PART PFT

General

PFT-1 General 138

Materials

PFT-5 General 138

Design

PFT-8 General 138
PFT-9 Thickness Requirements 138
PFT-10 Shell Joints. 138
PFT-11 Attachment of Heads and Tubesheets 139
PFT-12 Tubes. 139

Combustion Chambers

PFT-13 Combustion Chamber Tubesheet 140
PFT-14 General 141
PFT-15 Plain Circular Furnaces 141
PFT-16 Adamson Type 141
PFT-17 Ring Reinforced Type 142
PFT-18 Corrugated Furnaces. 143
PFT-19 Combined Plain Circular and Corrugated Type 143
PFT-20 Attachment of Furnaces. 144
PFT-21 Fireboxes and Waterlegs 145

Stayed Surfaces

PFT-22 General 145
PFT-23 Working Pressure for Stayed Curved Surfaces 145
PFT-24 Staying Horizontal Return Tube Boilers 147
PFT-25 Staying Segments of Heads 148
PFT-26 Area Supported by Stay 148
PFT-27 Maximum Spacing 148
PFT-28 Staybolts and Stays 150
PFT-29 Flexible Staybolts 150
PFT-30 Crown Bars and Girder Stays 150
PFT-31 Stay Tubes 151
PFT-32 Stresses in Diagonal Stays 151

Doors and Openings

PFT-40 Welded Door Openings 152

PFT-41 Openings in Wrapper Sheets . . . 152
PFT-42 Fireside Access Openings . . . 152
PFT-43 Requirements for Inspection Openings . . . 152
PFT-44 Opening Between Boiler and Safety Valve . . . 153

Domes
PFT-45 Requirements for Domes . . . 153

Setting
PFT-46 Method of Support . . . 153

Piping, Fittings, and Appliances
PFT-47 Water Glasses . . . 154
PFT-48 Feed Piping . . . 154.1
PFT-49 Blowoff Piping . . . 155
PFT-50 Thickness of Furnaces and Tubes Under External Pressure . . . 155
PFT-51 Maximum Allowable Working Pressure . . . 155

Figures
PFT-12.1 Some Acceptable Forms of Tube Attachment on Firetube Boilers . . . 140
PFT-16 Adamson Type Furnace Construction . . . 142
PFT-17.2 Acceptable Type of Ring Reinforced Furnace . . . 142
PFT-18.1 Morison Furnace . . . 143
PFT-19 Connection Between Plain and Corrugated Furnace . . . 144
PFT-20 Welding Ogee Ring . . . 144
PFT-21 Method of Forming Waterleg Joints by Welding . . . 146
PFT-23.1 Stayed Wrapper Sheet of Locomotive Type Boiler . . . 147
PFT-25 Example of Staying of Heads Adjacent to Cylindrical Furnaces . . . 148
PFT-27 Pitch of Staybolts Adjacent to Upper Corners of Fireboxes . . . 149
PFT-32 Measurements for Determining Stresses in Diagonal Stays . . . 151
PFT-46.1 Spacing and Weld Details for Wall-Support Lugs Set in Pairs on Horizontal-Return Tubular Boilers . . . 154
PFT-46.2 Welded Bracket Connection for Horizontal-Return Tubular Boilers . . . 155

PART PFT
REQUIREMENTS
FOR FIRETUBE BOILERS

GENERAL

PFT-1 GENERAL

The rules in Part PFT are applicable to firetube boilers and parts thereof and shall be used in conjunction with the general requirements in Part PG as well as with the specific requirements in the applicable Parts of this Section that apply to the method of fabrication used.

MATERIALS

PFT-5 GENERAL

PFT-5.1 Materials used in the construction of pressure parts for firetube boilers shall conform to one of the specifications given in Section II and shall be limited to those for which allowable stress values are given in Tables 1A and 1B of Section II, Part D, or as otherwise specifically permitted in Part PG and Part PFT.

PFT-5.2 Waterleg and doorframe rings of vertical firetube boilers and of locomotive and other type boilers shall be of wrought iron or steel, or cast steel as designated in the SA-216. The ogee or other flanged construction may be used as a substitute in any case.

DESIGN

PFT-8 GENERAL

The rules in the following paragraphs apply specifically to the design of firetube boilers and parts thereof and shall be used in conjunction with the general requirements for design in Part PG as well as with the specific requirements for design in the applicable Parts of this Section that apply to the method of fabrication used.

PFT-9 THICKNESS REQUIREMENTS

PFT-9.1 Shell and Dome. The thickness after forming shall be as determined in accordance with the rules in Part PG but shall not be less than the values shown in the following table.

Inside Diameter of Shell or Dome, in. (mm)	Minimum Thickness, in. (mm)
36 (914) or under	1/4 (6.4)
Over 36 (914) to 54 (1 372)	5/16 (8.0)
Over 54 (1 372) to 72 (1 829)	3/8 (9.5)
Over 72 (1 829)	1/2 (12.7)

PFT-9.2 Tubesheet

PFT-9.2.1 The thickness shall be as determined in accordance with Part PG and Part PFT but shall not be less than the values given in the following table.

Inside Diameter of Shell, in. (mm)	Minimum Thickness, in. (mm)
42 (1 067) or under	3/8 (9.5)
Over 42 (1 067) to 54 (1 372)	7/16 (11.2)
Over 54 (1 372) to 72 (1 829)	1/2 (12.7)
Over 72 (1 829)	9/16 (14.3)

PFT-9.2.2 When buttwelded to the shell of a firetube boiler, a formed tubesheet with a straight flange longer than $1\frac{1}{2}$ times the tubesheet thickness shall have a straight flange thickness not less than that specified in the table in PFT-9.2.1, but in no case less than 0.75 times the thickness of the shell to which it is attached.

PFT-10 SHELL JOINTS

Longitudinal and circumferential welded joints of a shell or drum shall comply with the rules in Part PW.

PFT-11 ATTACHMENT OF HEADS AND TUBESHEETS

Flat heads and tubesheets of firetube boilers shall be attached by one of the following methods.

PFT-11.2 By flanging and butt welding in accordance with Part PG and Part PW.

PFT-11.3 By attaching an outwardly or inwardly flanged tubesheet to the shell by fillet welding provided the following requirements are met.

PFT-11.3.1 The tubesheet is supported by tubes, or stays, or both.

PFT-11.3.2 The joint attaching an outwardly flanged tubesheet is wholly within the shell and forms no part thereof.

PFT-11.3.3 Inwardly flanged tubesheets are full fillet welded inside and outside.

PFT-11.3.4 The throat dimension of the full fillet weld is equal to not less than 0.7 of the thickness of the head.

PFT-11.3.5 The shell at the welds is not in contact with primary furnace gases.[1]

PFT-11.3.6 The construction conforms in all other respects to the requirements of this Section, including welding and postweld heat treating, except that radiographic examination is not required.

PFT-11.3.7 This construction shall not be used on the rear head of a horizontal-return tubular boiler and inwardly flanged tubesheets shall not be used on a boiler with an extended shell.

PFT-11.3.8 On inwardly flanged tubesheets, the length of flange shall conform to the requirements of PW-13 and the distance of the outside fillet weld to the point of tangency of the knuckle radius shall be not less than $\frac{1}{4}$ in. (6 mm).

PFT-11.4 By attaching an unflanged tubesheet to the shell by welding provided the following requirements are met.

PFT-11.4.1 The tubesheet is supported by tubes, or stays, or both.

PFT-11.4.2 The welded joint may be made through the tubesheet or shell thickness. When the weld joint is made through the shell, a minimum of 80% of the pressure load shall be carried by the tubes, stays, or both.

PFT-11.4.3 The weld is a full penetration weld equal at least to the full thickness of the base metal applied from either or both sides. When the full penetration weld is made through the shell, an external fillet weld with a minimum throat of $\frac{1}{4}$ in. shall be provided, and no weld prep machining shall be performed on the flat tubesheet. The distance from the edge of the completed weld to the peripheral edge of the tubesheet shall not be less than the thickness of the tubesheet.

PFT-11.4.4 The shell or wrapper sheet, where exposed to primary furnace gases[1] and not water cooled, does not extend more than $\frac{1}{8}$ in. (3.2 mm) beyond the outside face of the tubesheet.

PFT-11.4.5 The weld attaching a furnace or a lower tubesheet of a vertical firetube boiler to the furnace sheet is wholly within the furnace sheet and is ground flush with the upper or water side of the tubesheet.

PFT-11.4.6 The construction conforms in all other aspects to the requirements of this Section including welding, and postweld heat treatment, except that radiographic examination is not required.

PFT-11.4.7 This construction shall not be used on the rear head of a horizontal-return tubular boiler.

PFT-12 TUBES

PFT-12.1 Allowable Working Pressure

PFT-12.1.1 The maximum allowable working pressure of tubes or flues of firetube boilers shall be as given in PFT-50 and PFT-51.

PFT-12.1.2 The maximum allowable working pressure for copper tubes or nipples subjected to internal or external pressure shall not exceed 250 psi (1 720 kPa). The maximum temperature shall not exceed 406°F (208°C).

The maximum allowable working pressure for copper-clad tubes subjected to external pressure shall be determined by the formula in PFT-51, in which t may be increased by one-half the thickness of the cladding.

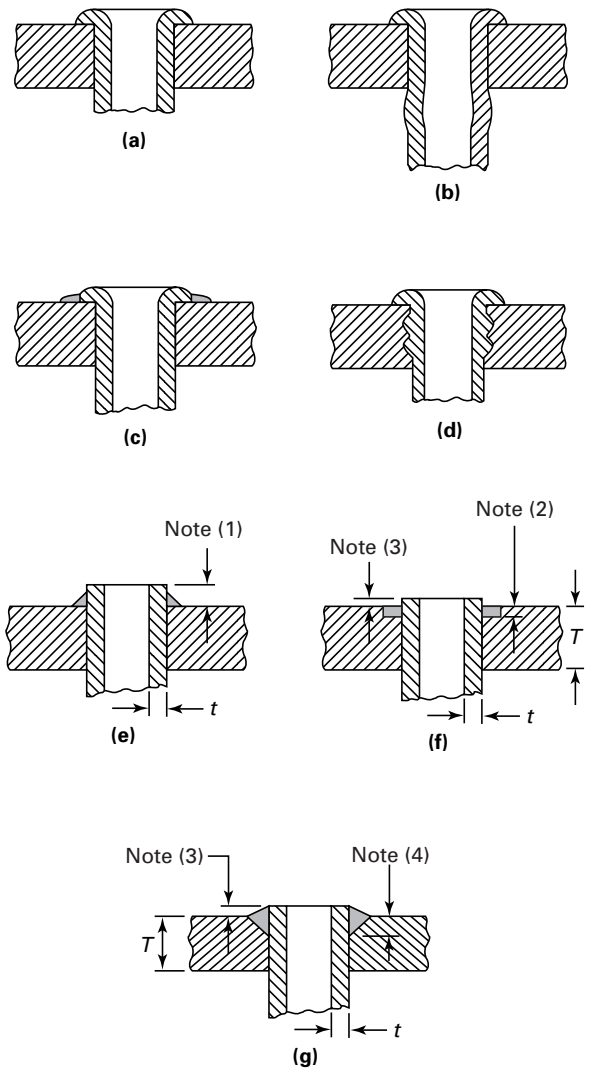
PFT-12.2 Attachment of Tubes

PFT-12.2.1 Figure PFT-12.1 illustrates some of the acceptable types of tube attachments. Such connections shall be:

(a) expanded and beaded as in sketches (a), (b), and (d);

(b) expanded and beaded and seal welded as in sketch (c);

[1] Primary furnace gases are those in a zone where the design temperature of those gases exceeds 850°F.



NOTES:
(1) Not less than t or $^1/_8$ in. (3.2 mm), whichever is the greater, nor more than $2t$ or $^1/_4$ in. (6 mm), whichever is the lesser.
(2) Not less than t or $^1/_8$ in. (3.2 mm), whichever is the greater, nor more than $T/3$ (see PFT-12.2.1.2).
(3) Not more than t.
(4) Not less than t or $^1/_8$ in. (3.2 mm), whichever is the greater, nor more than $T/3$ (see PFT-12.2.1.2).

A03 FIG. PFT-12.1 SOME ACCEPTABLE FORMS OF TUBE ATTACHMENT ON FIRETUBE BOILERS

(c) expanded and seal welded as in sketch (e);
(d) welded, as in sketches (f) and (g).

Tube ends attached by expanding and welding are subject to the following provisions.

PFT-12.2.1.1 Where no bevel or recess is employed, the tube shall extend beyond the tubesheet not less than a distance equal to the tube thickness or $^1/_8$ in. (3.2 mm), whichever is the greater, nor more than twice the tube thickness or $^1/_4$ in. (6 mm), whichever is the lesser [see Fig. PFT-12.1, sketch (e)].

PFT-12.2.1.2 The tubesheet hole may be beveled or recessed. The depth of any bevel or recess shall not be less than the tube thickness or $^1/_8$ in. (3.2 mm), whichever is greater, nor more than one-third of the tubesheet thickness, except that when tube thicknesses are equal to or greater than 0.150 in. (4 mm), the bevel or recess may exceed $T/3$. Where the hole is beveled or recessed, the projection of the tube beyond the tubesheet shall not exceed a distance equal to the tube wall thickness [see Fig. PFT-12.1, sketches (f) and (g)].

PFT-12.2.1.3 On types of welded attachment shown in Fig. PFT-12.1 sketches (c) and (e), the tubes shall be expanded before and after welding. On types shown in sketches (f) and (g), the tubes may be expanded.

PFT-12.2.2 Expanding of tubes by the Prosser method may be employed in combination with any beaded or seal welded attachment method [see Fig. PFT-12.1, sketch (b)].

PFT-12.2.3 After seal welding as shown by Fig. PFT-12.1 sketches (c) and (e), a single hydrostatic test of the boiler shall suffice.

PFT-12.2.4 The inner surface of the tube hole in any form of attachment may be grooved or chamfered.

PFT-12.2.5 The sharp edges of tube holes shall be taken off on both sides of the plate with a file or other tool.

COMBUSTION CHAMBERS

PFT-13 COMBUSTION CHAMBER TUBESHEET

PFT-13.1 The maximum allowable working pressure on a tubesheet of a combustion chamber, where the crown sheet is not suspended from the shell of the boiler, shall be determined by the following formula:

Customary Units

$$P = 27{,}000\,\frac{t(D - d)}{WD}$$

SI Units

$$P = 186\,000\,\frac{t(D - d)}{WD}$$

where

P = maximum allowable working pressure, psi (kPa)
D = least horizontal distance between tube centers on a horizontal row, in. (mm)
d = inside diameter of tubes, in. (mm)
t = thickness of tubesheet, in. (mm)
W = distance from the tubesheet to opposite combustion chamber sheet, in. (mm)

Where tubes are staggered the vertical distance between the center lines of tubes in adjacent rows must be not less than

$$1/2\,\sqrt{2dD + d^2}$$

Example: Required the maximum allowable working pressure of a tubesheet supporting a crown sheet stayed by crown bars. Horizontal distance between centers, $4\frac{1}{8}$ in.; inside diameter of tubes, 2.782 in.; thickness of tubesheets $\frac{11}{16}$ in.; distance from tubesheet to opposite combustion-chamber sheet, $34\frac{1}{4}$ in.; measured from outside of tubesheet to outside of back plate; material, steel. Substituting and solving:

$$P = \frac{(4.125 - 2.782) \times 0.6875 \times 27{,}000}{34.25 \times 4.125} = 176 \text{ psi}$$

PFT-13.2 Sling stays may be used in place of girders in all cases covered in PFT-13.1, provided, however, that when such sling stays are used, girders or screw stays of the same sectional area shall be used for securing the bottom of the combustion chamber to the boiler shell.

PFT-13.3 When girders are dispensed with and the top and bottom of combustion chambers are secured by sling stays, the sectional area of such stays shall conform to the requirements of rules for stayed surfaces.

PFT-14 GENERAL

PFT-14.1 Furnaces may be constructed using seamless pipe, electric resistance welded pipe within the limitations of PG-9.5, or fusion welded plate of the double welded butt type. A sample of the longitudinal weld, made with the addition of filler metal, of each section of a furnace shall be subjected to a bend test in accordance with PW-53. No radiography of the longitudinal or circumferential welds is required.

PFT-14.2 When the longitudinal joint will be subjected to complete radiographic examination in accordance with PW-51, the individual bend test for each section of the furnace is not required.

PFT-15 PLAIN CIRCULAR FURNACES

PFT-15.1 Plain circular furnaces may be made up to any length, using sections where desired. The thickness may not be less than $\frac{5}{16}$ in. (8 mm).

PFT-15.2 The maximum allowable working pressure shall be determined in accordance with PFT-51.

PFT-16 ADAMSON TYPE

When plain horizontal flues are made in sections not less than 18 in. (457 mm) in length and not less than $\frac{5}{16}$ in. (8 mm) in thickness:

PFT-16.1 They shall be flanged with a radius measured on the fire side of not less than three times the thickness of the plate, and the flat portion of the flange outside of the radius shall be at least $\frac{1}{2}$ in. (13 mm) plus three times the sum of the plate thickness plus $\frac{5}{16}$ in. (8 mm).

PFT-16.3 The depth of the Adamson ring between the flanges shall be not less than three times the sum of the plate thickness plus $\frac{5}{16}$ in. (8 mm), and the ring shall be welded inside and outside to each flange. The size of the welds shall be $\frac{1}{4}$ in. (6 mm). The fire edge of the ring shall be $\frac{1}{4}$ in. (6 mm) beyond the point of tangency of the flange and the outer edge of the ring shall be $\frac{1}{4}$ in. (6 mm) inside the flanges. See Fig. PFT-16.

PFT-16.4 An Adamson furnace may be assembled by welding, provided the outside edges of the flue flanges are attached to Adamson rings by full fillet welds, inside edges of the rings are welded to the flat portions of the flue flanges by full fillet welds, and the welds are postweld heat treated in accordance with PW-39.

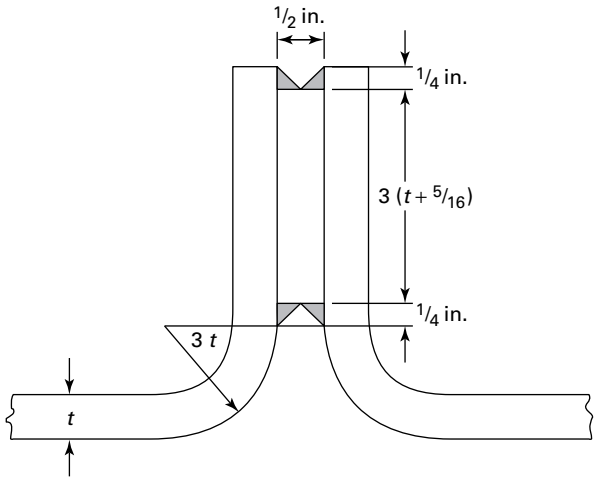


FIG. PFT-16 ADAMSON TYPE FURNACE CONSTRUCTION

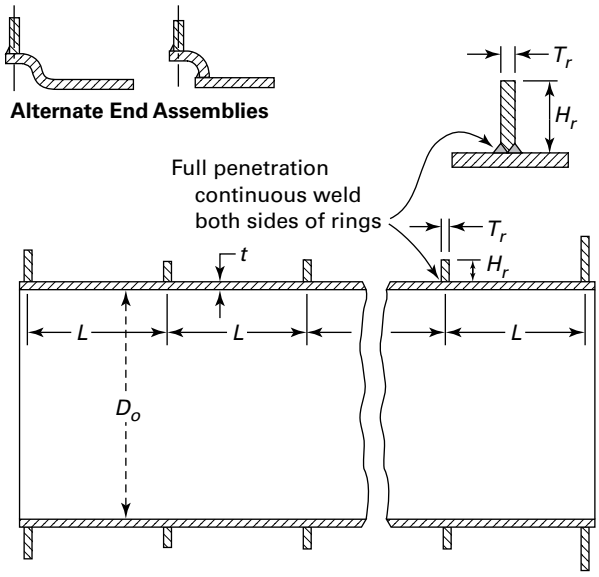


FIG. PFT-17.2 ACCEPTABLE TYPE OF RING REINFORCED FURNACE

PFT-16.5 The maximum allowable working pressure shall be determined in accordance with PFT-51.

PFT-17 RING REINFORCED TYPE

Horizontal cylindrical flues or furnaces (Fig. PFT-17.2) may be constructed with circular stiffening rings provided the following requirements are met.

PFT-17.1 The stiffening ring is rectangular in cross section and is fabricated from one piece of plate, or from plate sections or bars provided full penetration welds are used in assembling.

PFT-17.2 The stiffening ring after fabrication has a thickness of not less than $^5/_{16}$ in. (8 mm) and not more than $^{13}/_{16}$ in. (21 mm) and in no case thicker than $1^1/_4$ times the furnace wall thickness.

PFT-17.3 The ratio of the height of the stiffening ring to its thickness, H_r/T_r, is not greater than 8 nor less than 3.

PFT-17.4 The stiffening ring is attached to the furnace by a full penetration weld on each side.

PFT-17.5 The thickness of the furnace wall or flue is a minimum of $^5/_{16}$ in. (8 mm).

PFT-17.6 The spacing L of the rings on the furnace is not greater than 60t or 36 in. (914 mm), whichever is smaller.

PFT-17.8 The boiler design permits replacement of the furnace. A flared or welded ogee ring is an acceptable type of assembly.

PFT-17.10 The maximum allowable working pressure shall be determined in accordance with PFT-51.

PFT-17.11 The design of stiffening rings is determined by the use of the symbols given in PFT-51, and the formula given in this paragraph.

PFT-17.11.1 The moment of inertia for a stiffening ring shall be determined by the following procedure.

Step 1: Assuming that the furnace has been designed and D_o, L_s, and t are known, select a rectangular member to be used for a stiffening ring and determine its area A_s and its moment of inertia I. Then calculate B by the formula:

$$B = \frac{PD_o}{t + (A_s / L_s)}$$

where B = factor on the right-hand side of the applicable chart in Section II, Part D;

Step 2: Enter the right-hand side of the chart at the value of B determined in Step 1;

Step 3: Follow horizontally to the material line for the correct temperature;

Step 4: Move down vertically to the bottom of the chart and read the value of A;

Step 5: Compute the value of the required moment of inertia I_s by the formula:

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

Step 6: If the required I_s is greater than the momentof 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.

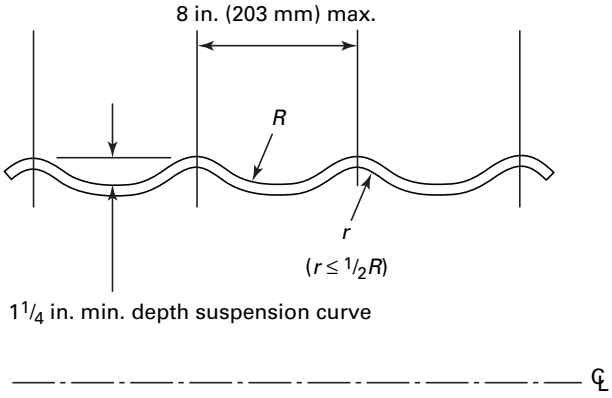


FIG. PFT-18.1 MORISON FURNACE

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. in length (except flues especially provided for), when new and practically circular, shall be computed as follows:

$$P = Ct/D$$

where

P = maximum allowable working pressure, psi (kPa)

t = thickness, in., not less than $^5/_{16}$ in. (8 mm) for Leeds, Morison, Fox, and Brown, and not less than $^7/_{16}$ in. (11 mm) for Purves furnaces

D = mean diameter, in. (mm)

C = 17,300 (81 000), a constant for Leeds furnaces, when corrugations are not more than 8 in. (203 mm) from center to center and not less than $2^1/_4$ in. (51 mm) deep

C = 15,600 (107 000), a constant for Morison furnaces, when corrugations are not more than 8 in. (203 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 Fig. PFT-18.1)

C = 14,000 (96 000), a constant for Fox furnaces, when corrugations are not more than 8 in. (203 mm) from center to center and not less than $1^1/_2$ in. (38 mm) deep

C = 14,000 (96 000), a constant for Purves furnaces, when rib projections are not more than 9 in. (230 mm) from center to center and not less than $1^3/_8$ in. (35 mm) deep

C = 14,000 (96 000), 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

In calculating the mean diameter of the Morison furnace, the least inside diameter plus 2 in. (51 mm) may be taken as the mean diameter.

PFT-18.2 The thickness of a corrugated or ribbed furnace shall be ascertained by actual measurement by the furnace manufacturer, by gaging the thickness of the corrugated portions. For the Brown and Purves furnaces, the measuring point shall be in the center of the second flat; for the Morison, Fox, and other similar types, in the center of the top corrugation, at least as far in as the fourth corrugation from the end of the furnace. A03

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 PFT-51 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 formulas, the value used shall always be twice the actual length of the plain section. The actual

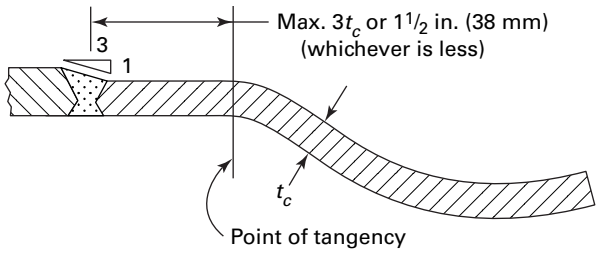


FIG. PFT-19 CONNECTION BETWEEN PLAIN AND CORRUGATED FURNACE

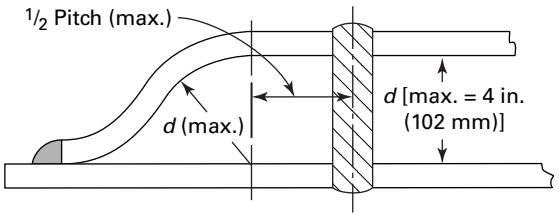


FIG. PFT-20 WELDING OGEE RING

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 Fig. PFT-19.

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 following requirements 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 radiographic 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 but not beyond the toe of the weld, and the toe shall not project beyond the face of the tubesheet 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 Fig. PFT-20 provided the following requirements 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.[2]

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., 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

[2] Primary furnace gases are those in a zone where the design temperature of those gases exceeds 850°F.

postweld heat treating, except that radiographic examination is not required.

PFT-21 FIREBOXES AND WATERLEGS

PFT-21.1 The width of waterlegs in vertical firetube and firebox boilers shall not exceed the maximum allowable pitch calculated using equation (1) of PG-46, using 2.1 or 2.2 for the value of *C* depending on the plate thickness. The bottom edges of the plates forming a waterleg may be joined by flanging one or both plates as shown in Fig. PFT-21, sketches (a), (b), and (c). Radiography of the weld joint is not required when the plates being joined form a corner joint, or when the width of the waterleg is limited to 4 in. or less.

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 Fig. PFT-21, sketches (d) and (e). The required thickness of the mudring shall be calculated using equation (1) of PG-46, 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, but shall be no less than $\frac{1}{2}$ in. (13mm). Radiography of the joining welds is not required.

01 **PFT-21.3** For waterlegs of vertical firetube boilers that are attached to tubesheets or crownsheets, the unstayed distance from a line of support on the tubesheet or crownsheet provided by tubes or stays to the inside surface of the outer wall of the waterleg shall comply with the spacing requirements of PFT-25.2 [see Fig. A-8, sketch (p)].

STAYED SURFACES

PFT-22 GENERAL

The rules of Part PG and Part PW pertaining to stays and stayed surfaces that are applicable to firetube boilers shall be used in conjunction with the following requirements.

PFT-23 WORKING PRESSURE FOR STAYED CURVED SURFACES

PFT-23.1 The maximum allowable working pressure for the surface shall be the sum of the pressure as determined in PFT 23.1.1 and the lesser pressure determined from either PFT-23.1.2 or PFT-23.1.3.

PFT-23.1.1 The maximum working pressure computed without allowing for the holding power of the stays, due allowance being made for the weakening effect of any holes provided for construction.

PFT-23.1.2 The maximum working pressure obtained by the formula given in PG-46 using 1.3 for the value of *C*.

PFT-23.1.3 The maximum working pressure obtained by the following formula:

$$P_1 = \frac{A_1 S}{A_2}$$

where

P_1 = pressure corresponding to the strength of the stay, psi (kPa)
S = allowable stress of stay as given in Table 1A of Section II, Part D, psi (kPa)
A_1 = cross-sectional area of stay, sq in. (mm^2)
A_2 = area supported by stay, sq in. (mm^2)

PFT-23.2 The maximum allowable working pressure for a stayed wrapper sheet of a locomotive type boiler shall be the lesser of the values obtained as defined in PFT-23.1 or by the following formula:

Customary Units

$$P = \frac{11{,}000tE}{R - \Sigma(s \times \sin a)}$$

SI Units

$$P = \frac{75\,000tE}{R - \Sigma(s \times \sin a)}$$

where

P = maximum allowable working pressure, psi (kPa)
t = thickness of wrapper sheet, in. (mm)
E = minimum efficiency of wrapper sheet through joints or stay holes
R = radius of wrapper sheet, in. (mm)
$\Sigma(s \times \sin a)$ = summated value of transverse spacing for all crown stays considered in one transverse plane and on one side of the vertical axis of the boiler
s = transverse spacing of crown stays in the crown sheet, in. (mm)
a = angle any crown stay makes with the vertical axis of boiler
11,000 = allowable stress, psi (kPa)

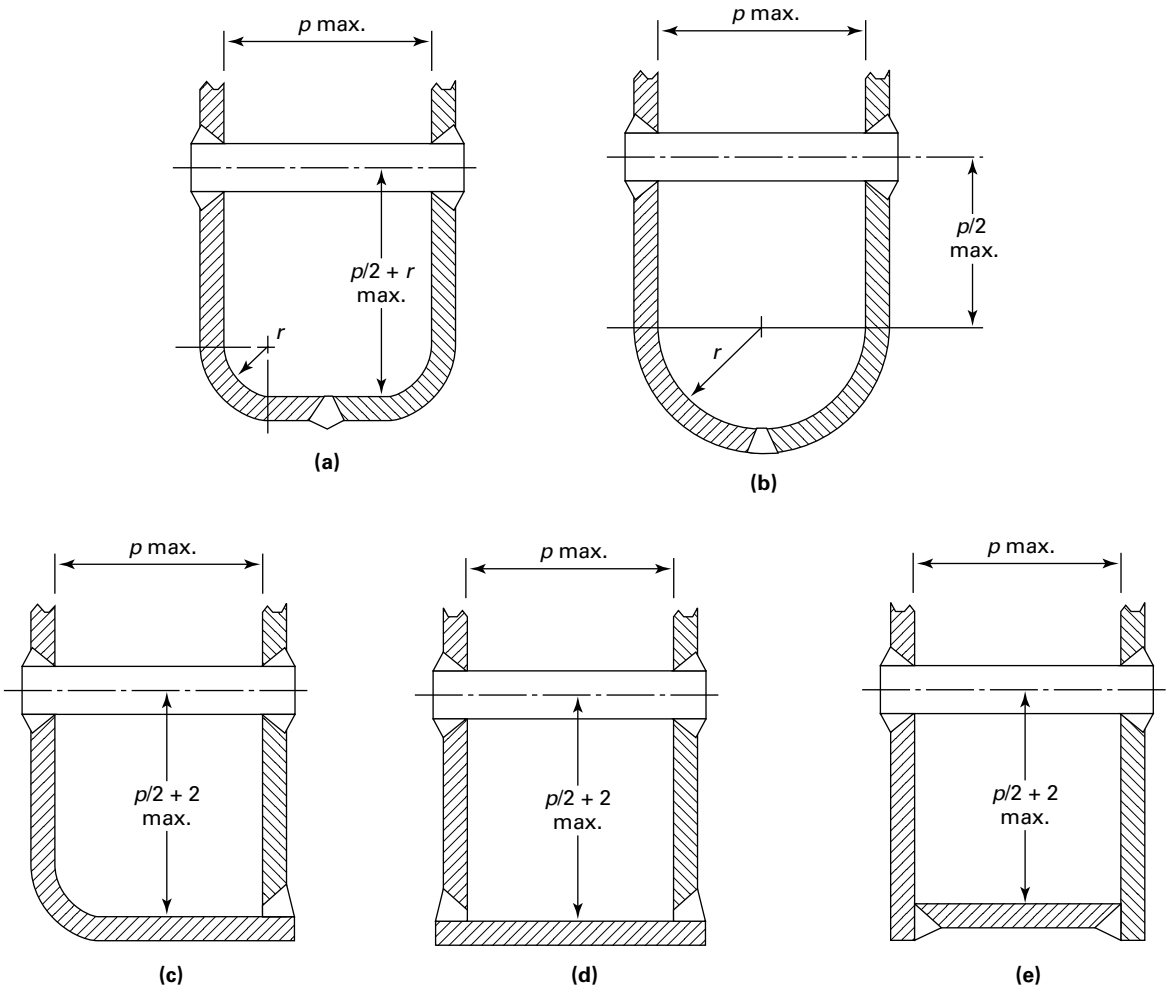


FIG. PFT-21 METHOD OF FORMING WATERLEG JOINTS BY WELDING

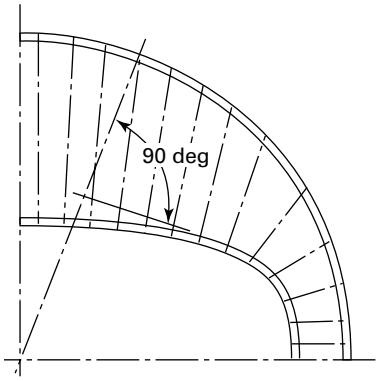


FIG. PFT-23.1 STAYED WRAPPER SHEET OF LOCOMOTIVE TYPE BOILER

The above formula applies to the longitudinal center section of the wrapper sheet, and in cases where E is reduced at another section, the maximum allowable working pressure based on the strength at that section may be increased in the proportion that the distance from the wrapper sheet to the top of the crown sheet at the center bears to the distance measured on a radial line through the other section, from the wrapper sheet to a line tangent to the crown sheet and at right angles to the radial lines (see Fig. PFT-23.1).

PFT-23.3 Furnaces of Vertical Boilers. In a vertical firetube boiler, the furnace length, for the purpose of calculating its strength and spacing staybolts over its surface, shall be measured from the fire side face of flat tubesheets or the point of tangency of flanged tubesheets to the inside of the lower mud ring.

PFT-23.3.1 A furnace for a vertical firetube boiler 38 in. (970 mm) or less in outside diameter that requires staying shall have the furnace sheet supported by one or more rows of staybolts, the circumferential pitch not to exceed 1.05 times that given by the formula in PG-46.

The longitudinal pitch between the staybolts shall not exceed that given by the following formula:

$$L = \left(\frac{56{,}320t^2}{PR}\right)^2$$

where

L = longitudinal pitch of staybolts
P = maximum allowable working pressure, psi (kPa)
t = thickness of furnace sheet, in. (mm)
R = outside radius of furnace, in. (mm)

When values by this formula are less than the circumferential pitch, the longitudinal pitch may be as large as the allowable circumferential pitch.

The stress in the staybolts shall not exceed the allowable stress given in Table 1A of Section II, Part D, and determined by PFT-26.1.

PFT-23.3.2 In furnaces over 38 in. (970 mm) in outside diameter and combustion chambers not covered by special rules in this Section which have curved sheets subject to pressure on the convex side, neither the circumferential nor longitudinal pitches of the staybolts shall exceed 1.05 times that given by the rules in PG-46.

PFT-23.4 Upper combustion chambers of vertical submerged tubular boilers made in the shape of a frustrum of a cone when not over 38 in. (970 mm) in outside diameter at the large end may be used without stays if computed by the rule for plain cylindrical furnaces in PFT-14, making D in the formula equal to the outside diameter at the large end, provided that the longitudinal joint conforms to the requirements of PFT-14.

PFT-23.5 For furnaces of PFT 23.4 when over 38 in. (970 mm) in outside diameter at the large end, that portion which is over 30 in. (762 mm) in diameter shall be fully supported by staybolts, and PFT-23.3.2 shall apply. The top row of staybolts shall be at a point where the cone top is 30 in. (762 mm) or less in diameter.

In calculating the pressure permissible on the unstayed portion of the cone, the vertical distance between the horizontal planes passing through the cone top and through the center of the top row of staybolts shall be taken as L in PFT-51. D_o in PFT-51 shall be taken as the inside diameter at the center of the top row of staybolts.

PFT-24 STAYING HORIZONTAL RETURN TUBE BOILERS

When stays are required, the portion of the heads below the tubes in a horizontal-return tubular boiler shall be supported by through-stays attached by welding under PW-19 or with nuts inside and outside at the front head and by attachments which distribute the stress at the rear head.

The distance in the clear between the bodies of the stays or of the inside stays where more than two are used shall not be less than 10 in. (254 mm) at any point.

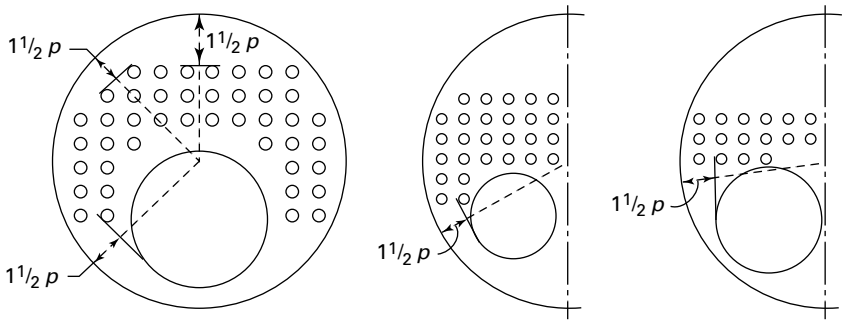


FIG. PFT-25 EXAMPLE OF STAYING OF HEADS ADJACENT TO CYLINDRICAL FURNACES

PFT-25 STAYING SEGMENTS OF HEADS

PFT-25.1 A segment of a head shall be stayed by head-to-head through stays or diagonal stays.

PFT-25.2 Stays shall be used in the tubesheets of a firetube boiler if the distance between the edges of the tube holes exceeds the maximum pitch of staybolts for the corresponding plate thickness and pressure given in PG-46.

Any part of the tubesheet which comes between the tube or cylindrical furnace and the shell need not be stayed if the greatest distance measured along a radial line from the inner surface of the shell to the center point of tangent to any two tube holes or tube hole and cylindrical furnace on the shell side of such holes does not exceed 1.5 times the value of p obtained by applying the formula of PG-46 with C equal to 1.8 or 1.9 depending upon the plate thickness. The tube holes, or tube hole and cylindrical furnace (see Fig. PFT-25), to which a common tangent may be drawn in applying this rule, shall not be at a greater distance from edge to edge than the maximum pitch referred to.

PFT-26 AREA SUPPORTED BY STAY

PFT-26.1 The full pitch dimensions of the stays shall be employed in determining the area to be supported by a stay, and the area occupied by the stay shall be deducted therefrom to obtain the net area. The product of the net area in square inches by the maximum allowable working pressure in pounds per square inch gives the load to be supported by the stay.

PFT-26.2 Where stays come near the outer edge of the surfaces to be stayed and special allowances are made for the spacing, the load to be carried by such stays shall be determined by neglecting the added area provided for by these special allowances.

Example: If the maximum pitch by PG-46 would make a staybolt come 6 in. (152 mm) from the edge of the plate and a special allowance would make it come 7 in. (178 mm), the distance of 6 in. (152 mm) shall be used in computing the load to be carried.

PFT-27 MAXIMUM SPACING

PFT-27.1 The maximum distance between the edges of tube holes and the centers of stays shall be p as determined by the formula in PG-46, using the value of C given for the thickness of plate and type of stay used.

PFT-27.2 For a flanged head welded to the shell, the maximum distance between the inner surface of the supporting flange and lines parallel to the surface of the shell passing through the center of the stays shall be p as determined by the formula in PG-46, plus the inside radius of the supporting flanges, using the C factor that applies to the thickness of the head plate and type of stay used [see Fig. A-8, sketches (i) and (j)].

PFT-27.3 For unflanged heads, the maximum distance between the inner surface of the shell and the centers of stays shall not be more than one-half the maximum allowable pitch as determined by PG-46, using 2.5 for the value of C, plus 2 in. (51 mm) [see Fig. A-8, sketch (k)].

PFT-27.4 The pitch of diagonal stays attached by welding between the shells and tubesheets of horizontal tubular and scotch boilers, and for other stays when the supported plate is not exposed to radiant heat, as determined by PG-46, may be greater than 8½ in. (216 mm), but shall not exceed 15 times the stay diameter.

PFT-27.5 The pitch of the lower row of staybolts of a vertical firetube boiler, which is required to be stayed by the rules in this Section, and which is fabricated by welding the ogee bottom of the furnace sheet to the outside shell, shall not exceed one-half the maximum allowable pitch as determined by PG-46, measured from the center of the staybolt to the tangent of the ogee (see Fig. PFT-20).

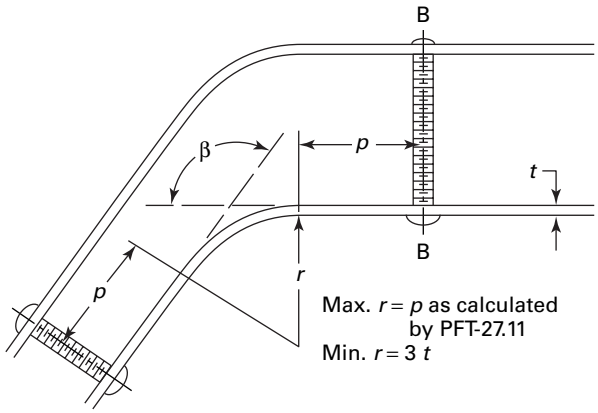
PFT-27.6 The spacing of staybolts around door holes fabricated by fusion welding of the full penetration type of two-flanged sheets, which are required to be stayed by the rules of this Section (see Fig. PWT-12.2), shall not exceed one-half the maximum allowable pitch determined by PG-46, measured from the center of the staybolt to the points of tangency of the flanges.

PFT-27.7 If the furnace sheets are required to be stayed by the rules of this Section, the spacing of staybolts around door holes and the spacing of the first row of staybolts from the bottom of a mud ring fabricated by fusion welding of the full penetration type when either or both sheets are not flanged [see Fig. A-8, sketches (1), (m), and (n)] shall not exceed one-half the maximum pitch determined by PG-46, plus 2 in. (51 mm), measured from the center of the staybolt to the root of the weld.

PFT-27.8 The maximum distance from the first row of stays to a full penetration weld in compression applied from either or both sides of the tubesheet, attaching the crown sheet of a furnace or combustion chamber to a stayed head or tubesheet shall not exceed the pitch determined by PG-46, measured from the center of the stay to the furnace or combustion chamber side of the head or tubesheet [see Figs. A-8, sketches (o) and (p)].

PFT-27.9 When a flanged-in manhole opening with a flange depth of not less than three times the required thickness of the head, or when an unflanged manhole ring meeting the requirements of PG-32 through PG-39 is provided in a flat stayed head of a firetube boiler, as shown in Fig. A-8, sketches (q) and (r), the load created by the unsupported area of the manway shall be supported by the stays surrounding the manway. When the manway is in close proximity to the shell, the load may be shared by the shell by reducing the area supported by the stays by 100 sq in. (64 500 mm^2), provided both the following requirements are met.

PFT-27.9.1 The distance between the manhole opening and the inside of the shell does not exceed one-half the maximum allowable pitch for an unflanged manhole and one-half the maximum allowable pitch plus the radius of the head flange for a flanged-in manhole in a flanged head.



GENERAL NOTE: If the radius r exceeds the pitch, the curved plate shall be stayed as a flat plate in accordance with PG-46.

FIG. PFT-27 PITCH OF STAYBOLTS ADJACENT TO UPPER CORNERS OF FIREBOXES

PFT-27.9.2 The distance between the centers of the first row of stays, or the edges of tube holes, and the manhole opening does not exceed one-half the maximum allowable pitch as determined by PG-46.

PFT-27.10 In applying these rules and those in PG-46 to a head or plate having a manhole or reinforced opening, the spacing applies only to the plate around the opening and not across the opening.

PFT-27.11 For stays at the upper corners of fireboxes, the pitch from the staybolt next to the corner to the point of tangency to the corner curve shall be (see Fig. PFT-27):

$$p = \left[\frac{90}{\text{Angularity of tangent lines } (\beta)}\right]\sqrt{C\frac{t^2 S}{P}}$$

where

t = thickness of plate, in.
S = maximum allowable stress value given in Table 1A of Section II, Part D, psi
P = maximum allowable working pressure, psi
C = factor for the thickness of plate and type of stay used as required in PG-46
β = angle, deg

PFT-28 STAYBOLTS AND STAYS

PFT-28.1 The required area at the point of least net cross section of staybolts and stays shall be as given in PG-49. The maximum allowable stress per square inch at point of least net cross-sectional area of staybolts and stays shall be given as in Table 1A of Section II, Part D. In determining the net cross-sectional area of drilled or hollow staybolts, the cross-sectional area of the hole shall be deducted.

PFT-28.2 The length of the stay between supports shall be measured from the inner faces of the stayed plates. The stresses are based on tension only. For computing stresses in diagonal stays, see PFT-32.

PFT-28.3 When stay rods are screwed through sheets and riveted over, they shall be supported at intervals not to exceed 6 ft (1.8 m). Stay rods over 6 ft (1.8 mm) in length may be used without support if fitted with nuts and washers or attached by welding under PW-19, provided the least cross-sectional area of the stay rod is not less than that of a circle 1 in. (25 mm) in diameter and the requirements of PG-46.8 are met.

PFT-29 FLEXIBLE STAYBOLTS

Flexible type staybolts having a cover cap welded under the provisions of PW-15 to the outer sheet may be used in the construction of locomotive type boilers provided the bolts are hollow-drilled from the threaded end into and partly through the ball head to allow for proper inspection, and so that any breakage is disclosed by leakage at the inner end. These welded joints need not be postweld heat treated or radiographed.

PFT-30 CROWN BARS AND GIRDER STAYS

PFT-30.1 Crown bars and girder stays for tops of combustion chambers and back connections, or wherever used, shall be proportioned to conform to the following formula:

$$P = \frac{Cd^2t}{(W - p)D_1W}$$

where

W = extreme distance between supports of, in a scotch marine boiler, the distance from the fire side of the tubesheet to the fire side of the back connection plate, in.
P = maximum allowable working pressure, psi
p = pitch of supporting bolts, in.
D_1 = distance between girders from center to center, in.
d = depth of girder, in.
t = thickness of girder, in.
C = 7,000 (48 000) when girder is fitted with one supporting bolt
C = 10,000 (69 000) when the girder is fitted with two or three supporting bolts
C = 11,000 (75 000) when the girder is fitted with four or five supporting bolts
C = 11,500 (79 000) when the girder is fitted with six or seven supporting bolts
C = 12,000 (82 000) when the girder is fitted with eight or more supporting bolts

Example: Given $W = 34$ in., $p = 7.5$ in., $D_1 = 7.75$ in., $d = 7.5$ in., $t = 2$ in.; three stays per girder, $C = 10{,}000$; then substituting in formula:

$$P = \frac{10{,}000 \times 7.5 \times 7.5 \times 2}{(34 - 7.5) \times 7.75 \times 34} = 161.1 \text{ psi}$$

Sling stays, if used between crown bars and boiler shell or wrapper sheet, shall be proportioned so as to carry the entire load without considering the strength of the crown bars.

PFT-30.2 In a form of reinforcement for crown sheets where the top sheet of the firebox is a semicircle and the top part of the circle not exceeding 120 deg in arc is reinforced by arch bars extending over the top and down below the top row of staybolts at the sides of the furnace beneath the semicircular crown sheet, the maximum allowable working pressure shall be determined by adding to the maximum allowable working pressure for a plain circular furnace of the same thickness, diameter, and length determined by the formula in PFT-51, the pressure P_1 determined from the following formula which is a modification of the formula in PFT-23:

Customary Units

$$P_1 = 10{,}000{,}000 \frac{bd^3}{D_1 D^3}$$

SI Units

$$P_1 = 69\,000\,000 \frac{bd^3}{D_1 D^3}$$

where

b = net width of crown bar, in.
d = depth of crown bar, in.
D_1 = longitudinal spacing of crown bar that shall not exceed twice the maximum allowable staybolt pitch, in.
D = two times the radius of the crown sheet, in.

provided that the maximum allowable working pressure must not exceed that determined by the formula for furnaces of the Adamson type, in PFT-51 when L is made equal to D_1, and also provided that the diameter of the holes for the staybolts in the crown bars does not exceed $\frac{1}{3}b$, and the cross-sectional areas of the crown bars is not less than 4 sq in. (2581 mm^2). PG-46 governs the spacing of the staybolts or bolts attaching the sheet to the bars, and PFT-28, the size of the staybolts or bolts.

For constructions in which the crown sheet is not semicircular, or in which other features differ from those specified above, a test shall be made in accordance with PG-100 and the working pressure shall be based thereon.

PFT-30.3 Cast iron supporting lugs, legs, or ends shall not be used.

PFT-31 STAY TUBES

PFT-31.1 When tubes are used as stays in multitubular boilers to give support to the tubesheets, the required cross-sectional area of such tubes shall be determined in accordance with PG-49.

PFT-31.2 The required tubesheet thickness and maximum pitch of stay tubes shall be calculated using the following equations:

$$t = \sqrt{\frac{P}{CS}\left(p^2 - \frac{\pi d^2}{4}\right)}$$

$$p = \sqrt{\frac{CSt^2}{P} + \frac{\pi d^2}{4}}$$

where

t = required thickness of tubesheet, in. (mm)
p = maximum pitch measured between the centers of tubes in different rows, which may be horizontal, vertical, or inclined, in. (mm)
C = 2.1 for tubesheets not over $\frac{7}{16}$ in. (11 mm) thick
= 2.2 for tubesheets over $\frac{7}{16}$ in. (11 mm) thick
S = maximum allowable stress value for the tubesheet material given in Table 1A of Section II, Part D, psi (kPa)
P = design pressure, psi (kPa)
d = outside diameter of the tube, in. (mm)

PFT-31.3 No calculation need be made to determine the availability of the required cross-sectional area or the maximum allowable pitch for tubes within or on the perimeter of a nest of tubes that are spaced at less than twice their average diameter.

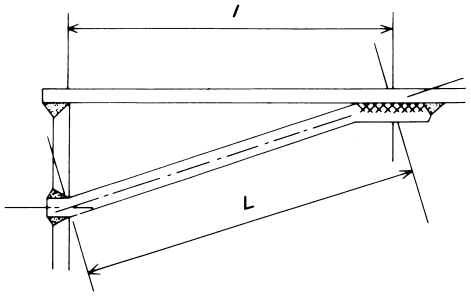


FIG. PFT-32 MEASUREMENTS FOR DETERMINING STRESSES IN DIAGONAL STAYS

PFT-31.4 Stay tubes may be attached by any of the acceptable means shown in Fig. PFT-12.1.

PFT-32 STRESSES IN DIAGONAL STAYS

PFT-32.1 To determine the required area of a diagonal stay, multiply the area of a direct stay required to support the surface by the slant or diagonal length of the stay; and divide this product by the length of a line drawn at right angles to surface supported to center of palm of diagonal stay, as follows:

$$A = aL/l$$

where

A = sectional area of diagonal stay, sq in. (mm^2)
a = sectional area of direct stay, sq in. (mm^2)
L = length of diagonal stay as indicated in Fig. PFT-32, in. (mm)
l = length of line drawn at right angles to boiler head or surface supported to center of palm of diagonal stay, as indicated in Fig. PFT-32, in. (mm)

Example: Given diameter of direct stay = 1 in., a = 0.7854 sq in., L = 60 in., l = 48 in.; substituting and solving:

$A = (0.7854 \times 60)/48$
= 0.98 sectional area, sq in.
Diameter = 1.11 in.
= $1\frac{1}{8}$ in.

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 Table 1A of Section II, Part D.

DOORS AND OPENINGS

PFT-40 WELDED DOOR OPENINGS

Arc or gas 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.

The fit-up of the several parts of an arc or gas welded door opening shall be such that the maximum gap between the two plates to be joined by welding does not exceed $\frac{1}{8}$ in. (3.2 mm).

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.

01 PFT-42 FIRESIDE ACCESS OPENINGS

The minimum size of an access or fire door opening, in which the minimum furnace dimension is 24 in. (610 mm), shall be not less than 12 in. × 16 in. (305 mm × 406 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. (381 mm) in diameter.

For furnace dimensions less than 24 in. (610 mm), the opening should be $2\frac{3}{4}$ in. × $3\frac{1}{2}$ in. (70 mm × 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 oppposite 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. × 8 in. (152 mm × 203 mm) for the purpose of inspection and cleaning the top head of the boiler.

PFT-43 REQUIREMENTS FOR INSPECTION OPENINGS

PFT-43.1 All openings shall meet the requirements of PG-32 through PG-44. Manholes may be substituted for handholes. Where washout plugs are used the minimum size shall be $1\frac{1}{2}$ in. (38 mm).

PFT-43.2 Horizontal-Return Tubular Boiler. A manhole shall be provided in the front head below the tubes. On boilers less than 48 in. (1 200 mm) in inside diameter a handhole may be used in lieu of the manhole. A manhole shall be provided in the upper part of the shell or head. On boilers 40 in. (1 000 mm) and under in inside diameter a handhole may be used in lieu of the manhole.

PFT-43.3 Traction, Stationary, or Portable Return Tube Firetube Boilers. Handholes or washout plugs, not less than six, shall be located as follows: one in the rear head below the tubes; four in the lower part of the waterleg, with one near the throat sheet when possible; one in the front head at the line of the crown sheet, except when the location would lie within a smoke box the handhole or washout plug shall be located on a side sheet.

Horizontal firetube boilers shall also have a manhole located above the tubes on the head or shell, except that on boilers 48 in. (1 200 mm) and under in inside diameter a handhole may be used in lieu of the manhole.

PFT-43.4 Scotch Boilers. Handholes or washout plugs, not less than four, shall be located as follows: one on the bottom of the shell; one above the furnace; one on each side of the front head or shell below the tubes and near the front head.

A manhole shall also be provided on the head or shell above the tubes, except on boilers 48 in. (1 200 mm) and under in inside diameter a handhole may be used in lieu of the manhole.

Scotch marine boilers (wet-back type) shall also have an opening for inspection of the water space at the rear of the combustion chamber.

PFT-43.5 Vertical Boilers

PFT-43.5.1 For sizes over 24 in. (610 mm) in outside diameter the following handholes, not less than four, shall be provided: one at or about the waterline (or opposite the fusible plug when used); three at or about the line of the lower tubesheet.

On internally fired types, three additional handholes shall be provided at the lowest part of the waterleg.

On flueless types, three handholes shall be provided at the bottom of the waterleg in lieu of the three required above.

On submerged tube types, two additional handholes shall be provided in line with the underside of the upper tubesheet.

PFT-43.5.2 For sizes under 24 in. (610 mm) in outside diameter, the following inspection openings, not less than three, shall be provided in the shell: one handhole at the waterline; two washout plugs near the bottom (the blowoff opening shall not be considered in lieu of this requirement).

On internally fired types, a handhole shall be provided in line with the lower tubesheet, in which case the handhole at the waterline may be omitted.

On flueless types, one additional washout plug shall be provided above and adjacent to the firing door.

On submerged tube types, a handhole shall also be provided in line with the upper tubesheet.

PFT-44 OPENING BETWEEN BOILER AND SAFETY VALVE

The opening or connection between the boiler and the safety 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 safety 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.

No valve of any description shall be placed between the required safety valve or safety relief valve or valves and the boiler, or on the discharge pipe between the safety valve or safety 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. Radiographic examination of the fillet welds may be omitted. The opening shall be reinforced in accordance with PG-32 through PG-44.

PFT-45.3 When a dome is located on the barrel of a locomotive type boiler or on the shell of a horizontal-return tubular boiler, the outside diameter of the dome shall not exceed six-tenths the inside diameter of the shell or barrel of the boiler unless the portion of the barrel or shell under the dome (the neutral sheet) is stayed to the head or shell of the dome by stays which conform in spacing and size to the requirements given in PG-46 and Table 1A of Section II, Part D. With such stayed construction the outside diameter of a dome located on the barrel or shell of a boiler is limited to eight-tenths of the barrel or shell inside diameter.

PFT-45.4 All domes shall be so arranged that any water can drain back into the boiler.

PFT-45.5 Flanges of domes shall be formed with a corner radius, measured on the inside, of at least twice the thickness of the plate for plates 1 in. (25 mm) in thickness or less, and at least three times the thickness of the plate for plates over 1 in. (25 mm) in thickness.

PFT-45.6 Domes and manhole frames attached to shells or heads of boilers shall be designed in accordance with PG-32 through PG-44.

PFT-45.7 In a locomotive type boiler with a dome on a tapered course, the maximum allowable diameter of the dome shall be based on that diameter of the tapered course which intersects the axis or center line of the dome.

SETTING

PFT-46 METHOD OF SUPPORT

PFT-46.1 The design and attachment of lugs, hangers, saddles, and other supports shall meet the requirements of PG-22.1 and PG-55.

PFT-46.2 In applying the requirements of PFT-46.1, localized stresses due to concentrated support loads, temperature changes, and restraint against dilation of the boiler due to pressure shall be provided for. Lugs, brackets, saddles, and pads shall conform satisfactorily to the shape of the shell or surface to which they are attached or with which they are in contact.

PFT-46.3 A horizontal-return tubular boiler over 72 in. (1 800 mm) in diameter shall be supported from steel hangers by the outside-suspension type setting, independent of the furnace side walls.

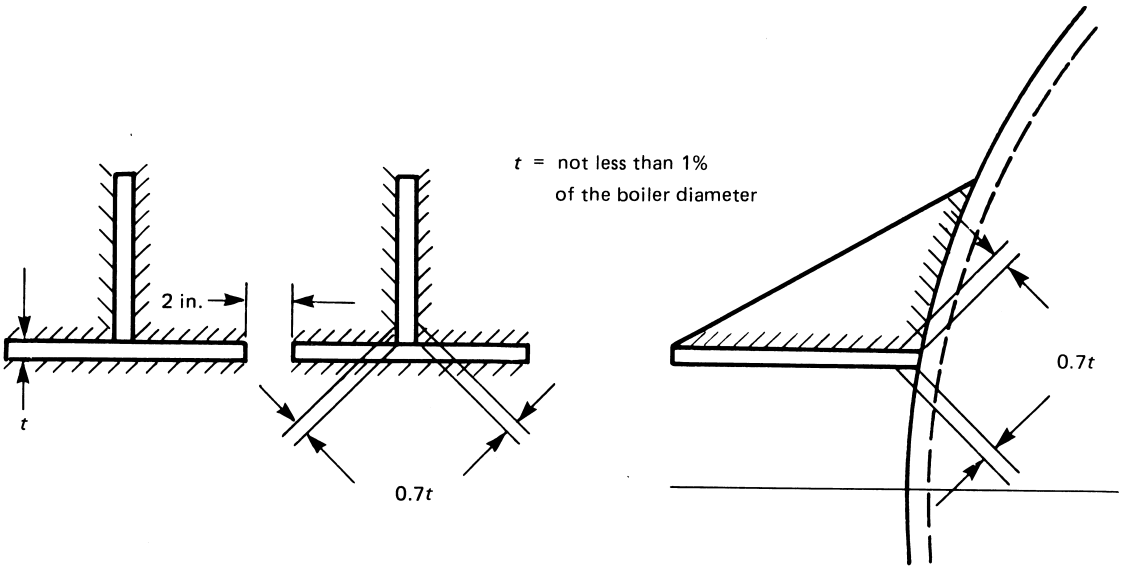


FIG. PFT-46.1 SPACING AND WELD DETAILS FOR WALL-SUPPORT LUGS SET IN PAIRS ON HORIZONTAL-RETURN TUBULAR BOILERS

PFT-46.4 A horizontal-return tubular boiler, 14 ft (4.3 m) or more in length, or over 54 in. (1 400 mm) and up to and including 72 in. (1 800 mm) in diameter, shall be supported by the outside-suspension type of setting as specified in PFT-46.3, or, for wall-supported boilers, at four points by not less than eight steel lugs set in pairs. A horizontal-return tubular boiler up to and including 54 in. (1 400 mm) in diameter shall be supported by the outside-suspension type of setting as specified in PFT-46.3, or, for wall-supported boilers, by not less than two steel lugs on each side. If more than four lugs are used on wall-supported boilers, they shall be set in four pairs, the lugs of each pair to be spaced not over 2 in. (51 mm) apart and the load to be equalized between them (see Fig. PFT-46.1). If the boiler is supported on structural steel work, the steel supporting members shall be so located that heat from the furnace cannot impair their strength.

PFT-46.5 Figure PFT-46.2 illustrates an acceptable design of hanger bracket for welded attachment to welded horizontal-return tubular boilers with the additional requirement that the hanger pin be located at the vertical center line over the center of a welded contact surface. The bracket plates shall be spaced at least $2\frac{1}{2}$ in. (64 mm) apart, but this dimension shall be increased if necessary to permit access for the welding operation.

PFT-46.6 Wet-bottom stationary boilers shall be supported so as to have a minimum clearance of 12 in. (305 mm) between the underside of the wet-bottom and the floor to facilitate inspection. Other types of firetube boilers set horizontally shall be supported so that they have a minimum clearance of 12 in. (305 mm) between the metal surface of the shell and the floor. Boiler insulation, saddles, or other supports shall be arranged so that inspection openings are readily accessible.

PIPING, FITTINGS, AND APPLIANCES

PFT-47 WATER LEVEL INDICATORS A02

PFT-47.1 Boilers of the horizontal firetube type shall be so set that when the water is at the lowest visible level in the gage glass there shall be at least 3 in. (76 mm) above the lowest permissible water level as determined by the Manufacturer.

PFT-47.2 Boilers of locomotives shall have at least one gage glass provided with top and bottom shutoff cocks and lamp.

The lowest visible level in the gage glass shall not be less than 2 in. (51 mm) above the lowest permissible water level as determined by the Manufacturer for

boilers 36 in. (914 mm) in diameter and under, nor less than 3 in. (76 mm) for boilers over 36 in. (914 mm) in diameter. These are minimum dimensions, and on large locomotives and those operating on steep grades, the height should be increased, if necessary, to compensate for change of water level on descending grades.

The bottom mounting for the gage glass and for water column if used must extend not less than $1\frac{1}{2}$ in. (38 mm) inside the boiler and beyond any obstacle immediately above it, and the passage therein must be straight and horizontal.

Tubular gage glasses must be equipped with a protecting shield.

PFT-48 FEED PIPING

PFT-48.1 When a horizontal-return tubular boiler exceeds 40 in. (1 000 mm) in diameter, the feedwater shall discharge at about three-fifths the length from the

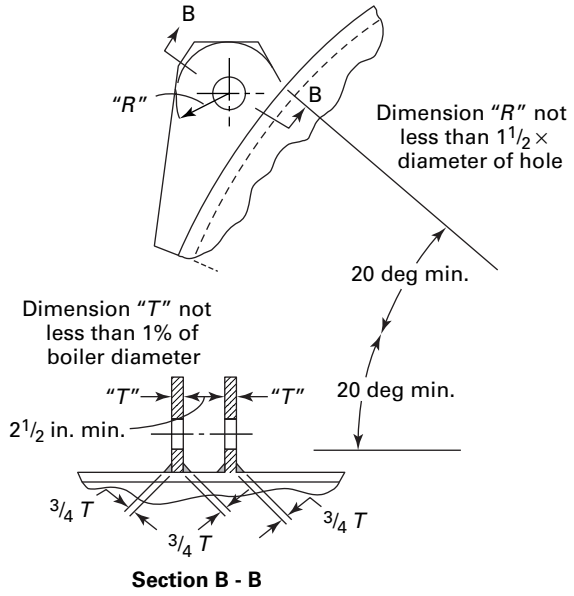


FIG. PFT-46.2 WELDED BRACKET CONNECTION FOR HORIZONTAL-RETURN TUBULAR BOILERS

end of the boiler that is subjected to the hottest gases of the furnace (except a horizontal-return tubular boiler equipped with an auxiliary feedwater heating and circulating device), above the central rows of tubes. The feed pipe shall be carried through the head or shell farthest from the point of discharge of the feedwater in the manner specified for a surface blowoff in PG-59.3.2, and be securely fastened inside the shell above the tubes.

PFT-48.2 In vertical tubular boilers the feedwater shall be introduced at a point not less than 12 in. (305 mm) above the crown sheet. When the boiler is under pressure, feedwater shall not be introduced through the openings or connections used for the water column or gage glass. In closed systems the water may be introduced through any opening when the boiler is not under pressure.

PFT-49 BLOWOFF PIPING

PFT-49.1 Blowoff piping of firetube boilers which is exposed to products of combustion shall be attached by screwing into a tapped opening with provisions for a screwed fitting or valve at the other end.

PFT-49.2 Blowoff piping of firetube boilers which is not exposed to products of combustion may be attached by any method provided in this Section except by expanding into grooved holes.

PFT-50 THICKNESS OF FURNACES AND TUBES UNDER EXTERNAL PRESSURE

PFT-50.1 Design Temperature shall not be less than the maximum expected mean wall temperature established by calculation or measurement. As an alternative to calculating or measuring the maximum expected mean metal temperature, 700°F (371°C) may be used as the design temperature.[3]

PFT-50.1.1 Temperatures in excess of the maximum temperature listed for each material given in Tables 1A and 1B of Section II, Part D, are not permitted.

PFT-50.1.2 Temperatures in excess of the maximum temperature given on the external pressure charts are not permitted.

PFT-50.1.3 Rounding off equation results to the next higher unit of 10 is permitted. (See PG-27.4, Note 8.)

PFT-51 MAXIMUM ALLOWABLE WORKING PRESSURE

PFT-51.1 The maximum allowable working pressure of tubes, flues, plain circular, Adamson, and ring reinforced furnaces of firetube boilers shall be as determined by the following rules. External pressure charts for use in determination of minimum requirements are given in Section II, Part D, Subpart 3. Figure numbers shown in this Article are contained in that Subpart.

PFT-51.1.1 The symbols defined below are used in the procedures of this Article:

A = factor determined from Fig. G and used to enter the applicable material chart in Section II, Part D. For the case of cylinders having D_o/t values less than 10, see PFT-51.1.2(b).

B = factor determined from the applicable material chart in Section II, Part D, for maximum design metal temperature, psi (kPa)

D_o = outside diameter of cylindrical furnace or tube, in. (mm)

[3] The designer is cautioned that the actual maximum mean metal temperature is dependent on the heat input to the furnace, the fuel type, and the design pressure. 700°F (371°C) may not be appropriate for higher design pressures resulting in furnaces over 1 in. (25 mm) thick, or for furnaces with high heat inputs.

E = modulus of elasticity of material at design temperature, psi (MPa) (For this value see the applicable materials chart in Section II, Part D. Interpolation may be made between the lines for intermediate temperatures.)

L = total length, in. (mm), of a furnace or tube between tubesheets, or design length of a furnace taken as the largest of the following:

(a) the greatest center-to-center distance between any two adjacent stiffening rings;

(b) the distance between the tubesheet and the center of the first stiffening ring (Adamson or ring reinforced);

(c) the distance from the center of the first stiffening ring to a circumferential line on a formed head at one-third the depth from the head tangent line.

L_s = one-half of the distance from the center line of the stiffening ring to the next line of support on one side, plus one-half of the center line distance to the next line of support on the other side of the stiffening ring, both measured parallel to the axis of the cylinder, in. (mm). A line of support is:

(a) a stiffening ring that meets the requirements of PFT-17.11;

(b) a circumferential connection to a tubesheet or jacket for a jacketed section of a cylindrical shell;

(c) a circumferential line on a formed head at one-third the depth of the head from the head tangent line.

I_S = required moment of inertia of stiffening ring about its neutral axis parallel to the axis of the furnace, in.^{4} (m^4)

A_S = cross-sectional area of stiffening ring, sq in. (m^2)

P = external design pressure, psi (kPa)

P_a = calculated value of allowable external working pressure for the assumed value of t, psi (kPa)

S = the maximum allowable stress value at design metal temperature, psi (MPa)

t = minimum required thickness of cylindrical furnaces or tubes, in. (mm)

t_S = nominal thickness of cylindrical furnace or tubes, in. (mm)

PFT-51.1.2 Cylindrical Furnaces and Tubes. The required minimum thickness of a cylindrical furnance or tube under external pressure, either seamless or with longitudinal butt joints, shall be determined by the following procedure.

(a) cylinder having D_o/t values equal to or greater than 10

Step 1: Assume a value of t and determine the ratios L/D_o and D_o/t.

Step 2: Enter Fig. G of Section II, Part D, at the value of L/D_o determined in Step 1. For values of L/D_o greater than 50, enter the chart at a value of $L/D_o = 50$. For values of L/D_o less than 0.05, enter the chart at a value of $L/D_o = 0.05$.

Step 3: Move horizontally to the line for the value of D_o/t determined in Step 1. Interpolation may be made for intermediate values of D_o/t. From this point of intersection, move vertically downward to determine the value of Factor A.

Step 4: Using the value of A calculated in Step 3, enter the applicable material chart in Section II, Part D, for the material under consideration. Move vertically to an intersection with the material/temperature line for the design temperature. Interpolation may be made between lines for intermediate temperatures. In cases where the A value falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of A falling to the left of the material/temperature line, see Step 7.

Step 5: From the intersection obtained in Step 4, move horizontally to the right and read the value of Factor B.

Step 6: Using the value of B, calculate the value of the maximum allowable external pressure, P_a, using the following formula:

$$P_a = \frac{4B}{3(D_o/t)}$$

Step 7: For values of A falling to the left of the applicable material/temperature line, the value of P_a shall be calculated using the following formula:

$$P_a = \frac{2\,AE}{3(D_o/t)}$$

Step 8: Compare the calculated value of P_a obtained in Step 6 or 7 with P. If P_a is smaller than P, select a larger value for t and repeat the design procedure until a value of P_a is obtained that is equal to or greater than P.

(b) cylinders having D_o/t values of less than 10

Step 1: Using the same procedure as given in (a) above, obtain the value of B. For values of D_o/t less

than 4, the value of A shall be calculated using the following formula:

$$A = \frac{1.1}{(D_o/t)^2}$$

For values of A greater than 0.10, use a value of 0.10.

Step 2: Using the value of B obtained in Step 1, calculate a value of P_{a1} using the following formula:

$$P_{a1} = \left[\frac{2.167}{D_o/t} - 0.0833\right] B$$

Step 3: Calculate a value of P_{a2} using the following formula:

$$P_{a2} = \frac{2S_B}{D_o/t}\left[1 - \frac{1}{D_o/t}\right]$$

where S_B is the lesser of 2 times themaximum allowable stress values at design metal temperature from Tables 1A and 1B of Section II, Part D; or, 1.8 times the yield strength of the material at Design Metal Temperature from Table Y-1 of Section II, Part D.

Step 4: The smaller of the values of P_{a1} calculated in Step 2, or P_{a2} calculated in Step 3 shall be used for the maximum allowable external pressure P_a. If P_a is smaller than P, select a larger value for t and repeat the design procedure until a value for P_a is obtained that is equal to or greater than P.

PFT-51.1.3 The design pressure or maximum allowable working pressure shall not be less than the maximum expected difference in operating pressure that may exist between the outside and the inside of the furnace or tube at any time.

PFT-51.1.4 When necessary, furnaces shall be provided with stiffeners or other additional means of support to prevent overstress or large distortions under the external loadings listed in PG-22 other than pressure and temperature.