PART PFT
REQUIREMENTS FOR FIREFLUE BOILERS

PFT-11.1 Flanged heads and tubesheets shall be formed with a minimum outside corner radius of three times the plate thickness [see Figure A-8, illustrations (a-1), (b-1), (c), (i) and (j)], and attached in accordance with either PFT-11.2 or PFT-11.3.

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 Section II, Part D, Subpart I, Tables 1A and 1B, or as otherwise specifically permitted in Parts PG and 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.

PFT-9.2 Tubesheet.

PFT-9.2.1 The thickness shall be as determined in accordance with Part PG and Part PFT.

PFT-9.2.2 When butt welded 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 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 Parts PG and 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-11.3.6 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-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 requirements of PFT-11.4.1 through PFT-11.4.7 are met

PFT-11.4.1 The tubesheet is supported by tubes, or stays, or both.
PFT-26.3 When stays are adjacent to a formed flange with a radius ranging from 3t to 32t, the flange may be considered self-supporting for a distance d, measured from the outer surface of the flange. The load on the area between the inside of the shell and this perimeter, shall not be considered when calculating the load on supports inboard of the perimeter. The area inboard of the perimeter is supported by the flange for a half pitch dimension. (see Figure PFT-26.3). For flange radii larger than 32t the requirements of PG-16.1 apply.

\[ d = \left( -0.00025 \left( \frac{t}{r} \right)^3 + 0.021 \left( \frac{t}{r} \right)^2 + 0.37 \frac{t}{r} + 0.36 \right) \]

Where
- \( d \) = flange self-support distance, in. (mm)
- \( t \) = thickness of plate, in. (mm)
- \( r \) = flange outside radius, in. (mm)

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 Figure A-8, illustrations (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. (50 mm) (see Figure A-8, illustration (k)).

PFT-27.4 The pitch of diagonal stays attached by welding between the shells and tubeshells 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 \( 8\frac{1}{2} \) 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 Figure 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 Figure PFT-21, illustrations (a) and (b)], 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 Figure A-8, illustrations (l) through (n)] shall not exceed one-half the maximum pitch determined by PG-46, plus 2 in. (50 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 the crown sheet of 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 Figure A-8, illustrations (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 Figure A-8, illustrations (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 in.² (64500 mm²), provided the requirements of both PFT-27.9.1 and PFT-27.9.2 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.

### 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 Figure PFT-27)

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

where

- \( C \) = factor for the thickness of plate and type of stay used as required in PG-46
- \( P \) = maximum allowable working pressure
- \( S \) = maximum allowable stress value given in Section II, Part D, Subpart 1, Table 1A
- \( t \) = thickness of plate
- \( \beta \) = angle, deg, 90 deg ≤ \( \beta \) ≤ 180 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 Section II, Part D, Subpart 1,
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 equation:

\[ P = \frac{C d^2 t}{(W - p) D_1} \]

where

- \( C = 7,000 \) when girder is fitted with one supporting bolt
- \( 10,000 \) when the girder is fitted with two or three supporting bolts
- \( 11,000 \) when the girder is fitted with four or five supporting bolts
- \( 11,500 \) when the girder is fitted with six or seven supporting bolts
- \( 12,000 \) when the girder is fitted with eight or more supporting bolts

- \( D_1 = \) distance between girders from center to center
- \( d = \) depth of girder
- \( P = \) maximum allowable working pressure
- \( p = \) pitch of supporting bolts
- \( t = \) thickness of girder
- \( W = \) extreme distance between supports of, in a scotch marine boiler, the distance from the fire side of the tubeshot to the fire side of the back connection plate

Example: Given \( W = 34 \text{ in.}, p = 7.5 \text{ in.}, D_1 = 7.75 \text{ in.}, d = 7.5 \text{ in.}, t = 2 \text{ in.}; \) three stays per girder, \( C = 10,000; \) then substituting in the following equation:

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

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
Figure A-8
Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers

(a-1)
Fillet weld
(see PFT-11.3)

Max. $r = 8t$
Min. $r = 3t$
$t =$ nominal thickness of tubesheet
$P = 3.2 \times \frac{t^2 s}{p^2}$

Min. (see PW-13)

(a-2)
Full penetration weld (see PFT-11.4)
$P = 3.2 \times \frac{t^2 s}{p^2}$

(b-1)
Screwed staybolt with end riveted over (see PG-47)

Door ring

Welded staybolt heads (see PW-19)

Min. (see PW-13)
$C = 2.1$ or $2.2$
Max. $r = 8t$
Min. $r = 3t$

$P = C \times \frac{t^2 s}{p^2}$

(b-2)
Door ring

Full penetration weld (see PFT-11.4)
$\frac{p}{2} + 2$ in. (50 mm)

Full penetration weld (see PFT-11.4)
$\frac{p}{2} + 2$ in. (50 mm)

$P = C \times \frac{t^2 s}{p^2}$
$C = 2.1$ or $2.2$

(c)
Combustion chamber head

Full penetration weld (see PW-19)

Full penetration weld (see PW-19)

Screwed staybolt with end riveted over (see PG-47)

Boiler shell
Max. $r = 8t$
Min. $r = 3t$
$P = C \times \frac{t^2 s}{p^2}$

$C = 2.1$ or $2.2$

Two fillet welds (see PFT-11.3)

Replace with updated versions shown on page 10 of the proposal.
Figure A-8
Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers (Cont'd)

Replace with updated version shown on page 10 of the proposal

$h$

$P = 2.2 \times \frac{\frac{L_g}{2}}{p^2} \times \left[ \frac{80}{\beta} \right]^2$

$\beta = \text{angularity of tangent lines in degrees}$
Figure A-8
Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers (Cont'd)

(i) (j)
(1) Weld in shear PW-19.1
(2) Maximum pitch 15 times stay diameter PFT-27.2
(3) Max. $r = 8t$
Min. $r = 3t$

$T$ = nominal thickness of tubesheet

(k) (l) (m)
(1) Weld in shear PW-19.1
(2) Maximum pitch 15 times stay diameter PFT-27.2
(3) Max. $r = 8t$
Min. $r = 3t$

$T$ = nominal thickness of tubesheet

(n) (o) (p)
PFT-27.4

$\frac{D}{2} + 2$ in. (50 mm) max.

$\frac{D}{2} + 2$ in. (50 mm) max.

$1\frac{1}{2}D$ max.

Full penetration weld may be applied from either or both sides of tubesheet.
Figure A-8
Detail Illustrations Showing Application of PG-48 and PFT-27 to the Staying of Boilers (Cont'd)

Maximum pitch “p” may be measured circumferentially and radially only

Maximum pitch “p” may be measured horizontally and vertically only

(1) Provide stay cross-sectional area required by PG-49 based upon allowable stresses from Section II, Part D, Subpart 1, Table 1A.
(2) Provide the number of stays required to not exceed the maximum calculated pitch.
(3) Diagonal stay stresses must not exceed limits computed from PFT-32.

Support Perimeter
d

General Note: "p" is same as given in PG-46.
Notes on the Proposal

The background material file features an FEA report that compiles the results of over 80 FEA of flange radii from 3t to 32t and thicknesses from 5/16” to 1”. The results of this FEA work make up the basis of this proposal. Background file 2.a contains the complete report with Appendix A and B. Background file 2.d contains an excel file that contains data obtained from the FEA work.

2.b and 2.c contain the appendixes to the FEA report in separate documents. Everything in these documents can be found in the report in 2.a and exist solely due to CSconnect issues.

List of Changes to Figure A-8

Figure A-8 (a-1)
Changes: d dimension added, p dimension changed to p/2 to match new PFT-26.3 and PFT-27.2, Max. r=8t removed, changed the end of the through stay to match Figure PG-46.2.

Figure A-8 (b-1)
Changes: d dimension added, p dimension changed to p/2 to match new PFT-26.3 and PFT-27.2, Max. r=8t removed, bottom p dimension changed to reflect that the pitch should be from weld to center of stay and not the point of tangency to the center of stay as shown before, added a t dimension

Figure A-8 (c)
Changes: d dimension added, p dimension changed to p/2 to match new PFT-26.3 and PFT-27.2, reference to PL-27.6 was added, Max. r=8t removed.

Figure A-8 (g-1)
Changes: d dimension added, p dimension changed to p/2 to match new PFT-26.3 and PFT-27.2, p dimensions changed to show center of stays to match the rest of the code rules, rivet hidden lines changed to more accurately reflect staggered construction

Figure A-8 (i)
Changes: d dimension added, p dimension changed to p/2 to match new PFT-26.3 and PFT-27.2, Max. r=8t removed, reference to PFT-27.2 updated to PFT-27.4

Figure A-8 (j)
Changes: d dimension added, p dimension changed to p/2 to match new PFT-26.3 and PFT-27.2, Max. r=8t removed, fillet weld added, reference to PFT-27.2 updated to PFT-27.4

Figure A-8 (k)
Changes: reference to PFT-27.3 updated to PFT-27.4
SECTION I – POWER BOILERS

FIG. PFT-31.1 METHOD OF DETERMINING NET AREA OF SEGMENT OF A HEAD

FIG. PFT-31.2 METHOD OF DETERMINING NET AREA OF IRREGULAR SEGMENT OF A HEAD

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

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staybolts and stays shall be given as in Table PG-23.3. In determining the net cross-sectional area of drilled or hollow staybolts, the cross-sectional area of the hole shall be deducted.

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.

28.3 When stay rods are screwed through sheets and riveted over, they shall be supported at intervals of not to exceed 6 ft. Stay rods over 6 ft 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. in diameter.

PFT-29 STRUCTURAL REINFORCEMENTS

29.1 When channels or other structural shapes are riveted to the boiler heads for attaching through-stays, the transverse stress on such members shall not exceed 12,500 psi. In computing the stress, the section modulus of the member shall be used without addition for the strength of the plate. The spacing of the rivets over the supported surface shall be determined by the formula in PG-46, using 135 for the value of C.

29.2 Provided the outstanding legs of the two members are fastened together so that they act as one member in resisting the bending action produced by the load on the rivets attaching the members to the head of the boiler, and provided that the spacing of these rivets attaching the members to the head is approximately uniform, the members may be computed as a single beam uniformly loaded and supported at the points where the through stays are attached.

PFT-30 STAYING SEGMENTS OF HEADS

30.1 A segment of a head shall be stayed by head-to-head, through, diagonal, crowfoot, or gusset stays, except that a horizontal-return tubular boiler may be stayed as provided in PFT-35.

30.2 Stays shall be used in the tube sheets 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 Table PG-46.

Any part of the tube sheet 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 112 or 120 depending upon the plate thickness. The tube holes, or tube hole and cylindrical furnace (see Fig. PFT-30), 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-31 AREAS OF HEADS TO BE STAYED

31.1 The area of a segment of a flanged head to be stayed shall be the area enclosed by lines drawn 2 in. from the tubes and a distance d from the shell as shown in Figs. PFT-31.1 and PFT-31.2. The value of d used may be the larger of the following values:

\[ d = \text{the outer radius of the flange, not exceeding } 8 \text{ times the thickness of the head} \]

\[ d = \frac{80t}{\sqrt{P}} \]

where \( d \) = unstayed distance from shell, inches

\( t \) = thickness of head in inches

\( P \) = maximum allowable working pressure, pounds per square inch

31.2 The area of a segment of an unflanged head to be stayed shall be the area enclosed by the shell and a line drawn 2 in. from the tubes.
31.3 The rules in PFT-30.2 shall be used to determine if staying is required.

31.3.1 The net area to be stayed in a segment of a flanged head may be determined by the following formula:

\[
A = \frac{4(H-d-2)^2}{3} \sqrt{\frac{2(R-d)}{(H-d-2)} - 0.608}
\]

where

- \(A\) = area to be stayed, square inches
- \(H\) = distance from tubes to shell, inches
- \(d\) = distance determined by formula in PFT-31.1 for flanged heads
- \(d\) = zero for unflanged heads
- \(R\) = radius of boiler head, inches

31.3.2 The net area to be stayed in a segment of an unflanged head may be determined by the following formula:

\[
A = \frac{4(H-2)^2}{3} \sqrt{\frac{2R}{(H-2)} - 0.608}
\]

where \(A\) = area to be stayed, square inches.

31.4 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. at any point.

When horizontal firetube boilers are set so that the products of combustion do not come in contact with the lower part of the shell, tubes may be used instead of through-stays at the sides of the manhole opening, if used.

PFT-32 STRESSES IN DIAGONAL AND GUSSET STAYS

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:

\[
A = \frac{aL}{l}
\]

where

- \(A\) = sectional area of diagonal stay, square inches
- \(a\) = sectional area of direct stay, square inches
- \(L\) = length of diagonal stay as indicated in Fig. PFT-32, inches
- \(l\) = 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

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

\[
A = \frac{0.7854 \times 60}{48} = 0.98\text{ sectional area, sq in.}
\]

Diameter = 1.11 in. = 1\(\frac{1}{8}\) in.

32.2 For staying segments of tube sheets 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 percent of the allowable stress value given in Table PG-23.3.

PFT-33 DESIGN OF STAYS AND STAY CONNECTIONS

All rivet holes and pinholes shall conform to the requirements of Part PR-32 and the pins shall be made a neat fit. To determine the sizes that shall be used, proceed as follows:

33.1 Determine the required cross-sectional area of the stay in accordance with PFT-29.

33.2 Design the body of the stay so that the cross-sectional area shall be at least equal to the required cross-sectional area of the stay for unwelded stays. Where the stays are forge welded, the cross-sectional area at the weld shall be at least as great as that computed for a stress of 6000 psi (see Table PG-23.3).

33.3 Make the area of pins to resist double shear at least three-quarters of the required cross-sectional area of the stay.

33.4 Make the combined cross section of the eye at the side of the pin (in crowfoot stays) at least 25 percent greater than the required cross-sectional area of the stay.

33.5 Make the cross-sectional areas through the blades of diagonal stays where attached to the shell of the boiler at least equal to the required rivet section, that is, at least equal to \(1\frac{1}{4}\) times the required cross-sectional area of the stay.

33.6 Design each branch of a crowfoot to carry two-thirds the total load on the stay.

33.7 Make the net sectional areas through the sides of the crowfoot, tee irons, or similar fastenings at the rivet holes at least equal to the required rivet section, that is, at least equal to \(1\frac{1}{4}\) times the required cross-sectional area of the stay.