provided at joints of Categories A and B between sections that differ in thickness by more than one-fourth of the thickness of the thinner section or by more than \( \frac{3}{8} \) in. (3 mm). The transition may be formed by any process that will provide a uniform taper. The weld may be partly or entirely in the tapered section. When Section III Appendices, Mandatory Appendix XIII, or Mandatory Appendix II are not used, the following requirements of (a) through (e) below shall also apply.

(a) The length of taper shall be not less than three times the offset between adjacent surfaces.

(b) Figure NCD-3361.1-1 shall apply to all joints of Categories A and B except joints connecting formed heads to main shells, for which case Figure NCD-3358.1(a)-1 shall apply.

(c) When a taper is required on any formed head intended for butt welded attachment, the skirt shall be long enough so that the required length of taper does not extend beyond the tangent line.

(d) An ellipsoidal or hemispherical head which has a greater thickness than a cylinder of the same inside diameter may be machined to the outside diameter of the cylinder, provided the remaining thickness is at least as great as that required for a shell of the same diameter.

(e) The requirements of this paragraph are not applicable to flange hubs.

NCD-3262 Bolted Flanged Connections

NCD-3262.1 Flanges and Flanged Fittings Conforming to ASME B16.5. Except as provided in NCD-3262.3, the dimensional requirements of flanges used in bolted flange connections to external piping shall conform to ASME B16.5, Steel Pipe Flanges and Flanged Fittings. Flanges and flanged fittings conforming to ASME B16.5 and listed in Tables 8 through 28 of that Standard, with the exception of threaded and socket welding types, may be used at the pressure-temperature ratings specified in that Standard.

NCD-3262.2 Slip-On Flanges Conforming to ASME B16.5. Slip-on flanges conforming to ASME B16.5 may be used, provided all the conditions of (a) through (e) below are met.

(a) The specified minimum tensile strengths of materials do not exceed 80.0 ksi (550 MPa).

(b) The minimum elongation of materials is 12% in 2 in. (50 mm).

(c) The thickness of the materials to which the flange is welded does not exceed \( 1\frac{1}{4} \) in. (32 mm).

(d) The throat thickness, taken as the minimum thickness in any direction through the attaching fillet welds, is at least 0.7 times the thickness of the material to which the flange is welded.

(e) The fatigue analysis required for nozzles with separate reinforcement and nonintegral attachments, as set forth in NCD-3219.3, is applied to the design.

NCD-3262.3 Flanges Not Conforming to ASME B16.5. Flanges that do not conform to ASME B16.5 shall be designed in accordance with the Rules for Bolted Flange Connections, Section III Appendices, Mandatory Appendix XI, or by the rules of Section III Appendices, Mandatory Appendices II and XIII.

NCD-3262.4 Studded Connections. 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 \( d \) or

\[
0.75d_s \times \frac{\text{Design stress intensity value of stud material at Design Temperature}}{\text{Design stress intensity value of tapped material at Design Temperature}}
\]

in which \( d \) is the root diameter of the stud, except that the thread engagement need not exceed \( 1\frac{1}{2} d_s \).

NCD-3263 Access and Inspection Openings

The requirements for access and inspection openings are given in NCD-3363.

NCD-3264 Attachments and Supports

NCD-3264.1 General Requirements. Supports, lugs, brackets, stiffeners, and other attachments may be welded or stud bolted to the outside or inside of a vessel wall. All stud bolted attachments require a detailed fatigue analysis in accordance with the requirements of Section III Appendices, Mandatory Appendix XIII unless the conditions of NCD-3219 are met. Attachments shall conform reasonably to the curvature of the shell to which they are to be attached. The fabrication requirements of NCD-4267 and the examination requirements of NCD-5250 shall be met.

NCD-3264.2 Attachment Materials. Materials welded directly to pressure parts shall meet the requirements of NCD-2190.

NCD-3264.3 Design of Attachments. The effects of attachments, including external and internal piping connections, shall be taken into account in the design. Attachments shall meet the requirements of NCD-3135.
NOTES:
(1) Circular covers, \( C = 0.33m, C \text{ min. } = 0.20. \)
(2) Noncircular covers, \( C = 0.33. \)
(3) When pipe threads are used, see Table NCD-3361.2.2-1.

\( t_f = \) actual thickness of the flange on a forged head, at the large end, exclusive of corrosion allowance, as indicated in Figure NCD-3325-1 sketches (b-1) and (b-2)

\( t_h = \) actual thickness of flat head or cover, exclusive of corrosion allowance

\( t_r = \) required thickness of seamless shell, for pressure

\( t_s = \) actual thickness of shell, exclusive of corrosion allowance

\( t_w = \) thickness through the weld joining the edge of a head to the inside of a vessel, as indicated in Figure NCD-3325-1 sketch (g)

\( W = \) total bolt load, given for circular heads for Section III Appendices, Mandatory Appendix XI, XI-3223, eqs. (3) and (4)

\( Z = \) a factor of noncircular heads and covers that depends on the ratio of short span to long span (NCD-3325.2), dimensionless

NCD-3325.2 Thickness. The thickness of unstayed flat heads, covers, and blind flanges shall conform to one of the following four requirements.

NOTE: The equations provide structural integrity as far as stress is concerned. Greater thicknesses may be necessary if deflection would cause leakage at threaded or gasketed joints.

(a) Circular blind flanges of ferrous materials conforming to ASME B16.5 shall be acceptable for the diameters and pressure–temperature ratings in Tables 3 through 6 of that Standard, when of the types shown in Figure NCD-3325-1 sketches (j) and (k).

(b) The minimum required thickness of flat unstayed circular heads, covers, and blind flanges shall be calculated by eq. (4)

\[ t = d \sqrt{CP/S} \]  

except when the head, cover, or blind flange is attached by bolts causing an edge moment [Figure NCD-3325-1 sketches (j) and (k)], in which case the thickness shall be calculated by eq. (5)

\[ t = d \sqrt{CP/S} + 1.27 WH_G/Sd^3 \]  

When using eq. (5), the thickness \( t \) shall be calculated for both Service Loadings and gasket seating and the greater of the two values shall be used. For Service Loadings, the value of \( P \) shall be the Design Pressure and the values of \( S \) at the Design Temperature and \( W \) from Section III Appendices, Mandatory Appendix XI, XI-3223, eq. (3) shall be used. For gasket seating, \( P \) equals zero and the values of \( S \) at atmospheric temperature and \( W \) from Section III Appendices, Mandatory Appendix XI, XI-3223, eq. (4) shall be used.

(c) For Class 3 vessels only, flat unstayed heads, covers, or blind flanges may be square, rectangular, elliptical, obround, segmental, or otherwise noncircular. Their required thickness shall be calculated by eqs. (6) and (7)

\[ t = d \sqrt{CP/S} \]  

where

\[ Z = 3.4 - \frac{2.4d}{D} \]  

with the limitation that \( Z \) need not be greater than 2.5.

(d) For Class 3 vessels only, (c) eq. (6) does not apply to noncircular heads, covers, or blind flanges attached by bolts causing a bolt edge moment [Figure NCD-3325-1 sketches (j) and (k)]. For noncircular heads of this type, the required thickness shall be calculated by the following equation:

\[ t = d \sqrt{ZCP/S} + 4 WH_G/SLd^2 \]  

When using eq. (8), the thickness \( t \) shall be calculated in the same way as specified above for (b) eq. (5).

NCD-3325.3 Values of \( C \). For the types of construction shown in Figures NCD-3325-1, NCD-4243.1-1, NCD-4243.1-2, and NCD-4243.3-1, the minimum values of \( C \) to be used in NCD-3325.2(b) eqs. (4) and (5), NCD-3325.2(c) eq. (6), and NCD-3325.2(d) eq. (8) are given in (a) through (q) below.

(a) In sketch (a), \( C = 0.17 \) for flanged circular and noncircular heads forged integral with or butt welded to the vessel with an inside corner radius not less than three times the required head thickness, with no special requirement with regard to length of flange.

\[ C = 0.10 \text{ for circular heads, when the flange length for heads of the above design is not less than} \]

\[ l = \left( 1.1 - 0.8 \frac{t_h^2}{t_f^2} \right) \sqrt{\frac{W_h}{G}} \]

(2) \( C = 0.10 \) for circular heads, when the flange length \( l \) is less than the requirement in (1) above but the shell thickness is not less than

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\[ d = \text{diameter, measured as indicated in Figure NE-3325-1} \]

\[ h_G = \text{gasket moment arm, equal to the radial distance from the center line of the bolts to the line of the gasket reaction, as shown in Section III Appendices, Mandatory Appendix XI, Table XI-3221.2-2} \]

\[ l = \text{length of flange of flanged heads, measured from the tangent line of knuckle, as indicated in Figure NE-3325-1, sketches (a) and (c)} \]

\[ m = \text{the ratio } t_f/t_s \]

\[ P = \text{Design Pressure, psi (MPa)} \]

\[ r = \text{inside corner radius on a head formed by flanging or forging} \]

\[ S = \text{maximum allowable stress, psi (MPa), as defined in NE-3112.4(b)} \]

\[ t = \text{minimum required thickness of flat head or cover, exclusive of corrosion allowance} \]

\[ t_1 = \text{throat dimension of the closure weld, as indicated in Figure NE-3325-1, sketch (p)} \]

\[ t_f = \text{actual thickness of the flange on a forged head, at the large end, exclusive of corrosion allowance, as indicated in Figure NE-3325-1, sketches (b-1) and (b-2)} \]

\[ t_h = \text{actual thickness of flat head or cover, exclusive of corrosion allowance} \]

\[ t_p = \text{the smallest dimension from the face of the head to the edge of the weld preparation} \]

\[ t_s = \text{actual thickness of shell, for pressure} \]

\[ t_w = \text{thickness through the weld joining the edge of a head to the inside of a vessel, as indicated in Figure NE-3325-1, sketch (t)} \]

\[ W = \text{total bolt load, lb (kN), given for circular heads for Section III Appendices, Mandatory Appendix XI, Article XI-3000, eqs. XI-3223(3) and XI-3223(4)} \]

\[ W = \text{total bolt load, lb (kN), given for circular heads for Section III Appendices, Mandatory Appendix XI, Article XI-3000, eqs. XI-3223(3) and XI-3223(4)} \]

\[ NE-3325.2 \text{ Thickness.} \] The thickness of flat unstayed heads, covers, and blind flanges shall conform to one of the following two requirements.

**NOTE:** The equations provide structural integrity as far as stress is concerned. Greater thicknesses may be necessary if deflection would cause leakage at threaded or gasketed joints.

(a) Circular blind flanges of ferrous materials conforming to ASME B16.5 shall be acceptable for the diameters and pressure-temperature ratings in Tables 2 to 8 of that Standard, when of the types shown in Figure NE-3325-1, sketches (j) and (k).

(b) The minimum required thickness of flat unstayed circular heads, covers, and blind flanges shall be calculated by the equation:

\[ t = d \sqrt{CP/S} \quad (1) \]

except when the head, cover, or blind flange is attached by bolts causing an edge moment [Figure NE-3325-1 sketches (i), (j), and (n)], in which case the thickness shall be calculated by:

\[ t = d \sqrt{CP/S + 1.27 Wh_G/Sd^3} \quad (2) \]

When using eq. (2), the thickness \( t \) shall be calculated for both Service Loadings and gasket seating, and the greater of the two values shall be used. For Service Loadings, the value of \( P \) shall be the Design Pressure, and the values of \( S \) at the Design Temperature and \( W \) from Section III Appendices, Mandatory Appendix XI, Article XI-3000, eq. XI-3223(3) shall be used. For gasket seating, \( P \) equals zero, and the values of \( S \) at atmospheric temperature and \( W \) from Section III Appendices, Mandatory Appendix XI, Article XI-3000, eq. XI-3223(4) shall be used.

**NE-3325.3 Values of \( C \).** For the types of construction shown in Figure NE-3325-1 and Figure NE-4243.1-1, the minimum values of \( C \) to be used in eqs. NE-3325.2(b)(1) and NE-3325.2(b)(2) shall be as given in (a) through (l) below for Figure NE-3325-1 and in (m) below for Figure NE-4243.1-1.

(a) In sketch (a), \( C = 0.17 \) for flanged circular heads forged integral with or buttwelded to the vessel with an inside corner radius not less than three times the required head thickness, with no special requirement with regard to length of flange.

(1) \( C = 0.10 \) for circular heads, when the flange length for heads of the above design is not less than:

\[ l = 1.1 - 0.8 \frac{t_s^2}{t_h} \sqrt{d_t h} \quad (3) \]

(2) \( C = 0.10 \) for circular heads, when the flange length \( l \) is less than the requirement in eq. (1)(3) but the shell thickness is not less than:

\[ t_s = 1.12 t_h \sqrt{1.1 - l / \sqrt{d_t h}} \quad (4) \]

for a length of at least \( 2 \sqrt{d_t} \).

(3) When \( C = 0.10 \) is used, the taper shall be 1:4.

(b) In sketch (b-1), \( C = 0.17 \) for forged circular heads integral with or buttwelded to the vessel, where the flange thickness is not less than two times the shell thickness, the corner radius on the inside is not less than three times the flange thickness and the welding meets all the requirements of Article NE-4000.

(c) In sketch (b-2), \( C = 0.33 m \) but not less than 0.20 for forged circular heads integral with or buttwelded to the vessel, where the flange thickness is not less than the shell thickness and the corner radius on the inside is not less than 1.5 times the flange thickness. [See Figure