MANDATORY APPENDIX 2
RULES FOR BOLTED FLANGE CONNECTIONS WITH RING TYPE GASKETS

2-1 SCOPE

(a) The rules in Mandatory Appendix 2 apply specifically to the design of bolted flange connections with gaskets that are entirely within the circle enclosed by the bolt holes and with no contact outside this circle, and are to be used in conjunction with the applicable requirements in Subsections A, B, and C of this Division. The hub thickness of weld neck flanges designed to this Appendix shall also comply with the minimum thickness requirements in Subsection A of this Division. These rules are not to be used for the determination of the thickness of tubesheets integral with a bolting flange as illustrated in Figure UW-13.2, sketches (h) through (l) or Figure UW-13.3, sketch (c). Nonmandatory Appendix S provides discussion on Design Considerations for Bolted Flanged Connections.

These rules provide only for hydrostatic end loads and gasket seating. The flange design methods outlined in 2-4 through 2-8 are applicable to circular flanges under internal pressure. Modifications of these methods are outlined in 2-9 and 2-10 for the design of split and noncircular flanges. See 2-11 for flanges with ring type gaskets subject to external pressure, 2-12 for flanges with nut-stops, and 2-13 for reverse flanges. Rules for calculating rigidity factors for flanges are provided in 2-14. Recommendations for qualification of assembly procedures and assemblers are in 2-15. Proper allowance shall be made if connections are subject to external loads other than external pressure.

(b) The design of a flange involves the selection of the gasket (material, type, and dimensions), flange facing, bolting, hub proportions, flange width, and flange thickness. See Note in 2-5(c)(1). Flange dimensions shall be such that the stresses in the flange, calculated in accordance with 2-7, do not exceed the allowable flange stresses specified in 2-8. Except as provided for in 2-14(a), flanges designed to the rules of this Appendix shall also meet the rigidity requirements of 2-14. All [illegible] shall be made on dimensions in the corroded condition.

(c) It is recommended that bolted flange connections conforming to the standards listed in UG-44(a) be used for connections to external piping. These standards may be used for other bolted flange connections and dished covers within the limits of size in the standards and the pressure–temperature ratings permitted in UG-44(a). The ratings in these standards are based on the hub dimensions given or on the minimum specified thickness of flanged fittings of integral construction. Flanges fabricated from rings may be used in place of the hub flanges in these standards provided that their strength, calculated by the rules in this Appendix, is not less than that calculated for the corresponding size of hub flange.

(d) Except as otherwise provided in (c) above, bolted flange connections for unfired pressure vessels shall satisfy the requirements in this Appendix.

(e) The rules of this Appendix should not be construed to prohibit the use of other types of flanged connections, provided they are designed in accordance with good engineering practice and method of design is acceptable to the Inspector. Some examples of flanged connections which might fall in this category are as follows:

(1) flanged covers as shown in Mandatory Appendix 1, Figure 1-6;

(2) bolted flanges using full-face gaskets;

(3) flanges using means other than bolting to restrain the flange assembly against pressure and other applied loads.

2-2 MATERIALS

(a) Materials used in the construction of bolted flange connections shall comply with the requirements given in UG-4 through UG-14.

(b) Flanges made from ferritic steel and designed in accordance with this Appendix shall be full-annealed, normalized, normalized and tempered, or quenched and tempered when the thickness of the flange, t (see Figure 2-4), exceeds 3 in. (75 mm).

(c) Material on which welding is to be performed shall be proved of good weldable quality. Satisfactory qualification of the welding procedure under Section IX is considered as proof. Welding shall not be performed on steel that has a carbon content greater than 0.35%. All welding on flange connections shall comply with the requirements for postweld heat treatment given in this Division.

(d) ~~Flanges with hubs that are machined from plate, bar stock, or billet~~ shall not be machined from plate or bar material [except as permitted in UG-14(b)] unless the material has been formed into a ring and the following additional conditions are met:

Hubbed flanges

(1) In a ring formed from plate, the original plate surfaces are parallel to the axis of the finished flange. (This is not intended to imply that the original plate surface should be present in the finished flange.)

(2) The joints in the ring are welded butt joints that conform to the requirements of this Division. Thickness to be used to determine postweld heat treatment and radiography requirements shall be the lesser of

$$t \text{ or } \frac{(A-B)}{2}$$

where these symbols are as defined in 2-3.

(3) The back of the flange and the outer surface of the hub are examined by either the magnetic particle method as per Mandatory Appendix 6 or the liquid penetrant method as per Mandatory Appendix 8.

(e) Bolts, studs, nuts, and washers shall comply with the requirements in this Division. It is recommended that bolts and studs have a nominal diameter of not less than $^1/_2$ in. (13 mm). If bolts or studs smaller than $^1/_2$ in. (13 mm) are used, ferrous bolting material shall be of alloy steel. Precautions shall be taken to avoid overstressing small-diameter bolts.

(23) 2-3 NOTATION

The symbols described below are used in the equations for the design of flanges (see also Figure 2-4):

A = outside diameter of flange or, where slotted holes extend to the outside of the flange, the diameter to the bottom of the slots

a = nominal bolt diameter

A_b = Total cross-sectional area of all the bolts based on the smaller of
(a) root diameter of the thread
(b) least diameter of any unthreaded portion
ASME PCC-1, Nonmandatory Appendix H contains root areas for common bolt sizes that may be used.

A_m = total required cross-sectional area of bolts, taken as the greater of A_{m1} and A_{m2}

A_{m1} = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for the operating conditions
= W_{m1}/S_b

A_{m2} = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for gasket seating
= W_{m2}/S_a

B = inside diameter of flange. When B is less than $20g_1$, it will be optional for the designer to substitute B_1 for B in the formula for longitudinal stress S_H.

b = effective gasket or joint-contact-surface seating width [see Note in 2-5(c)(1)]

B_1 = $B + g_1$ for loose type flanges and for integral type flanges that have calculated values h/h_o and g_1/g_o which would indicate an f value of less than 1.0, although the minimum value of f permitted is 1.0.
= $B + g_o$ for integral type flanges when f is equal to or greater than one

b_o = basic gasket seating width (from Table 2-5.2)

B_s = bolt spacing. The bolt spacing may be taken as the bolt circle circumference divided by the number of bolts or as the chord length between adjacent bolt locations.

B_{sc} = bolt spacing factor

B_{smax} = maximum bolt spacing

C = bolt-circle diameter

c = basic dimension used for the minimum sizing of welds equal to t_n or t_x, whichever is less

C_b = conversion factor
= 0.5 for U.S. Customary calculations; 2.5 for SI calculations

d = factor
= $\frac{U}{V}h_o{g_o}^2$ for integral type flanges
= $\frac{U}{V_L}h_o{g_o}^2$ for loose type flanges

e = factor
= $\frac{F}{h_o}$ for integral type flanges
= $\frac{F_L}{h_o}$ for loose type flanges

F = factor for integral type flanges (from Figure 2-7.2)

f = hub stress correction factor for integral flanges from Figure 2-7.6 (When greater than one, this is the ratio of the stress in the small end of hub to the stress in the large end.) (For values below limit of figure, use f = 1.)

F_L = factor for loose type flanges (from Figure 2-7.4)

G = diameter at location of gasket load reaction. Except as noted in sketch (1) of Figure 2-4, G is defined as follows (see Table 2-5.2):
(a) when $b_o \le {}^1/_4$ in. (6 mm), G = mean diameter of gasket contact face
(b) when $b_o > {}^1/_4$ in. (6 mm), G = outside diameter of gasket contact face less $2b$

g_1 = thickness of hub at back of flange

g_o = thickness of hub at small end
(a) for optional type flanges calculated as integral and for integral type flanges per Figure 2-4, sketch (7), $g_o = t_n$
(b) for other integral type flanges, g_o = the smaller of t_n or the thickness of the hub at the small end

H = total hydrostatic end force
= $0.785G^2P$

h = hub length

Errata

(b) Loose Type Flanges - This type covers those designs in which the flange has no substantial integral connection to the nozzle neck, vessel, or pipe wall, and includes welded flange connections where the welds are not considered to give the mechanical strength equivalent of an integral attachment. Loose type flanges are referenced below. The design flange and bolt loads are shown in Figures 4.16.5 and 4.16.6.

(1) Loose type flanges - Figure 4.16.5 and Table 4.2.9, Details 1,2,3 and 4

(2) Loose type lap joint flanges - Figure 4.16.6 and Table 4.2.9, Detail 5

4.16.3.2 The integral and loose type flanges described above can also be applied to reverse flange configurations. Integral and loose type reverse flanges are shown in Figure 4.16.7.

4.16.4 FLANGE MATERIALS

4.16.4.1 Materials used in the construction of bolted flange connections, excluding gasket materials, shall comply with the requirements given in Part 3.

Fabricated flanges with hubs

4.16.4.2 Flanges made from ferritic steel shall be given a normalizing or full-annealing heat treatment when the thickness of the flange, t (see Figures 4.16.1 through 4.16.7), exceeds 75 mm (3 in.).

4.16.4.3 ~~Flanges with hubs that are machined from plate, bar stock, or billet~~ shall be in accordance with the following:

(a) Flanges with hubs shall not be machined from plate or bar (except as permitted in 3.2.5.2) material unless the material has been formed into a ring and the following additional conditions are met:

(1) In a ring formed from plate, the original plate surfaces are parallel to the axis of the finished flange.

(2) The joints in the ring are welded butt joints that conform to the requirements of Part 6. The thickness to be used to determine postweld heat treatment and radiographic requirements shall be $\min[t, (A - B)/2]$.

(3) The back of the flange and outer surface of the hub shall be examined by either the magnetic particle method or the liquid penetrant method in accordance with Part 7.

4.16.4.4 Bolts, studs, nuts, and washers shall comply with the requirements of Part 3 and referenced standards. It is recommended that bolts and studs have a nominal diameter of not less than 12 mm (0.5 in.). If bolts or studs smaller than 12 mm (0.5 in.) are used, then ferrous bolting material shall be of alloy steel. Precautions shall be taken to avoid overstressing small-diameter bolts. When washers are used, they shall be through hardened to minimize the potential for galling.

4.16.5 GASKET MATERIALS

4.16.5.1 The gasket constants for the design of the bolt load (m and y), are provided in Table 4.16.1. Other values for the gasket constants may be used if based on actual testing or data in the literature, as agreed upon between designer and the user.

4.16.5.2 The minimum width of sheet and composite gaskets, N, is recommended to be no less than that given in Table 4.16.2.

NOTE: Gasket materials should be selected that are suitable for the design conditions. Corrosion, chemical attack, creep and thermal degradation of gasket materials over time should be considered.

4.16.6 DESIGN BOLT LOADS

4.16.6.1 The procedure to determine the bolt loads for the operating and gasket seating conditions is shown below.

Step 1. Determine the design pressure and temperature of the flange joint.

Step 2. Select a gasket and determine the gasket factors m and y from Table 4.16.1, or other sources. The selected gasket width should comply with the guidelines detailed in Table 4.16.2.

Step 3. Determine the width of the gasket, N, basic gasket seating width, b_0, the effective gasket seating width, b, and the location of the gasket reaction, G, based on the flange and gasket geometry, the information in Table 4.16.3 and Figure 4.16.8, and the equations shown below. Note that for lap joint flanges, G is equal to the midpoint of contact between the flange and the lap, see Figure 4.16.6 and Figure 4.16.8.

(a) For $b_0 \le 6$ mm (0.25 in.), G is the mean diameter of the gasket contact face and

$$b = b_0 \tag{4.16.1}$$

(b) For $b_0 > 6$ mm (0.25 in.)

$$b = 0.5 C_{ul} \sqrt{\frac{b_0}{C_{ul}}} \tag{4.16.2}$$

Note to Voters: This Proposal is a clean copy version of the final product without the markups from the E19-approved version, but with markups since the last Letter Ballot.

17-1800 Proposal (~~12/4/17~~2/7/18)

UG-14 RODS AND BARS

(a) Rod and bar may be used in pressure vessel construction for pressure parts such as flange rings (see 2-2(d)~~(1)~~), stiffening rings, frames for reinforced openings, stays and stay-bolts, and similar parts. Rod and bar materials shall conform to the requirements for bars or bolting in the applicable part of Subsection C.

(b) **Parts machined from rod and bar** Pressure parts such as ~~H~~hollow cylindrically-shaped parts, heads, caps, flanges, elbows, return bends, tees, and header tees may be machined directly from rod or bar as provided below:

(1) Examination by the magnetic particle or liquid penetrant method in accordance with the requirements of Mandatory Appendix 6 or 8, respectively, shall be as follows:

(-a) For flanges – ~~,~~the back of the flange and the outer surface of the hub

(-b) For~~, and~~ heads, caps, elbows, return bends, tees and header tees – all surfaces~~shall be examined by the magnetic particle or liquid penetrant method in accordance with the requirements of Mandatory Appendix 6 or 8, respectively.~~

~~(1)~~(-c) Hollow cylindrically-shaped parts need not be surface examined

(2) Parts may be machined from rod or bar having a ~~starting~~hot-worked diameter not greater than 5.50 in. (140 mm), provided that the axial length of the part is approximately parallel to the metal flow lines of the stock.

(3) Parts may be machined from rod or bar having a ~~starting~~hot-worked diameter greater than 5.50 in. (140 mm), but not greater than 8.00 in. (205 mm), provided the axial length of the part is approximately parallel to the metal flow lines of the stock, and the minimum required thickness of the component is calculated following the rules of this Division using 50% of the specified allowable stress.

(4) As an alternative to (b)(3) above and for rod or bar having a ~~starting~~hot-worked diameter greater than 8.00 in. (205 mm), parts may be machined from such rod or bar, if the following requirements are met:

(-a) The longitudinal axis of the part shall be parallel to the longitudinal axis of the rod or bar.

(-b) At least two transverse tension test specimens shall be taken from each lot (as defined in the material specification) of rod or bar material, and having the same diameter.

(i) The second specimen shall be taken at 90 degrees around the perimeter from the first specimen.

(ii) The axis of the tension test specimen shall be located, as nearly as practicable, midway between the center thickness and the surface of the rod or bar.

(iii) Both specimens shall meet the mechanical property requirements of the material specification.

(iv) For Table UCS-23 materials, the reduction of area shall be not less than 30%.

(-c) Each rod or bar, before machining, shall be 100% ultrasonically examined perpendicular to the longitudinal axis by the straight beam technique in accordance with SA-388. The rod or bar shall be unacceptable if:

(i) the examination results show one or more indications accompanied by loss of back reflection larger than 60% of the reference back reflection, or

(ii) the examination results show indications larger than 40% of the reference back reflection when accompanied by a 40% loss of back reflection.

(-d) For heads and the flat portion of caps, the examinations of (-c) shall also be performed in the axial direction.

(-e) Before welding, the cut surfaces of the part adjacent to the weld shall be examined by magnetic particle or liquid penetrant methods in accordance with Appendix 6 or 8, respectively.

Revisions to App 2:

(d) ~~(1)~~ Hubbed flanges shall not be machined from plate or bar (except as permitted in UG-14(b)) material unless the material has been formed into a ring, and further provided that:

(~~a~~1) in a ring formed from plate, the original plate surfaces are parallel to the axis of the finished flange. (This is not intended to imply that the original plate surface be present in the finished flange.)

(~~b~~2) the joints in the ring are welded butt joints that conform to the requirements of this Division. Thickness to be used to determine postweld heat treatment and radiography requirements shall be the lesser of

$$t \text{ or } \frac{(A - B)}{2}$$

where these symbols are as defined in 2-3.

(~~c~~3) the back of the flange and the outer surface of the hub are examined by either the magnetic particle method as per Mandatory Appendix 6 or the liquid penetrant method as per Mandatory Appendix 8.

FOR REFERENCE ONLY
See Approved Revisions in green highlight

VIII-2 changes

3.2.5.2 (a) Rods and bars may be used in pressure vessel construction for pressure parts such as flange rings (see 4.16.4.3(~~a~~b)), stiffening rings, frames for reinforced openings, stays and staybolts, and similar parts.

(b) **Parts machined from rod and bar** Pressure parts such as ~~H~~hollow cylindrically-shaped parts, heads, caps, flanges, elbows, return bends, tees, and header tees may be machined directly from rod or bar as provided below:

(1) Examination by the magnetic particle or liquid penetrant method in accordance with the requirements of Part 7 shall be as follows:

(-a) For flanges, the back of the flange and the outer surface of the hub~~, and~~

(-b) For heads, caps, elbows, return bends, tees and header tees ~~shall be examined by the magnetic particle or liquid penetrant method in accordance with the requirements of Part 7~~.

~~(1)~~(-c) Hollow cylindrically-shaped parts need not be surface examined

(2) Parts may be machined from rod or bar having a ~~starting~~hot-worked diameter not greater than 140 mm (5.50 in.), provided that the axial length of the part is approximately parallel to the metal flow lines of the stock.

(3) Parts may be machined from rod or bar having a ~~starting~~hot-worked diameter greater than 140 mm (5.50 in.), but not greater than 205 mm (8.00 in.), provided the axial length of the part is approximately parallel to the metal flow lines of the stock, and the minimum required thickness of the component is calculated following the rules of this Division using 50% of the specified allowable stress.

(4) As an alternative to (3) above and for rod or bar having a ~~starting~~hot-worked diameter greater than 205 mm (8.00 in.), parts may be machined from such rod or bar, if the following requirements are met:

(-a) The longitudinal axis of the part shall be parallel to the longitudinal axis of the rod or bar.

(-b) In addition to the tension test specimens required by the material specification, at least two transverse tension test specimens shall be taken from each lot of rod or bar material, with lot as defined in the material specification and having the same diameter.

(-1) The second specimen shall be taken at 90 degrees around the perimeter from the first specimen.

(-2) The axis of the tension test specimen shall be located, as nearly as practicable, midway between the center thickness and the surface of the rod or bar.

(-3) Both specimens shall meet the mechanical property requirements of the material specification.

(-4) For Table 3-A.1 materials, the reduction of area shall be not less than 30%.

(-c) Each rod or bar, before machining, shall be 100% ultrasonically examined perpendicular to the longitudinal axis by the straight beam technique in accordance with SA-388. The rod or bar shall be unacceptable if:

(-1) the examination results show one or more indications accompanied by loss of back reflection larger than 60% of the reference back reflection, or

(-2) the examination results show indications larger than 40% of the reference back reflection when accompanied by a 40% loss of back reflection.

(-d) For heads and the flat portion of caps, the examinations of (-c) shall also be performed in the axial direction.

(-e) Before welding, the cut surfaces of the part adjacent to the weld shall be examined by magnetic particle or liquid penetrant methods in accordance with Part 7.

4.16.4.3 Fabricated flanges with hubs shall be in accordance with the following:

(a) Flanges with hubs shall not be machined from plate or bar (except as permitted in 3.2.5.2) material unless the material has been formed into a ring, and further, provided that:

(1) In a ring formed from plate, the original plate surfaces are parallel to the axis of the finished flange;

(2) The joints in the ring are welded butt joints that conform to the requirements of Part 6. The thickness to be used to determine postweld heat treatment and radiographic requirements shall be $\min[t, (A - B)/2]$.

(~~b~~3) The back of the flange and the outer surface of the hub shall be examined by either the magnetic particle method or the liquid penetrant method in accordance with Part 7.