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

\[ C = 0.33 \text{ for noncircular plates, welded to the inside of a drum, pipe, or header, and otherwise meeting the requirements for the respective types of welded boiler drums, including postweld heat treatment when required for the drum, but omitting volumetric examination. The throat thickness of the fillet welds in Figure PG-31, illustrations (e) and (f) shall be at least } 0.7 t_s. \]

\[ \text{The size of the weld } t_w \text{ in illustration (g-1) shall be not less than } 2t_s \text{ or } 1/4 \text{ in. (3 mm) and the exposed edge not less than } t_s \text{ or } 1/4 \text{ in. (6 mm), whichever is smaller.} \]

\[ \text{Figure PG-31, illustration (i-2): } C = 0.33 \text{ for circular plates welded to the end of the drum, pipe, or header. The minimum throat thickness of the inside fillet weld shall be } 0.7 t_s. \]

\[ \text{The width at the bottom of the welding groove shall be not less than } 1/6 \text{ in. (3 mm) and the exposed edge not less than } t_s \text{ or } 1/4 \text{ in. (6 mm), whichever is smaller.} \]

\[ \text{The circular plate shall be inserted a minimum of } 1/6 \text{ in. (3 mm) into the end of the drum, pipe, or header.} \]

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

\[ d \sqrt{1.9Wh_G / Sd^3} \text{ for circular heads and covers, and not less than } \]

\[ d \sqrt{6Wh_G / Sld^2} \text{ for noncircular heads and covers.} \]

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

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

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

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

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

**OPENINGS AND COMPENSATION**

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

**PG-32.1** The rules for openings and compensation in PG-32 through PG-39 shall apply to all openings in shells, headers, and dished heads except as otherwise provided in PG-29.3, PG-29.7, PG-29.12, PG-32.1.2, PG-32.1.4, PG-32.1.5, and PFT-40.
The notations used throughout PG-32.1 are defined as follows:

- **D** = the outside diameter of the shell, header, or dished head containing the opening, in. (mm)
- **d** = diameter of a finished opening, in. (mm) (see PG-33.3)
- **d<sub>max</sub>** = the maximum permissible finished opening diameter for an uncompensated opening, in. (mm) (see PG-32.1.4)
- **K** = for openings in
  - (a) cylindrical shells and headers and dished heads, \( K = K_1 \)
  - (b) full-hemispherical heads, \( K = K_2 \)
- \( K_1 = \) lesser of 0.990 or \( PD /(1.82 St ) \)
- \( K_2 = \) lesser of 0.990 or \( PD /(3.64 St ) \)
- **L<sub>co</sub>** = the distance between centers of two openings measured on the surface of the head, shell, or header, in. (mm)
- **P** = the maximum allowable working pressure
- **S** = the maximum allowable stress value, taken from Section II, Part D, Subpart 1, Tables 1A and 1B
- **t** = the nominal thickness of the head, shell, or header, in. (mm)
- **X<sub>1</sub>, X<sub>2</sub>** = the limits of compensation parallel to the vessel wall (see PG-36.2) of any two finished openings under construction, in. (mm)

**PG-32.1.2 Multiple Openings.** Groups of openings may be designed in accordance with the rules for ligaments in PG-52 or PG-53. Multiple openings that are not designed as ligaments shall comply with PG-38.

**PG-32.1.3 Single Openings.** Single openings are defined as openings that have a minimum center-to-center distance between adjacent openings not less than \( L_{co} \), where

\[
L_{co} = X_1 + X_2
\]

**PG-32.1.4 Openings in Shells and Headers.** No calculation need be made to determine the availability of compensation for a single opening (see PG-32.1.3), not covered by PG-38, PG-52, or PG-53, in shells or headers when the diameter of the finished opening, \( d \), as defined in PG-33.3 does not exceed the larger of (a) or (b) below.

- (a) the value of \( d_{max} \) as follows:
  - (U.S. Customary Units)
    \[
d_{max} = 2.75 \left[ Dt (1 - K) \right]^{1/3}
\]
  - (SI Units)
    \[
d_{max} = 8.08 \left[ Dt (1 - K) \right]^{1/3}
\]
- (b) the smaller of one-fourth the inside diameter of the shell or header or \( 23/8 \) in. (60 mm)

**PG-32.1.5 Openings in Dished Heads.** No calculation need be made to determine the availability of compensation for a single opening in dished heads under the same conditions stipulated for openings in shells and headers in PG-32.1.4, provided the following additional requirements are met.

**PG-32.1.5.1** The openings shall be located completely within the center portion of a dished head bounded by the tangent line between the spherically dished portion and the knuckle radius, but not closer than the thickness of the head to the edge of this circle or to a flanged-in manway. For a 2:1 ellipsoidal head, the opening shall be located completely within the center portion of the head bounded by a circle equal to 80% of the inside diameter, but not closer than the thickness of the head to the edge of this circle.

**PG-32.1.5.2** For dished heads other than full-hemispherical heads, the maximum allowable opening diameter shall not exceed that permitted in PG-32.1.4 using \( K = K_1 \) for an equivalent shell constructed of the same material, outside diameter, and the maximum allowable working pressure of the head.

**PG-32.1.5.3** For full-hemispherical heads, the maximum allowable opening diameter shall not exceed that permitted in PG-32.1.4 using \( K = K_2 \) for an equivalent shell constructed of the same material, outside diameter, and the maximum allowable working pressure of the head.

**PG-32.2 Shape of Openings.**

**PG-32.2.1** Openings in cylindrical portions of vessels or in formed heads shall preferably be circular, elliptical, or obround. When the long dimension of an elliptical or obround opening exceeds twice the short dimension, the compensation across the short dimension shall be increased as necessary to provide against excessive distortion due to twisting moment.

**PG-32.2.2** Openings may be of other shapes than those given in PG-32.2.1, and all corners shall be provided with a suitable radius. When the openings are of such proportions that their strength cannot be computed with assurance of accuracy, or when doubt exists as to the safety of a vessel with such openings, the part of the vessel affected shall meet the requirements of PG-16.1.

**PG-32.3 Size of Openings.**

**PG-32.3.1** Properly reinforced openings in cylindrical and spherical shells are not limited as to size and shall comply with the provisions that follow, and with the additional provisions given under PG-32.3.2.
**PG-32.3.2** The rules given herein for compensation apply to openings not exceeding the following dimensions:

(a) for vessels 60 in. (1 500 mm) inside diameter and less, one-half the vessel inside diameter but not over 20 in. (500 mm)

(b) for vessels over 60 in. (1 500 mm) inside diameter, one-third the vessel inside diameter but not over 40 in. (1 000 mm)

**PG-32.3.3** Larger openings should be given special attention and may be provided with compensation in any suitable manner that complies with the intent of the Code rules. It is recommended that the compensation provided be distributed close to the opening. (A provision of about two-thirds of the required compensation within a distance of three-fourths times the limit established in PG-36.2 on each side of the opening as measured from the center of the opening is suggested.) Special consideration should be given to the fabrication details used and the inspection employed on critical openings; compensation often may be advantageously obtained by use of a thicker shell plate for a vessel course or inserted locally around the opening; welds may be ground to concave contour and the inside corners of the opening rounded to a generous radius to reduce stress concentrations. In extreme cases of large openings approaching full vessel diameter, openings of unusual shape, etc., the requirements of PG-16.1 may be advisable.

**PG-33 COMPENSATION REQUIRED FOR OPENINGS IN SHELLS AND DISCHED HEADS**

**PG-33.1 General.** The rules in this subparagraph apply to all openings other than flanged-in openings in dished heads covered by PG-29.3, PG-29.7, and PG-29.12; openings in flat heads covered by PG-35; and openings covered within PG-32.1.2, PG-32.1.4, and PG-32.1.5.

When required, compensation shall be provided in such amount and distribution that the requirements for area of compensation are satisfied for all planes through the center of the opening and normal to the vessel surface. For a circular opening in a cylindrical shell, the plane containing the axis of the shell is the plane of greatest loading due to pressure.

**PG-33.2 Area Required.** The total cross-sectional area of compensation required in any given plane for a vessel under internal pressure shall be not less than $A$, as defined in Figure PG-33.1.

**PG-33.3** The notation used in this paragraph is defined as follows:

\[ d = \text{diameter in the plane under consideration of the finished opening (see Figure PG-33.2)} \]

- $D_p$ = outside diameter of reinforcing element (The actual size of reinforcing element may exceed the limits of reinforcement established by PG-36; however, credit cannot be taken for any material outside these limits.)
- $F = \text{factor from PG-33 and Figure PG-33.3, which compensates for the variation in pressure stresses on different planes with respect to the longitudinal axis of a cylindrical shell. } F = 1.0 \text{ for formed or flat heads.}$
- $f_r = \text{strength reduction factor, not greater than 1.0 (see Figure PG-33.1)}$
- $f_{r1} = \frac{S_n}{S_v}$
- $f_{r2} = \text{(lesser of } S_n \text{ or } S_p \text{)/}S_v$
- $f_{r3} = \frac{S_p}{S_v}$
- $h = \text{distance nozzle projects inward from the outer surface of the vessel wall (Extension of the nozzle beyond the inside surface of the vessel wall is not limited; however, for reinforcement calculations, credit shall not be taken for material outside the limits of reinforcement established by PG-36.)}$
- $R_n = \text{inside radius of the nozzle under consideration}$
- $S = \text{allowable stress value in tension (from Section II, Part D, Subpart 1, Tables 1A and 1B)}$
- $S_n = \text{allowable stress in nozzle (see S)}$
- $S_p = \text{allowable stress in reinforcing element (plate) (see S)}$
- $S_v = \text{allowable stress in vessel (see S)}$
- $t = \text{specified vessel wall thickness (excluding any corrosion, erosion, and forming allowances).}$ For pipe, it is the nominal thickness less manufacturing undertolerance allowed in the pipe specification.
- $t_o = \text{thickness of attached reinforcing pad or height of the largest 60 deg right triangle supported by the vessel and nozzle outside diameter projected surfaces and lying completely within the area of integral reinforcement (see Figure PG-33.2)}$
- $t_n = \text{nozzle wall thickness (excluding any corrosion or erosion allowances).}$ Except for pipe, this is the wall thickness not including forming allowances. For pipe, use the nominal thickness.
- $t_r = \text{required thickness of a seamless shell or head computed by the rules of the Code for the designated pressure, except when}$
  - (a) the opening and its compensation are in a torispherical head and are entirely within the spherical portion; $t_r$ is the thickness required for a seamless hemispherical head of the same radius as that of the spherical portion
  - (b) the opening and its compensation are in an ellipsoidal head in which one-half of the minor axis is equal to one-fourth of the inside diameter, and are located entirely within a circle the center of which coincides with the center of the head and

For openings--nozzles that penetrate partially or fully through the shell $d = \text{the nozzle inside diameter.}$ For set on nozzles $d = \text{the diameter of the opening in the shell.}$
Figure PG-33.1
Nomenclature and Equations for Reinforced Openings

Area required

Area available in shell: use larger value

Area available in nozzle projecting outward; use smaller value

Area available in nozzle projecting inward

Area available in outward nozzle weld

Area available in inward nozzle weld

Area available in element [Note (2)]

With reinforcing element added:

Area available in outer element weld

Area available in element [Note (2)]

If $A_1 + A_2 + A_3 + A_4 + A_5 > A$, Opening is adequately reinforced

If $A_1 + A_2 + A_3 + A_4 + A_5 < A$, Opening is not adequately reinforced so reinforcing elements must be added and/or thickness must be increased

GENERAL NOTES:

(a) This figure illustrates common nozzle configurations and is not intended to prohibit other configurations permitted by the Code.

(b) See PG-33.3 and PG-36 for definitions of nomenclature.

NOTES:

(1) For the left-hand side of the illustration, $w_d = 0$.

(2) This formula is applicable for a rectangular cross-sectional element that falls within the limits of reinforcement.
the diameter of which is equal to 80% of the shell inside diameter, \( \tau_n \), is the thickness required for a seamless hemispherical head of radius equal to 90% of the inside diameter of the shell

\[
\tau_{rn} = \text{required thickness of seamless nozzle wall; found by the formula used for } \tau_n \text{ for the shell, omitting the } C \text{ factor (the value of } S \text{ used in determining } \tau_{rn} \text{ shall be based on the nozzle material). The value of } \tau_{rn} \text{ shall be taken as zero for the entire wall of manhole and handhole rings projecting internally with the cover on the inside.}
\]

\[
w_d = \text{width of the nozzle inserted into the vessel wall beyond } \tau_n, \text{ not greater than the larger of } d/2 - \tau_n \text{ or } t \text{ (see Figure PG-33.2)}
\]

**PG-34 FLANGED-IN OPENINGS IN FORMED HEADS**

**PG-34.1** All openings in torispherical, ellipsoidal, and hemispherical heads shall be provided with reinforcement in accordance with PG-33, except for heads that meet the requirements in PG-34.2 and PG-29.3, PG-29.7, and PG-29.12.

**PG-34.2** A flanged-in manhole opening in a dished head shall be flanged to a depth of not less than three times the required thickness of the head for plate up to 1 1/2 in. (38 mm) in thickness. For plate exceeding 1 1/2 in. (38 mm) in thickness, the depth shall be the thickness of the plate plus 3 in. (75 mm). The depth of flange shall be determined by placing a straight edge across the outside opening along the major axis and measuring from the straight edge to the edge of the flanged opening. A manhole opening may be compensated by a manhole ring or other attachment in place of flanging in accordance with PG-33.

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

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

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

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

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

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

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

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

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

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

**PG-36 LIMITS OF METAL AVAILABLE FOR COMPENSATION**

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

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

**PG-36.2.1** The diameter of the finished opening.

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

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

**PG-36.3.1** 2 1/2 times the nominal shell thickness.

**PG-36.3.2** 2 1/2 times the nozzle-wall thickness plus the thickness of any added compensation, exclusive of weld metal on the side of the shell under consideration.

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

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

**PG-36.4.2** Metal over and above the thickness required to resist pressure in that part of a nozzle wall extending outside the vessel wall. The maximum area in the
Figure PG-33.2
Some Representative Configurations Describing the Dimensions $t_e$, $h$, and $d$

(a) \( t_n = 0 \), \( h = 0 \)

(b) \( w_d = 0 \)

(c) \( w_d = 0 \)

(d) 30 deg min.

(e) 30 deg max.

(e-1) 30 deg max.

(e-2) 30 deg max.

(f) 30 deg max.

(g) 30 deg max.

(h) 60 deg

(i) 60 deg

(j) 3/8 in. (19 mm)

3R min.

GENERAL NOTE: Use illustration (e) to determine whether illustration (e-1) or (e-2) applies:
(1) If \( L < 2.5t_e \), use illustration (e-1).
(2) If \( L \geq 2.5t_e \), use illustration (e-2).
(3) The 30 deg min. transition shown at illustration (e) is typical for illustrations (e-1) and (e-2).
nozzle wall available as compensation is the smaller of the values of $A_2$ given by the equations shown in Figure PG-33.1.

All metal in the nozzle wall extending inward from the outer surface of the vessel wall may be included. No allowance shall be taken for the fact that a differential pressure on an inwardly extending nozzle may cause opposing stress to that of the stress in the shell around the opening.

**PG-36.3** Metal added as compensation (continuously about the nozzle) when welded to both the vessel and nozzle, and metal provided in attachment welds.

**PG-36.5** Typical examples of the application of the above rules are presented in A-65 through A-69.

**PG-37** STRENGTH OF COMPENSATION

**PG-37.1** Material used for compensation shall have an allowable stress value equal to or greater than that of the material in the vessel wall, except that material of lower strength may be used provided the area of compensation is increased in inverse proportion to the ratio of the allowable stress values of the two materials to compensate for the lower allowable stress value of the compensation. No credit may be taken for the additional strength of any compensation having a higher allowable stress value than that of the vessel wall. Deposited weld metal outside of either the vessel wall or any reinforcing pad used as reinforcement shall be credited with an allowable stress value equivalent to the weaker of the materials connected by the weld. Vessel-to-nozzle or pad-to-nozzle attachment weld metal within the vessel wall or within the pad may be credited with a stress value equal to that of the vessel wall or pad, respectively.

**PG-37.2** The welds that attach elements of compensation that are not an integral part of the vessel wall shall have a strength, $W$, not less than the load carried by those elements defined as follows:

$$W = (A_1 - A_2)S_v$$

where $A_1$, $A_2$, and $S_v$ are defined in PG-33.3 and Figure PG-33.1.

**PG-37.3** When a reinforcing pad is required by the rules of PG-33, the welds attaching the nozzle to the pad and shell shall be checked independently to assure that the loads carried by the individual elements can be transmitted by the attaching welds. For detailed requirements and examples of calculating the strength of welds, see PW-15.

**PG-37.4** Welds attaching elements of compensation need not satisfy the weld strength requirements of PG-37.2 under the following circumstances:

(a) openings that are exempt in PG-32 from compensation calculations

(b) openings designed by ligaments rules of PG-52 and PG-53 and/or

(c) openings with elements of compensation attached by full penetration welds as listed in PW-15.1.6

**PG-37.5** The minimum weld sizes shall not be smaller than the minimum required by PW-16.

**PG-38** COMPENSATION FOR MULTIPLE OPENINGS

**PG-38.1** When any two adjacent openings that require compensation are spaced at less than two times the distance defined in PG-36.2 so that their limits of compensation overlap (see Figure PG-38.1-1), the two openings shall be compensated in the plane connecting the centers of the openings in accordance with PG-33 with a compensation that has an area equal to the combined area of the compensation required for the separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area. The available area of the head or shell between openings having an overlap area shall be proportioned between the two openings by the ratio of their diameters.
PG-38.2 When more than two openings are spaced at less than two times the distance defined in PG-36.2 so that their limits overlap with each other (see Figure PG-38.2-1) and are to be provided with a combined reinforcement, the minimum distance between centers of any two of these openings shall be 1\(\frac{1}{3}\) times their average diameter, and the area of reinforcement between any two openings shall be at least equal to 50% of the total required for the two openings. If the distance between centers of two such openings is less than 1\(\frac{1}{3}\) times their average diameter, no credit for reinforcement shall be taken for any of the material between these openings. Such openings must be reinforced as described in PG-38.3.

PG-38.3 Alternatively, any number of adjacent openings, in any arrangement, may be reinforced by using an assumed opening enclosing all such openings. The limits for reinforcement of the assumed opening shall be those given in PG-36.2.1 and PG-36.3.1. The nozzle walls of the actual openings shall not be considered to have reinforcing value. For shells and headers, when the diameter of the assumed opening exceeds the limits in PG-32.3.2, the recommendations in PG-32.3.3 may be considered.

PG-38.4 When a shell or drum has a series of openings (three or more) in a definite pattern, the distance between centers of any two adjacent finished openings shall not be less than 1\(\frac{1}{3}\) times their average diameter, and shall be reinforced per PG-38.1 for any two adjacent finished openings. Also, the net cross-sectional area between these adjacent openings within the limits of the actual shell wall, excluding the portion of the compensation not fused to the shell wall, shall equal at least 0.7\(F\) of the cross-sectional area obtained by multiplying the center-to-center distance of the openings by the required thickness of a seamless shell, where the factor \(F\) is taken from Figure PG-33.3 for the plane under consideration (see Figure PG-38.4-1). Alternately, per PG-32.1.2, groups of openings may be designed in accordance with the rules for ligaments in PG-52 or PG-53.

PG-38.5 When a group of openings is provided with compensation by a thicker section buttwelded into the shell or head, the edges of the inserted section shall be tapered as prescribed in PW-9.3.

PG-39 METHODS OF ATTACHMENT OF PIPE AND NOZZLE NECKS TO VESSEL WALLS

PG-39.1 General. Except as limited in PG-32, nozzles may be attached to the shell or head of a vessel by any of the methods of attachment given in this paragraph.

PG-39.2 Welded Connections. Attachment by welding shall be in accordance with the requirements of PW-15 and PW-16.

PG-39.4 Studded Connections. Connections may be made by means of bolt studs. The vessel shall have a flat surface machined on the shell, or on a built-up pad, or on a properly attached plate or fitting. Drilled holes to be tapped for straight threads shall not penetrate within one-fourth of the wall thickness from the inside surface of the vessel, unless at least the minimum thickness required as above is maintained by adding metal to the inside surface of the vessel. Where tapped holes are provided for studs, the threads shall be full and clean and shall engage the stud for a length not less than the larger of \(d_s\) or \(d_{sp}\).
in which \( d_s \) is the diameter of the stud, except that the thread engagement need not exceed 1.75 \( d_s \). Studded connections shall meet the requirements for compensation. No credit for compensation shall be allowed for any areas attached by studs only.

**PG-39.5 Threaded Connections.**

**PG-39.5.1** Where a threaded connection is to be made to a boiler component it shall be into a threaded hole. The threads shall conform to the requirements of ASME B1.20.1 and provide for the pipe to engage the minimum number of threads specified in Table PG-39 after allowance has been made for curvature of the vessel wall. A built-up pad or properly attached plate or fitting may be used to provide the metal thickness and number of threads required in Table PG-39, or to furnish compensation when required.

**PG-39.5.2** Threaded joints for boiler connections for external piping shall be in accordance with the following size and pressure limitations and shall not be used where the temperature exceeds 925°F (495°C).

<table>
<thead>
<tr>
<th>Maximum Size, NPS (DN)</th>
<th>Maximum Pressure, psi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (80)</td>
<td>400 (3)</td>
</tr>
<tr>
<td>2 7/8 (65)</td>
<td>500 (3.5)</td>
</tr>
<tr>
<td>2 (50)</td>
<td>600 (4)</td>
</tr>
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<td>1 1/2 (40)</td>
<td>900 (6)</td>
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<td>1 3/4 (32)</td>
<td>1,000 (7)</td>
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<td>1 (25)</td>
<td>1,200 (8)</td>
</tr>
<tr>
<td>3/4 (20) and smaller</td>
<td>1,500 (10)</td>
</tr>
</tbody>
</table>

**PG-39.5.3** Threaded connections for plug closures used for inspection openings, end closures, and similar purposes may be used within the size and pressure limitations of Table PG-39.

**PG-39.6 Expanded Connections.** Provided the requirements for compensation are met, a pipe, tube, or forging not exceeding 6 in. (150 mm) in outside diameter may be attached to shells, heads, headers, or fittings by inserting through an opening and expanding in accordance with the rules for tube attachment in Parts PWT and PFT, whichever is applicable.

The sharp edges left in drilling tube holes shall be removed on both sides of the plate with a file or other tool. The inner surface of the tube hole in any form of attachment may be grooved or chamfered.

**PG-39.7** All welded connections shall be postweld heat treated after attachment unless specifically allowed otherwise.

**PG-42 GENERAL REQUIREMENTS FOR FLANGES, PIPE FITTINGS, AND VALVES**

**PG-42.1** The following standards covering flanges and pipe fittings are acceptable for use under this Section in accordance with the requirements of PG-11. Pressure-temperature ratings shall be in accordance with the appropriate standard except that the pressure-temperature ratings for ASME B16.9 and ASME B16.11 fittings shall be calculated as for straight seamless pipe in accordance with the rules of this Section, including the maximum allowable stress for the material. The thickness tolerance of the ASME standards shall apply.

- ASME B16.1, Gray Iron Pipe Flanges and Flanged Fittings, Classes 25, 125, and 250
- ASME B16.3, Malleable Iron Threaded Fittings, Classes 150 and 300
- ASME B16.4, Gray Iron Threaded Fittings, Classes 125 and 250
- ASME B16.5, Pipe Flanges and Flanged Fittings, NPS \( \frac{3}{2} \) Through NPS 24 Metric/Inch Standard (see PG-11.3)
  - Pressure-temperature ratings per Table 2-1.1 through 2-3.19
  - Facing dimensions (other than ring-joint) per Table 4