(10) The Manufacturer of the completed vessel shall fulfill these responsibilities by one of the following methods:

- (a) Obtain, when necessary, documentation as provided below, provide for retention of this documentation, and have such documentation available for examination by the Inspector when requested, or;
- (b) Perform an analysis of the pressure part in accordance with the rules of this Division. [See also U-2(g).] This analysis shall be included in the documentation and shall be made available for examination by the Inspector when requested.

(11) The documentation shall contain at a minimum:

- (a) material used
- (b) temperature rating of the part
- (c) the basis for establishing the pressure-temperature rating
- (d) a written certification by the pressure parts manufacturer that all welding and brazing complies with Code requirements

(e) The Code recognizes that a Certificate Holder may fabricate parts in accordance with UG-11(d), and that are marked in accordance with UG-11(d)(8). In lieu of the requirement in UG-11(d)(4)(-a), the Certificate Holder may subcontract to an individual or organization not holding an ASME Certificate standard pressure parts that are fabricated to a standard other than an ASME product standard provided all the following conditions are met:

(1) The activities to be performed by the subcontractor are included within the Certificate Holder’s Quality Control System.

(2) The Certificate Holder’s Quality Control System provides for the following activities associated with subcontracting of welding operations, and these provisions shall be acceptable to the Manufacturer’s Authorized Inspection Agency:

- (a) the welding processes permitted by this Division that are permitted to be subcontracted
- (b) welding operations
- (c) Authorized Inspection activities
- (d) placement of the Certificate Holder’s marking in accordance with UG-11(d)(8)

(3) The Certificate Holder’s Quality Control System provides for the requirements of UG-92 to be met at the subcontractor’s facility.

(4) The Certificate Holder shall be responsible for reviewing and accepting the Quality Control Programs of the subcontractor.

(5) The Certificate Holder shall ensure that the subcontractor uses written procedures and welding operations that have been qualified as required by this Division.

(6) The Certificate Holder shall ensure that the subcontractor uses personnel that have been qualified as required by this Division.

(7) The Certificate Holder and the subcontractor shall describe in their Quality Control Systems the operational control of procedure and personnel qualifications of the subcontracted welding operations.

(8) The Certificate Holder shall be responsible for controlling the quality and ensuring that all materials and parts that are welded by subcontractors and submitted to the Inspector for acceptance, conform to all applicable requirements of this Division.

(9) The Certificate Holder shall describe in their Quality Control Systems the operational control for maintaining traceability of materials received from the subcontractor.

(10) The Certificate Holder shall receive approval for subcontracting from the Authorized Inspection Agency prior to commencing of activities.

UG-12 BOLTS AND STUDS

(a) Bolts and studs may be used for the attachment of removable parts. Specifications, supplementary rules, and maximum allowable stress values for acceptable bolting materials are given in the tables referenced in UG-23.

(b) Stubs shall be threaded full length or shall be machined down to the root diameter of the thread in the unthreaded portion, provided that the threaded portions are at least 1½ diameters in length.

Studs greater than eight diameters in length may have an unthreaded portion that has the nominal diameter of the thread, provided the following requirements are met:

(1) the threaded portions shall be at least 1½ diameters in length;

(2) the stud shall be machined down to the root diameter of the thread for a minimum distance of 0.5 diameters adjacent to the threaded portion;

(3) a suitable transition shall be provided between the root diameter and the unthreaded portion; and

(4) particular consideration shall be given to any dynamic loadings.

UG-13 NUTS AND WASHERS

(a) Nuts shall conform to the requirements in the applicable Part of Subsection C (see UCS-11 and UNF-13).

(b) The use of washers is optional. When used, they shall be of wrought materials.

UG-14 RODS AND BARS

(a) Rods and Bars Used for Pressure Parts. Rod and bar may be used in pressure vessel construction for pressure parts such as flange rings [see 2-2(d)], 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 hollow cylindrically shaped parts, heads, caps, flanges, elbows, return bends, tees, and header tees may be machined directly from rod or bar as provided in (1) through (4) below.

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

(-a) for flanges: the back of the flange and the outer surface of the hub
(-b) for heads, caps, elbows, return bends, tees, and header tees: all surfaces
(-c) for hollow, cylindrically shaped parts: no surface examination needed

(2) Parts may be machined from rod or bar having a 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 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 (3) above and for rod or bar having a 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 that have the same diameter shall be taken from each lot (as defined in the material specification) of rod or bar material.
(-c) The second specimen shall be taken at 90 deg around the perimeter from the first specimen.
(-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 Mandatory Appendix 6 or Mandatory Appendix 8, respectively.

UG-15 PRODUCT SPECIFICATION

When there is no material specification listed in Subsection C covering a particular wrought product of a grade, but there is an approved specification listed in Subsection C covering some other wrought product of that grade, the product for which there is no specification may be used provided:

(a) the chemical and physical properties, heat treating requirements, and requirements for deoxidation, or grain size requirements conform to the approved specification listed in Subsection C. The stress values for that specification given in the tables referenced in UG-23 shall be used.
(b) the manufacturing procedures, tolerances, tests, and marking are in accordance with a Section II specification covering the same product form of a similar material;
(c) for the case of welded tubing made of plate, sheet, or strip, without the addition of filler metal, the appropriate stress values are multiplied by a factor of 0.85;
(d) the product is not pipe or tubing fabricated by fusion welding with the addition of filler metal unless it is fabricated in accordance with the rules of this Division as a pressure part;
(e) mill test reports reference the specifications used in producing the material and in addition make reference to this paragraph.

Note to voters and Editor: it's the bar that's of the same diameter, not the specimens.
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 gasket 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 calculations 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 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:

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 \( \frac{1}{2} \) in. (13 mm). If bolts or studs smaller than \( \frac{1}{2} \) in. (13 mm) are used, ferrous bolting material shall be of alloy steel. Precautions shall be taken to avoid overstressing small-diameter bolts.

(19) 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
- \( A_b \) = cross-sectional area of the bolts using the root diameter of the thread or least diameter of unthreaded position, if less
- \( A_m \) = 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
  \[ = \frac{W_{m1}}{S_b} \]
- \( A_{m2} \) = total cross-sectional area of bolts at root of thread or section of least diameter under stress, required for gasket seating
  \[ = \frac{W_{m2}}{S_b} \]
- \( B \) = 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 \( S_{ln} \)
- \( b \) = effective gasket or joint-contact-surface seating width [see Note in 2-5(c)(1)]

\[ B_{1} = B + g_{1} \text{ for loose type flanges and for integral type flanges that have calculated values } h / h_{o} \text{ and } g_{1} / g_{o} \text{ which would indicate an } f \text{ value of less than } 1.0, \text{ although the minimum value of } f \text{ permitted is } 1.0. \]

\[ = B + g_{o} \text{ for integral type flanges when } f \text{ is equal to or greater than one} \]

\[ b_{o} = \text{ basic gasket seating width (from Table 2-5.2) } \]

\[ B_{s} = \text{ bolt spacing. The bolt spacing may be taken as the bolt circle circumference divided by the number of bolts or as the chord length between adjacent bolt locations.} \]

\[ B_{smax} = B_{sc} \text{ factor for loose type flanges} \]

\[ A_{B} = \text{bolt spacing factor} \]

\[ C = \text{bolt-circle diameter} \]

\[ c = \text{basic dimension used for the minimum sizing of welds equal to } t_{o} \text{ or } t_{ew}, \text{ whichever is less} \]

\[ C_{o} = \text{conversion factor} \]

\[ = 0.5 \text{ for U.S. Customary calculations; } 2.5 \text{ for SI calculations} \]

\[ d = \text{factor} \]

\[ = \frac{v}{h_{o}b_{o}} \text{ for integral type flanges} \]

\[ = \frac{v}{h_{L}b_{L}} \text{ for loose type flanges} \]

\[ e = \text{factor} \]

\[ = \frac{F}{h_{o}} \text{ for integral type flanges} \]

\[ = \frac{F_{L}}{h_{L}} \text{ for loose type flanges} \]

\[ F = \text{factor for integral type flanges (from Figure 2-7.2)} \]

\[ f = \text{hub stress correction factor for integral flanges from Figure 2-7.6} \]

\[ (\text{When greater than one, this is the ratio of the stress in the small end of hub to the stress in the large end. (For values below limit of figure, use } f = 1.)} \]

\[ F_{L} = \text{factor for loose type flanges (from Figure 2-7.4)} \]

\[ G = \text{diameter at location of gasket load reaction. Except as noted in sketch (1) of Figure 2-4, } G \text{ is defined as follows (see Table 2-5.2):} \]

\[ (a) \text{ when } b_{o} \leq \frac{1}{4} \text{ in. (6 mm), } G = \text{mean diameter of gasket contact face} \]

\[ (b) \text{ when } b_{o} > \frac{1}{4} \text{ in. (6 mm), } G = \text{outside diameter of gasket contact face less } 2b \]

\[ g_{1} = \text{thickness of hub at back of flange} \]

\[ g_{o} = \text{thickness of hub at small end} \]

\[ (a) \text{ for optional type flanges calculated as integral and for integral type flanges per Figure 2-4, sketch (7), } g_{o} = t_{n} \]

\[ (b) \text{ for other integral type flanges, } g_{o} = \text{the smaller of } t_{n} \text{ or the thickness of the hub at the small end} \]

\[ H = \text{total hydrostatic end force} \]

\[ = 0.785G^{2}P \]

\[ h = \text{hub length} \]
3.2.3 WELDING MATERIALS

3.2.3.1 Welding materials used for the construction of pressure parts shall comply with the requirements of this Division, those of Section IX, and the applicable qualified welding procedure specification.

3.2.3.2 When the welding materials comply with one of the specifications in Section II, Part C, the marking or tagging of the material, containers, or packages as required by the applicable Section II specification may be adopted for identification in lieu of a Test Report or a Certificate of Compliance. When the welding materials do not comply with one of the specifications of Section II, the marking or tagging shall be identifiable with the welding materials set forth in the welding procedure specification, and may be acceptable in lieu of a Test Report or a Certificate of Compliance.

3.2.4 DISSIMILAR MATERIALS

3.2.4.1 The user or his designated agent shall ensure that the coupling of dissimilar materials will not have a detrimental effect on the corrosion rate or service life of the vessel (see Section II, Part D, Nonmandatory Appendix A).

3.2.4.2 The requirements for the base metals, heat-affected zones (HAZ), and weld metals of weldments between metals having different impact testing requirements and acceptance criteria shall be applied in accordance with the rules of this Division.

3.2.5 PRODUCT SPECIFICATIONS

3.2.5.1 The term plate as used in this Division also includes sheet and strip.

3.2.5.2 See below.

(a) Rods and Bars Used for Pressure Parts. Rods and bars may be used in pressure vessel construction for pressure parts such as flange rings [see 4.16.4.3(a)], stiffening rings, frames for reinforced openings, stays and staybolts, and similar parts.

(b) Parts Machined From Rod and Bar. Pressure parts such as 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 outer surface of the hub
(-b) for heads, caps, elbows, return bends, tees, and header tees: all surfaces
(-c) for hollow, cylindrically shaped parts: no surface examination needed

(2) Parts may be machined from rod or bar having a 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 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) and for rod or bar having a 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 that have the same diameter shall be taken from each lot (as defined in the material specification) of rod or bar material and having the same diameter.

(-1) The second specimen shall be taken at 90° 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 either of the following occurs:
The examination results show one or more indications accompanied by loss of back reflection larger than 60% of the reference back reflection.

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

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

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.

3.2.5.3 When a material specification is not listed in this Division covering a particular wrought product of a grade, but there is an approved specification listed in this Division covering some other wrought product of that grade, the product for which there is no specification listed may be used, provided:

(a) The chemical and mechanical properties, heat treating requirements, and requirements for deoxidation, or grain size requirements conform to the approved specification listed in this Division. The stress values for that specification given in Annex 3-A shall be used.

(b) The material specification is published Section II and covers that grade.

(c) For the case of welded product forms without the addition of filler metal, the appropriate stress intensity values are multiplied by 0.85.

(d) The product is not fabricated by fusion welding with the addition of filler metal unless it is fabricated in accordance with the rules of this Division as a pressure part.

(e) The mill test reports reference the specifications used in producing the material and in addition make reference to this paragraph.

3.2.5.4 Forgings certified to SA-105, SA-181, SA-182, SA-350, SA-403, and SA-420 may be used as tubesheets and hollow cylindrical forgings for pressure vessel shells that otherwise meet all the rules of this Division, provided that the following additional requirements are met:

(a) Forgings certified to SA-105 or SA-181 shall be subject to one of the austenitizing heat treatments permitted by these specifications.

(b) One tension test specimen shall be taken from each forging weighing more than 2 250 kg (5,000 lb). The largest obtainable tension test specimen as specified by the test methods referenced in the applicable specification shall be used. Except for upset-disk forgings, the longitudinal axis of the test specimen shall be taken parallel to the direction of major working of the forging. For upset-disk forgings, the longitudinal axis of the test specimen shall be taken in the tangential direction. When agreed to by the Manufacturer, and when not prohibited by the material specification, test specimens may be machined from specially forged test blocks meeting the provisions for such as provided in SA-266 or other similar specifications for large forgings.

(c) For quenched and tempered forgings weighing more than 4 500 kg (10,000 lb) at the time of heat treatment, two tension test specimens shall be taken from each forging. These shall be offset 180° from each other, except if the length of the forging, excluding test prolongations, exceeds 3.7 m (12 ft); then one specimen shall be taken from each end of the forging.

3.2.6 CERTIFICATION

3.2.6.1 Certificate of Compliance and Material Test Report.

(a) The Manufacturer shall ensure all requirements of the material specification, and all special requirements of Part 3 of this Division, that are to be fulfilled by the materials manufacturer have been complied with. The Manufacturer shall accomplish this by obtaining Certificates of Compliance or Material Test Reports. These documents shall include results of all required tests and examinations, evidence of compliance with the material specifications and additional requirements as applicable. When the specification permits certain specific requirements to be completed later, those incomplete items shall be noted on the material documentation. When these specific requirements have been completed by someone other than the material manufacturer, this completion shall be documented and attached to the material documentation.

(b) For plates, the Manufacturer shall receive a copy of the test report or reports as prepared by the material manufacturer or by the material manufacturer and subsequent processors, if any, responsible for the data, and shall maintain the reports as part of his construction records.

(c) For all other product forms, the Manufacturer shall receive a copy of the test report as prepared by the material manufacturer. When preparing a test report, a material manufacturer may transcribe data produced by other organizations, provided he accepts responsibility for the accuracy and authenticity of the data.

(d) All conflicts between the material specification and the supplemental requirements stipulated in this Part shall be noted, and compliance with the supplemental requirements shall be certified.
(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.

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 \[ t_{\min} = \left( A - B \right)/2 \].
   (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.

(b) Flanges with hubs, except as permitted in (a), shall not be machined from plate or bar stock 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 \[ t_{\min} = \left( A - B \right)/2 \].
   (c) 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.

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. (19)

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.
NOTE: In case of axial displacement only, \( \Delta q = |\Delta q_{x,1} - \Delta q_{x,0}| \).

(c) Bellows operating between two operating positions - If the bellows is subjected to displacements from operating position number 1 \((x_1, y_1, \theta_1)\) to the operating position number 2 \((x_2, y_2, \theta_2)\) (see Figure 4.19.10), the total equivalent axial displacements per convolution, on the extended side and the compressed side, for operating positions number 1 and 2 and the total equivalent axial displacement range are given by the following equations. An initial cold spring (initial position 0) has no effect on the results.

Position Number 1:

\[
\begin{align*}
\Delta q_{e,1} &= \Delta q_{x,1} + \Delta q_{y,1} + \Delta \theta_{1} \\
\Delta q_{c,1} &= \Delta q_{x,1} - \Delta q_{y,1} - \Delta \theta_{1}
\end{align*}
\] (4.19.57)

Position Number 2:

\[
\begin{align*}
\Delta q_{e,2} &= \Delta q_{x,2} + \Delta q_{y,2} + \Delta \theta_{2} \\
\Delta q_{c,2} &= \Delta q_{x,2} - \Delta q_{y,2} - \Delta \theta_{2}
\end{align*}
\] (4.19.59)

Total Equivalent Axial Displacement Range:

\[
\Delta q = \max\left[ |\Delta q_{e,2} - \Delta q_{c,1}|, |\Delta q_{c,2} - \Delta q_{e,1}| \right]
\] (4.19.61)

Alternatively, if the neutral position for lateral deflection and angular rotation is not passed between operating positions 1 and 2, the total equivalent axial displacement range may be written as

\[
\Delta q = \max\left[ |\Delta q_{e,2} - \Delta q_{e,1}|, |\Delta q_{c,2} - \Delta q_{c,1}| \right]
\] (4.19.62)

NOTE: In case of axial displacement only, \( \Delta q = |\Delta q_{x,2} - \Delta q_{x,1}| \).

### 4.19.9 PRESSURE TEST DESIGN REQUIREMENTS

The designer shall consider the possibility of instability of the bellows due to internal pressure if the test pressure exceeds the value determined using the following applicable equation. In such a case, the designer shall redesign the bellows to satisfy the test condition.

For unreinforced bellows

\[
P_{t,s} = 1.5 \min (P_{sc}, P_d)
\] (4.19.63)

For reinforced and toroidal bellows

\[
P_{t,s} = 1.5 P_{sc}
\] (4.19.64)

### 4.19.10 MARKING AND REPORTS

(a) The expansion joint Manufacturer, whether the vessel Manufacturer or a parts Manufacturer, shall have a valid ASME Code U2 Certificate of Authorization and shall complete the appropriate Data Report in accordance with Part 2.

(b) The Manufacturer responsible for the expansion joint design shall include the following additional data and statements on the appropriate Data Report:

1. Axial movement \((\pm)\), associated design life in cycles, and associated loading condition, if applicable;
2. Spring rate; and
3. That the expansion joint has been constructed to the rules of this paragraph.

(c) A parts Manufacturer shall identify the vessel for which the expansion joint is intended on the Partial Data Report.

(d) Markings shall not be stamped on the flexible elements of the expansion joint.
Total Equivalent Axial Displacement Range:

\[ \Delta q = \max \left[ |\Delta q_{e,1}|, |\Delta q_{c,1}| \right] \]  \hspace{1cm} (4.19.45)

Note: In case of axial displacement only \( \Delta q = |\Delta q_{e,1}| \)

(b) Bellows installed with cold spring – If the bellows is subjected to displacements from an initial position \((x_0', y_0', \theta_0')\), which is not the neutral position to the operating position \((x_1', y_1', \theta_1')\) (see Figure 4.19.9), the total equivalent axial displacements per convolution, in extension or compression on the extended side and on the compressed side, for the initial and operating positions and the total equivalent axial displacement range are given by the following equations.

**Initial Position:**

\[ \Delta q_{e,0} = \Delta q_{x,0} + \Delta q_{y,0} + \Delta q_{\theta,0} \]  \hspace{1cm} (extension extended side)  \hspace{1cm} (4.19.46)

\[ \Delta q_{c,0} = \Delta q_{x,0} - \Delta q_{y,0} - \Delta q_{\theta,0} \]  \hspace{1cm} (compression compressed side)  \hspace{1cm} (4.19.47)

**Operating Position:**

\[ \Delta q_{e,1} = \Delta q_{x,1} + \Delta q_{y,1} + \Delta q_{\theta,1} \]  \hspace{1cm} (extension extended side)  \hspace{1cm} (4.19.48)

\[ \Delta q_{c,1} = \Delta q_{x,1} - \Delta q_{y,1} - \Delta q_{\theta,1} \]  \hspace{1cm} (compression compressed side)  \hspace{1cm} (4.19.49)

**Total Equivalent Axial Displacement Range:**

\[ \Delta q = \max \left[ |\Delta q_{e,1} - \Delta q_{e,0}|, |\Delta q_{c,1} - \Delta q_{c,0}| \right] \]  \hspace{1cm} (4.19.50)

Alternatively, if the neutral position for lateral deflection and angular rotation, is not passed between the initial position and the operating position, the total equivalent axial displacement range may be written as:

\[ \Delta q = \max \left[ |\Delta q_{e,1} - \Delta q_{e,0}|, |\Delta q_{c,1} - \Delta q_{c,0}| \right] \]  \hspace{1cm} (4.19.51)

Note: In case of axial displacement only \( \Delta q = |\Delta q_{e,1} - \Delta q_{e,0}| \)

(c) Bellows operating between two operating positions – If the bellows is subjected to displacements from operating position number 1 \((x_1', y_1', \theta_1')\) to the operating position number 2 \((x_2', y_2', \theta_2')\) (see Figure 4.19.10), the total equivalent axial displacements per convolution, in extension or compression on the extended side and on the compressed side, for operating positions number 1 and 2 and the total equivalent axial displacement range are given by the following equations. An initial cold spring (initial position 0) has no effect on the results.

**Position Number 1:**

\[ \Delta q_{e,1} = \Delta q_{x,1} + \Delta q_{y,1} + \Delta q_{\theta,1} \]  \hspace{1cm} (extension extended side)  \hspace{1cm} (4.19.52)

\[ \Delta q_{c,1} = \Delta q_{x,1} - \Delta q_{y,1} - \Delta q_{\theta,1} \]  \hspace{1cm} (compression compressed side)  \hspace{1cm} (4.19.53)

**Position Number 2:**

\[ \Delta q_{e,2} = \Delta q_{x,2} + \Delta q_{y,2} + \Delta q_{\theta,2} \]  \hspace{1cm} (extension extended side)  \hspace{1cm} (4.19.54)

\[ \Delta q_{c,2} = \Delta q_{x,2} - \Delta q_{y,2} - \Delta q_{\theta,2} \]  \hspace{1cm} (compression compressed side)  \hspace{1cm} (4.19.55)

**Total Equivalent Axial Displacement Range:**

\[ \Delta q = \max \left[ |\Delta q_{e,2} - \Delta q_{e,1}|, |\Delta q_{c,2} - \Delta q_{c,1}| \right] \]  \hspace{1cm} (4.19.56)

Alternatively, if the neutral position for lateral deflection and angular rotation, is not passed between operating positions 1 and 2, the total equivalent axial displacement range may be written as:

\[ \Delta q = \max \left[ |\Delta q_{e,2} - \Delta q_{e,1}|, |\Delta q_{c,2} - \Delta q_{c,1}| \right] \]  \hspace{1cm} (4.19.57)