickness of the girder in millimetres;

l is the length of the girder in millimetres between supports, e.g. measured between the inside of the tube-plate and the firehole (or back) plate, or between the inside of the sideplates, according to the method of support;

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

s_1 is the pitch of the girders in millimetres;

d is the effective depth of the girder in millimetres i.e. the total depth less depth of water way, where such is provided;

R_{20} is the minimum specified tensile strength in N/mm^2 of the steel at room temperature;

$c = 0.31$ for steel plates;

$c = 0.25$ for steel castings.

23.5.2 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 of the welds attaching each girder multiplied by the effective throat thickness, shall not exceed 52 N/mm^2 multiplied by the appropriate weld factor in table 6 ('effective length' and 'effective throat thickness' are defined in 23.9.3). 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 23.5.1.

23.6 Stays for fireboxes, circular furnaces and combustion chambers

23.6.1 Stays for flat plates. The permissible stress in the stays calculated on the net sectional area shall not exceed 62 N/mm^2 . 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 69 N/mm^2 . The stress in a plate stay secured at either end to the plate by fillet welds in accordance with figure 21 shall not exceed 52 N/mm^2 .

23.6.2 Circumferential stays for circular furnace and fireboxes. The diameter of the stay shall be not less than 22 mm nor 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.

23.7 Longitudinal bar stays

23.7.1 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.

23.7.2 Where bar stays are fitted in vertical boilers, not less than four bar stays shall be fitted to boilers of 1200 mm and over but under 1500 mm in diameter; five bar stays to boilers of 1500 mm and over but under 1800 mm in diameter; six bar stays to boilers of 1800 mm and over in diameter.

23.7.3 Supports shall be provided for longitudinal bar stays of 4900 mm in length and longer.

23.8 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 millimetres, 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.

(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 square millimetres enclosed by lines bisecting at right angles the lines joining the stay and the adjacent points of support and by the boundary margin (see 23.1) less the area of any tubes or stays embraced (see figures 15 (a) and 15 (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.

23.9 Gusset stays

23.9.1 Load on each stay. Each gusset stay supporting a flat plate of a boiler shall be designed to carry the whole load due to 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 25).

23.9.2 Gusset plate. Gusset plates shall be so proportioned that the angle V (see figure 25) 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 above) calculated on the smallest cross section on line XX or YY (figure 25) 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 25).

23.9.3 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 6.

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.

Table 7. Weld attachments

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

24. Tubes and tube plates

24.1 Wide water spaces between and around tube nests

24.1.1 Except as specified in 24.2 stay tubes shall be fitted in the tube nests. The thickness of the tube plate in the wide water space between tube nests shall be determined from the following formula.

$$t = Cd \sqrt{\frac{p}{f_s}} + 0.75; \quad \text{Equation 16}$$

where

t is the thickness of the tube plate in millimetres;

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

$f_s = 0.85f$ where f is the allowable stress in N/mm^2 (see 17.1);

$d = \sqrt{A^2 + B^2}$ where A is the width in millimetres of the wide water space between the tube nests (measured at the centre line of the stay tubes), and B is the pitch in millimetres of the stay tubes in the boundary rows of the wide water space.

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

C = constant, as given below. Where various forms of support are used, the value of C shall be the mean of the values for the respective methods adopted.

For stay tubes welded to the tube plates in accordance with figures 26 (a), (b) and (c) with tubes having a maximum clearance in the tube hole of 0.75 mm on the diameter or lightly expanded before welding the value of the constant C shall be as shown in those figures.

24.1.2 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 millimetres 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 millimetres between the centres of bar stays or other method of support; and

A_2 is the horizontal distance in millimetres between the centre of one stay tube and the centre of the next stay tube in the top boundary row.

24.1.3 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 23.3, and the value of the constant C for the top row of tubes shall be taken as

$C = 0.88$ for plates exposed to flame;

$C = 0.78$ for plates not exposed to flame.

Where no stay tubes are fitted the support afforded by the plain tubes shall not be taken 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, there may be an unsupported width equal to the flat plate margin as given by equation 12.

24.2 Parts of flat tube plates within tube nests

24.2.1 Stay tubes shall be fitted in the following cases.

(a) In directly fired, multitubular boilers in which the total number of tubes is arranged in one nest, the area of which exceeds 0.65 m^2 .

(b) In multitubular, and waste-heat boilers in which the total number of tubes is arranged in one nest, the area of which exceeds 1.95 m^2 .

(c) In all cases where the total number of tubes is arranged in more than one nest.

24.2.2 Where stay tubes are fitted and secured as shown in figures 26 (a), (b) and (c) the thickness of those parts of the tube plates within the tube nests shall be determined from the following formula.

$$t = CM \sqrt{\frac{p}{f_s}} + 0.75 \quad \text{Equation 17}$$

where

t is the thickness of the tube plate in millimetres;

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

$f_s = 0.85f$, where f is the allowable stress in N/mm^2 (see 17.1);

M is the mean pitch of the stay tubes in millimetres, being the sum of the four sides of any quadrilateral bounded by four adjacent stay tubes divided by 4;

C is the constant, as given in figures 26 (a), (b) and (c).

24.2.3 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 determined by equation 17 where all the symbols have the same significance except that

M is four times the mean pitch in millimetres of the plain tubes in the nest;

$C = 0.49$ for plates exposed to flame;

$C = 0.45$ 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 and beaded at the inlet end, and expanded and seal-welded or expanded only at the outlet end.

24.2.4 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. In the case of strength welded tubes only, with or without expansion before welding, these thicknesses may be reduced to 8 mm and 10 mm respectively (for tube hole clearance see 24.1.1).

24.3 Tubes subject to internal or external pressure

24.3.1 Stay tubes. Each stay tube shall be designed to carry its due 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 69 N/mm^2 .

24.3.2 Pitch of tubes. The spacing of tube-holes shall be such that the minimum width, in millimetres of any ligament between the tube-holes shall be not less than

$$0.125d + 12.5$$

where

d is the diameter of the tube hole in millimetres. See 24.2.4 for the minimum thickness of tube plate.

24.3.3 Plain tubes. The thickness of plain tubes under internal or external pressure shall be that shown in table 8. In determining the thicknesses in table 8 the negative manufacturing tolerances have been taken into account (see 16.5).

Table 8. Minimum thickness of plain tubes under internal or external pressure

Outside diameter	Minimum thickness
mm	mm
up to and including 38 mm o.d. tube	2.9
over 38 mm and up to and including 76.1 mm o.d. tube	3.2
over 76.1 mm and up to and including 101.6 mm o.d. tube	3.6

NOTE. Table 8 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.

24.3.4 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.

24.4 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 shall be determined by the following formula.

$$t = \frac{2pD}{JR_{20}} + C \quad \text{Equation 18}$$

where

t is the thickness of the tube plate in millimetres;

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 millimetres;

C is a corrosion allowance of 0.75 mm;

R_{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 millimetres;

d is the diameter of the tube holes in millimetres.

NOTE. Tube plates between the stay tubes shall comply with the requirements for tube plates (see 24.1 and 24.2).

24.5 Horizontal shelves of tube plates forming part of the shell

24.5.1 To withstand the vertical load due to pressure on the boiler ends the horizontal shelves of the tube plates shall be supported by gussets as determined by the following formula:

$$C = \frac{AD_1 p}{t} \quad \text{Equation 19}$$

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_1 is the inside diameter of the boiler, in millimetres;

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

t is the thickness of the tube plate, in millimetres.

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

1 gusset where C exceeds 25 000;

2 gussets where C exceeds 35 000;

3 gussets where C exceeds 42 000.

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

1 gusset where C exceeds 25 000;

2 gussets where C exceeds 47 000.

24.5.2 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 (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 R_{20} .

25. Cylindrical furnaces and combustion chambers subject to external pressure

25.1 Plain furnace and flue sections

25.1.1 Thickness. The thickness of plain furnaces and flue sections shall be the greater of those obtained by the use of equations 20 and 21, but the thickness shall not exceed 22 mm nor be less than the minimum thickness indicated in table 9.

Table 9. Minimum thickness of cylindrical shells subject to external pressure

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

$$t = \sqrt{\frac{p D_0 (L + 610)}{1.03 \times 10^4}} + 0.75 \quad \text{Equation 20}$$

$$t = \frac{C p D_0}{110} + \frac{L}{320} + 0.75 \quad \text{Equation 21}$$

where

t is the thickness of the plate in millimetres;

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

D_0 is the external diameter of the furnace or flue in millimetres;

L is the length of the section in millimetres between the centres of points of substantial support (see figure 35);

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

E_{tx} is the minimum specified 0.2 % proof stress, in N/mm^2 for material to BS 1501 – 151 or 161, grade 26 B (see table in 17.1.2);

E_t is the minimum specified 0.2 % proof stress, in N/mm^2 , for the material to be used, determined from table 2 in 17.1.2.

25.1.2 Stiffeners. Where stiffeners are used on furnaces as shown in figure 26 the second moment of area I of the stiffener shall be not less than that determined by

$$I = \frac{D_0^3 p l}{1.33 \times 10^6} \quad \text{Equation 22}$$

where

I is the second moment of area in mm^4 of the stiffener about its neutral axis;

D_0 is the external diameter of the furnace in millimetres;

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

l is the length of the section in millimetres between centres of points of substantial support.

NOTE. Equation 22 includes the value of Young's Modulus of Elasticity which has been taken as 185 kN/mm².

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 should be kept to the minimum required, but in no case shall it exceed 1½ times the thickness of the furnace plate.

25.2 Corrugated furnaces. For corrugated furnaces refer to BS 1971 : 1969.

25.3 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.

26. Fireboxes

26.1 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_0 is the external diameter of the firebox in millimetres. 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 millimetres of the firebox as indicated in figure 28 (see also 23.6.2).

In no case, however, shall the thickness be more than 22 mm. For minimum thickness see table 9 under 25.1.1.

26.2 Uptakes. The thickness of the uptake shall be the greater of those obtained from equations 23 and 24 but the thickness shall not be less than 8.0 mm.

$$t = \sqrt{\frac{pD_0(L+610)}{1.03 \times 10^4}} + 4 \quad \text{Equation 23}$$

$$t = \frac{pD_0}{110} + \frac{L}{320} + 4 \quad \text{Equation 24}$$

where

t is the thickness of the uptake in millimetres;

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

D_0 is the external diameter of the uptake in millimetres;

L is the length of uptake, in millimetres, measured between the points of substantial support.

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

tubes 102 mm nominal bore and smaller	6.35 mm thick
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tubes above 102 mm nominal bore and up to and including 152 mm nominal bore	8.0 mm thick
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tubes above 152 mm nominal bore and up to and including 305 mm nominal bore	9.5 mm thick
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Tubes of 102 mm nominal bore and smaller expanded in and readily renewable shall not be less than 4.75 mm thick.

26.4 Hemispherical fireboxes. The thickness of unsupported hemispherical fireboxes subject to pressure on the convex surface shall not be less in any part than that obtained by

$$t = \frac{CpR_0}{60.5} + 0.75 \quad \text{Equation 25}$$

where

t is the thickness of plate in millimetres;

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

R_0 is the outer radius of curvature of the firebox in millimetres;

$C = \frac{E_{tx}}{E_t}$ which must not be less than 0.85;

E_{tx} is the minimum specified 0.2 % proof stress, in N/mm^2 for material to BS 1501 – 151 or 161, grade 26 B (see table in 17.1.2);

E_t is the minimum specified 0.2 % proof stress, in N/mm^2 for the material to be used from table in 17.1.2.

26.5 Rings

26.5 Ogee rings. The thickness 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 determined by

$$t = \sqrt{\frac{pD_1(D_1 - d_o)}{990}} + 0.75 \quad \text{Equation 26}$$

where

t is the thickness of the Ogee ring in millimetres;

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

D_1 inside diameter of the boiler shell in millimetres;

d_o is the outside diameter of the lower part of the firebox where it joins the Ogee ring in millimetres.

26.6 Firebox plates under compression. The thickness of firebox tube plates under compression due to the pressure on the crown plate, based on a compressive stress of 97 N/mm^2 shall not be less than that given by

$$t = \frac{pIV}{193(V - d_i)} \quad \text{Equation 27}$$

where

t is the thickness of plate in millimetres;

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

I is the internal length of firebox in millimetres, measured at the top between the tube plate and the back plate.

V is the pitch of tubes in millimetres, 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 millimetres.

Section four. Manufacture and workmanship

27. Pressure parts

27.1 Cylindrical shells

27.1.1 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 longitudinal seam or seams may be placed in any suitable position(s), but the seams in successive rings shall not fall in line. In the case of brick set boilers the seam or seams shall be kept clear of the brickwork as far as practicable.

27.1.2 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 degree gauge) shall not exceed 3 mm plus 5 % of the nominal plate thickness. This maximum value may be increased by 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. There shall not be flats at the welded seams, and any local departure from circularity shall 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.

27.1.3 Compensating plates. Compensating plates shall be of steel and, before attachment, shall bed closely to the plates to which they are to be connected. Any welds therein shall be on the transverse centre line. See 19.3 regarding the sizes of fillet welds. Tell-tale holes shall be drilled in compensating plates.

27.2 End plates, crown plates and tube plates

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

27.2.2 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 figures 30 (a) or (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 27.8.2 shall apply.

27.2.3 Flanging of plates shall be done by machine. Such flanging shall be done hot, preferably 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.

After completion of the flanging operation flanges shall 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 the plate shall be free from set or distortion.

27.2.4 Where flats are pressed in dished end plates for the attachment of mountings they shall be formed with an ample radius at the junction of the flat and curved surfaces, and shall be free from sharp corners or tool marks; the plate shall not be unduly thinned.

27.2.5 Plates which are flanged in accordance with 27.2.3 shall be welded to the parts to which they are to be connected as follows:

- (a) to shells or cylindrical fireboxes as shown in figures 31 (a), (b) or (c), or 32 (a) or (b);
- (b) to internal flue tubes as shown in figures 14 (b) and (c);
- (c) to uptakes as shown in figures 31 (a), (b) or (c);
- (d) to combustion chamber or firebox wrapper plates as shown in figure 3 (a).

27.2.6 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 13 (a) and (b);
- (b) to internal flue tubes or uptakes as shown in figure 14;
- (c) to combustion chamber or firebox wrapper plates as shown in figures 33 (b), (c) and (d).

27.2.7 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.

27.2.8 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 30 (a) and (b)).

27.3 Plain tubes and stay tubes

27.3.1 Plain tubes shall be secured by any one of the following methods.

- (a) Fully expanded both ends.
- (b) Lightly expanded and welded both ends.
- (c) Lightly expanded and welded at inlet end and fully expanded at outlet end.
- (d) Welded only at both ends in tube holes having a maximum clearance of 0.75 mm on diameter.

27.3.2 Where the 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. In addition to expanding, tubes may be bell-mouthed or beaded at the inlet end.

27.3.3 A typical plain tube weld detail is shown in figure 34.

27.3.4 Stay tubes shall be fitted in all cases where the total number of tubes is arranged in more than one nest. Where stay tubes are not fitted, the ends of all tubes shall be secured by the following methods.

- (a) Lightly expanded and welded at both ends.
- (b) Fully expanded and beaded at inlet and fully expanded at outlet.
- (c) Fully expanded and beaded at inlet, and lightly expanded and welded at outlet.
- (d) Welded only at both ends in tube holes having a maximum clearance of 0.75 mm on diameter.

27.3.5 Stay tubes shall be secured as detailed in figures 26 (a), (b) and (c) and 24.1.1.

27.3.6 Welded stay tubes shall not be adjacent within the same tube nest except in local areas where, subject to agreement between the manufacturer and purchaser/inspecting authority not more than two adjacent stay tubes may be attached by welding.

27.4 Access openings for steam boilers

27.4.1 At least one man hole or head hole shall be provided in the upper part of the boiler, except as allowed by 27.4.2, the dimensions being not less than those in table 10 for the given size of the boiler.

Table 10. Dimensions of manholes and headholes

Diameter of boiler	Minimum size of hole
mm	mm
Over 600 but not exceeding 750	230 X 180
Over 750 but not exceeding 900	300 X 230
Over 900 but not exceeding 1050	350 X 250
Over 1050 but not exceeding 1500	380 X 280
Over 1500	400 X 300

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

As an alternative, raised circular manholes or inspection openings may be used, the diameter of which shall be not less than the major axis listed above (reference must be made to 22.1).

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

27.4.3 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 of sufficient size to permit of their replacement shall be provided.

27.4.4 At the bottom of the narrow water space in vertical boilers, openings not less in number than given in table 11 shall be provided for cleaning and inspection purposes. The openings shall be spaced at equal distances around the circumference of the boiler.

Table 11. Number of lower openings

Internal diameter of boiler	Number of openings
Up to and including 900 mm	Three
Exceeding 900 mm	Four

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

27.5 Manhole frames, mouthpieces and doors

27.5.1 Requirements. Manhole frames, mouthpieces, doors and cover plates shall be of steel complying with the requirements of clause 16.

27.5.2 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.

27.5.3 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.

Typical forms of manhole frames and attachments are shown in figures 3 (a), (b) and (c), figure 11 and figure 35.

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

27.5.5 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. 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 manhole and sight-hole 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 clause 16) and shall be forged or cut from plate having a minimum specified tensile strength of 432/494 N/mm². The seating surface shall be faced.

27.6 Seatings for mountings

27.6.1 General. Mountings over 25 mm internal diameter, except flanged mountings up to and including 75 mm bore, shall not be attached direct to any boiler plate, but shall be carried on suitable forged, cast or fabricated steel seatings. These seatings shall take the form of short standpipes, forged pads or pads cut from plate or round bar as may be convenient.

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

Flanges and pads in contact with the boiler shall be formed to bed closely to the plate to which they are to be attached.

27.6.2 Standpipes. Where standpipes are used, the flanges shall be machined or flame-cut by machines on the edges. The bolting flanges shall be machined on the jointing face and a satisfactory bearing surface for bolts and nuts provided.

27.6.3 Pads. Where pads are used, the jointing surfaces shall be machined. The pads shall have sufficient thickness 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.

27.6.4 Methods of attachment. The seatings shall be attached to the shell or end plates by one of the following methods.

(a) Where the internal diameter of the standpipe does not exceed 32 mm, the standpipe may be screwed through the plate, and fitted with a nut on the water side, or seal welded.

(b) Mountings with screwed ends not exceeding 25 mm diameter may be used. The screwed portion of any such mounting shall be an integral part thereof.

Such mountings may be screwed directly into the plate, nuts being fitted on the water side, or may be 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.

The distance pieces shall be made from solid steel in accordance with clause 16. They shall be screwed into the plate and fitted with nuts on the water side. The walls of the distance pieces shall not be less than 6.5 mm thick at the bottom of the thread.

Typical methods of attachment are shown in appendix A, but other methods of equivalent efficiency may be used subject to agreement between the inspecting authority and the manufacturer.

All bolt and stud holes shall be drilled.

27.7 Cylindrical furnaces (or flues)

27.7.1 Sections of cylindrical furnaces shall each be made from one plate which shall be bent while cold to circular form. The longitudinal seam shall be fusion butt welded by the metal arc process, in accordance with clause 28. Alternatively, furnaces may be made from hot finished seamless carbon steel pipes to BS 3602 grades 27 HFS or CDS, or from BS 3601 grade 27 HFS, the tensile strength and minus tolerances on thickness being taken into account.

27.7.2 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.

27.7.3 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.

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

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

27.7.6 Where sufficient longitudinal flexibility is provided, the cylindrical sections may be connected to each other by fusion butt welded circumferential seams.

27.7.7 Where stiffeners are used these shall have a second moment of area not less than that required by 25.1.2 and shall be securely attached externally by means of continuous full penetration welds on each side (see figure 27).

27.7.8 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 an adequate point of support and longitudinal flexibility, and butt welded together.

The dimensions shall comply with figure 36.

27.7.9 Forms of furnace connections to end plates are shown in figures 14 (a), (b) and (c). Where the furnace is inserted into a hole in the end plate it shall be a good fit around the whole periphery.

27.8 Fireboxes

27.8.1 Plain circular fireboxes. The cylindrical portion shall preferably be formed from one plate in a similar manner to the shell plates. 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.

Vertical fireboxes shall 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 clause 28.

Flats formed in the firebox for the insertion of water tubes shall have an ample radius at the junction of the flat and the curved surfaces and shall be free from sharp corners or tool marks. The plate shall not be unduly thinned.

Ogee flanging, whether integral with the firebox or made as a separate ring, shall preferably be formed at one heat by suitable machinery and shall be allowed to cool gradually to avoid internal stresses. Rings for firehole mouthpieces or foundation rings shall be made of steel in accordance with clause 16. 'Z' sections shall not be used for foundation rings.

Attachment of fireboxes to cylindrical shells shall be in accordance with figure 29. Typical methods of attachment of firehole mouthpieces are shown in figure 37 (a) or 37 (b).

27.8.2 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 29. Typical methods of attachment of firehole mouthpieces are shown in figures 37 (a) and 37 (b) and for flue pipes in figures 38 (a) and 38 (b).

27.8.3 Water-cooled combustion chambers. The attachment of the combustion chamber tube plates and back plates to the wrapper plate shall be in accordance with figures 33 (a), (b), (c) and (d) 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.

Typical methods of attachment of furnaces and access opening frames are shown in figures 14 (a), 14 (c) or figure 12 as appropriate.

27.8.4 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.

The uptake may be attached to the shell crown as indicated in figure 14 (a) or 14 (b) or by other approved methods.

Where the vertical seam of the uptake is fusion welded the welding shall comply with clause 28 and the weld shall be arranged so that it is directly facing the manhole. 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.

27.9 Cross tubes and stays

27.9.1 Cross tubes. Cross tubes shall be made from seamless steel tubes (see 16.1.4). 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, the holes in the firebox plate shall be suitably chamfered, and care taken to ensure good penetration (see figure 39).

27.9.2 Stays. All bar stays or firebox stays shall be made from a solid rolled bar without weld in its length, except those attaching them to the plates they support. It is recommended that when a stay is in position in the boiler, its axis shall be normal to the plate it supports.

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

- (a) Plain bars passing through clearing holes in the plates and welded thereto (see figure 18 (a), (b) (c) and (d)).
- (b) Plain bars passing through clearing 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 19 (a) or 19 (b).

27.9.4 Firebox stays. Firebox stays shall be secured to the plates which they support by welding (see figures 18 (a) and 18 (b) and 18 (c)).

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

27.9.6 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 24. Each girder shall 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 shall have sufficient cross-sectional area to carry the applied load. (See 23.9.3).

28. Welding

NOTE. The welding terms used in this standard are defined in BS 499 'Welding'.

28.1 Approval of welding procedures

28.1.1 This clause does not specify individual processes or procedures. The manufacturer shall 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.

28.1.2 In order that only competent and efficient welders are employed, routine tests of competence shall be made and recorded in accordance with the requirements of BS 4870 : Part 1.

28.1.3 Welded shells and other similar pressure parts of boilers shall comply with all the clauses of this section, except those in which divergence is permissible solely because of special requirements, essential for the most efficient use of the particular process.

28.1.4 Each manufacturer shall accept responsibility for the welding procedures used, and for the ability of the operators and welders to apply the procedures selected.

28.2 Welding method

28.2.1 Any fusion welding process may be used, provided that the welds in boilers are made in exact conformity with approved procedures by welders or welding machine operators whose competence has been established. It is recommended that the requirements of BS 4871 : Part 1 are adopted.

28.2.2 If requested the manufacturer shall supply to the purchaser and/or the inspecting authority 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 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.

28.2.3 Care shall be taken when designing the attachment of 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.

28.3 Welding materials. Electrodes, filler wires, filler rods and fusible inserts shall comply with the relevant British Standards. In the absence of a relevant British Standard, the welding materials used shall be as agreed between the purchaser, inspecting authority, if any, and the manufacturer.

28.4 Welding equipment. Welding plant, instruments, cables and accessories shall comply with the requirements of the relevant British Standards. All welding plant and auxiliary equipment shall be maintained in good working order and adequate means of measuring current shall be provided. In the case of machine welding, means shall be provided for measuring the arc voltage. All electrical plant used in connection with the welding operation shall be adequately earthed.

28.5 Preparation for welding

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