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S/S 87 1985 ED. 30-4-1985 (5) AMD

BRITISH STANDARD 1113 : 1969
UDC 621. 181. 5
METRIC UNITS

SPECIFICATION FOR WATER-TUBE STEAM GENERATING PLANT

(INCLUDING SUPERHEATERS, REHEATERS AND STEEL TUBE ECONOMISERS)

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AMD 911

Amendment Slip No. 1, published 20 March, 1972

to BS 1113 : 1969

Water tube steam generating plant

Revised text

Page 2. Add the following to the list of reference standards:

'BS 1560. Steel pipe flanges and flanged fittings (nominal sizes ½ in to 24 in) for the petroleum industry.
BS 4165. Electrode wires and fluxes for the submerged arc welding of mild steel and medium tensile steel.
BS 4504. Flanges and bolting for pipes, valves and fittings (Metric).'

Foreword. In the fourth line between the words 'requirements' and 'of' insert the words: 'and agreed revisions'

Insert the following reference standards in their appropriate places:

'BS 1560. Steel pipe flanges and flanged fittings (nominal sizes ½ in to 24 in) for the petroleum industry.'
BS 4504. Flanges and bolting for pipes, valves and fittings (Metric).'

In the Note, delete 'and in PD 5686, 'The use of SI units'' and add

'1 N/mm²=1 MN/m².'

Section 2. Materials and design stresses

Clause 2.2.2.1 Delete the existing footnote ‡ and substitute the following:

'‡ For cylindrical shells designed to 3.2.1.1 where the minimum efficiency η is less than 1·0, the factor of safety of 1·5 shall be increased by 0·02 for each 1 % by which the elongation (based on a gauge length of $5{\cdot}65\sqrt{S_o}$) is less than 20 %. Where room temperature elongation is given as a function of tensile strength, it shall be calculated from the minimum tensile strength.'

Section 3. Design

Fig. 2. *a* and *b*. Delete 'Tube thickness t_a' and substitute:

'Stub thickness t_a'.

Clause 3.2.6.1 Add the following additional text:

'When a hole in the shell is wholly or partly reinforced by the attaching nozzle the hole size shall be reduced accordingly: refer to 3.2.3.3.'

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Clause 3.2.6.3 Add the following extra paragraph after ' See also 3.2.6.4 ':

' If a welded nozzle has been designed fully to compensate for the removal of drum material (i.e. when $\eta = 1{\cdot}0$) the nozzle and its opening may be assumed to be absent in calculating the longitudinal bending stress. If the nozzle is designed to compensate only for part of the material removed from the drum, the Moment of Inertia of the drum section shall be calculated assuming the size of the hole to be reduced by the amount of compensation provided by the nozzle: refer to 3.2.3.3.'

Clause 3.2.9.2 Delete the second sentence (lines two, three and four) of this clause and substitute the following:

' One method of reinforcement is by taking account of the cross-sectional area of locally disposed material including the attachment welds in excess of the minimum requirements for plate and branch thicknesses as shown in Fig. 11, the branch thickness being increased where required as shown in Figs. 38, 40 and 44.'

Delete the fourth sentence (lines seven and eight) of this clause and substitute the following:

' It is recommended that its use be restricted to cases where experience has shown it to be satisfactory.'

In the fifth sentence of the first paragraph (line nine) delete ' designed ' and substitute ' design '.

Clause 3.4 Rectangular section headers. Delete the existing clause and substitute the attached new text and new Figs. 15A, B and C:

Clause 3.5.3 (2) In the first line, insert the word ' unpierced ', between the words ' of ' and ' flat '.

Immediately prior to the last sentence insert the following new paragraph;

' When flat end plates are to be pierced concentrically, the thickness determined by the formula 14 shall be increased by 15 %. The thickness of end plates pierced eccentrically shall be specially considered.'

Also in the last line of the last sentence delete ' BS 10* ' and the relevant footnote, and substitute the words ' The appropriate British Standard '.

Errata

Page 11 (iii) *c* delete ' local to the branch '

Page 13 **4.4.3.2** (4) alter 54° to read 45°

' 3.4 RECTANGULAR SECTION HEADERS

3.4.1 Straight rectangular headers

3.4.1.1 *Determination of thickness.* To determine the thickness of headers of rectangular section with solid walls, it is necessary to consider the thickness required at the centre of the sides, at the line of the holes and at the corners. The required thickness will be the greatest value so determined. In the case of staggered holes it is necessary to investigate the effect of the off-set by considering the diagonal ligaments (see Fig. 15C).

The thickness is calculated by equation (13A).

$$t = \frac{pn}{2f\eta} + \sqrt{\frac{4Yp}{f\eta'}} + c \qquad (13A)$$

where

p = the calculation pressure in N/mm².

f = the allowable stress in N/mm² at the metal temperature of the wall as defined in 3.4.1.2.

Y = a coefficient given by equation (13B), (13C), (13D) or (13E).

$2m$ = the internal width of the wall referred to in the calculation in mm (see Fig. 15A).

$2n$ = the internal width of the wall perpendicular to that referred to in the calculation in mm.

η = the ligament efficiency referring to the membrane stresses and is calculated by the use of equation (13F) or (13G).

η' = the ligament efficiency referring to the bending stresses and is calculated by use of equation (13H), (13K), (13L) or (13M).

c = a corrosion allowance. This shall be taken as 0·75 mm, unless a higher figure is agreed to take account of adverse conditions.

The coefficient Y to be used in determining the thickness required at the centre of the side with internal width $2m$ is determined from equation (13B).

$$Y = \tfrac{1}{3}\left[\frac{m^3 + n^3}{m + n}\right] - \tfrac{1}{2}m^2 \qquad (13B)$$

The coefficient Y to be used in determining the thickness required at a line of holes parallel to the longitudinal axis of the header on the wall of width $2m$ is determined from equation (13C).

$$Y = \tfrac{1}{3}\left[\frac{m^3 + n^3}{m + n}\right] - \frac{m^2 - k^2}{2} \qquad (13C)$$

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where

k = the distance from the centre of the holes to the centre line of the wall in mm as shown in Figs. 15B and 15C.

To check the effect of the off-set on a staggered hole arrangement where the holes are positioned equidistant from the centre line of the wall the coefficient Y is calculated using equation (13D).

$$Y = \left\{ \tfrac{1}{3} \left[\frac{m^3 + n^3}{m + n} \right] - \frac{m^2}{2} \right\} \cos \alpha \qquad (13D)$$

where

α = the angle of stagger as indicated in Fig. 15C.

The coefficient Y to be used in determining the thickness required due to the stresses at the corners is determined from equation (13E)

$$Y = \tfrac{1}{3} \left[\frac{m^3 + n^3}{m + n} \right] \qquad (13E)$$

It should be noted in this case the value of η and η' in equation (13A) will be equal to 1·0.

If the value of coefficient Y is negative the sign does not have to be considered.

The ligament efficiency η in the case of a line of holes parallel to the longitudinal axis of the header is determined from equation (13F).

$$\eta = \frac{s - d}{s} \qquad (13F)$$

The ligament efficiency η to be considered across the diagonals of a staggered arrangement of holes is determined from equation (13G)

$$\eta = \frac{s_3 - d}{s_3} \qquad (13G)$$

The ligament efficiency η' for a line of holes parallel to the longitudinal axis is determined using equation (13H) or (13K)

$$\eta' = \frac{s - d}{s} \text{ for } d < 0{\cdot}6\, m \qquad (13H)$$

$$\eta' = \frac{s - 0{\cdot}6\, m}{s} \text{ for } d \geqslant 0{\cdot}6\, m \qquad (13K)$$

The ligament efficiency η' to be considered across the diagonals is determined using equation (13L) or (13M)

$$\eta' = \frac{s_3 - d}{s_3} \text{ for } d < 0{\cdot}6\, m \qquad (13L)$$

$$\eta' = \frac{s_3 - 0{\cdot}6\, m}{s_3} \text{ for } d \geqslant 0{\cdot}6\, m \qquad (13M)$$

The following definitions apply in equations (13F) to (13M) inclusive

s = the pitch of the tube holes parallel to the longitudinal axis of the header in mm.

s_3 = the diagonal pitch of the tube holes in mm as shown in Fig. 15C.

d = the mean effective diameter of the tube holes after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stubs (see 3.2.3.3) in mm.
In the case of elliptical holes the value of d used in the formulae for η and η' shall be the inside dimension of the hole measured parallel to the longitudinal axis of the header. For the evaluation of the two limiting values of d in equations (13H) to (13M) inclusive the value of d shall be the inside dimension of the hole measured perpendicular to the longitudinal axis of the header.

3.4.1.2 *Metal temperature of the wall.* The mean temperature of the wall used to evaluate the allowable stress f shall be determined as follows:

a. for headers not heated by the hot gases and those headers adequately protected from the hot gases, T shall equal the maximum temperature of the contained fluid.

b. for headers heated by the hot gases, the mean wall temperature T shall be determined by the manufacturer and shall not be less than 25 degC in excess of the maximum temperature of the contained fluid where the header is exposed mainly to convection heating, or 50 degC in excess of the maximum temperature of the contained fluid where the header is exposed mainly to radiant heating.

Headers of thicknesses greater than 30 mm shall not be exposed to hot gases having an anticipated temperature greater than 650 °C unless the header wall is effectively cooled by closely grouped tubes in the exposed area.

3.4.1.3 *Corner radius.* To avoid excessive discontinuity stresses at the corners it is necessary to satisfy the condition.

$$r \geqslant \tfrac{1}{3}\, t_1 \qquad (13N)$$

where

r = the internal corner radius (see Fig. 15A).

t_1 = the mean nominal thickness of the two sides.

In any case r should not be taken as less than 8 mm.

3.4.2 Rectangular headers other than straight. The scantlings of rectangular section headers of the curved, staggered sinuous or corrugated type, shall be subject to agreement between the manufacturer, the purchaser and the inspecting authority. Where sufficient experience of previous satisfactory service of similar headers cannot be shown, the suitability of the headers shall be proved in accordance with the provisions of 3.6.

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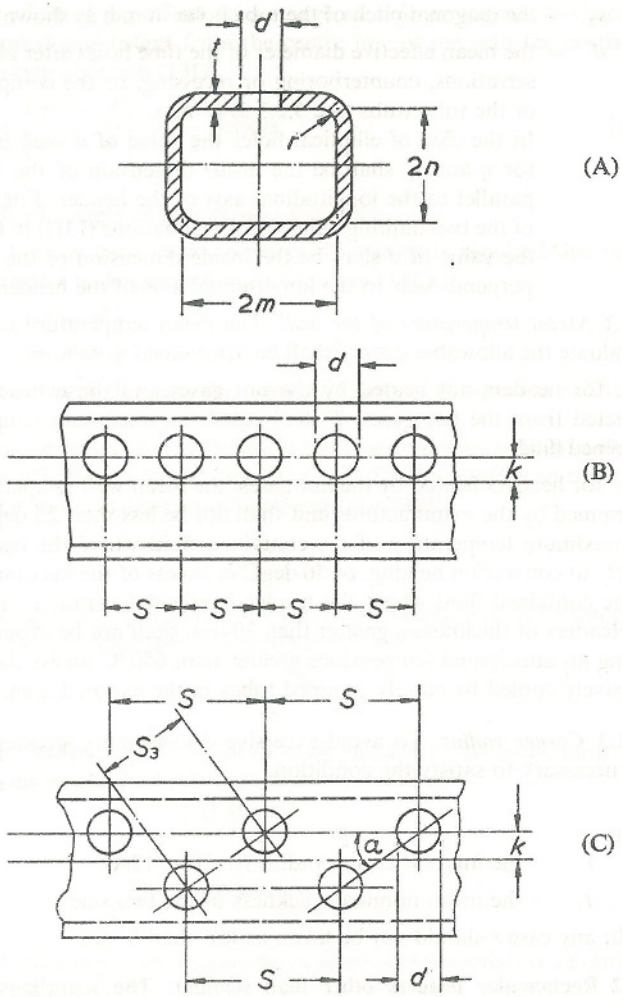
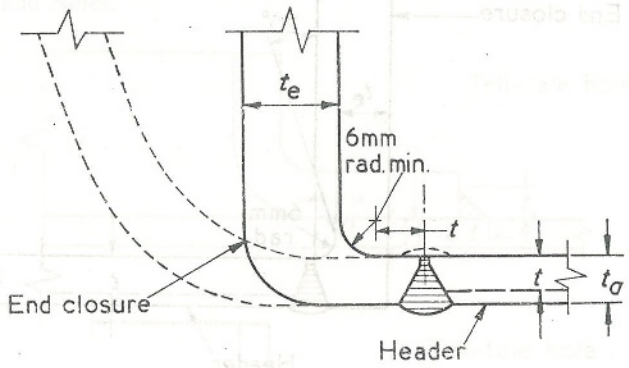


Fig. 15 A, B, C. Rectangular section headers

Fig. 16. Replace the existing Figs. 16*a*, 16*b* and 16*c* with the attached new figures and notes.



NOTE. To be welded from both sides of the shell plate, but where this is impracticable welding may be done from only one side, care being taken to ensure full penetration; backing strips may be used.

Fig. 16*a*

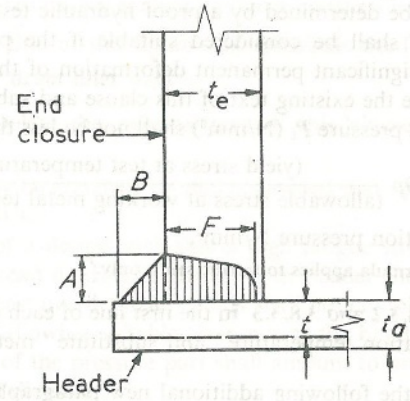


Fig. 16*b*

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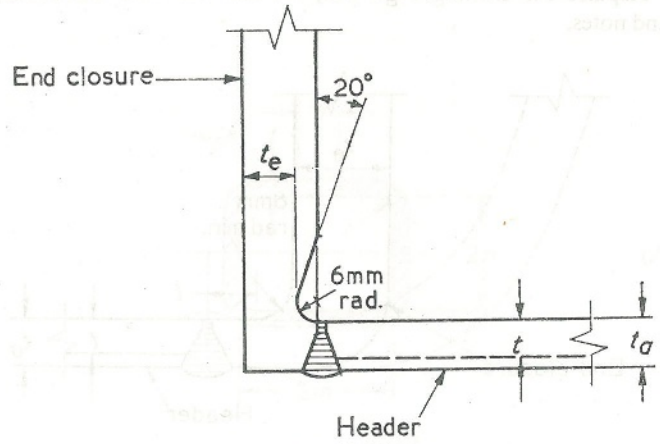


Fig. 16c

$A \geqslant t$
$B \geqslant t$
$F \geqslant 2t$ or ($t_e - 1{\cdot}5$ mm) whichever is less.

t_a = actual thickness of header shell.
t_e = thickness of end plate.
t = thickness of unpierced shell as determined by formula (1) with $\eta = 1{\cdot}0$.

Fig. 16. Typical methods of attachment of header end closures

Clause 3.6.1 Delete the existing text of this clause and substitute the following:

'Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae the suitability of their construction shall be determined by a proof hydraulic test of a prototype. The component design shall be considered suitable if the proof test pressure is achieved without significant permanent deformation of the prototype.'

Clause 3.6.2 Delete the existing text of this clause and substitute the following:

'The proof test pressure P_t (N/mm²) shall not be less than:

$$P_t = 0{\cdot}9p \frac{\text{(yield stress at test temperature)}}{\text{(allowable stress at working metal temperature)}}$$

where p = calculation pressure N/mm².

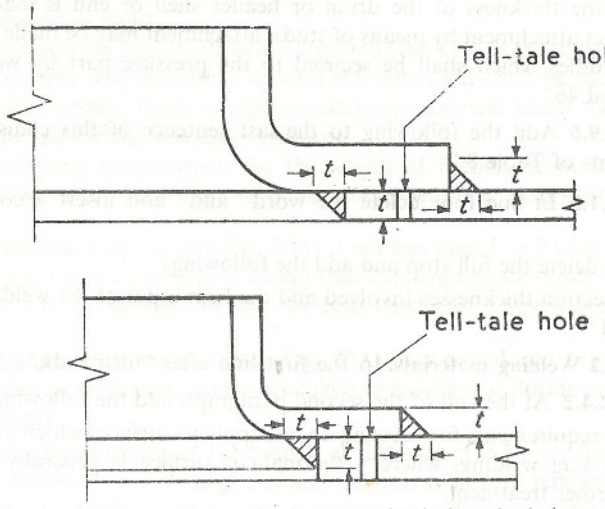
NOTE. The above formula applies to ferritic steels only.'

Clauses 3.8.3.1, 3.8.3.2 and 3.8.3.3 In the first line of each of these clauses delete the words 'calculation temperature' and substitute 'metal temperature'.

Clause 3.9.2 Add the following additional new paragraph:

'Where attachments are welded to thin walled tubes special care should be taken to avoid burn through or burning of the tube metal.'

Fig. 20. Frame-drum fillet weld. Replace the existing figure with the attached drawing and Notes.



NOTE 1. The use of this type of connection is not permitted where the design pressure exceeds 4 N/mm².

NOTE 2. Fillet-welded details are not recommended if the vessel is subjected to pulsating loads when preference should be given to the details shown in Figs. 45*a* to *d*.

NOTE 3. The sizes of the fillet welds should be based on the loads transmitted paying due regard to all fabrication and service requirements but in any case should not be less than 6 mm.

NOTE 4. Avoid use when thermal gradient may cause overstress in welds.

Delete the existing title of this figure and substitute the following:

'Fig. 20. Frame or drum fillet weld'.

Clause 4.1.7.2(4) Delete the existing text of this clause and substitute the following:

'Mountings may be attached by studs provided that the design temperature does not exceed 400 °C.

Studs shall be of a design such that a high fatigue strength is ensured and shall have a full thread holding in the drum or header shell or end plate for a length equal to at least one diameter. Studs shall not completely pierce the pressure part and after allowing suitable clearance at the blind end of the stud, the unpierced material of the pressure part shall amount to not less than a quarter of the stud nominal diameter.

Studs and nuts shall be made of a material suitable for the operating conditions; see BS 10†.

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After machining of jointing faces the final thickness of ends shall be not less than the minimum calculated thickness and the final thickness of shells shall be not less than the minimum calculated unpierced thickness.

Where the thickness of the drum or header shell or end is inadequate to permit direct attachment by means of studs, attachment may be made to suitable pads or saddles which shall be secured to the pressure part by welding; see Figs. 45 and 46.'

Clause 4.1.9.6 Add the following to the last sentence of this clause: ' to the requirements of Table 8 '.

Clause 4.2.1.3 In line four delete the word ' and ' and insert a comma after ' welds '.

In line five delete the full stop and add the following:

' , the section thicknesses involved and the heat input of the welding process to be used '.

Clause 4.2.2 Welding materials. In the first line after ' filler rods,' add ' fluxes '.

Clauses 4.2.4.2 At the end of the second paragraph add the following:

' These requirements for dressing do not apply to surfaces which are prepared for electro slag welding, where a thermal-cut surface is generally acceptable without further treatment.'

Clause 4.2.8.1 Attachment by welding of pressure parts to drums, shells and headers

In the second line of the third paragraph add a fullstop after ' runs ' and delete the remaining three lines.

In the third line of the fourth paragraph delete ' will ' and substitute ' may '.

The original fourth paragraph will now read as a continuation of the modified third paragraph.

Clause 4.2.8.2 Attachment by welding of non-pressure parts to drums, shells and headers. Insert the following new paragraph after the existing first paragraph:

' Wherever practicable the toes of all fillet welds attaching brackets, lugs, flats, etc., shall not be located closer than 40 mm from the toes of large fillet welds of branches, nozzles or undressed main seam welds. Where this is impracticable, in the case of carbon and carbon/manganese steel having a minimum specified ultimate tensile strength greater than 495 N/mm² and all alloy steels, special consideration shall be given to the non-destructive examination of the attachment welds as agreed between manufacturer and Inspecting Authority.'

Clause 4.2.9.2 Evaporation tubes. In the third line round off the value of ' 4·13 N/mm² to ' 4 N/mm² '.

Clause 4.3.3.1 In the third, line after the word ' demonstrated ', insert the following: ' before the work is started '.

New Clause 4.3.4.1 (5) Add the following text after Clause 4.3.4.1 (4).

' (5) Where branches, nozzles or stubs on a vessel are subsequently welded to other connections such as pipes, tubes or fittings care shall be taken that the welding and any post-weld heat treatment of the butt-weld does not cause harmful temperature gradients local to the junction between the vessel and the branch, (nozzle or stub).

Where post-weld heat treatment is required (see 4.3.3.1) the disposition of the heating elements and insulation around the butt-weld shall be such to obtain a temperature profile which is approximately symmetrical about the centre line of the weld and circumferentially uniform.

The following requirements for the length of branch, from the adjoining surface of the vessel, shall apply in those cases where heat treatment is required.

(i) Where the length L (see Fig. 20A) is not less than $L = 7\sqrt{rt_1}$ the requirement of (ii) *a*, *b* and *c* shall apply except that the temperature limits in (ii) *a* shall be within $-\ 0\ +\ 100$ degC of half the heat treatment temperature.

(ii) The minimum length L (see Fig. 20A) may be reduced to $L = 5\sqrt{rt_1}$ provided that suitable precautions are taken to ensure that during any post-weld heat treatment

a. the temperature of the branch at distance of $2{\cdot}5\sqrt{rt_1}$ from the butt-weld is within $-\ 0\ +\ 40$ degC, of half the heat treatment temperature in °C,

and *b.* the temperature of the pipe or tube at a distance of $2{\cdot}5\sqrt{rt_1}$ from the butt-weld is not less than half the heat treatment temperature,

and *c.* thermocouples are applied at not less than three sections in order to check peak and half peak temperatures (see 4.3.4.2 Notes 1 and 2).

(iii) Where the length of the branch is less than $5\sqrt{rt_1}$ heating elements and insulation shall be installed both around the butt-weld and around the vessel symmetrically about the branch intersection. The disposition of heating elements and insulation shall be such as to obtain a temperature profile which is approximately symmetrical about the centre line of the butt-weld and circumferentially uniform around the branch. In the vessel the temperature profile shall be approximately symmetrical about the branch intersection and circumferentially uniform. During the heat treatment precautions shall be taken to ensure that:

a. the temperature of the branch at a distance of $2{\cdot}5\sqrt{rt_1}$ from the butt-weld is not less than half the heat treatment temperature,

b. the temperature of the pipe or tube at a distance of $2{\cdot}5\sqrt{rt_1}$ from the butt-weld is not less than half the heat treatment temperature,

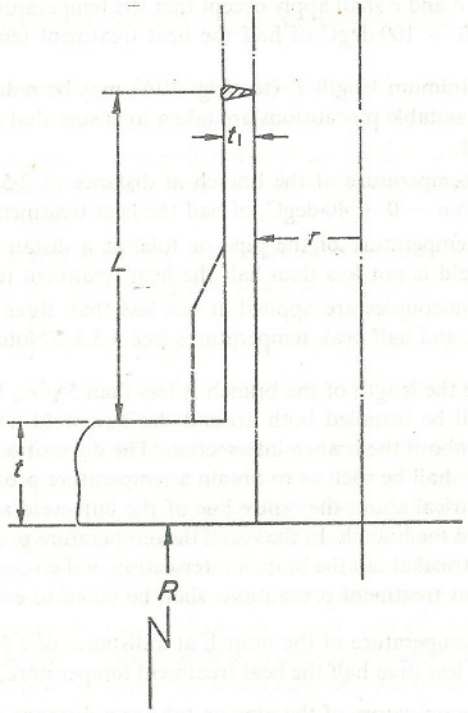
c. the temperature of the vessel at a distance of $2{\cdot}5\sqrt{Rt}$ local to the branch from the outer surface of the branch at its junction with the vessel, is not less than half the temperature measured at the junction,

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d. thermocouples are applied at not less than three sections in the branch and four sections in the vessel to check the temperatures.

(iv) Where the branch has a length less than $2{\cdot}5\sqrt{rt_1}$ the conditions in (iii) above shall apply except that in *a* the whole of the branch shall be raised to the heat treatment temperature.

(v) For a multiple branch configuration where the length L is not less than $7\sqrt{rt_1}$ thermocouples need not be attached to every branch at more than one section provided a procedure test is made to demonstrate that the temperature limits in (ii) *a* and *b* are met by the heat treatment procedure.



where t_1 = actual thickness of branch at the butt weld,
t = actual thickness of vessel local to branch,
R = internal radius of vessel,
r = internal radius of branch.

Fig. 20A. Length of branch, nozzle or stub subjected to post weld heat treatment

Table 8 Post-weld heat treatment. In the first line of the first column delete '0·25 °C' and substitute '0·25 %'.

In the first line of the Note, delete 'electric-slag' and substitute 'electro-slag'.

Clause 4.4.3.1 Insert the following title to this clause:

'*Manual and automatic arc welding processes*'.

Clause 4.4.3.2 Delete the existing text of this clause and substitute the following:

'Welding shall be undertaken in a position representing that which will be used in production. If various production positions are to be used, qualification under (4) may be considered as including qualification under (2) and (3).'

(1) Rotated in the horizontal position.

(2) Fixed in the horizontal position.

(3) Fixed in the vertical position.

(4) Inclined at 54° to the horizontal.

New clause. Add the following new clause to follow Clause 4.4.3.11:

'**4.4.3.12** *Flash butt welding processes.* The test procedure to be used for flash butt welding of pipes and tubes shall be in accordance with BS 4204*.'

Add the following footnote:

'*BS 4204, 'General requirements for the flash welding of steel pipes and tubes for pressure and other high duty applications'.'

Clause 4.5.3.4 Fillet welds. Add a final paragraph to the end of this clause;

'Qualification under this clause is not necessary if qualification under any of 4.5.3.2, 4.5.3.3 or 4.5.3.5 has been previously obtained.'

Section 5. Inspection and testing

Clause 5.2.2 Weld cylindrical shells, drums and headers. In the heading delete 'weld' and substitute 'welded'.

Items (8) and (9). Transfer the second sentence from (9) to the end of (8).

Clause 5.2.3 Seamless cylindrical shells, drums and headers

Items (3) and (4). Transfer the second sentence of (4) to the end of (3).

Clause 5.4.1.2 Add a continuation of the text of this clause as follows:

'. . . ultrasonic examination, with the exception of welds made by the flash welding process which shall be to the requirements of BS 4204* (see also 4.2.9.1).'

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Clause 5.4.1.3 Add a continuation of the text of this clause as follows:

'. . . ultrasonic examination with the exception of welds made by the flash welding process which shall be to the requirements of BS 4204* (see also 4.2.9.1).'

Add the following footnote:

'*BS 4204, 'General requirements for the flash-welding of steel pipes and tubes for pressure and other high duty applications'.'

Clause 5.4.1.6 Delete the existing text of this clause and substitute the following:

'The stages of manufacture, at which radiography and other forms of non destructive testing should be carried out, shall be the subject of agreement between manufacturer, purchaser and or Inspecting Authority. This agreement however shall not override the requirements of 5.2.2(8) and 5.2.3(3).'

Clause 5.4.1.8 Delete this clause completely, together with the footnotes for BS 2600 and BS 2910.

Clause 5.4.2.1(4) In the first line after 'Porosity', insert 'In general,' before 'no individual gas . . . '.

In the second and third lines delete 'shall' and substitute 'should'.

Clause 5.6.1.1 Components. Delete the last line and substitute the following:

'internal diameter greater than 305 mm except that by agreement it may be extended to 600 mm.'

Clause 5.6.1.2 In the first line 'Completed boilers after erection' is a clause heading and should be in italics.

In the second line delete the words 'on site'.

Section 6. Documentation and marking

Clause 6.3 Marking. Delete the existing text of this clause and substitute the following:

'**6.3 MARKING**

6.3.1 Each boiler and separate unit as defined in 1.1.1(1) to 1.1.1(5) shall be permanently and legibly marked to show its identity and origin. This marking may be made above the manhole of the main steam and water drum or preferably on a plate permanently attached to a principal pressure part or on the steel structure of the boiler. The marking shall show the following particulars.

(1) The name and domicile of the manufacturer.

(2) The manufacturer's serial number.

(3) The design pressure.

(4) The year of manufacture.

(5) The date of hydraulic test and the test pressure.

(6) The mark of the Inspecting Authority.

(7) Any other mark required by statute in the country in which the boiler will operate.

(8) The number of this British Standard, i.e. BS 1113.

6.3.2 Each pressure part which must be identifiable during manufacture in order to implement, for example, the recording procedure required by this standard (see 4.4.6) shall be temporarily marked.

6.3.3 Metal stamps shall not be used for permanent marking directly on to pressure parts of ferritic alloy or austenitic steels.

6.3.4 Temporary marks may be made with metal stamps having radiused edges providing that these marks are made lightly and before final heat treatment. Temporary marks shall be subject to visual examination by the Inspecting Authority who may, at their discretion require them to be removed by grinding after final inspection.'

Fig. 34. Set-through branches *a* and *b*. In the Note after 'including 100 mm bore' add 'for carbon and carbon manganese steels only'.

c and *d*. Delete the existing first two lines of the Note and substitute the following:

'Permitted for branches up to and including 200 mm bore for carbon or carbon manganese steels, or 100 mm bore for alloy steels, but in no case for branch thicknesses over 25 mm.'

Fig. 44. Compensated set-through branches. Letter the left hand diagram 'a' and the right hand diagram 'b'.

Fig. 46. Fillet-welded studded connections. Renumber the Notes 1, 2 and 3 as 2, 3 and 4 respectively. Insert the following new Note 1:

'NOTE 1. The use of this type of connection is not permitted where the design pressure exceeds 4 N/mm².'

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Full document details: BS 1113:1969

Amendment Slip No. 2, published 18 June, 1976

to BS 1113 : 1969

Water-tube steam generating plant
(including superheaters, reheaters and
steel tube economisers)

NOTE. The page numbers given on the replacement pages contained in this amendment relate to the original printing of BS 1113. For holders of copies of the reprint of BS 1113, which incorporates Amendment No. 1 (AMD 911) issued March 1972, these pages should be renumbered as follows:

page 54 becomes page 56
page 61 becomes page 63
page 86 becomes page 88
page 87 becomes page 89.

Revised text

UDC number. Delete the existing UDC number and substitute '621.181.125 .126: 621.181.14: 621.184.3/.4'.

Clause 1.2 Definitions. Delete the existing item (5) and substitute the following:

'(5) *Integral piping*. That piping within the whole of the circulatory system of the boiler between the feed inlet valve and the steam stop valve and, in the case of the reheater, between the reheater inlet header and the reheater outlet header.

In addition certain pipework connected to the boiler pressure parts or to the pipes forming the main circulatory system should be included in this category. Such pipes include integral boiler sootblower piping to the drain valves, blowdown, drain, sampling and air release piping between the point of take-off and the appropriate regulating valves, also boiler unit instrument and impulse piping including piping to the water gauges, alarms and transmitters.'

Clause 2.1.2. Delete the existing text and substitute the following:

'**2.1.2** Subject to agreement between the purchaser and the manufacturer, materials other than those listed in Table 1 may be used provided that they otherwise comply with 2.1.3 and that their suitability, with regard to tensile, proof and creep rupture stress as appropriate, has been proved to the satisfaction of the inspecting authority.'

Clause 2.1.3. Renumber this clause as 2.1.4.

New clause. Insert the following new subclause 2.1.3:

'**2.1.3** In selecting materials, attention shall be given to the suitability of the material proposed for weldability, cold forming and expanding as appropriate. No material shall have a specified elongation on a gauge length of $5.65\sqrt{S_o}$ less than 16 % for plates, 15 % for castings and 14 % for tubes and forgings.'

Table 1. Materials. In the section for plates insert the following, maintaining the numerical order of references:

'Carbon manganese steel (silicon-killed, niobium-treated)	BS 1501-223'

In the section for forgings insert the following, maintaining the numerical order of references:

'Carbon manganese steel (silicon-killed, niobium-treated)	BS 1503-223
Carbon manganese steel (silicon-killed, aluminium-treated)	BS 1503-224
1¼ % chromium ½ % molybdenum steel	BS 1503-621'

In the section for pipes delete all the information regarding 17 % chromium 13 % nickel-molybdenum and substitute the following:

'18 % chromium 8 % nickel steel	BS 3605-304S59
18 % chromium 12 % nickel-molybdenum steel	BS 3605-316S59
18 % chromium 10 % nickel-titanium steel	BS 3605-321S59
18 % chromium 12 % nickel-niobium steel	BS 3605-347S59'

Clause 2.2.2.1. In the expression $f = \frac{E_T‡}{1.5}$ delete the symbol '‡'. Also delete the associated footnote.

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Clause 3.2.3 Ligament efficiency. Delete this clause and substitute the following:

'3.2.3 *Ligament efficiency*. Where openings such as tube holes are drilled in a definite pattern, the efficiency of the ligaments shall be determined by the methods given in 3.2.3.1 to 3.2.5.2 provided that the diameter of the largest hole in the group does not exceed that permitted by the following.

(1) The maximum diameter d of any opening designed by this method shall be obtained from the curves in Fig. 9 or 10.

In Figs. 9 and 10 the value of K to be used is calculated from the following expression:

$$K=\frac{pD_0}{1.82ft}$$

where p = calculation pressure in N/mm²;
D_0 = outside diameter of shell in mm;
f = allowable stress (as used in equation (1)) in N/mm²;
t = actual thickness of shell in mm.

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

(2) No opening designed by this method shall exceed 200 mm in diameter.

Openings larger than those premitted by (1) and (2) shall be compensated in accordance with 3.2.9.'

Clause 3.2.9 Openings in cylindrical shells. Delete the whole of this clause (i.e. including 3.2.9.1 and 3.2.9.2) and Fig 11, but retain Figs. 8, 9 and 10. Substitute the attached replacement pages 21 and 21A to 21G.

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3.2.9 *Openings and branch connections in cylindrical shells*

3.2.9.1 *General.* The amount of compensation to be provided at an opening, from the point of view of internal pressure and anticipated loads, shall be not less than is specified in 3.2.9.2 or than is in accordance with the requirements of 3.2.3 for ligament efficiency.

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.

3.2.9.2 *Analytical design method for openings and branches*

3.2.9.2.1 *General.* Openings and branches, arranged singly or in groups, shall be reinforced to the following design methods which provide for compensation where necessary, either wholly in the shell or in both shell and branches.

The amount of compensation to be provided shall be not less than that specified in 3.2.9.2. In no case shall the thickness of the nozzle be less than the minimum pressure strength thickness t_m from equation (22) or (23).

(1) If $E_T < S_R$ (see Note 1) for branch and nozzle connections where the loads acting are essentially due to the internal pressure only, or where, due to the arrangement of any connected piping system, etc., the external loads are negligible, the factor C, used in the parameter Ca_1 in the tabulated data in Figs. 10A, 10B and 10C, shall be taken as not more than 1.1 (see Note 2).

(2) If $E_T < S_R$ (see Note 1) for branch and nozzle connections attached to integral piping designed in accordance with 3.8.7 or attached to piping designed in accordance with the flexibility requirements of BS 806, the factor C, used in the parameter Ca_1 in the tabulated data in Figs. 10A, 10B and 10C, shall be taken as not more than 1.0 (see Note 3).

(3) If $E_T < S_R$ (see Note 1) for openings without branch connections, take $t_2/t_1 = 0$ in Fig. 10B and use factor $C = 1.1$ to obtain shell thickness.

(4) If $S_R < E_T$ (see Note 1) at the design temperature, the factor C, used in the parameter Ca_1 in the tabulated data in Figs. 10A, 10B and 10C, shall be taken as not more than 1.0 (see Note 4).

(5) The effect of any other loads shall be taken into account and evaluated in accordance with Appendix A of BS 1515 : Part 1 : 1965 and the thickness of shell or branch or nozzle shall be increased if necessary, such as by selection of a value for C of less than 1.0. Similarly, the effect of attachments and discontinuities in the proximity of the openings shall be taken into account.

NOTE 1. E_T and S_R are as defined in 2.2.2.1 except that, where the design life is specified, S_R is the average stress to produce rupture for the specified design life at temperature T.

NOTE 2. The value of $C = 1.1$ ensures that the design pressure is approximately 10 % below the pressure at which shakedown is predicted by the design methods of 3.2.9.2.

NOTE 3. The value of $C = 1.0$ provides an additional margin to cater for extraneous loads such that the design pressure is approximately 20 % below the pressure at which shakedown is predicted by the design methods of 3.2.9.2.

NOTE 4. The value of $C = 1.0$ applied to design under creep conditions ensures that a minimum creep rupture stress 20 % below average at temperature T is not exceeded. It is also intended as a provision for extraneous loads which can be expected to be subject to creep relaxation.

For the purposes of the calculations in 3.2.9.2 the following symbols apply.

t_1 = final thickness of shell, excluding corrosion allowance, in mm;

R = mean radius of shell at thickness t_1, in mm;

D = mean diameter of shell at thickness t_1, in mm;

R_i = inside radius of shell, in mm;

t_{m1} = minimum thickness of shell for internal pressure $= \dfrac{pR_i}{f - 0.5p}$ mm;

f = allowable stress, in N/mm²* (see 2.2.2);

p = calculation pressure, in N/mm²*;

t_2 = actual minimum thickness of branch or nozzle, or total thickness of branch or nozzle, in mm;

t_{m2} = minimum thickness of nozzle for internal pressure $= \dfrac{pr_i}{f - 0.5p}$ mm;

r = mean radius of branch or nozzle at thickness t_2, in mm;

r_i = inside radius of branch or nozzle, in mm;

d = mean diameter of branch or nozzle at thickness t_2, or inside diameter of opening without a branch, in mm;

d_i = inside diameter of branch or nozzle, in mm;

d_0 = outside diameter of branch or nozzle, in mm;

d_A = average value of d_i for any two adjacent openings being considered, in mm;

P = pitch measured between any two openings on mid-thickness of shell, in mm;

A_s = cross-sectional area of shell between bores of the two adjacent openings considered, in mm (see Fig. 11*b*);

A_n = half the cross-sectional area of the two nozzles, taken within the distance $0.64\sqrt{dt_2}$ from the shell in the plane containing the pitch and nozzle axis, together with half the cross-sectional area of the weld metal lying outside the surfaces of the shell and branch, in mm² (see Fig. 11*b*);

A_t = sum of the two products $0.64\sqrt{dt_2}$ for the two openings considered, in mm² (see Fig. 11*b*);

g = arrangements factor from Fig. 11*a*;

a_1 = thickening factor for shell $= t_1/t_{m1}$;

Y = factor for Fig. 10A;

H = minimum width of thickened shell at thickness t_1, in mm;

h = minimum length of thickened branch at thickness t_2, in mm;

C = factor in tabulated data in Figs. 10A, 10B and 10C (see 3.2.9.2.1(1));

$\rho = \dfrac{r}{R}\sqrt{\dfrac{R}{t_1}}$

* 1 N/mm² = 1 MN/m² = 1 MPa = 10 bar.

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3.2.9.2.2 *Limits of application.* The following rules shall be used provided that:

(1) The ratio of the major to minor axes of the opening does not exceed 2.

(2) The branch is of circular cross section and the angle between the axis of the branch and a line normal to the shell does not exceed 50°.

(3) The ratio of radius to minimum thickness of the shell is not less than 2.5 or more than 50, i.e.

$$2.5 \leqslant \frac{R}{t_{m1}} \leqslant 50$$

(4) For protruding branches $r/R \leqslant 0.3$

(5) Where the reinforcement of the shell is in the form of pads, the amount of compensation to be provided shall be equal to the amount which would have been necessary if the compensation had been integral. Where material having a lower design stress than that of the vessel shell or end is taken as compensation, its effective area shall be assumed to be reduced in the ratio of the allowable design stress at the design temperature.

Reinforcement of the shell in the form of pads is limited to:

a. $r/R > 0.3$;
b. a width of the pad not less than $H/2$;
c. a thickness of the pad not exceeding t_1 or 40 mm, whichever is the lesser;
d. a thickness of the pad not less than $t_{m1}/4$;
e. weld preparations for the pads in accordance with Figs. 39 and 41*a*;
f. carbon and carbon manganese steels;
g. designs where severe thermal gradients are not likely to occur across the thickness of the shell.

(6) All branches and nozzles not covered by (1) to (5) shall be designed on the basis of special analysis, experimental evidence, operating experience (see Appendix F for reference to area replacement design method) or tests to the satisfaction of the inspecting authority and the purchaser.

3.2.9.2.3 *Design method for isolated openings or branches.* A trial process is used to determine the reinforced thickness t_1 of shell or t_2 of branch or nozzle as follows.

(1) First evaluate r/R from the nominal thickness and diameter of shell and branch. As at this stage the actual (minimum) thickness of shell only may be known, the pressure strength thickness of the branch or nozzle, t_{m2}, may be used for the calculation of r in the first trial process.

(2) For $r/R \geqslant 0.3$, use tabulated data in Fig. 10A.
First calculate Ca_1 and derive Y.
t_2 can then be calculated from:

$$t_2 = \frac{d_0}{\frac{2}{Y}\sqrt{\frac{R}{t_1}} + 1} \qquad (12A)$$

$$t_2 = \frac{d_0}{\frac{2}{Y}\sqrt{\frac{R}{t_1}} - 1} \qquad (12B)$$

(3) For $r/R \leqslant 0.2$, use tabulated data in Fig. 10B for flush branches and tabulated data in Fig. 10C for protruding branches.

First calculate the value for $\rho = \frac{r}{R}\sqrt{\frac{R}{t_1}}$ and calculate Ca_1. In the first instance ρ will have been derived using a mean radius r based on the pressure strength thickness t_{m2}. The required reinforced thickness t_2 can then be derived from the abscissa t_2 in Fig. 10B.

An iteration should then be made using the revised value for ρ until the assumed and required values for t_2 are equal.

(4) For $0.2 < r/R < 0.3$, use tabulated data in Fig. 10A together with 10B for flush branches or 10C for protruding branches.

It is necessary to derive t_a and t_b and to interpolate linearly between these two values to obtain the required reinforced thickness t_2, i.e.

$$t_2 = t_b + 10\left(\frac{r}{R} - 0.2\right)(t_a - t_b)$$

where t_2 = actual branch thickness required, in mm;
t_a = the t_2 thickness derived from Fig. 10A and equation 12A or 12B, in mm;
t_b = the t_2 thickness derived from Fig. 10B or 10C, in mm;
r = mean radius calculated from the thickness t_b derived from Fig. 10B or 10C, in mm;
R = mean radius of shell, in mm.

(5) Use of tabulated data. Where it is required to determine t_2/t_1 for ρ and Ca_1 values which are not explicitly tabulated, the following procedure shall be used.

a. For the nearest listed ρ value *below* that required, find the nearest tabulated Ca_1 values bounding the exact value above and below. Interpolate linearly to obtain t_2/t_1 corresponding to the required value of Ca_1.

b. Similarly obtain t_2/t_1 for the exact Ca_1 value for the nearest tabulated ρ value *greater* than that required.

c. Finally interpolate linearly to obtain t_2/t_1 for the exact value of ρ.

(6) Where the material of the branch has a lower allowable stress than that of the shell, the effective compensation, i.e. t_2-t_{m2}, shall be increased in the ratio of allowable stress, except that in no case shall a material having an allowable stress less than 60 % of the allowable stress of the shell material be used. No credit shall be taken for the additional strength of material having a higher design stress value than that in the shell.

(7) If the reinforced thickness t_2 of the branch, derived from items (2) to (5), exceeds the limit $t_2/t_1 = (2 - r/R)$, then the shell thickness shall be increased and the reinforced thickness t_2 recalculated. If this requirement is not met then the design shall comply with the requirements of 3.2.9.2.2(5), i.e. reinforcement of the shell in the form of pads.

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NOTE. The graphical presentations in Figs. 10A, 10B and 10C are included for ease of application and are derived from the tabulated data which should be used for comfirmation purposes.

3.2.9.2.4 *Extent of reinforcement.* Reinforcement, where required by the design rules of 3.2.9.2, shall be subject to the following limitations.

(1) The thickness t_2 of the branch or nozzle shall not be reduced within a distance $h=\sqrt{dt_2}$ measured from the relevant surface of the shell of thickness t_1.

(2) The thickness t_1 of the shell shall not be reduced within a distance H measured from the outer surface of the branch of thickness t_2 where H is the smaller of $H=d'_2$ and $H=\sqrt{Dt_1}$.

(3) Any necessary taper section to the appropriate unreinforced shell or branch connection shall have a slope no steeper than 1:4.

3.2.9.2.5 *Design method for groups of openings or branches*

(1) A group of openings is defined as being where the shortest pitch P between any two adjacent openings is than $d_A+3\sqrt{Dt_{m1}}$.

(2) Calculate reinforcement required assuming that the branch is isolated and that the full width H is available.

(3) Where the shortest pitch between adjacent openings is such that $P<d_A+2\sqrt{Dt_{m1}}$, the reinforcement calculated in (2) shall be increased if required so that for each ligament (see Fig. 11a and 11b) $A_s+A_n-A_t \geqslant gPt_{m1}$.

(4) Where the shortest pitch P between adjacent openings lies between $P_1=d_A+2\sqrt{Dt_{m1}}$ and $P_2=d_A+3\sqrt{Dt_{m1}}$, thereinforcement required shall be determined by linear interpolation as follows, using the dimensions determined in (2).

a. Calculate the compensation ratio K for pitch P_2:

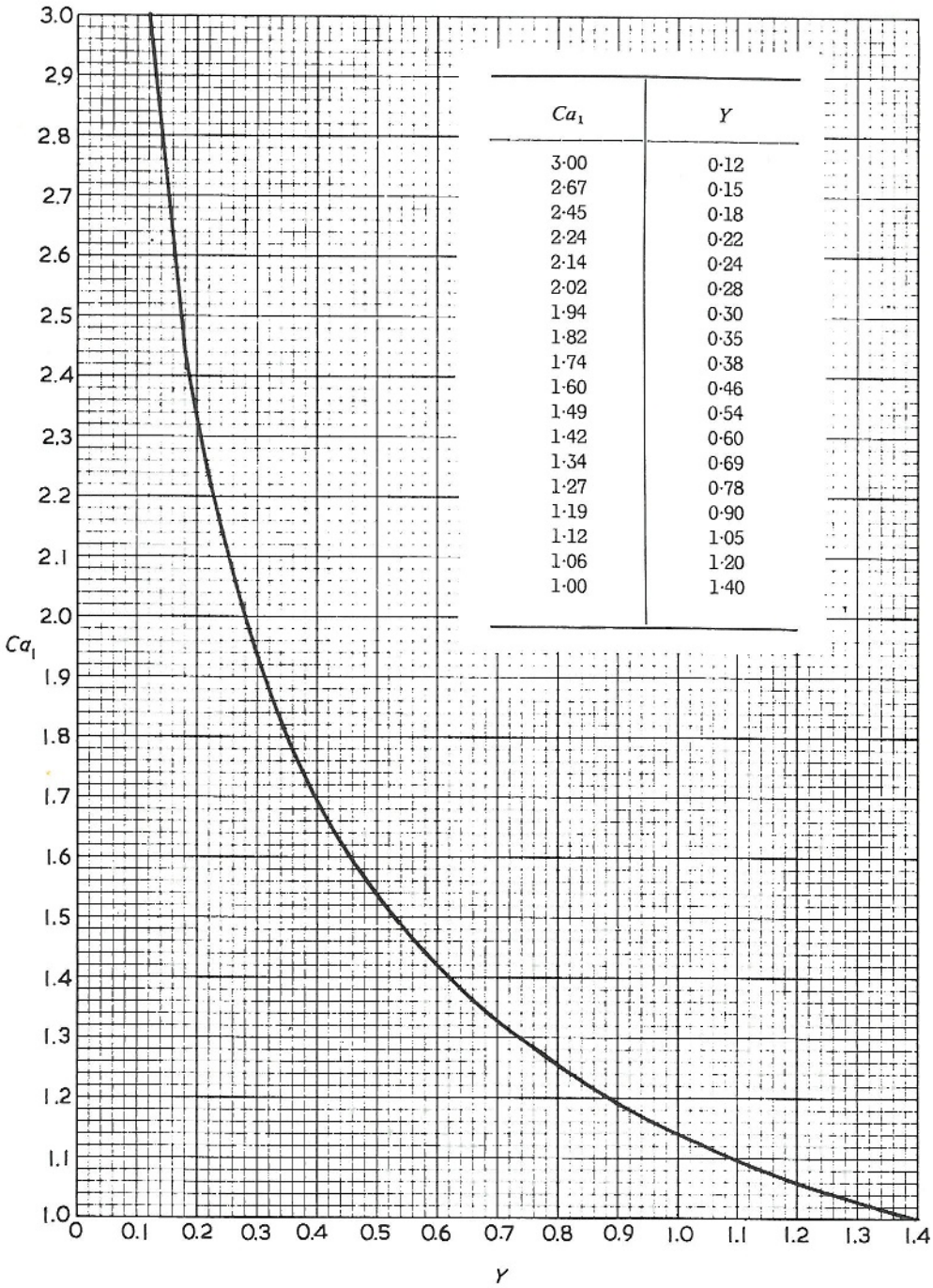
$K=\dfrac{A_s+A_n-A_t}{gP_2t_{m1}}$ (K shall not be taken as greater than 1.0)

b. The compensation ratio K_2 required at actual pitch P shall be $K_2=1-\dfrac{P-P_1}{P_2-P_1}(1-K)$

c. The dimension calculated in (2) shall be increased if required so that for each ligament $A_s+A_n-A_t \geqslant K_2gPt_{m1}$.

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Ca_1	Y
3·00	0·12
2·67	0·15
2·45	0·18
2·24	0·22
2·14	0·24
2·02	0·28
1·94	0·30
1·82	0·35
1·74	0·38
1·60	0·46
1·49	0·54
1·42	0·60
1·34	0·69
1·27	0·78
1·19	0·90
1·12	1·05
1·06	1·20
1·00	1·40

Fig. 10A. Flush nozzles in cylindrical shells ($r/R \geqslant 0.3$)

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$\rho=2{\cdot}0$	
Ca_1	t_2/t_1
1·17	2·00
1·20	1·78
1·24	1·60
1·32	1·40
1·42	1·20
1·54	1·00
1·70	0·80
1·81	0·70
1·94	0·60
2·10	0·50
2·30	0·40
2·60	0·27
2·80	0·19
2·90	0·15
3·01	0·10
3·10	0·04
3·15	0·00

$\rho=1{\cdot}8$	
Ca_1	t_2/t_1
1·12	1·96
1·20	1·59
1·26	1·40
1·35	1·20
1·46	1·00
1·62	0·80
1·71	0·70
1·83	0·60
2·00	0·50
2·19	0·40
2·41	0·30
2·64	0·20
2·80	0·13
2·87	0·08
2·92	0·04
2·95	0·00

$\rho=1{\cdot}6$	
Ca_1	t_2/t_1
1·06	1·97
1·12	1·77
1·20	1·43
1·24	1·31
1·30	1·17
1·40	0·98
1·50	0·84
1·60	0·72
1·74	0·60
1·91	0·49
2·07	0·40
2·30	0·27
2·45	0·20
2·60	0·13
2·68	0·1
2·72	0·05
2·76	0·00

$\rho=1{\cdot}4$	
Ca_1	t_2/t_1
1·00	1·96
1·10	1·57
1·20	1·25
1·30	1·02
1·40	0·85
1·50	0·72
1·63	0·60
1·81	0·47
1·93	0·40
2·10	0·30
2·29	0·19
2·45	0·10
2·50	0·06
2·54	0·00

$\rho=1{\cdot}2$	
Ca_1	t_2/t_1
1·00	1·68
1·04	1·53
1·10	1·33
1·20	1·05
1·30	0·85
1·40	0·70
1·50	0·59
1·60	0·51
1·78	0·40
1·90	0·33
2·12	0·20
2·26	0·10
2·36	0·00

$\rho=1{\cdot}0$	
Ca_1	t_2/t_1
1·00	1·42
1·06	1·22
1·10	1·10
1·20	0·85
1·30	0·67
1·40	0·55
1·51	0·45
1·70	0·33
1·90	0·23
2·00	0·16
2·07	0·10
2·15	0·00

$\rho=0{\cdot}9$	
Ca_1	t_2/t_1
1·00	1·22
1·10	0·95
1·20	0·73
1·30	0·58
1·40	0·46
1·50	0·38
1·70	0·26
1·81	0·20
1·90	0·15
2·00	0·06
2·04	0·00

$\rho=0{\cdot}8$	
Ca_1	t_2/t_1
1·00	1·04
1·06	0·88
1·15	0·69
1·24	0·56
1·32	0·47
1·42	0·38
1·61	0·26
1·71	0·20
1·80	0·14
1·90	0·05
1·94	0·00

$\rho=0{\cdot}7$	
Ca_1	t_2/t_1
1·00	0·83
1·08	0·68
1·20	0·51
1·31	0·40
1·44	0·30
1·60	0·20
1·73	0·10
1·82	0·00

$\rho=0{\cdot}6$	
Ca_1	t_1/t_2
1·00	0·67
1·06	0·58
1·12	0·50
1·23	0·40
1·35	0·30
1·50	0·20
1·60	0·12
1·70	0·00

$\rho=0{\cdot}5$	
Ca_1	t_2/t_1
1·00	0·54
1·08	0·46
1·20	0·34
1·39	0·20
1·49	0·10
1·56	0·00

$\rho=0{\cdot}4$	
Ca_1	t_2/t_1
1·00	0·45
1·10	0·35
1·20	0·26
1·30	0·16
1·40	0·04
1·42	0·00

$\rho=0{\cdot}3$	
Ca_1	t_2/t_1
1·00	0·34
1·10	0·25
1·20	0·14
1·29	0·00

$\rho=0{\cdot}2$	
Ca_1	t_2/t_1
1·00	0·23
1·10	0·10
1·16	0·00

$\rho=0{\cdot}1$	
Ca_1	t_2/t_1
1·00	0·10
1·05	0·00

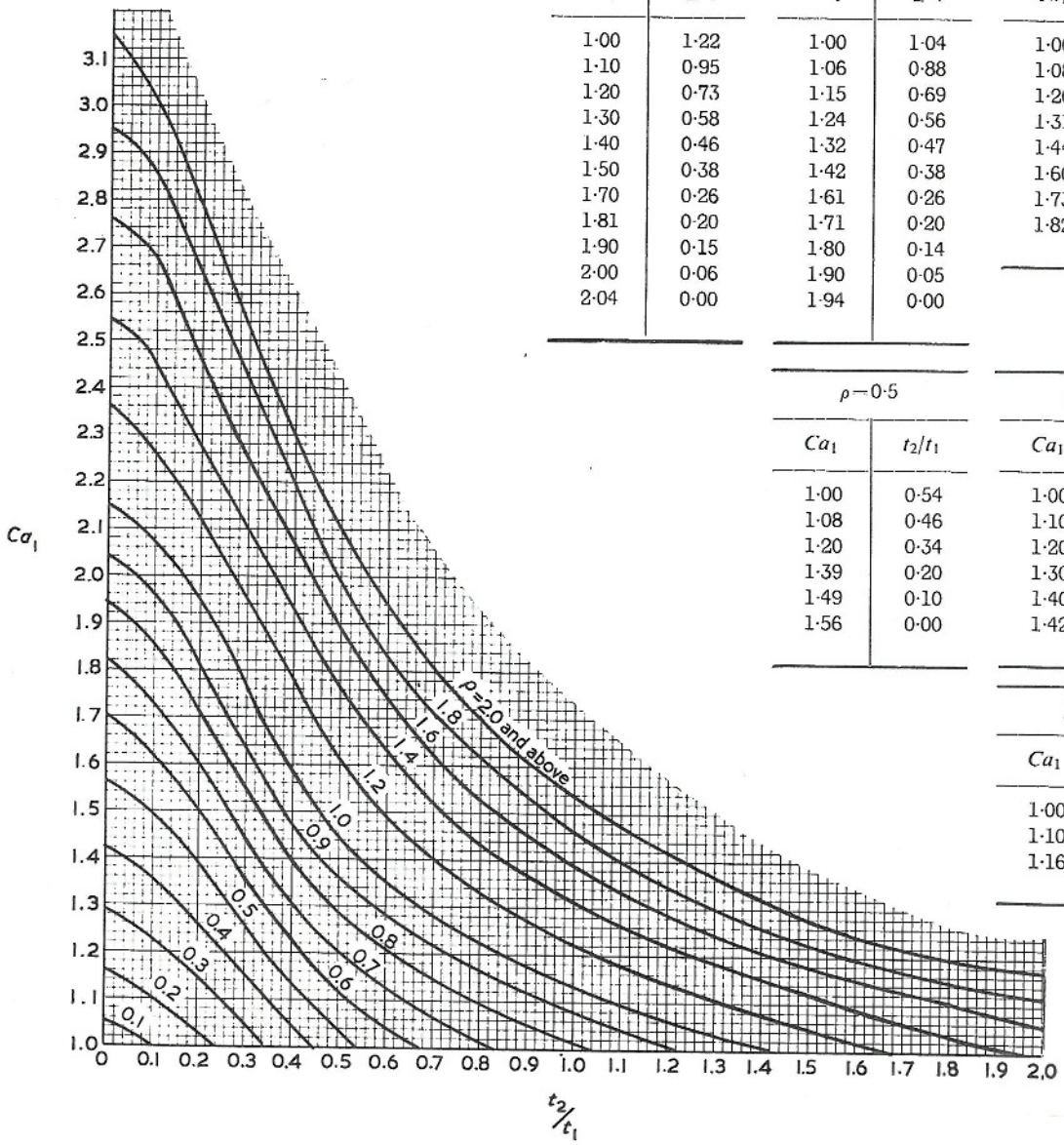


Fig. 10B. Flush nozzles in cylindrical shells ($r/R \leqslant 0.2$)

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$\rho=2{\cdot}0$	
Ca_1	t_2/t_1
1·00	1·53
1·10	1·37
1·20	1·22
1·28	1·11
1·36	1·01
1·42	0·94
1·48	0·87
1·56	0·79
1·62	0·74
1·70	0·68
1·80	0·61
1·90	0·55
2·00	0·49
2·10	0·45
2·20	0·40
2·28	0·37
2·36	0·34
2·44	0·31
2·50	0·29
2·56	0·27
2·64	0·24
2·74	0·21
2·80	0·19
2·86	0·17
2·90	0·15
2·95	0·13
3·02	0·09
3·10	0·04
3·15	0·00

$\rho=1{\cdot}8$	
Ca_1	t_2/t_1
1·00	1·44
1·10	1·29
1·20	1·14
1·30	1·00
1·38	0·90
1·44	0·83
1·50	0·77
1·56	0·72
1·62	0·67
1·70	0·61
1·80	0·54
1·90	0·49
2·00	0·44
2·10	0·39
2·20	0·35
2·30	0·31
2·40	0·28
2·50	0·24
2·60	0·21
2·68	0·18
2·76	0·15
2·82	0·12
2·86	0·09
2·90	0·06
2·95	0·00

$\rho=1{\cdot}6$	
Ca_1	t_2/t_1
1·00	1·35
1·10	1·19
1·20	1·04
1·28	0·93
1·34	0·86
1·40	0·79
1·46	0·72
1·52	0·66
1·58	0·61
1·64	0·56
1·72	0·51
1·80	0·46
1·88	0·42
1·96	0·39
2·08	0·34
2·20	0·29
2·30	0·25
2·40	0·21
2·50	0·17
2·60	0·13
2·66	0·10
2·70	0·07
2·73	0·04
2·76	0·00

$\rho=1{\cdot}4$	
Ca_1	t_2/t_1
1·00	1·24
1·10	1·08
1·20	0·93
1·28	0·82
1·34	0·75
1·42	0·66
1·48	0·60
1·56	0·54
1·64	0·48
1·71	0·44
1·79	0·40
1·90	0·35
2·00	0·30
2·10	0·26
2·20	0·22
2·30	0·18
2·40	0·13
2·44	0·11
2·48	0·08
2·52	0·04
2·54	0·00

$\rho=1{\cdot}2$	
Ca_1	t_2/t_1
1·00	1·13
1·08	0·99
1·14	0·90
1·20	0·81
1·26	0·73
1·32	0·66
1·38	0·59
1·44	0·54
1·50	0·49
1·56	0·45
1·64	0·40
1·74	0·35
1·82	0·31
1·91	0·27
2·02	0·22
2·12	0·17
2·20	0·13
2·25	0·09
2·30	0·04
2·32	0·01

$\rho=1{\cdot}0$	
Ca_1	t_2/t_1
1·00	0·99
1·08	0·85
1·14	0·76
1·20	0·68
1·26	0·61
1·31	0·55
1·36	0·51
1·42	0·46
1·51	0·40
1·60	0·35
1·70	0·30
1·80	0·25
1·86	0·22
1·92	0·18
1·98	0·14
2·02	0·10
2·06	0·06
2·10	0·00

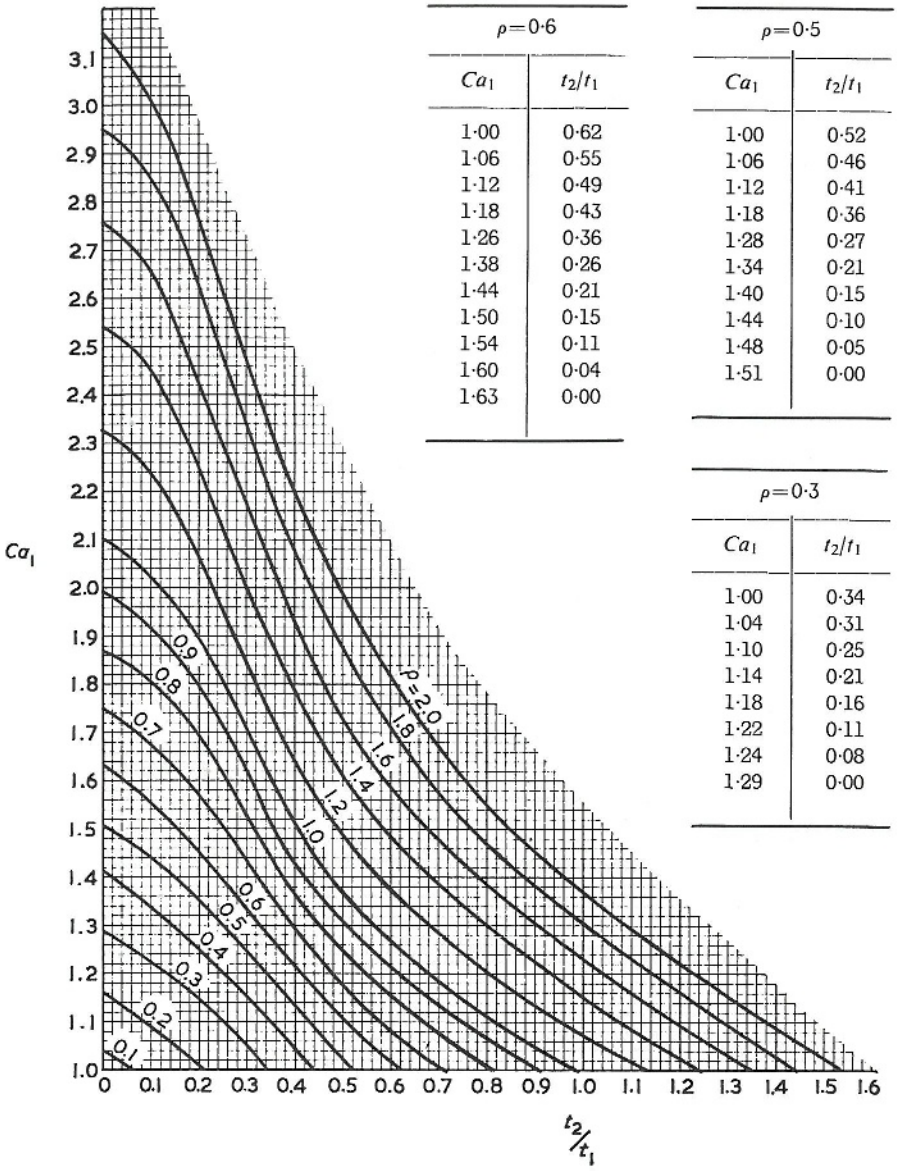
$\rho=0{\cdot}9$	
Ca_1	t_2/t_1
1·00	0·91
1·06	0·81
1·12	0·72
1·18	0·64
1·24	0·57
1·30	0·51
1·38	0·44
1·46	0·38
1·56	0·33
1·66	0·28
1·72	0·25
1·78	0·21
1·82	0·18
1·86	0·15
1·90	0·11
1·94	0·07
1·99	0·00

$\rho=0{\cdot}8$	
Ca_1	t_2/t_1
1·00	0·81
1·08	0·70
1·14	0·62
1·22	0·53
1·28	0·47
1·38	0·39
1·44	0·35
1·52	0·30
1·60	0·26
1·66	0·22
1·72	0·18
1·78	0·12
1·82	0·08
1·84	0·05
1·87	0·00

$\rho=0{\cdot}7$	
Ca_1	t_2/t_1
1·00	0·71
1·06	0·63
1·12	0·56
1·20	0·48
1·28	0·41
1·36	0·35
1·46	0·28
1·52	0·24
1·58	0·19
1·64	0·14
1·68	0·09
1·72	0·04
1·75	0·00

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ρ=0·6	
Ca_1	t_2/t_1
1·00	0·62
1·06	0·55
1·12	0·49
1·18	0·43
1·26	0·36
1·38	0·26
1·44	0·21
1·50	0·15
1·54	0·11
1·60	0·04
1·63	0·00

ρ=0·5	
Ca_1	t_2/t_1
1·00	0·52
1·06	0·46
1·12	0·41
1·18	0·36
1·28	0·27
1·34	0·21
1·40	0·15
1·44	0·10
1·48	0·05
1·51	0·00

ρ=0·4	
Ca_1	t_2/t_1
1·00	0·44
1·04	0·40
1·14	0·31
1·20	0·25
1·24	0·21
1·28	0·16
1·32	0·12
1·36	0·07
1·41	0·00

ρ=0·3	
Ca_1	t_2/t_1
1·00	0·34
1·04	0·31
1·10	0·25
1·14	0·21
1·18	0·16
1·22	0·11
1·24	0·08
1·29	0·00

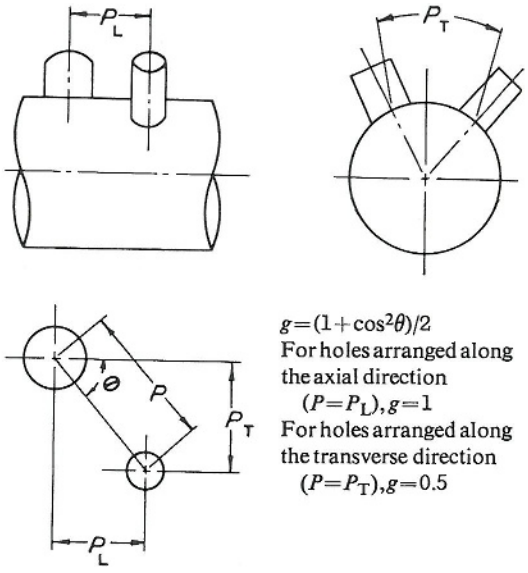
ρ=0·2	
Ca_1	t_2/t_1
1·00	0·21
1·04	0·16
1·08	0·11
1·12	0·06
1·16	0·00

ρ=0·1	
Ca_1	t_2/t_1
1·00	0·06
1·04	0·00

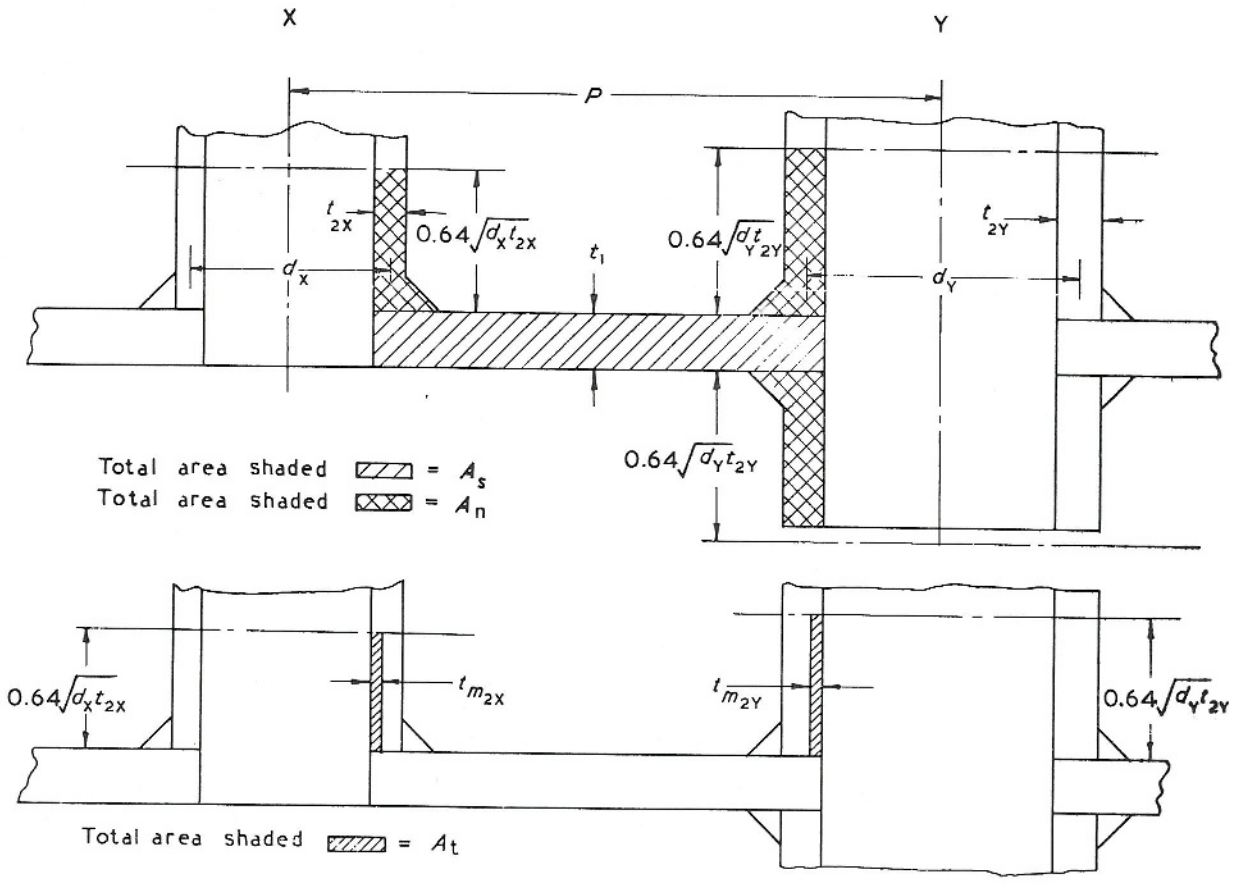
Fig. 10C. Protruding nozzles in cylindrical shells

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a. Arrangement factor *g*



b. Branch compensation

Fig. 11. Arrangement factor *g* and branch compensation (See 3.2.9.2.5)

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Clause 3.5.3 (as amended by Amendment No. 1). Delete the penultimate paragraph of item (2) and substitute the following:

'Where flat end plates are to be pierced concentrically or eccentrically, the thickness determined by equation (14) shall be increased by 15 %. Where end detail as in Fig. 16*b* is employed, care shall be taken that any eccentrically positioned hole does not encroach into the attachment weld.'

Clause 3.7.2 Integral piping branches. Delete this clause (i.e. 3.7.2.1 to 3.7.2.7) and Table 2 entirely.

Clause 4.1.5.2. In line 4 delete 'BS 10*' and substitute 'the appropriate British Standard'.

Delete the asterisk footnote at the bottom of the page.

Clause 4.1.7.4. In line 2 delete 'BS 10†' and substitute 'the appropriate British Standard'.

Delete the footnote marked '†' at the bottom of the page.

Table 8. Post-weld heat treatment. In the column headed 'Material' delete the first entry and substitute the following:

'Carbon steel, 0.25 % max. (not exceeding 30 mm thick at the weld)‡‡'

In the second entry in the column headed 'Material' delete '19 mm thick and over' and substitute 'above 30 mm thick'. Beneath the table insert the following new footnote:

'‡‡Where the welded joint connects parts that are of different thickness, the thicknesses to be considered in applying the limiting thickness of 30 mm for carbon steel shall be the following nominal thickness including corrosion allowance:

(1) the thinner of two adjacent butt welded components including shell to end connections;
(2) the thickness of the shell in connections to flat ends;
(3) the thickness of the shell or end in nozzle attachment welds;
(4) the thickness of the nozzle at the joint in nozzle to flange connections;
(5) the thickness of the pressure part, at the point of attachment, where a non-pressure part is welded to a pressure part (but see 4.3.3.1)'.

Clause 4.5.3.2 Butt welds in plates. Delete the last paragraph and substitute the following:

'Where the weld is made by the oxy-acetylene process or by the MIG dip transfer (short arc) process, in addition, as many root bend tests shall be made as the size of the specimen permits.'

Clause 4.5.3.3 Butt welds in pipes and tubes. In line 3 delete '4.4.3' and substitute 'BS 1821 or BS 2633'.

Page 54. Delete item (4) of 5.5.1 and the whole of clause 5.6 and substitute the attached replacement page 54.

Clause 6.3.1 (as amended by Amendment No. 1). Delete item (5) and substitute the following:

'(5) The date of hydraulic test, the test pressure and the actual test temperature'.

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(4) Castings to which a quality factor of 0.90 is assigned shall be clearly and permanently marked with a suitable symbol after being examined as above and found satisfactory.

5.6 HYDRAULIC TESTS

5.6.1 General requirements. In order to demonstrate so far as is practicable the strength and integrity of the completed boiler and to establish that no major error or defect in design, materials or fabrication has occurred, all completed boilers, reheaters, independently fired superheaters and separate economisers shall be hydraulically tested to the pressure specified in 5.6.1.1 without any sign of weakness or defect. Adequate facilities and equipment shall be provided by the manufacturer to enable the test and inspection requirements to be implemented.

5.6.1.1 *Test pressure.* The test pressure for completed boilers, reheaters, independently fired superheaters and separate economisers shall be 1.5 times the design pressure or 1.25 times the highest calculation pressure in the assembly being tested, whichever is the greater, except where all the components in the assembly have been individually tested in accordance with 5.6.2 when the test pressure may be reduced to 1.25 times the design pressure or 1.1 times the highest calculation pressure in the assembly being tested, whichever is the greater.

5.6.2 Component testing

5.6.2.1 Components which have been tested to 1.5 times the design pressure or 1.25 times the highest calculation pressure in the assembly being tested, and joined during assembly or erection by circumferential butt welds which have been welded in accordance with 4.2 and non-destructively tested in accordance with 5.4, shall not require further testing as components. Cylindrical components up to 300 mm internal diameter may, by agreement between the manufacturer, the purchaser and the inspecting authority, be subjected to additional non-destructive testing procedures and shall not then require further testing as components.

5.6.2.2 Boiler drums and other cylindrical components having an internal diameter greater than 300 mm* and where the design stress is based on the ultimate tensile strength (UTS) or 0.2 % proof stress, shall be hydraulically tested to 1.5 times the design pressure or 1.25 times the highest calculation pressure, whichever is the greater, before assembly into the boiler.

Where the boiler pressure parts are to assembled and hydraulically tested in accordance with 5.6.1.1 within the manufacturer's workshops, then the above test may be waived.

All components which are not reasonably accessible for inspection after assembly into the boiler shall be hydraulically tested to 1.5 times the design pressure or 1.25 times the highest calculation pressure, whichever is the greater.

The hydraulic test shall be carried out after all welding and heat treatment is completed, but may be carried out prior to the drilling of tube holes for expanded tubes.

5.6.3 Hydraulic test procedure. The hazards involved in pressure testing shall be considered by the manufacturer and adequate precautions shall be taken.

5.6.3.1 There is a technical need to avoid the risk of over-pressurization. It is therefore recommended that a preliminary examination of the boiler or component for the purpose of identifying any significant leaks prior to the hydraulic test should be carried out at the design pressure of the boiler or component.

5.6.3.2 Water at a suitable temperature shall be used as a pressurizing agent. To avoid the risk of freezing it is recommended that this temperature should not be less than 7 °C during the hydraulic test. The quality of water used shall be such as to prevent corrosion and a residue of injurious solids.

5.6.3.3 The boiler or components being tested and their connections shall be properly vented or evacuated to prevent formation of air pockets.

5.6.3.4 All temporary pipes, connections and blanking devices shall be designed to withstand the appropriate test pressure.

5.6.3.5 No component undergoing pressure testing shall be subjected to any form of shock loading, e.g. hammer testing, thermal shock or rapid application of pressure.

5.6.3.6 The full test pressure shall be maintained for 30 min for boilers and large components and an appropriate time for smaller components, whereupon it shall be reduced to a pressure not lower than the design pressure or calculation pressure as appropriate and not higher than 90 % of the test pressure prior to close examination.

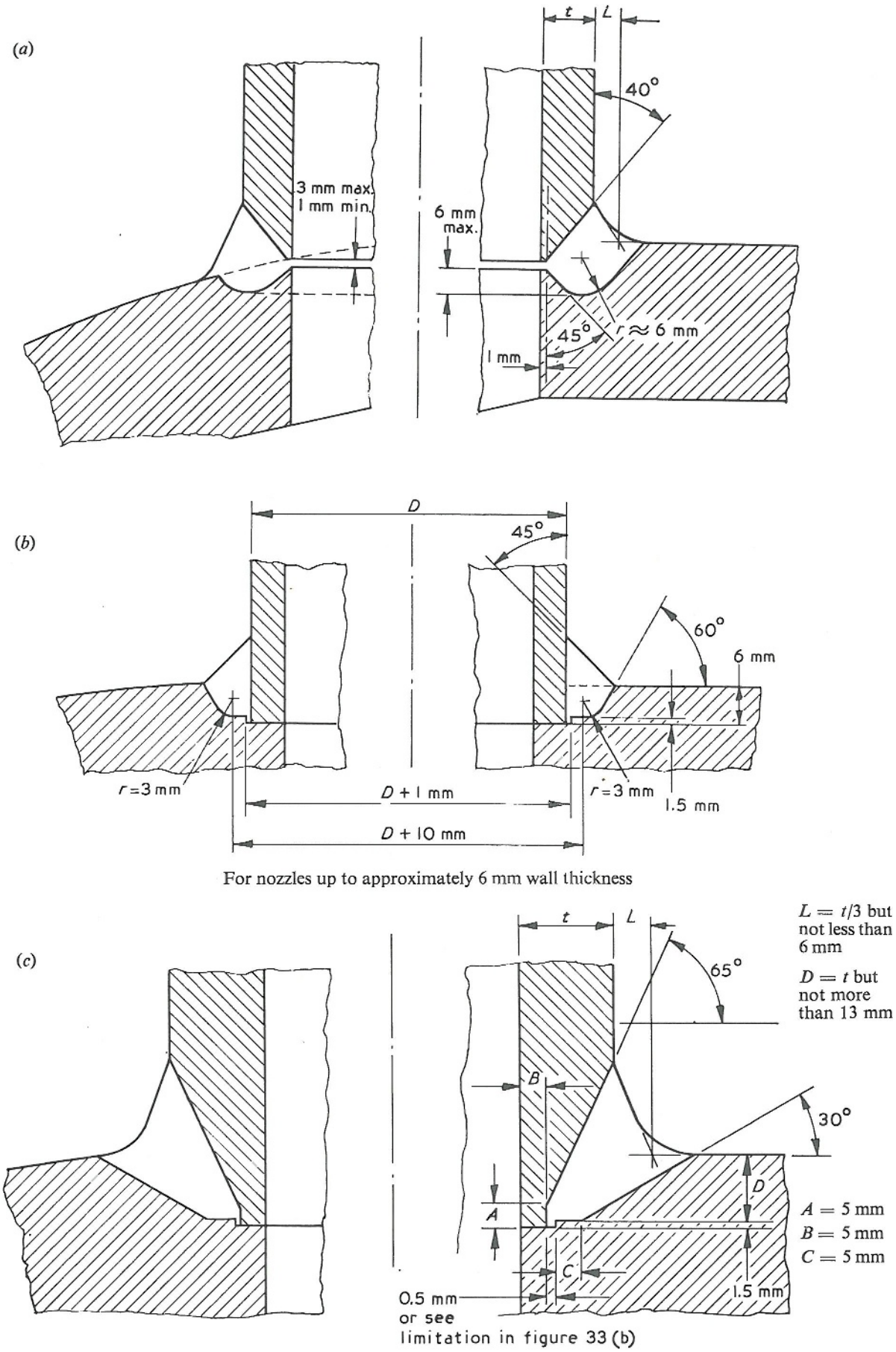
*By agreement between manufacturer, purchaser and inspecting authority this requirement may be extended to components having an internal diameter of not greater than 600 mm.

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Fig. 33. Set-on branches. Delete this figure and substitute the attached replacement page 61.



For nozzles up to approximately 6 mm wall thickness

For nozzles with a wall thickness over 6 mm

NOTE. Diagrams (b) and (c) are for nozzles up to and including 150 mm bore.

Fig. 33. Set-on branches

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New appendix. At the end of the standard insert the attached new Appendix F.

APPENDIX F

AREA REPLACEMENT DESIGN METHOD

F.1 This method of compensation has been widely used and has a satisfactory history. However it will sometimes provide excessive thickness because of the simplified nature of the calculations and is not suitable in all cases. It is recommended that its use be restricted to cases where experience has shown it to be satisfactory.

F.2 This method of compensation takes account of the cross-sectional area of locally disposed material, including the attachment welds, in excess of the minimum requirements for plate and branch thicknesses as shown in Fig. 54*a* and *b*, the branch thickness being increased where required as shown in Figs. 38, 40 and 44. For compensation of openings without a branch see Fig. 56*c*.

Area X shall be calculated as the product of the inside radius of the branch or opening 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 drum and shall be calculated as follows:

(1) 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 in accordance with equation (22) or (23) disregarding the minimum thickness from Table 3.

(2) 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.

(3) Add to it the sectional area of the fillet welds on both sizes of the shell.

(4) Add to it the area obtained by multiplying the difference between the actual shell thickness and the unpierced shell thickness A by 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 Fig. 38, 39, 41, 42 or 43 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 Fig. 54 and C being amended to equal the smaller of the two values $2.5t$ or $t_r+2.5t_a$ where t = the actual thickness of the shell plate, in mm;

t_a = the actual thickness of the branch wall, in mm; and

t_r = the actual thickness of the added reinforcement on the outside of the shell plate, in mm.

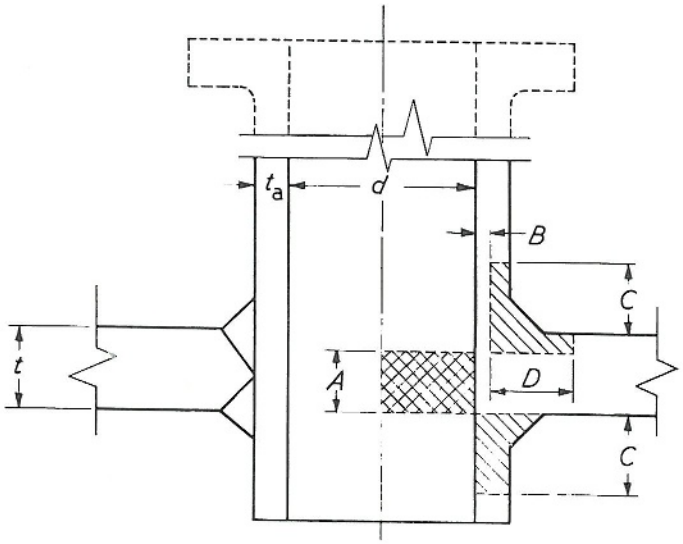
Where material having a lower allowable stress than that of the shell or end is taken as compensation, its effective area shall be assumed to be reduced in the ratio of the allowable stresses at the design temperature. No credit shall be taken for the additional strength of material having a higher stress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

Where reinforcement is achieved by taking account of the cross-sectional area, compensation shall be considered adequate when the compensation area Y is equal to or greater than the area X requiring compensation.

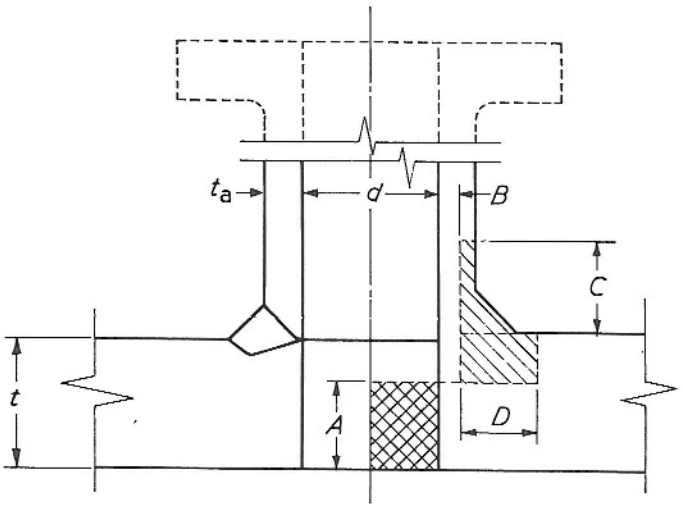
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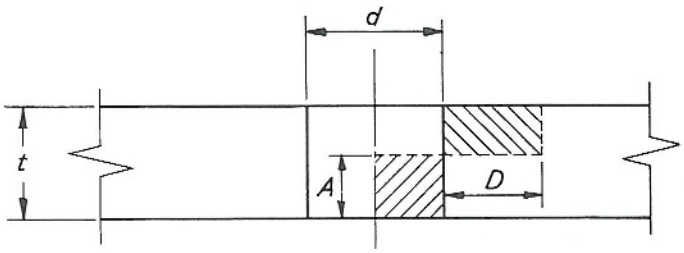
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a. Set-through branch



b. Set-on branch



c. Opening

The area *Y* ▨ should not be less than the area *X* ▩

A = thickness calculated in accordance with equation (1), disregarding the minimum thickness required by 3.2.1.2.
B = thickness calculated in accordance with equation (22) or (23) disregarding the minimum thickness from Table 3.
C = the smaller of the two values: $2.5t$ or $2.5t_a$.
D = the greater of the two values $(t+75\text{ mm})$ or $d/2$.

Fig. 54. Compensation of welded branch or standpipe

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AMD 2283

Amendment Slip No. 3, published 31 May 1977
to BS 1113 : 1969

Water-tube steam generating plant (including superheaters, reheaters and steel tube economisers)

Revised text

Page 2. In the list of reference standards delete the entry for BS 3889. After the entry for BS 4204 insert the following:

'BS 4397. Methods for magnetic particle testing of welds.'

In the final entry in the list delete 'BS. . . . . *' and insert 'BS 4677'. At the bottom of the page delete the associated asterisk footnote.

Contents. Under the heading 'Appendices' insert the following new entry:
'F. Area replacement design method'.

Clause 3. 2. 9. 2. 3 Design method for isolated openings or branches (as added by Amendment No. 2). In equation (12B) delete 'd_0' and substitute 'd_i'.

Clause 3. 2. 9. 2. 5 Design method for groups of openings or branches (as added by Amendment No. 2). In item (1), line 3, before 'than' insert 'less'.

Fig. 10B. Flush nozzles in cylindrical shells ($r/R \leqslant 0.2$) (as added by Amendment No. 2). In the table for $\rho = 0{\cdot}6$ delete the right-hand column heading 't_1/t_2' and substitute 't_2/t_1'.

Clause 4.1.6.2 Size. Delete the existing text and note and substitute the following:

'Elliptical manholes shall be not smaller than 400 mm × 300 mm. Circular manholes shall be not smaller than 400 mm diameter. Hand hole openings shall be not less than 90 mm × 70 mm but larger sizes are recommended.'

Clause 4.1.6.4 Doors. Delete the existing item (6) and substitute the following:

'(6) Door spigots, when the door is in a central position, shall have a clearance of approximately 1·5 mm all round and at no point shall the clearance exceed 3 mm.'

Clause 4.3.4.1 At the end of item (4) insert the following two new paragraphs:

'Wherever practicable, the location of large branches or nozzles where the distance between the toe of the branch weld and the centre line of a locally heat treated butt weld would be less than $5\sqrt{rt}$ should be avoided.

Where the positioning of such branches or nozzles is not so located, it is recommended to heat uniformly the branch weld when stress relieving the butt weld.'

Clause 5.3.4.4 Notched bar impact test. Delete the existing text and substitute the following:

'The results obtained from the Charpy V-notch test specimens shall comply with the following requirements.

(1) The minimum result obtained from each of the Charpy V-notch test specimens (see 5.3.3(4)) shall be 40 J (30 ft lbf), except as otherwise permitted by (2) below, when the temperature of the specimens at the time of test does not exceed the lower of the following two values:

a. 50 °C; or

b. 30 °C above the lowest permissible hydraulic test temperature (see 5.6.1).

(2) Provided that only one of the three test specimens fails to meet the requirement in (1) above and by not more than 10% (i.e. CVN ⩾ 36 J), a retest of three additional test specimens shall be made. Provided that each of the three retest specimens meets the minimum requirement of 40 J in accordance with (1) above, the retest values shall be accepted.

(3) In the event of the results of the Charpy V-notch test specimens failing to comply with the requirements of (1) and (2) above, the following provision may be permitted.

a. The manufacturer may carry out heat treatment of the production test plates provided that the same heat treatment cycle is applied to those parts of the boiler drum(s) represented and that no undue adverse effects are caused. After such repeat heat treatment, all the tests specified in 5.3.3 shall be carried out. The tests shall meet the requirements specified in 5.3.4.

or

b. Subject to specific agreement between the purchaser, the manufacturer and the Inspecting Authority, the welds represented by the test specimens having particular Charpy V-notch values less than required by (1) and (2) above may be accepted as fit for the intended purpose after due consideration of the specific cause and level of impact test results and of the weld quality.

No rules are given here for fracture mechanics tests and, if such tests are required by agreement between the manufacturer, the purchaser and the Inspecting

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Authority, the specimen type, notch location and acceptance criteria are to be the subject of agreement. The test methods to be used here are detailed in BS 5447* and DD 19*.'

At the bottom of the page insert the following footnote:

'*BS 5447, 'Methods of test for plane strain fracture toughness (K_{Ic}) of metallic materials'.
DD 19, 'Methods for crack opening displacement (COD) testing'.'

Clause 5.4.2 Standards of acceptance. Delete this clause entirely and substitute the following (including Figs. 28A, 28B, 28C, 28D, 28E and 28F and Table 11A):

'5.4.2 Standards of acceptance

5.4.2.1 *General.* The following subclauses (5.4.2.2 to 5.4.2.6) apply to butt welds in drums, shells and headers. Standards of acceptance for branch and nozzle welds to drums, shells and headers shall be the subject of agreement between the parties involved.

5.4.2.2 *Quality control level of acceptance.* The defect acceptance levels given in 5.4.2.4 and 5.4.2.5 shall be imposed during fabrication as a means of quality control.

The acceptance levels given in 5 4.2.4 are applicable only when the inspection techniques employed enable the through thickness location and height (h) of the defect to be determined. Where the through thickness location and height (h) of the defect cannot be determined, the acceptance levels in 5.4.2.5 shall apply.

Although the existence of adjacent groups of defects is permitted (see 5.4.2.4(3)), the systematic occurrence of such defects in weld seams should be investigated and any remedial action agreed between the parties concerned.

5.4.2.3 *Assessment of defects.* Defects may be assessed according to one of the following.

(1) If the defects do not exceed the levels specified in 5.4.2.4 or 5.4.2.5 as appropriate, the weld shall be accepted without further action (but see 5.4.2.2).

(2) When acceptance levels different from those given in 5.4.2.4 or 5.4.2.5 have been established for a particular application and are suitably documented, they may be adopted by specific agreement.

(3) Welds having particular defects in excess of those permitted in 5.4.2.4 and 5.4.2.5 may be accepted as fit for intended purpose by specific agreement between the purchaser, the manufacturer and the Inspecting Authority after due consideration of material, stress and environmental factors.

Defects that are unacceptable shall be rejected or repaired in accordance with 4.2.10.

5.4.2.4 *Butt welds ⩾ 25 mm thick, designed to tensile or 0·2% proof stress criteria.* The following requirements apply when the inspection techniques employed enable the through thickness location and height (h) of the defect to be determined.

(1) The significant dimension of a defect in terms of its effect on the service performance is its cross-sectional dimension in the component through thickness direction (h), its location relative to the surface and the actual thickness of the component.

When ultrasonic flaw detection is employed it is probable that defect indications from flaws of minor cross section will be obtained. In interpreting the requirements of Table 11A such indications should be considered on the basis of dividing the through thickness into zones as indicated in Fig. 28A.

(2) Except as otherwise provided in 5.4.2.3 and in (1) above, the acceptance levels given in Table 11A and in (3) below shall be applied to butt welds equal to or greater than 25 mm thick where the design stress is based on the tensile or proof stress criteria. (For all other conditions and weld thicknesses see 5.4.2.5.)

Attention is drawn to Figs. 28A, 28B, 28C, 28D, 28E and 28F.

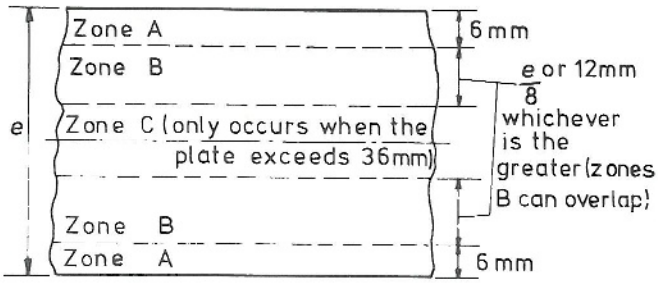
(3) *Groups of inclusions.* Inclusions are considered to be isolated only if they are separated as follows.

a. Linearly aligned (curvilinear or rectilinear, see Figs. 28B and 28C). Linearly aligned inclusions shall be separated by a minimum distance of twice the length of the largest inclusion (see Fig. 28D).

Where inclusions are separated by a distance of less than twice the length of the largest defect they shall be assumed to be continuous and are acceptable up to the length of the longest acceptable defect as given in Table 11A (see Fig. 28D).

Inclusions shall be considered in linear alignment and interacting for the purpose of this clause when they are contained within the envelope defined in Fig. 28D.

b. Randomly oriented inclusions (see Fig. 28E). Inclusions that overlap are acceptable provided that they are contained within an envelope not exceeding 3 mm or $e/15$, whichever is the greater, and are separated by at least $e/4$ from any other envelope or individual inclusion.



Zones A. Indications may only be disregarded by agreement between the manufacturer, the purchaser and the Inspecting Authority. It is recognized that when circumferential welds are made from one side the application of zone A to the inner region may not be practicable. In such cases reference may be made to the requirements of BS 2633 for the root condition.

Zones B. Indications having a dimension h of 2 mm or less may be disregarded provided that the length of an individual indication does not exceed dimension e, with a maximum of 100 mm, and that there is shown to be a separation not less than that specified in 5.4.2.4(3) from any other defect indication.

Zones C. Indications having a dimension h of 3 mm or less may be disregarded provided that the length of an individual indication does not exceed dimension e, with a maximum of 100 mm, and that there is shown to be a separation not less than that specified in 5.4.2.4(3) from any other defect indication. When the through thickness dimension is such that the inner boundaries of zone B overlap, the rules for zone C will not apply.

Fig. 28A. Zoning of weld defects

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TABLE 11A. ACCEPTANCE LEVELS

The acceptance levels given for non-planar defects apply only to zones B and C as defined in 5.4.2.4.

	Defect type	Permitted maximum
Planar defects	Cracks and lamellar tears	Not permitted (but see 5.4.2.4)
	Lack of root fusion Lack of side fusion Lack or inter-run fusion	Not permitted (but see 5.4.2.4)
	Lack of root penetration	Not permitted (but see 5.4.2.4)
Cavities	Isolated pores	Ø not greater than 4 mm
	Uniformly distributed localized porosity, including group porosity, e.g. stop start	2% by area* for e not greater than 50 mm and pro rata for greater thicknesses
	Linear porosity	Linear porosity, i.e. as isolated pores but in alignment, is permitted only if the separation between individual pores is 4 mm or greater to ensure that lack of fusion or lack of penetration is not present
	Wormholes, isolated, or crater pipes	h not greater than 4 mm, w not greater than 2 mm
	Wormholes, aligned	As linear porosity
Slag inclusions	Individual and parallel to major axis	$l = e$ but not greater than 100 mm, w or $h = e/10$ but not greater than 4 mm
	Group of inclusions	See 5.4.2.4(3)

*Area is the product of length and width of an envelope enclosing the affected volume of weld metal measured on a plane substantially parallel to the weld face (i.e. as would appear on a radiograph).

NOTE. For definitions of symbols see Fig. 28F.

5.4.2.5 *Butt welds other than those in 5.4.2.4.* Except as otherwise provided in 5.4.2.3, no butt weld in a drum, shell or header designed to stress rupture criteria or below 25 mm thick designed to tensile or 0·2% proof stress criteria shall be acceptable if it has one or more of the following defects.

(1) Cracks or areas of lack of fusion or incomplete penetration.

(2) Any elongated inclusion having a width exceeding 1·5 mm or length exceeding

a. 6 mm for thicknesses not exceeding 25 mm;

b. one-quarter of the thickness with a maximum of 13 mm for any thickness exceeding 25 mm.

(3) Any group of inclusions in alignment, the total length of which exceeds the thickness over a length of 12 times the thickness, except where the distance between successive defects exceeds six times the length of the longest defect in the group.

(4) *Porosity.* In general no individual gas pocket or porosity should exceed 1·5 mm in its greatest dimension. The total area of porosity projected radially through the weld should not exceed 1% of any 600 mm² of projected weld area in each 25 mm of wall thickness, considering the thinner of the components being joined.

5.4.2.6 *Welds in integral pipework.* Welds in integral pipework shall comply with the requirements of BS 2633 and BS 1821.

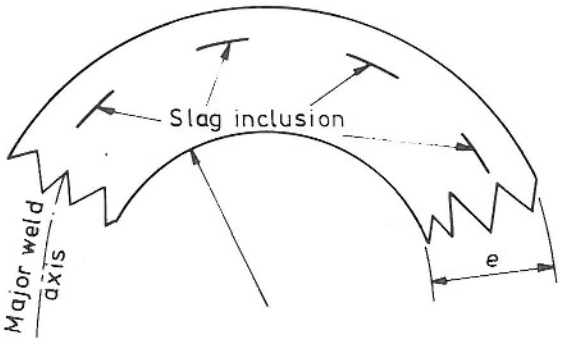


Fig. 28B. Curvilinear (circumferential seam)

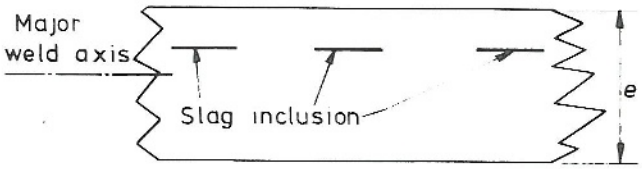


Fig. 28C. Rectilinear (longitudinal seam)

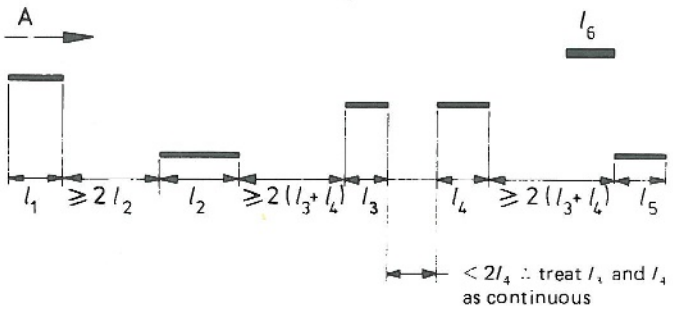


Fig. 28D. Typical example of a group of defects linearly aligned

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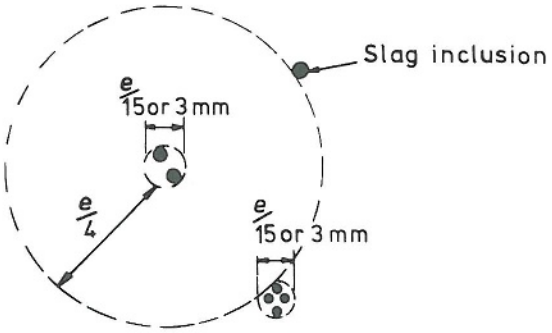
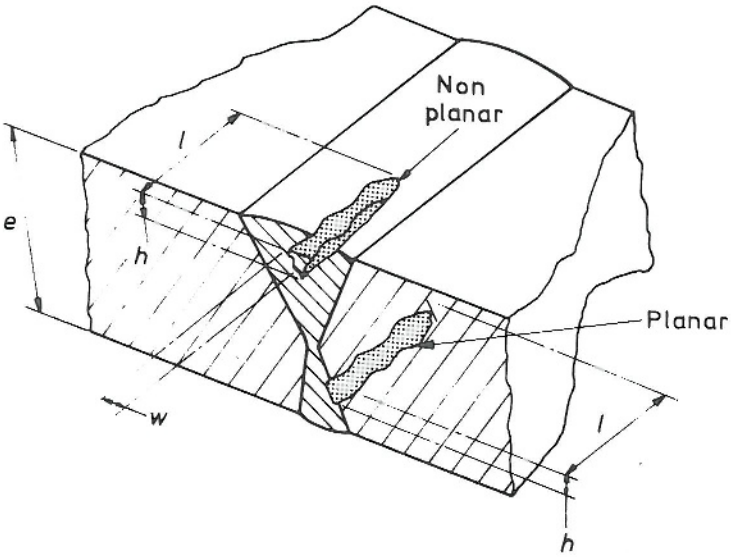


Fig. 28E. Randomly orientated inclusions



Key
l length
h height of defect through the weld
w width of defect accross the weld
e parent metal thickness
In the case of dissimilar thicknesses *e* applies to the thinner component.

Fig. 28F. Dimensioning of defects

Clause 5.4.4.3 In lines 2 and 3 delete 'BS 3889*, Part 4A' and substitute 'BS 4397*'.

At the bottom of the page delete the existing asterisk footnote and substitute the following:

'*BS 4397, 'Methods for magnetic particle testing of welds'.'

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AMD 2464

Amendment Slip No.4, published 28 February 1978
to BS 1113 : 1969

Water tube steam generating plant
(including superheaters, reheaters and steel tube economisers)

Revised text

Clause 5.3.4.4 (1) *b.* (as amended by Amendment No.3)

Delete '(see 5.6.1)' and substitute '(see 5.6.3.2)'.

Clause 5.3.4.6 *Retests.*

Delete first sentence and substitute the following:

'If any test piece shows a result less satisfactory than that which is specified in 5.3.4.1, 5.3.4.2, 5.3.4.3 or 5.3.4.5, the reason for the failure shall be investigated and two retest specimens shall be prepared and tested.'

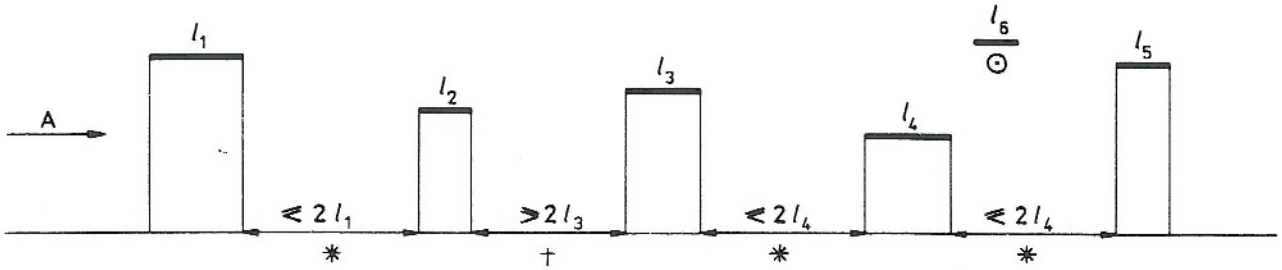
Clause 5.4.2.4 (3) *a. Linearly aligned* (as inserted by Amendment No.3)

At end insert a new fourth paragraph as follows.

'In determining any interaction between adjacent inclusions only the actual inclusion length shall be considered.'

Fig.28D. Typical example of a group of defects linearly aligned (as inserted by Amendment No.3)

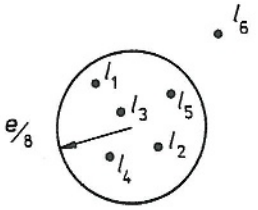
Delete the existing figure and substitute a new figure 28D and associated notes:



* Adjacent defects interactive, refer to table 11A.

† Adjacent defects not interactive

⊙ Defect not enclosed in $e/8$ envelope



1. Inclusions within a group shall be first assessed individually against table 11A.
2. Adjacent inclusions contained within any envelope of radius $e/8$ shall be projected onto a polar centreline and they shall be considered as being linearly aligned.
3. Adjacent inclusions shall be considered as being interactive if the linear separation is equal to or less than twice the length of the longest inclusion in the pair under consideration.
4. If the inclusions are found to be interactive, the actual length of each inclusion plus its separation from its neighbour shall be summated and the resulting length taken as the effective defect length for assessment in accordance with table 11A.

NOTE. Only the actual length of adjacent defects, not their effective length, shall be taken into account when assessing whether they are interactive.

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AMD 3480

Amendment Slip No. 5, published and effective from 30 June 1981
to BS 1113 : 1969

Specification for water-tube steam generating plant
(including superheaters, reheaters and steel tube economisers)

Revised text

Correction to reprints. In the reprints of BS 1113 : 1969 dated May 1978 (code 7805-0.6k at the foot of the last page of the standard) and July 1980 (code 8007.1k) incorporating AMD 1886 dated June 1976, in **3.2.9.2.3**, subclause (3), in lines 5 and 10, delete 'p' and substitute 'ρ'; in subclause (5), in lines 2, 5, 11 and 14 delete '$_p$' and substitute 'ρ'.

CONTENTS. Delete the title of appendix A and substitute the following new title:
'Derivation of material nominal design strengths'.
In the title of appendix E delete 'tables 3, 4, 6 and 12' and substitute 'tables 3, 4 and 6'.

TABLE 1. MATERIALS. Delete the existing table and associated notes and substitute the following new table and notes.

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2)

PLATES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding													Design lifetime h	Notes
				250	300	350	390	400	410	420	430	440	450	460	470	480		
Carbon steel (semi or fully-killed) to BS 1501: Part 1																		
151, 161, 360 (A and B)	360	205	3 to 16	100)	86	81		78		77	76	69	60	52	44	36	100 000	
		195	40	96)							74	65	56	48	40	32	150 000	
		185	63	95)							71	62	53	45	37	28	200 000	
		175	100	91)							68	59	51	42	35	26	250 000	
		170	150	88)														
151, 161, 400 (A and B)	400	225	3 to 16	117)	97	92		89	88	87	79	69	60	52	44	36	100 000	
		215	40	110)					88	83	74	65	56	48	40	32	150 000	
		205	63	108)					88	80	71	62	53	45	37	28	200 000	
		200	100	105)					87	78	68	59	51	42	35	26	250 000	
		195	150	102)														
151, 161, 430 (A and B)	430	250	3 to 16	128)	107	102	100	99	98	88	79	69	60	52	44	36	100 000	
		240	40	121)				99	93	83	74	65	56	48	40	32	150 000	
		230	63	119)				99	90	80	71	62	53	45	37	28	200 000	
		220	100	115)				97	87	78	68	59	51	42	35	26	250 000	
		210	150	110)														

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

PLATES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding													Design lifetime h	Notes
				250	300	350	390	400	410	420	430	440	450	460	470	480		
Carbon steel (fully killed aluminium treated) to BS 1501: Part 1																		
164, 360A	360	255	3 to 16	97	86	79		73	73	72	71	69	60	52	44	36	100 000	
		235	40								71	65	56	48	40	32	150 000	
		220	63								71	62	53	45	37	28	200 000	
		202	100								68	59	51	42	35	26	250 000	
		180	150															
164, 360B	360	255	3 to 16	107	95	87		83	82	81	79	69	60	52	44	36	100 000	
		235	40							81	74	65	56	48	40	32	150 000	
		220	63							80	71	62	53	45	37	28	200 000	
		202	100							78	68	59	51	42	35	26	250 000	
		180	150															
164, 400A	400	275	3 to 16	111	98	91		86	85	84	79	69	60	52	44	36	100 000	
		265	40							83	74	65	56	48	40	32	150 000	
		245	63							80	71	62	53	45	37	28	200 000	
		225	100							78	68	59	51	42	35	26	250 000	
		201	150															
164, 400B	400	275	3 to 16	121	108	101		95	94	88	79	69	60	52	44	36	100 000	
		265	40						93	83	74	65	56	48	40	32	150 000	
		245	63						90	80	71	62	53	45	37	28	200 000	
		225	100						87	78	68	59	51	42	35	26	250 000	
		201	150															
Carbon manganese steel (fully killed niobium treated) to BS 1501: Part 1																		
223, 460A	460	340	3 to 16	143	130	124	117	115	114	104	90	77	65	56	48	42	100 000	
		330	40					115	111	95	81	68	58	50	43	37	150 000	
		320	63					115	104	88	75	63	54	46	40	34	200 000	
		294	100					115	98	83	70	59	51	43	37	31	250 000	
		262	150															

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

PLATES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding													Design lifetime h	Notes
				250	300	350	390	400	410	420	430	440	450	460	470	480		
Carbon manganese steel (fully killed niobium treated) to BS 1501: Part 1																		
223, 460B	460	340	3 to 16	158	139	131	125	124	121	104	90	77	65	56	48	42	100 000	
		330	40					124	111	95	81	68	58	50	43	37	150 000	
		320	63					121	104	88	75	63	54	46	40	34	200 000	
		294	100					115	98	83	70	59	51	43	37	31	250 000	
		262	150															
223, 490A	490	355	3 to 16	158	139	131	123	122	121	104	90	77	65	56	48	42	100 000	
		345	40					122	111	95	81	68	58	50	43	37	150 000	
		340	63					121	104	88	75	63	54	46	40	34	200 000	
		313	100					115	98	83	70	59	51	43	37	31	250 000	
		279	150															
223, 490B	490	355	3 to 16	168	147	137	133	132	121	104	90	77	65	56	48	42	100 000	
		345	40					128	111	95	81	68	58	50	43	37	150 000	
		340	63					121	104	88	75	63	54	46	40	34	200 000	
		313	100					115	98	83	70	59	51	43	37	31	250 000	
		279	150															
Carbon manganese steel (fully killed aluminium treated) to BS 1501: Part 1																		
224, 400A	400	275	3 to 16	111	98	91		86	85	84	83	77	65	56	48	42	100 000	
		265	40							84	81	68	58	50	43	37	150 000	
		245	63							84	75	63	54	46	40	34	200 000	
		225	100							83	70	59	51	43	37	31	250 000	
		201	150															
224, 400B	400	275	3 to 16	121	108	101		95	94	93	90	77	65	56	48	42	100 000	
		265	40							93	81	68	58	50	43	37	150 000	
		245	63							88	75	63	54	46	40	34	200 000	
		225	100							83	70	59	51	43	37	31	250 000	
		201	150															

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (continued)

PLATES

Grade, type and method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding													Design lifetime h	Notes
				250	300	350	390	400	410	420	430	440	450	460	470	480		
Carbon manganese steel (fully killed aluminium treated) to BS 1501: Part 1																		
224, 430A	430	305 285 275 253 225	3 to 16 40 63 100 150	121	108	101		95	94	93 93 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	
224, 430B	430	305 285 275 253 225	3 to 16 40 63 100 150	132	117	111		105	104 104 104 98	103 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	
224, 460A	460	325 315 305 281 250	3 to 16 40 63 100 150	132	117	111		105	104 104 104 98	103 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	
224, 460B		325 315 305 281 250	3 to 16 40 63 100 150	142	128	121	116	115 115 115 115	114 111 104 98	104 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	
224, 490 (A and B)	490	325 315 305 281 250	3 to 16 40 63 100 150	142	128	121	116	115 115 115 115	114 111 104 98	104 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

PLATES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding 250	300	350	390	400	410	420	430	440	450	460	470	480	Design lifetime h	Notes
Carbon manganese steel (fully killed niobium and aluminium treated) to BS 1501: Part 1																		
225, 490A	490	355	3 to 16	158	139	131	123	124	121	104	90	77	65	56	48	42	100 000	
		345	40					124	111	95	81	68	58	50	43	37	150 000	
		340	63					121	104	88	75	63	54	46	40	34	200 000	
		313	100					115	98	83	70	59	51	43	37	31	250 000	
		279	150															
225, 490B	490	355	3 to 16	168	147	137	133	132	121	104	90	77	65	56	48	42	100 000	
		345	40					128	111	95	81	68	58	50	43	37	150 000	
		340	63					121	104	88	75	63	54	46	40	34	200 000	
		313	100					115	98	83	70	59	51	43	37	31	250 000	
		279	150															

PLATES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding 250	300	350	400	440	450	460	480	490	500	510	520	530	540	550	560	570	580	Design lifetime h	Notes
Low alloy steel to BS 1501: Part 2																							
271	586	464	Up to 25	217	217	217	217		217)	209*	155		107		69		41	30				100 000	10(a)
MnCrMoV	556	417	25 to 76	206	206	206	206		206)														
	556	386	76 to 152	206	206	201	194		193)	192	131		87		51		36	18				200 000	
281	586	464	Up to 25	217	217	217	217)	201*	188	168	124				55		33	24				100 000	10(b)
NiCrMoV	556	417	25 to 76	206	206	206	206)																
	556	386	76 to 152	206	206	201	194)	193	177	152	105		69		40		21	14				200 000	

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

PLATES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding																	Design lifetime h	Notes
				250	300	350	400	440	450	460	480	490	500	510	520	530	540	550	560	570	580	
Low alloy steel to BS 1501: Part 2																						
620-27A 1Cr½Mo	417	286	Up to 152	115	98	93	90		89													
620-27B 1Cr½Mo	417	286	Up to 152	124	105	100	97		95			94	94 94 94 87	93 83 76 70	76 67 61 57	62 55 49 45	51 44 40 37	42 35 32 30	33 29 26 25	27 24 22 20		100 000 150 000 200 000 250 000	
620-621 31A 1Cr½Mo 1¼Cr½Mo	479 448	340 317	Up to 75 75 to 152	154 136	141 120	133 114	129 109		126 108		120 106											
620-621 31B 1Cr½Mo 1¼Cr½Mo	479 448	340 317	Up to 75 75 to 152	166 146	151 129	143 122	139 117		134 115		120) 113)	113 113 113 107	112 101 94 87	93 83 76 70	76 67 61 57	62 55 49 45	51 44 40 37	42 35 32 30	33 29 26 25	27 24 22 20		100 000 150 000 200 000 250 000	
622-31A 2¼Cr1Mo	479	278	Up to 152	125	123	120	115		110		105											
622-31B 2¼Cr1Mo	479	278	Up to 152	134	132	129	124		117		112	109 108 104 100	105 97 91 87	94 85 79 75	82 73 68 65	72 63 59 57	61 56 52 49	53 48 45 42	45 41 38 36	39 36 33 32	34 31 28 27	100 000 150 000 200 000 250 000	5
622-45A 2¼Cr1Mo	687	556	Up to 152	254	254	254	206		145		126											
622-45B 2¼Cr1Mo	687	556	Up to 152	254	254	254	220		170 161 156 152	157 148 143 139	131 121 117 113	118 108 104 100	105 97 91 87	94 85 79 75	82 73 68 65	72 63 59 57	61 56 52 49	53 48 45 42	45 41 38 36	39 36 33 32	34 31 28 27	100 000 150 000 200 000 250 000	5

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PLATES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding																				Design lifetime h	Notes
				250	300	350	400	450	500	520	540	550	560	580	600	620	640	650	660	680	700	720	740	750	
High alloy steel to BS 1501: Part 3																									
304-S49	510	216	Up to 51	97	94	90	88	86	82		82	81 81 78 75	81 76 72 68	68 62 58 56	57 51 48 45	47 41 38 36	38 33 31 28	35 30 27 25	31 26 24 22	23 20 18 17	18 15				100 000 150 000 200 000 250 000	6
321-S12	510	247	Up to 20	132	128	126	122	119	116	115	124* 113 109 102	114 109 102 95	104 94 88 83	86 78 74 71	71 64 58 55	57 49 45 42	42 36 33 31	36 32 28 26	31 27 25 22						100 000 150 000 200 000 250 000	11
321-S49	490	193	Up to 51	106	103	99	96	94	90	88	87	86	85	83	81 76 72 68	68 61 58 55	55 50 46 44	49 44 41 38	44 38 35 33	34 29 27 25	26				100 000 150 000 200 000 250 000	
347-S49	510	216	Up to 51	116	114	113	111	107	104	102	99	98	96	93 93 88 85	81 75 71 68	66 61 58 55	53 48 45 42	47 41 39 37	41 37 34 31	31 28 25 24	24 21 19 19				100 000 150 000 200 000 250 000	7

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

PLATES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding																					Design lifetime h	Notes
				250	300	350	400	450	500	520	540	550	560	580	600	620	640	650	660	680	700	720	740	750		
High alloy steel to BS 1501: Part 3																										
316-S49	510	216	Up to 51	97	94	90	88	86	82	80	79	78	77	75	74	72 66 61 58	58 52 48 45	53 46 43 40	46 41 37 35	35 31 29 27	28 25 22 21	23 19 18 18			100 000 150 000 200 000 250 000	6

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

STEEL BOILER AND SUPERHEATER TUBES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding													Design lifetime h	Notes
				250	300	350	390	400	410	420	430	440	450	460	470	480		
Carbon steel to BS 3059: Part 1																		
320 HFS, CFS, ERW & CEW	320	195		86	77	71		68										
Carbon and carbon manganese steel tubes to BS 3059: Part 2																		
360 S1, S2, ERW & CEW	360	215		111	97	87		78		77	76 73 71 68	69 65 62 59	60 56 53 51	52 48 45 42	44 40 37 35	36 32 28 26	100 000 150 000 200 000 250 000	8
440 S1, S2, ERW & CEW	440	245		134	119	106		101	101	100 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	8

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

STEEL BOILER AND SUPERHEATER TUBES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding																				Design lifetime h	Notes
				250	300	350	400	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	
Alloy steel to BS 3059: Part 2																									
243–450 0.3 Mo S1, S2, ERW & CEW	450	250		137	117	106	103		100		98	97 97 97 95	94 87 81 77	78 70 65 62	62 57 53 50	52 46 42 40	41 37 34 32	32 30 28 25							100 000 150 000 200 000 250 000	
620–460 1Cr ½Mo S1, S2, ERW & CEW	460	180		129	129	129	120		116			114	113 113 113 107	112 102 94 88	93 83 76 70	76 67 61 57	62 55 49 45	52 44 40 37	42 35 32 30	33 29 26 25	27 25 22 20				100 000 150 000 200 000 250 000	8
622–490 2¼Cr 1Mo S1, S2	490	275		157	153	149	145		137	135	133 133 130 126	131 122 117 113	118 108 104 100	105 97 92 87	94 85 79 75	82 73 68 65	72 63 59 57	61 56 52 49	53 48 45 42	45 42 38 36	39 36 33 32	34 31 28 27	29 27 25 23	26 23 22 20	100 000 150 000 200 000 250 000	2, 5
629–590 9Cr 1Mo S1, S2	590	400		219	217	215	211	208	207 207 204 199	195 188 183 179	176 169 165 159	159 152 147 144	144 137 132 129	129 123 118 114	115 110 105 101	103 97 93 89	91 85 81 78	80 74 69 66	68 62 58 54	57 52 47 44	48 42 38 35	38 34 31 28	31 28 25 24	26 23 22 21	100 000 150 000 200 000 250 000	
762–720 12CrMo V S1, S2	720	470		241	234	230	225		215			205	201 199 194 190	191 184 180 176	173 168 164 160	155 152 146 142	138 135 128 124	122 115 110 105	107 98 94 90	93 85 80 77	80 72 68 65	69 62 58 55	58 52 49 46	48 44 41 38	100 000 150 000 200 000 250 000	

[AMD 3480]

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) *(continued)*

STEEL BOILER AND SUPERHEATER TUBES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding																				Design lifetime h	Notes
				250	300	350	400	450	500	540	550	560	570	580	590	600	610	620	630	640	650	660	680	700		
Austenitic steel to BS 3059: Part 2																									
304-S59 (490) CFS	490	235		101	97	94	91	88	86	82	81 81 78 75	81 76 72 68	75 68 65 61	68 62 58 56	62 57 53 51	57 51 48 45	52 46 43 41	47 41 38 36	42 37 35 32	38 33 31 28	35 30 27 25	31 26 24 22	23 20 18 17	18 15	100 000 150 000 200 000 250 000	6, 8
316-S59 CFS	510	245		111	106	102	98	96	93		90			89	88 88 88 85	88 85 79 75	81 75 70 66	74 66 61 58	66 58 55 51	58 52 48 45	53 46 43 40	46 41 37 35	35 31 29 27	28 25 22 21	100 000 150 000 200 000 250 000	8 6
321-S59 (1010)	510	235		121	117	112	110	107	104	102	102 101 97 93	101 93 89 85	95 86 82 78	86 78 74 71	78 71 66 62	71 64 58 55	63 56 51 48	57 49 45 42	49 42 38 35	42 36 33 31	36 31 28 26				100 000 150 000 200 000 250 000	
321-S59 (1105) CFS	490	195		93	87	84	82	79	77		76				75	75 75 71 68	74 68 65 61	68 61 58 55	60 56 52 49	55 50 46 44	49 44 41 38	44 38 35 33	34 29 27 25		100 000 150 000 200 000 250 000	8
347-S59 CFS	510	245		135	130	124	122	119	119	117	117 117* 116 112	116 111 106 102	109 102 98 94	99 93 88 85	91 84 79 76	81 75 71 68	74 68 64 61	66 61 58 55	59 54 51 48	53 48 45 42	47 41 39 37	41 37 34 31	31 28 25 24		100 000 150 000 200 000 250 000	7, 8
1250	540	270		141	138	136	135	133	132		130					126		124 124 124 118	123 114 104 96	107 93 83 76	87 75 67 62	71 62 56 52	52 46 42 40	40 35 32	100 000 150 000 200 000 250 000	

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

STEEL PIPES AND TUBES FOR PRESSURE PURPOSES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding													Design lifetime h	Notes
				250	300	350	390	400	410	420	430	440	450	460	470	480		
Seamless and electric resistance welded carbon and carbon manganese steel to BS 3601																		
320 ERW, S	320	195		86	77	71		68										
360 ERW, S	360	215		96	86	79		75										
410 ERW, S	410	235		109	98	90		82										
Seamless, electric resistance, induction or submerged arc welded carbon and carbon manganese steel to BS 3602: Parts 1 and 2																		
360 HFS, CFS, ERW & CEW	360	215		111	97	87		78		77	76 73 71 68	69 65 62 59	60 56 53 51	52 48 45 42	44 40 37 35	36 32 28 26	100 000 150 000 200 000 250 000	8
410 HFS, CFS, ERW, CEW & SAW	410	245		119	105	96		92	91 91 89 87	88 83 80 78	78 74 71 68	69 65 62 59	60 56 53 51	52 48 45 42	44 40 37 35	36 32 28 26	100 000 150 000 200 000 250 000	8, 9
460 HFS, CFS, ERW, CEW & SAW	460	280		135	121	112		106	105 105 104 98	104 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 38 34 32	100 000 150 000 200 000 250 000	4, 9
490-Nb HFS, CFS	490	340		160	145	133	125	123 123 121 115	121 111 104 98	105 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 38 34 32	100 000 150 000 200 000 250 000	

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

STEEL PIPES AND TUBES FOR PRESSURE PURPOSES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding																					Design lifetime h	Notes
				250	300	350	400	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600		
Seamless, electric resistance or induction welded alloy steel to BS 3604																										
620–440 1Cr ½Mo HFS, CFS, ERW & CEW	440	290		157	128	121	116		112			112	111 111 111 107	111 102 94 88	93 83 76 70	76 67 61 57	62 55 49 45	52 44 40 37	42 35 32 30	33 29 26 25	27 25 22 20				100 000 150 000 200 000 250 000	
620–460 1Cr ½Mo HFS, CFS, ERW & CEW	460	180				129	120		116			114	113 113 113 107	112 102 94 88	93 83 76 70	76 67 61 57	62 55 49 45	52 44 40 37	42 35 32 30	33 29 26 25	27 25 22 20				100 000 150 000 200 000 250 000	3, 8
621–420 1¼Cr ½Mo HFS, CFS, ERW & CEW	420	275		145	116	110	105		101			100	100	100 100 94 88	93 83 76 70	76 67 61 57	62 55 49 45	52 44 40 37	42 35 32 30	33 29 26 25	27 24 22 20				100 000 150 000 200 000 250 000	
660–460 ½Cr Mo V HFS, CFS	460	300		161	150	144	139		135			134	133 133 130 123	131 120 112 106	115 105 98 92	101 92 84 78	89 78 70 64	77 65 58 52	65 54 47 42	55 44 37 32	45 35 28 25				100 000 150 000 200 000 250 000	5
622–490 2¼Cr 1Mo HFS, CFS	490	275		157	153	149	145		137	135	133 133 130 126	131 122 117 113	118 108 104 100	105 97 92 87	94 85 79 75	82 73 68 65	72 63 59 57	61 56 52 49	53 48 45 42	45 42 38 36	39 36 33 32	34 31 28 27	29 27 25 23	26 23 22 20	100 000 150 000 200 000 250 000	2, [illegible]
623–590 ¼Cr 1Mo HFS, CFS	590	400		219	217	215	211	208	207 207 204 199	195 188 183 179	176 169 165 159	159 152 147 144	144 137 132 129	129 123 118 114	115 110 105 101	103 97 93 89	91 85 81 78	80 74 69 66	68 62 58 54	57 52 47 44	48 42 38 35	38 34 31 28	31 28 25 24	26 23 22 21	100 000 150 000 200 000 250 000	
722–720 ¼Cr Mo V HFS, CFS	720	470		241	234	230	225		215			205	201 199 194 190	191 184 180 176	173 168 164 160	155 152 146 142	138 135 128 124	122 115 110 105	107 98 94 90	93 85 80 77	80 72 68 65	69 62 58 55	58 52 49 46	48 44 41 38	100 000 150 000 200 000 250 000	

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

STEEL PIPES AND TUBES FOR PRESSURE PURPOSES

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Values of f for design temperatures (°C) not exceeding																				Design lifetime h	Notes
				250	300	350	400	450	500	520	540	550	560	580	600	620	640	650	660	680	700	720	740	750		
Seamless and welded austenitic stainless steel to BS 3605																									
304-S59E (S)	490	235		101	97	94	91	88	82		82	81 81 78 75	81 76 72 68	68 62 58 56	57 51 48 45	47 41 38 36	38 33 31 28	35 30 27 25	31 26 24 22	23 20 18 17	18 15				100 000 150 000 200 000 250 000	6
316-S59E (S)	510	245		122	117	112	108	104				96		94	91 85 79 75	72 66 61 58	58 52 48 45	53 46 43 40	46 41 37 35	35 31 29 27	28 25 22 21	23 19 18 18			100 000 150 000 200 000 250 000	6
321-S59E (S) (1010)	510	235		127	125	122	118	116	115	115	114 113 109 102	114 109 102 95	104 94 88 83	86 78 74 71	71 64 58 55	57 49 45 42	42 36 33 31	36 32 28 26	31 27 25 22						100 000 150 000 200 000 250 000	
321-S59E (S) (1105)	490	195		102	99	96	93	89	87			84		83	81 76 72 68	68 61 58 55	55 50 46 44	49 44 41 38	44 38 35 33	34 29 27 25	26				100 000 150 000 200 000 250 000	
347-S59E (S)	510	245		136	132	128	125	122	120		118	118 118 116 112	118 111 106 102	99 93 88 85	81 75 71 68	66 61 58 55	53 48 45 42	47 41 39 37	41 37 34 31	31 28 25 24	24 21 19 19				100 000 150 000 200 000 250 000	7

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

SECTIONS AND BARS

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Thickness mm	Diameter	Values of f for design temperatures (°C) not exceeding									Design lifetime h	Notes
					250	300	350	400	410	420	430	440	450		
Carbon steel (semi or silicon killed) to BS 1502															
151, 161 28	432	247 231 228	Up to 16 16 to 32 32 to 64	Up to 25 25 to 51 51 to 102	115	104	95	89		87 87 82 78	84 75 69 65	71 63 58 54	60 54 49 46	100 000 150 000 200 000 250 000	1(d)
Carbon manganese steel (semi or silicon killed) to BS 1502															
211, 221 28	432	254 246 239	Up to 16 16 to 32 32 to 64	Up to 25 25 to 51 51 to 102	126	107	98	94	93	92 92 88 83	90 81 75 70	77 68 63 59	65 58 54 51	100 000 150 000 200 000 250 000	1(d)
Carbon manganese steel (silicon killed, aluminium treated) to BS 1502															
224 28	432	285 270 254	Up to 25 25 to 51 51 to 102		116	104	97	91	90 90 90 87	88 83 80 77	79 74 71 68	69 64 61 59	60 56 53 51	100 000 150 000 200 000 250 000	1(d)

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TABLE 1. DESIGN STRENGTH VALUES (N/mm^2) (*continued*)

FORGINGS

Grade, type & method of manufacture	R_m N/mm^2	R_e N/mm^2	Ruling section (see note (d)) mm	Values of f for design temperatures (°C) not exceeding													Design lifetime h	Notes
				250	300	350	390	400	410	420	430	440	450	460	470	480		
Carbon manganese steel to BS 1503																		
221-410	410	215 205	⩽ 100 > 100	112) 108)	100	95		92		92 92 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	1(a), 12
221-430	430	225 215	⩽ 100 > 100	119) 115)	107	102		99	99 99 99 98	98 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	1(a), 12
221-460	460	245 235	⩽ 100 > 100	129) 125)	117	112		108	108 108 104 98	104 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	1(a), 12
221-490	490	265 255	⩽ 100 > 100	140) 135)	128	122	119	118 118 118 115	118 111 104 98	104 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	1(a), 12
221-510	510	285	⩽ 100	147	135	129	125	124 124 121 115	121 111 104 98	104 95 88 83	90 81 75 70	77 68 63 59	65 58 54 51	56 50 46 43	48 43 40 37	42 37 34 31	100 000 150 000 200 000 250 000	1(a), 12

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