heat treatment when required for the drum, but omitting volumetric examination. When the weld is not deposited at the inner face of the header, the thickness of the head that remains unwelded shall be in addition to the thickness of the head calculated per PG-31.3.2. The drum or header shall be limited to NPS 4 or less.

\[ C = 0.33 \text{ for noncircular plates, welded to the inside of a drum, pipe, or header. The minimum throat thickness of the inside fillet weld shall be } 0.7 t_w \text{. The size of the weld } t_w \text{ in illustration (g-1) shall be not less than } 2 \text{ times the required thickness of a seamless shell and not less than } 1.25 \text{ times the nominal shell thickness but need not be greater than the head thickness; the weld shall be deposited in a welding groove with the root of the weld at the inner face of the header as shown in the figure.}\]

Figure PG-31, illustration (i-1): \( C = 0.33 \) but not less than 0.20 for circular plates welded to the end of the drum, pipe, or header. The minimum throat thickness of the inside fillet weld shall be 0.7 \( t_s \), the width at the bottom of the welding groove shall be not less than \( \frac{1}{3} d \), and the exposed edge not less than \( t_s \) or \( \frac{1}{4} d \), whichever is smaller.

Figure PG-31, illustration (i-2): \( C = 0.33 \) for circular plates welded to the end of the drum, pipe, or header. The thickness \( t_s \) shall not be less than 1.25\( t_w \). The width at the bottom of the welding groove shall be not less than \( \frac{1}{3} d \), and the exposed edge not less than \( t_s \) or \( \frac{1}{4} d \), whichever is smaller. The circular plate shall be inserted a minimum of \( \frac{1}{3} d \) into the end of the drum, pipe, or header.

Figure PG-31, illustrations (j) and (k): \( C = 0.3 \) for circular and noncircular heads and covers bolted to the shell, flange, or side plate as indicated in the figures. Note that eq. PG-31.3.2(2) or eq. PG-31.3.3(5) shall be used because of the extra moment applied to the bolting by the bolting. When the cover plate is grooved for a peripheral gasket, as shown in illustration (k), the net cover plate thickness under the groove or between the groove and the outer edge of the cover plate shall be not less than

\[ d \left( \frac{1.9W h_G}{S d^3} \right) \]

for circular heads and covers, and not less than

\[ d \left( \frac{6W h_G}{S L d^2} \right) \]

for noncircular heads and covers.

Figure PG-31, illustrations (m), (n), and (o): \( C = 0.3 \) for a circular plate inserted into the end of a shell, pipe, or header and held in place by a positive mechanical locking arrangement, and when all possible means of failure either by shear, tension, compression, or radial deformation, including flaring, resulting from pressure and differential thermal expansion, are resisted with a factor of safety of at least 4. Seal welding may be used, if desired.

Figure PG-31, illustration (p): \( C = 0.25 \) for circular and noncircular covers bolted with a full-face gasket to shell, flanges, or side plates.

Figure PG-31, illustration (q): \( C = 0.75 \) for circular plates screwed into the end of a shell, pipe, or header having an inside diameter \( d \) not exceeding 12 in. (300 mm); or for heads having an integral flange screwed over the end of a shell, pipe, or header having an inside diameter \( d \) not exceeding 12 in. (300 mm); and when the design of the threaded joint against failure by shear, tension, compression, or radial deformation, including flaring, resulting from pressure and differential thermal expansion, is based on a factor of safety of at least 4. If a tapered pipe thread is used, the requirements of Table PG-39 shall be met. Seal welding may be used, if desired.

Figure PG-31, illustration (r): \( C = 0.33 \) for circular plates having a dimension \( d \) not exceeding 18 in. (450 mm) inserted into the shell, pipe, or header and welded as shown, and otherwise meeting the requirements for welded boiler drums including postweld heat treatment but omitting volumetric examination. The end of the shell, pipe, or header shall be crimped over at least 30 deg, but not more than 45 deg. The crimping may be done cold only when this operation will not injure the metal. The throat of the weld shall be not less than the thickness of the flat head or the shell, pipe, or header, whichever is greater.

Figure PG-31, illustration (s): \( C = 0.33 \) for circular beveled plates having a diameter \( d \), not exceeding 18 in. (450 mm) inserted into a shell, pipe, or header, the end of which is crimped over at least 30 deg, but not more than 45 deg, and when the undercutting for seating leaves at least 80% of the shell thickness. The beveling shall be not less than 75% of the head thickness. The crimping shall be done when the entire circumference of the cylinder is uniformly heated to the proper forging temperature for the material used. For this construction, the ratio \( t_w/d \) shall be not less than the ratio \( P/S \) and not less than 0.05. The maximum allowable working pressure for this construction shall not exceed \( P = S/5d \) \((P = 5S/d)\).

**OPENINGS AND COMPENSATION**

PG-32 OPENINGS IN SHELLS, HEADERS, AND DISHED HEADS

PG-32.1 The rules for openings and compensation in PG-32 through PG-39 shall apply to all openings in shells, headers, and dished heads except as otherwise provided in PG-29.3, PG-29.7, PG-29.12, PG-32.1.2, PG-32.1.4, PG-32.1.5, and PFT-40.
the diameter of which is equal to 80% of the shell inside diameter, \( t_r \), is the thickness required for a seamless hemispherical head of radius equal to 90% of the inside diameter of the shell 

\[
t_{rn} = \frac{90}{80} \times t_r 
\]

by the formula used for \( t_r \) for the shell, omitting the \( C \) factor (the value of \( S \) used in determining \( t_{rn} \) shall be based on the nozzle material). The value of \( t_{rn} \) shall be taken as zero for the entire wall of manhole and handhole rings projecting internally with the cover on the inside.

\[
w_d = \frac{90}{80} \times t_r 
\]

width of the nozzle inserted into the vessel wall beyond \( t_n \), not greater than the larger of \( d/2 - t_n \) or \( t \) (see Figure PG-33.2)

PG-34 FLANGED-IN OPENINGS IN FORMED HEADS

PG-34.1 All openings in torispherical, ellipsoidal, and hemispherical heads shall be provided with reinforce-

PG-35 COMPENSATION REQUIRED FOR OPENINGS IN FLAT UNSTAYED HEADS AND FLAT STAYED PLATES

PG-35.1 General. The rules in this paragraph apply to all openings other than small openings covered by PG-32.1.4(b).

PG-35.2 Flat unstayed heads that have an opening with a diameter that does not exceed one-half of the head diameter or shortest span, as defined in PG-31, shall have a total cross-sectional area of compensation not less than 0.5 times the required area specified in PG-33.2.

As an alternative, the thickness may be increased to provide the necessary openings compensation as specified in PG-35.2.1 and PG-35.2.2

PG-35.2.1 By using \( 2C \) or 0.75 in place of \( C \), whichever is less, in eq. PG-31.3.2(1) or eq. PG-31.3.3(3) for calculating head thickness in PG-31.3 or

PG-35.2.2 In eq. PG-31.3.2(2) or eq. PG-31.3.3(5) by doubling the quantity under the square root sign.

PG-35.3 Flat unstayed heads that have an opening with a diameter that exceeds one-half of the head diameter or shortest span, as defined in PG-31.3, shall be designed as provided in PG-16.1.

PG-35.4 Openings in flat stayed plates such as waterlegs and tubesheets of firetube boilers shall have a total cross-sectional area of compensation not less than 0.5 \( d t \), where

\[
d = \text{for circular openings, the diameter of the finished opening; for elliptical openings, the major axis of the finished opening; or for other shapes, the maximum span}
\]

\[
t = \text{the required thickness for the stayed surface calculated in accordance with PG-46 using the maximum distance between stays, tubes, or other support in the area where the opening resides}
\]

PG-36 LIMITS OF METAL AVAILABLE FOR COMPENSATION

PG-36.1 The boundaries of the cross-sectional area any plane normal to the vessel wall and passing through the center of the opening within which area metal must be located in order to have value as compensation are designated as the limits of compensation for that plane (see Figure PG-33.1).

PG-36.2 The limits of compensation, measured parallel to the vessel wall, shall be at a distance, on each side of the axis of the opening, equal to the greater of the following:

PG-36.2.1 The diameter of the finished opening.

PG-36.2.2 The radius of the finished opening plus the thickness of the vessel wall, plus the thickness of the nozzle wall.

PG-36.3 The limits of compensation, measured normal to the vessel wall, shall conform to the contour of the surface at a distance from each surface equal to the smaller of the following:

PG-36.3.1 2\( \text{\( \frac{1}{2} \)} \) times the nominal shell thickness.

PG-36.3.2 2\( \text{\( \frac{1}{2} \)} \) times the nozzle-wall thickness plus the thickness of any added compensation, exclusive of weld metal on the side of the shell under consideration.

PG-36.4 Metal within the limits of reinforcement that may be considered to have reinforcing value shall include the following:

PG-36.4.1 Metal in the vessel wall over and above the thickness required to resist pressure. The area of the vessel wall available as compensation is the larger of the values of \( A_1 \) given by the equations shown in Figure PG-33.1.

PG-36.4.2 Metal over and above the thickness required to resist pressure in that part of a nozzle wall extending outside the vessel wall. The maximum area in the
Step 5. Compute the value of the required moment of inertia $I_s$ by the following equation:

$$I_s = \frac{D_0^2I_s[t + (A_s/L_s)]A}{14}$$

Step 6. If the required $I_s$ is greater than the moment of inertia $I$ for the section selected in Step 1, select a new section with a larger moment of inertia and determine a new value of $I_s$.

If the required $I_s$ is smaller than $I$ for the section selected in Step 1, that section should be satisfactory.

**PFT-18 CORRUGATED FURNACES**

**PFT-18.1** The maximum allowable working pressure on corrugated furnaces, such as the Leeds suspension bulb, Morison, Fox, Purves, or Brown, having plain portions at the ends not exceeding 9 in. (230 mm) in length (except flues especially provided for), when new and practically circular, shall be computed as follows:

$$P = \frac{Cl}{D}$$

where

$C = 17,300$ (119), a constant for Leeds furnaces, when corrugations are not more than 8 in. (200 mm) from center to center and not less than $2^{1/4}$ in. (57 mm) deep

$= 15,600$ (108), a constant for Morison furnaces, when corrugations are not more than 8 in. (200 mm) from center to center and not less than $1^{1/4}$ in. (32 mm) deep, and the radius of the outer corrugation $r$, is not more than one-half of the radius of the suspension curve $R$ (see Figure PFT-18.1)

$= 14,000$ (97), a constant for Fox furnaces, when corrugations are not more than 8 in. (200 mm) from center to center and not less than $1^{1/2}$ in. (38 mm) deep

$= 14,000$ (97), a constant for Purves furnaces, when rib projections are not more than 9 in. (230 mm) from center to center and not less than $1^{3/9}$ in. (35 mm) deep

$= 14,000$ (97), a constant for Brown furnaces, when corrugations are not more than 9 in. (230 mm) from center to center and not less than $1^{5/8}$ in. (41 mm) deep

$D =$ mean diameter

$P =$ maximum allowable working pressure

$t =$ thickness, not less than $\frac{3}{16}$ in. (8 mm) for Leeds, Morison, Fox, and Brown, and not less than $\frac{7}{16}$ in. (11 mm) for Purves furnaces

In calculating the mean diameter of the Morison furnace, the least inside diameter plus 2 in. (50 mm) may be taken as the mean diameter.

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**PFT-19 COMBINED PLAIN CIRCULAR AND CORRUGATED TYPE**

Combination type furnaces for external pressure may be constructed by combining a plain circular section and a corrugated section provided

**PFT-19.1** Each type of furnace is designed to be self-supporting, requiring no support from the other furnace at their point of connection.

**PFT-19.2** Paragraphs PG-28.3 and PFT-15 are used for calculating the maximum allowable working pressure of the plain section. In applying the length in the text, or $L$ in the equations, the value used shall always be twice the actual length of the plain section. The actual length of the plain section is the distance measured from the center line of the head attachment weld to the center line of the full penetration weld joining the two sections.

**PFT-19.3** The maximum allowable working pressure of the corrugated section shall be determined from PFT-18.

**PFT-19.4** The full penetration weld joining a plain self-supporting section to a corrugated self-supporting section shall be located as shown in Figure PFT-19.

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**PFT-20 ATTACHMENT OF FURNACES**

**PFT-20.2** Fillet-Welded Construction. In a scotch type boiler, a furnace may be attached to an outwardly flanged opening in a front tubesheet by a circumferential
fillet weld, or a furnace may be attached to either tubesheet by flaring the end that extends beyond the outside face of the head to an angle of 20 deg to 30 deg, and using a circumferential fillet weld, provided the requirements of PFT-20.2.1 through PFT-20.2.5 are met.

PFT-20.2.1 The area of the head around the furnace is stayed by tubes, stays, or both in accordance with the requirements of this Section.

PFT-20.2.2 The joint is wholly outside the furnace.

PFT-20.2.3 The throat dimension of the full fillet weld is not less than 0.7 times the thickness of the head.

PFT-20.2.4 Unless protected by refractory material, the furnace does not extend beyond the outside face of the tubesheet a distance greater than the thickness of the tubesheet. Any excess shall be removed before welding.

PFT-20.2.5 The construction conforms in all other respects to the requirements of this Section including welding and postweld heat treating, except that volumetric examination is not required.

PFT-20.3 Full Penetration Weld Construction. A furnace may be attached by a full penetration weld with the furnace extending at least through the full thickness of the tubesheet or head but not beyond the toe of the weld, and the toe shall not project beyond the face of the tubesheet or head by more than \( \frac{3}{8} \) in. (10 mm) unless protected from overheating by refractory material or other means. Alternatively, the furnace may abut the tubesheet or head with a full-penetration weld made through the furnace. The weld may be applied from either or both sides and shall have an external fillet weld with a minimum throat of \( \frac{3}{8} \) in. (6 mm). No weld preparation machining shall be performed on the flat tubesheet or head. The edge of the tubesheet or head shall be examined when required by PG-93 and shall not extend beyond the edge of the furnace by more than \( \frac{3}{8} \) in. (10 mm) unless protected from overheating by refractory material or other means.

PFT-20.4 Throat Sheets. Throat sheets and inside and outside front furnace sheets when fully stayed may be attached as required in PFT-11.4.

PFT-20.5 Furnace Sheets Attached by Welding. Vertical firetube boilers may be constructed by welding the ogee bottom of the furnace sheet to the outside shell as shown in Figure PFT-20, provided the requirements of PFT-20.5.1 through PFT-20.5.7 are met.

PFT-20.5.1 The tube or crown sheet is fully supported by tubes, or stays, or both.

PFT-20.5.2 The joint is wholly within the shell and forms no part thereof.

PFT-20.5.3 The weld is not in contact with primary furnace gases.\(^{23}\)

PFT-20.5.4 The throat dimension of the full fillet weld is not less than 0.7 times the thickness of the furnace sheet.

PFT-20.5.5 The maximum depth of the waterleg does not exceed 4 in. (100 mm), and the radius of the ogee is not greater than the inside width of the waterleg.

PFT-20.5.6 The pitch of the lower row of staybolts meets the requirements of PFT-27.5.

PFT-20.5.7 The construction conforms in all other respects to Code requirements including welding and postweld heat treating, except that volumetric examination is not required.

PFT-21 FIREBOXES AND WATERLEGS

PFT-21.1 The width of waterlegs at the mudring in vertical firetube and firebox boilers shall not exceed the maximum allowable pitch calculated using eq. PG-46.1(1), using 2.1 or 2.2 for the value of \( C \) depending on the thickness of the sheet, and \( C \) is...

PFT-20.6 No calculation need be made to determine the availability of compensation for openings in tubesheets or heads for furnace connections that span between the tubesheets or heads.

PFT-21.2 As an alternative, the bottom edges of the plates forming a waterleg may be joined using a flat plate, or mudring, attached between the waterleg sides as shown in Figure PFT-21, illustrations (d) and (e). The required thickness of the mudring shall be calculated using eq. PG-46.1(1), using 2.1 or 2.2 for the value of \( C \),...
Diameter (of diagonal stay) = \sqrt{\left(\frac{0.9817 \text{ in.}^2 \times 4}{3.14}\right)}

= 1.118 \text{ in.}^2

Consequently, the next larger standard size of 1\(\frac{3}{16}\) in. diameter is selected.

PFT-32.2 For staying segments of tubesheets such as in horizontal-return tubular boilers, where \(L\) is not more than 1.15 times \(l\) for any stay, the stays may be calculated as direct stays allowing 90% of the allowable stress value given in Section II, Part D, Subpart 1, Table 1A.

DOORS AND OPENINGS

PFT-40 WELDED DOOR OPENINGS

Welding may be used in the fabrication of door holes provided the sheets are stayed around the opening in accordance with the requirements of PFT-27.6 and PFT-27.7.

No calculations need be made to determine the availability of compensation for door openings spanning between the plates of waterlegs. The required thickness of circular access openings shall be determined in accordance with PG-28.3. The required thickness of door openings of other than circular shape shall be calculated using eq. PG-46.1(1), using 2.1 or 2.2 for the value of \(C\), depending on the plate thickness, and a value of \(p\) equal to the waterleg inside width. Volumetric examination of the joining welds is not required.

PFT-41 OPENINGS IN WRAPPER SHEETS

Openings located in the curved portion of the wrapper sheet of a locomotive type boiler shall be designed in accordance with the rules in PG-32.

PFT-42 FIRESIDE ACCESS OPENINGS

The minimum size of an access or fire door opening, in which the minimum furnace dimension is 24 in. (600 mm), shall be not less than 12 in. \(\times\) 16 in. (300 mm \(\times\) 400 mm) or equivalent area, 11 in. (280 mm) to be the least dimension in any case. A circular opening shall be not less than 15 in. (380 mm) in diameter.

For furnace dimensions less than 24 in. (600 mm), the opening should be 2\(\frac{3}{4}\) in. \(\times\) 3\(\frac{1}{2}\) in. (70 mm \(\times\) 89 mm) or larger where possible. In cases where the size or shape of the boiler prohibits an opening of that size, two openings with a minimum size of 1 in. (25 mm) may be used, preferably opposite each other, to permit inspection and cleaning of the furnace. If the burner is removable so as to permit inspection and cleaning through the burner opening, a separate access opening need not be provided.

The bonnet or smoke hood of a vertical flue or tubular boiler shall be provided with an access opening at least 6 in. \(\times\) 8 in. (150 mm \(\times\) 200 mm) for the purpose of inspection and cleaning the top head of the boiler.

PFT-43 REQUIREMENTS FOR INSPECTION OPENINGS

All firetube boilers shall have sufficient inspection openings, handholes, or washout plugs with a minimum of four openings to permit inspection of the waterside of the tubesheets, furnaces, and tubes and to permit flushing of loose scale and sediment from the boiler. Except where space restrictions would prohibit entry to the boiler, a manhole shall be provided in the upper portion of the shell. All openings shall meet the requirements of PG-32 through PG-44. Where washout plugs are used, the minimum size shall be NPS 1\(\frac{1}{2}\) (DN 40), except for boilers 16 in. (400 mm) or less in inside diameter, the minimum size shall be NPS 1 (DN 25).

PFT-44 OPENING BETWEEN BOILER AND PRESSURE RELIEF VALVE

The opening or connection between the boiler and the pressure relief valve shall have at least the area of the valve inlet.

After the boiler Manufacturer provides for the opening required by the Code, a bushing may be inserted in the opening in the shell to suit a pressure relief valve that will have the capacity to relieve all the steam that can be generated in the boiler and which will meet the Code requirements. The minimum size of the connection and opening for the pressure relief valve shall be not less than NPS 1\(\frac{1}{2}\) (DN 15).

No valve of any description shall be placed between the required pressure relief valve or valves and the boiler, or on the discharge pipe between the pressure relief valve and the atmosphere. When a discharge pipe is used, the cross-sectional area shall be not less than the full area of the valve outlet or of the total of the areas of the valve outlets discharging thereinto and shall be as short and straight as possible and so arranged as to avoid undue stresses on the valve or valves.

DOMES

PFT-45 REQUIREMENTS FOR DOMES

PFT-45.1 The longitudinal joint of a dome may be butt welded or the dome may be made without a seam of one piece of steel pressed into shape. The dome flange may be double full fillet lap welded to the shell if all welding complies fully with the requirements for welding in Part PW. Volumetric examination of the fillet welds may be omitted. The opening shall be reinforced in accordance with PG-32 through PG-44.