Article NCD-3000
Design

NCD-3100 General Design

NCD-3110 Loading Criteria

NCD-3111 Loading Conditions

The loadings that shall be taken into account in designing a component shall include, but are not limited to, those in (a) through (g) below:

(a) internal and external pressure;

(b) impact loads, including rapidly fluctuating pressures;

(c) weight of the component and normal contents under operating or test conditions, including additional pressure due to static and dynamic head of liquids;

(d) superimposed loads such as other components, operating equipment, insulation, corrosion resistant or erosion resistant linings, and piping;

(e) wind loads, snow loads, vibrations, and earthquake loads, where specified;

(f) reactions of supporting lugs, rings, saddles, or other types of supports;

(g) temperature effects.

NCD-3112 Design Loadings

The Design Loadings shall be established in accordance with NCA-2142.1 and the following subparagraphs.

NCD-3112.1 Design Pressure.
The specified internal and external Design Pressures to be used in this Subsection shall be established in accordance with NCA-2142.1(a).

NCD-3112.2 Design Temperature.
The specified Design Temperature shall be established in accordance with NCA-2142.1(b). It shall be used in conjunction with the Design Pressure. If necessary, the metal temperature shall be determined by computation using accepted heat transfer procedures or by measurement from equipment in service under equivalent operating conditions. In no case shall the temperature at the surface of the metal exceed the maximum temperature listed in the applicability column of
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Section II, Part D, Subpart 1, Tables 1A, 1B, and 3, nor exceed the maximum temperature limitations specified elsewhere in this Subsection.

NCD-3112.3 Design Mechanical Loads.
The specified Design Mechanical Loads shall be established in accordance with NCA-2142.1(c). They shall be used in conjunction with the Design Pressure.

NCD-3112.4 Design Allowable Stress Values.

(a) Allowable stresses for design for materials are listed in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3., except for vessels designed to the requirements of NC-3200, for which the Design stress intensity values for Class 2 vessels designed to NCD-3200 are listed in Section II, Part D, Subpart 1, Tables 2A, 2B, and 4. The materials shall not be used at metal and design temperatures that exceed the temperature limit in the applicability column for which stress or stress intensity values are given. The values in the Tables may be interpolated for intermediate temperatures.

(b) The maximum allowable compressive stress to be used in the design of cylindrical shells subjected to loadings that produce longitudinal compressive stress in the shell shall be the smaller of the following values:

1. the maximum allowable tensile stress value permitted in (a) above;
2. the value of the factor B determined from NCD-3133.6(b).

(c) The wall thickness of a component computed by the rules of this Subsection shall be determined so that the general membrane stress due to any combination of mechanical loadings listed in NCD-3111 which are expected to occur simultaneously during a condition of loading for which service Level A is designated for the component does not exceed the maximum allowable stress permitted at the Design Temperature unless specifically permitted in other paragraphs of this Subsection. These allowable stress values may be interpolated for intermediate Design Temperature.

(d) For Class 3 Items, when welding or brazing is performed on nonferrous material having increased tensile strength produced by hot or cold working, the allowable stress value for the material in the annealed condition shall be used for the joint design. One piece heads and seamless shells may be designed on the basis of the actual temper of the material.

(e) For Class 3 Items, when welding or brazing is performed on nonferrous material having increased tensile strength produced by heat treatment, the allowable stress value for the material in the annealed condition shall be used for the joint design unless the stress values for welded construction are given in Section II, Part D, Subpart 1, Tables 1A and 1B or unless the finished construction is subjected to the same heat treatment as that which produced the temper in the as-received material, provided the welded joint and the base metal are similarly affected by the heat treatment.
**NCD-3113 Service Conditions**

(a) Each service condition to which the components may be subjected shall be classified in accordance with NCA-2142, and Service Limits [NCA-2142.4(b)] shall be designated in the Design Specifications in such detail as will provide a complete basis for design in accordance with this Article.

(b) When any loadings for which Level B, C, or D Service Limits are designated are specified in the Design Specifications, they shall be evaluated in accordance with NCA-2140 and in compliance with the applicable design and stress limits of this Article.

**NCD-3115 Casting Quality Factors (Class 3 Only)**

A casting quality factor shall be applied to the allowable stress values for cast material given in Section II, Part D, Subpart 1, Tables 1A and 1B.

**NCD-3120 Special Considerations**

**NCD-3121 Corrosion**

(a) Materials subject to thinning by corrosion, erosion, mechanical abrasion, or other environmental effects shall have provision made in the Design Specifications for these effects by indicating the increase in the thickness of the base metal over that determined by the design equations (NC-2160). Other suitable methods of protection may be used. Material added or included for these purposes need not be of the same thickness for all areas of the component if different rates of attack are expected for the various areas.

(b) For Class 3 items only, except as required in (c) below, no additional thickness need be provided when previous experience in like service has shown that corrosion does not occur or is of only a superficial nature.

(c) Class 3 vessels constructed of materials listed in Section II, Part D, Subpart 1, Tables 1A and 1B with a required minimum thickness of less than 1/4 in. (6 mm) that are to be used in compressed air service, steam service, or water service shall be provided with a corrosion allowance on the metal surface in contact with such substance of not less than one-sixth of the calculated plate thickness.

(d) For Class 3 items only, telltale holes may be used to provide some positive indication when the thickness has been reduced to a minimum. When telltale holes are provided, they shall be at least 3/16 in. (5 mm) in diameter and have a depth not less than 80% of the thickness required for a section of like dimensions. These holes shall be provided in the surface opposite to that where deterioration is expected.
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**NCD-3122 Cladding**

The rules of this paragraph apply to the design of clad components constructed of material permitted in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3.

**NCD-3122.1 Stresses.**

Except as permitted by NCD-3214 for Class 2 vessels, no structural strength shall be attributed to the cladding.

**NCD-3122.2 Design Dimensions.**

The dimensions given in (a) and (b) below shall be used in the design of the component:

(a) for components subjected to internal pressure, the inside diameter shall be taken at the nominal inner face of the cladding;

(b) for components subjected to external pressure, the outside diameter shall be taken at the outer face of the base metal.

**NCD-3123 Welds Between Dissimilar Metals**

In satisfying the requirements of this subarticle, caution shall be exercised in construction involving dissimilar metals having different chemical compositions, mechanical properties, and coefficients of thermal expansion in order to avoid difficulties in service.

**NCD-3124 Ductile Behavior Evaluation (Class 2 Only)**

For Class 2 Items, the use of material below the temperature established by the methods of NCD-2331(a) may be justified by methods equivalent to those contained in Section III Appendices, Nonmandatory Appendix G.

**NCD-3125 Configuration**

Accessibility to permit the examinations required by the Edition and Addenda of Section XI as specified in the Design Specification for the component shall be provided in the design of the component.

**NCD-3130 General Design Rules**

**NCD-3131 General Requirements**

The design shall be such that the rules of this Article are satisfied for all configurations and loadings, using the maximum allowable stress values $S$ of Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 in the various equations and including the use of the standard products listed in Table NCA-7100-1. Use of the maximum allowable stress values of Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 does not apply to Class 2 vessels designed to the rules of NCD-3200.
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NCD-3131.1 Design Reports.

(a) The N Certificate Holder is required to provide a Design Report as part of the responsibility for achieving structural integrity of the component. The Design Report shall be certified when required by NCA-3550.

(b) The Certificate Holder for construction of a Class 2 vessel conforming to the design requirements of NCD-3200 shall provide a Design Report conforming to the requirements of NCD-3211 and NCD-3223.2.

NCD-3131.2 Proof Test to Establish Maximum Design Pressure.

When the configuration of a component is such that the stresses resulting from internal or external pressure cannot be determined with adequate accuracy by the rules of this Article, the maximum Design Pressure shall be determined by proof testing in accordance with the rules of NCD-6900 except for piping as otherwise provided in this Article. This procedure does not apply to Class 2 vessels designed to the requirements of NCD-3200.

NCD-3132 Dimensional Standards for Standard Products

Dimensions of standard products shall comply with the standards and specifications listed in Table NCA-7100-1 when the standard or specification is referenced in the specific design subarticle. However, compliance with these standards does not replace or eliminate the requirements for stress analysis when called for by the design subarticle for a specific component.

NCD-3133 Components Under External Pressure

NCD-3133.1 General.

Rules are given in this paragraph for determining the thickness under external pressure loading in spherical shells, conical sections, cylindrical shells with or without stiffening rings, formed heads, and tubular products consisting of pipes, tubes, and fittings. Charts for determining the stresses in shells and hemispherical heads are given in Section II, Part D, Subpart 3. For Class 2 vessels designed to NCD-3200, see NCD-3240.

NCD-3133.2 Nomenclature.

The symbols used in this paragraph are defined as follows:

\[ A = \text{factor determined from Section II, Part D, Subpart 3, Figure G and used to enter the applicable material chart in Section II, Part D, Subpart 3. For the case of cylinders having } D_o/T \text{ values less than 10, see NCD-3133.3(b)} \]

\[ B = \text{factor determined from the applicable chart in Section II, Part D, Subpart 3 for the material used in a stiffening ring, corresponding to the factor } B \text{ and the design metal temperature for the shell under consideration} \]

\[ A_s = \text{cross-sectional area of a stiffening ring} \]
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\[ B = \text{factor determined from the applicable chart in Section II, Part D, Subpart 3 for the material used in a shell or stiffening ring at the design metal temperature, psi (MPa)} \]

\[ D_L = \text{outside diameter at large end of conical section under consideration} \]

\[ D_o = \text{outside diameter of the cylindrical shell course, head skirt, or tube under consideration} \]

\[ = \text{Class 2 spherical shells and formed heads only, outside diameter of the head skirt or the outside diameter of a cone head at the point under consideration, measured perpendicular to the longitudinal axis of the cone} \]

\[ D_o/2h_o = \text{Class 3 only, ratio of the major to the minor axis of ellipsoidal heads, which equals the outside diameter of the head skirt divided by twice the outside height of the head (see Table NCD-3332.2-1)} \]

\[ D_s = \text{Class 3 only, outside diameter at small end of conical section under consideration} \]

\[ E = \text{modulus of elasticity of material at Design Temperature, psi (MPa)}. \text{For external pressure and axial compression design in accordance with this Section the modulus of elasticity to be used shall be taken from the applicable materials chart in Section II, Part D, Subpart 3. (Interpolation may be made between lines for intermediate temperatures.) The modulus of elasticity values shown in Section II, Part D, Subpart 3 for material groups may differ from those values listed in Section II, Part D, Subpart 2, Tables TM for specific materials. Section II, Part D, Subpart 3 values shall be applied only to external pressure and axial compression design.} \]

\[ h_o = \text{Class 3 only, one-half of the length of the outside minor axis of the ellipsoidal head, or the outside height of the ellipsoidal head measured from the tangent line (head-bend line)} \]

\[ I = \text{available moment of inertia of the stiffening ring about its neutral axis, parallel to the axis of the shell} \]

\[ I' = \text{available moment of inertia of the combined ring-shell cross section about its neutral axis, parallel to the shell. The width of the shell, which is taken as contributing to the combined moment of inertia, shall not be greater than 1.10}\sqrt{\frac{D_oT_n}{2h_o}} \text{and shall be taken as lying one half on each side of the centroid of the ring. Portions of shell plates shall not be considered as contributing to more than one stiffening ring.} \]

\[ I_s = \text{required moment of inertia of the stiffening ring about its neutral axis parallel to the axis of the shell} \]

\[ I_s' = \text{required moment of inertia of the combined ring-shell section about its neutral axis parallel to the axis of the shell} \]

\[ K_1 = \text{Class 2 only, factor depending on the ellipsoidal head proportions (see Table NCD-3332.2-1)} \]

\[ \text{Class 3 only, factor depending on the ellipsoidal head proportions } D_o/2h_o \text{ (see Table NCD-3332.2-1)} \]

\[ L = \text{total length of a tube between tubesheets, or the design length of a vessel section, taken as the largest of the following:} \]
(a) the distance between head tangent lines plus one-third of the depth of each head if there are no stiffening rings (excluding conical heads and sections);

(b) the distance between cone-to-cylinder junctions for vessels with a cone or conical head if there are no stiffening rings;

(c) the greatest center-to-center distance between any two adjacent stiffening rings

(de) the distance from the center of the first stiffening ring to the head tangent line plus one-third of the depth of the head (excluding conical heads and sections), all measured parallel to the axis of the vessel

(e) the distance from the first stiffening ring in the cylinder to the cone-to-cylinder junction; or

(f) the axial length of the conical heads and sections as given in NCD-3133.4(e), and Section III Appendices, Mandatory Appendix XXII.

\[ L_e = \text{equivalent length of conical section} \]
\[ = \frac{L}{2} \left( 1 + \frac{D_s}{D_L} \right) \]

\[ L_s = \text{one-half of the distance from the center line of the stiffening ring to the next line of support on one side, plus one-half of the center line distance to the next line of support on the other side of the stiffening ring, both measured parallel to the axis of the component. A line of support is} \]

(a) a stiffening ring that meets the requirements of this paragraph

(b) a circumferential line on a head at one-third the depth of the head from the head tangent line

(c) a circumferential connection to a jacket for a jacketed section of a cylindrical shell; or

(d) a cone-to-cylinder junction.

\[ P = \text{external Design Pressure, psi (MPa) (gage or absolute, as required)} \]
\[ P_a = \text{allowable external pressure, psi (MPa) (gage or absolute, as required)} \]
\[ R = \text{Class 2 only, inside radius of spherical shell, cylindrical shell or tubular product} \]
\[ = \text{Class 2 only, for hemispherical heads, the inside radius in the corroded condition} \]
\[ = \text{Class 2 only, for ellipsoidal heads, the equivalent inside spherical radius taken as} \]
\[ = K_1D_o \]
\[ = \text{Class 2 only, for torispherical heads, the inside radius of the crown portion of the head in the corroded condition} \]
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- Class 3 only, inside radius of cylindrical shell or tubular product in the corroded condition
- Class 3 only, for hemispherical heads, the outside radius in the corroded condition
- Class 3 only, for ellipsoidal heads, the equivalent outside spherical radius taken as $K_1 D_o$ in the corroded condition
- Class 3 only, for torispherical heads, the outside radius of the crown portion of the head in the corroded condition

$S = \text{the lesser of twice the allowable stress at design metal temperature from Section II, Part D, Subpart 1, Tables 1A, 1B, and 3 or 0.9 times the tabulated yield strength at design metal temperature from Section II, Part D, Subpart 1, Table Y-1, psi (MPa)}$

$T = \text{minimum required thickness of cylindrical shell or tube, or spherical shell, or formed head after forming. For Class 2 applications, this does not consider the corroded condition. For Class 3 applications, this does consider the corroded condition.}$

$T_e = \text{effective thickness of conical section} = T \cos \alpha$

$T_n = \text{nominal thickness used, less corrosion allowance, of a cylindrical shell or tube}$

$\alpha = \text{one-half the apex angle in conical heads and sections, deg}$

NCD-3133.3 Cylindrical Shells and Tubular Products.

The thickness of cylinders under external pressure shall be determined by the procedure given in (a) or (b) below.

(a) Cylinders having $D_o/T$ values $\geq 10$:

Step 1. Assume a value for $T$ and determine the ratios $L/D_o$ and $D_o/T$.

Step 2. Enter Section II, Part D, Subpart 3, Figure G at the value of $L/D_o$ determined in Step 1. For values of $L/D_o$ greater than 50, enter the chart at a value of $L/D_o = 50$. For values of $L/D_o$ less than 0.05, enter the chart at a value of $L/D_o$ of 0.05.

Step 3. Move horizontally to the line for the value of $D_o/T$ determined in Step 1. Interpolation may be made for immediate values of $D_o/T$. From this point of intersection move vertically downward to determine the value of factor $A$.

Step 4. Using the value of $A$ calculated in Step 3, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/temperature line for the Design Temperature. Interpolation may be made between lines for intermediate temperatures. In cases where the value of $A$ falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of $A$ falling to the left of the material/temperature line, see Step 7.
Step 5. From the intersection obtained in Step 4, move horizontally to the right and read the value of $B$.

Step 6. Using this value of $B$, calculate the value of the maximum allowable external pressure $P_a$ using the following equation:

$$P_a = \frac{4B}{3(D_o/T)}$$

Step 7. For values of $A$ falling to the left of the applicable material/temperature line, the value of $P_a$ can be calculated using the following equation:

$$P_a = \frac{2AE}{3(D_o/T)}$$

Step 8. Compare $P_a$ with $P$. If $P_a$ is smaller than $P$, select a larger value for $T$ and repeat the design procedure until a value of $P_a$ is obtained that is equal to or greater than $P$.

(b) Cylinders having $D_o/T$ values $< 10$:

Step 1. Using the same procedure as given in (a) above, obtain the value of $B$. For values of $D_o/T$ less than 4, the value of factor $A$ can be calculated using the following equation:

$$A = \frac{1.1}{(D_o/T)^2}$$

For values of $A$ greater than 0.10, use a value of 0.10.

Step 2. Using the value of $B$ obtained in Step 1, calculate a value $P_{a1}$ using the following equation:

$$P_{a1} = \left[\frac{2.167}{D_o/T} - 0.0833\right]B$$

Step 3. Calculate a value $P_{a2}$ using the following equation:

$$P_{a2} = \frac{2S}{D_o/T} \left[1 - \frac{1}{D_o/T}\right]$$

Step 4. The smaller of the values of $P_{a1}$ calculated in Step 2, or $P_{a2}$ calculated in Step 3 shall be used for the maximum allowable external pressure $P_a$. Compare $P_a$ with $P$. If $P_a$ is smaller than $P$, select a larger value for $T$ and repeat the design procedure until a value for $P_a$ is obtained that is equal to or greater than $P$. 
(a) **Spherical Shells.** The minimum required thickness of a spherical shell under external pressure, either seamless or of built-up construction with butt joints, shall be determined by the procedure given in Steps 1 through 6.

Step 1. Assume a value for $T$ and calculate the value of factor $A$ using the following equation:

$$A = \frac{0.125}{R/T}$$

Step 2. Using the value of $A$ calculated in Step 1, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/temperature line for the Design Temperature. Interpolation may be made between lines for intermediate temperatures. In cases where the value at $A$ falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of $A$ falling to the left of the material/temperature line, see Step 5.

Step 3. From the intersection obtained in Step 2, move horizontally to the right and read the value of factor $B$.

Step 4. Using the value of $B$ obtained in Step 3, calculate the value of the maximum allowable external pressure $P_a$ using the following equation:

$$P_a = \frac{B}{R/T}$$

Step 5. For values of $A$ falling to the left of the applicable material/temperature line for the Design Temperature, the value of $P_a$ can be calculated using the following equation:

$$P_a = \frac{0.0625E}{(R/T)^2}$$

Step 6. Compare $P_a$ obtained in Step 4 or Step 5 with $P$. If $P_a$ is smaller than $P$, select a larger value for $T$ and repeat the design procedure until a value for $P_a$ is obtained that is equal to or greater than $P$.

(b) The nomenclature defined below is used in the equations of (c) through (e) below.

- $D_o =$ outside diameter of the head skirt or the outside diameter of a cone head at the point under consideration, measured perpendicular to the longitudinal axis of the cone, in. (mm)
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\[ K_1 = \text{a factor depending on the ellipsoidal head proportions, given in Table NC-3332.2-1} \]

\[ R = \text{for hemispherical heads, the inside radius in the corroded condition, in. (mm)} \]

\[ = \text{for ellipsoidal heads, the equivalent inside spherical radius taken as } K_1 D_o \text{ in the corrosed condition, in. (mm)} \]

\[ = \text{for torispherical heads, the inside radius of the crown portion of the head in the corroded condition, in. (mm)} \]

\[ T = \text{minimum required thickness of head after forming, exclusive of corrosion allowance, in. (mm)} \]

(b) Hemispherical Heads. The required thickness of a hemispherical head having pressure on the convex side shall be determined in the same manner as outlined in (a) above for determining the thickness for a spherical shell.

(c) Ellipsoidal Heads. The required thickness of an ellipsoidal head having pressure on the convex side, either seamless or of built-up construction with butt joints, shall not be less than that determined by the following procedure.

Step 1. Assume a value for \( T \) and calculate the value of factor \( A \) using the following equation:

\[ A = 0.125 \frac{R}{T} \]

Step 2. Using the value of \( A \) calculated in Step 1, follow the same procedure as that given for spherical shells in (a) above, Steps 2 through 6.

(d) Torispherical Heads. The required thickness of a torispherical head having pressure on the convex side, either seamless or of built-up construction with butt joints, shall not be less than that determined by the same design procedure as is used for ellipsoidal heads given in (c) above, using the appropriate value for \( R \).

(e) Class 3 items only. The required thickness of toriconical head having pressure on the convex side, either seamless or of built-up construction with butt joints within the head, shall not be less than that determined from NCD-3133.7(b) with the exception that \( L_e \), shall be determined as follows:

(1) For sketch (c) in Figure NCD-3133.4-1

\[ L_e = r_1 \sin \theta_1 + \frac{L}{2} \left( \frac{D_L + D_S}{D_{LS}} \right) \]

(2) For sketch (d) in Figure NCD-3133.4-1

\[ L_e = r_2 \left( \frac{D_{SS}}{D_L} \right) \sin \theta_2 \left( \frac{L}{2} \right) \left( \frac{D_L + D_S}{D_L} \right) \]
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(3) For sketch (e) in Figure NCD-3133.4-1

\[ L_e = r_1 \sin \theta_1 + r_2 \left( \frac{D_{ss}}{D_L} \right) \sin \theta_2 + \left( \frac{L}{2} \right) \left( \frac{D_L + D_S}{D_{LS}} \right) \]

(f) Class 3 items only. When lap joints are used in formed head construction or for longitudinal joints in a conical head under external pressure, the thickness shall be determined by the rules in this paragraph, except \(2P\) shall be used instead of \(P\) in the calculations for the required thickness.

(g) Class 3 items only. The required length of skirt on heads convex to pressure shall comply with the provision of NCD-3324.5(c), and NCD-3324.5(i) for heads concave to pressure.

(h) Class 3 items only. Openings in heads convex to pressure shall comply with the requirements of NCD-3330.

(i) Class 3 items only. When necessary, provision shall be made to vessels and heads to prevent overstressing and excessive distortion due to external loads other than pressure and temperature (see NCD-3111).
**NCD-3133.5 Stiffening Rings for Cylindrical Shells.**

(a) The required moment of inertia of a circumferential stiffening ring shall be not less than that determined by one of the following two equations:

\[ I_S = \frac{D_o^2 L S_5 (T + A S / L S) A}{14} \]  \hfill (1)

\[ I'_S = \frac{D_o^2 L S_5 (T + A S / L S) A}{10.9} \]  \hfill (2)

If the stiffeners should be so located that the maximum permissible effective shell sections overlap on either or both sides of a stiffener, the effective shell section for that stiffener shall be shortened by one-half of each overlap. Stiffening rings shall be designed to preclude lateral buckling.

(b) The available moment of inertia \( I \) or \( I' \) for a stiffening ring shall be determined by the following procedure.
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Step 1. Assuming that the shell has been designed and $D_o$, $L_s$, and $T_n$ are known, select a member to be used for the stiffening ring and determine its cross-sectional area $A_s$. Then calculate factor $B$ using the following equation:

$$B = \frac{3}{4}\left(\frac{PD_o}{T_n + A_s/L_s}\right)$$

Step 2. Enter the right-hand side of the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration at the value of $B$ determined by Step 1. If different materials are used for the shell and stiffening ring, use the material chart resulting in the larger value of $A$ in Step 4 or Step 5, below.

Step 3. Move horizontally to the left to the material/temperature line for the design metal temperature. For values of $B$ falling below the left end of the material/temperature line, see Step 5.

Step 4. Move vertically to the bottom of the chart and read the value of $A$.

Step 5. For values of $B$ falling below the left end of the material/temperature line for the design temperature, the value of $A$ can be calculated using the equation

$$A = \frac{2B}{E}$$

Step 6. Compute the value of the required moment of inertia from the equations provided in eqs. (a)(1) and (a)(2), above.

Step 7. Calculate the available moment of inertia $I$ or $I'$ of the stiffening ring using the section corresponding to that used in Step 6.

Step 8. If the required moment of inertia is greater than the moment of inertia for the section selected in Step 1, a new section with a larger moment of inertia must be selected and a new moment of inertia determined. If the required moment of inertia is smaller than the moment of inertia for the section selected in Step 1, that section should be satisfactory.

(c) For fabrication and installation requirements for stiffening rings, see NCD-4437.

**NCD-3133.6 Cylinders Under Axial Compression.**

The maximum allowable compressive stress to be used in the design of cylindrical shells and tubular products subjected to loadings that produce longitudinal compressive stresses in the shell or wall shall be the lesser of the values given in (a) or (b) below:

(a) the $S$ value for the applicable material at design temperature given in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3;

(b) the value of the $B$ determined from the applicable chart in Section II, Part D, Subpart 3. The value of $B$ shall be determined from the applicable chart contained in Section II, Part D,
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Subpart 3 as given in Steps 1 through 5 using the following definitions for the symbols on the charts:

\[ R = \text{inside radius of the cylindrical shell or tubular product} \]
\[ T = \text{minimum required thickness of the shell or tubular product, exclusive of the corrosion allowance} \]

The value of \( B \) shall be determined from the applicable chart contained in Section II, Part D, Subpart 3 as given in Steps 1 through 5.

Step 1. Using the selected values of \( T \) and \( R \), calculate the value of factor \( A \) using the following equation:

\[ A = \frac{0.125}{(R/T)} \]

Step 2. Using the value of \( A \) calculated in Step 1, enter the applicable material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with the material/temperature line for the Design Temperature. Interpolation may be made between lines for intermediate temperatures. In cases where the value at \( A \) falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of \( A \) falling to the left of the material/temperature line, see Step 4.

Step 3. From the intersection obtained in Step 2, move horizontally to the right and read the value of factor \( B \). This is the maximum allowable compressive stress for the values of \( T \) and \( R \) used in Step 1.

Step 4. For values of \( A \) falling to the left of the applicable material/temperature line, the value of \( B \) shall be calculated using the following equation:

\[ B = \frac{AE}{2} \]

Step 5. Compare the value of \( B \) determined in Step 3 or 4 with the computed longitudinal compressive stress in the cylindrical shell or tube, using the selected values of \( T \) and \( R \). If the value of \( B \) is smaller than the computed compressive stress, a greater value of \( T \) must be selected and the design procedure repeated until a value of \( B \) is obtained which is greater than the compressive stress computed for the loading on the cylindrical shell or tube. For Class 3 only, the joint efficiency for butt-welded joints may be taken as unity.

**NCD-3133.7 Conical Heads and Sections.**

(a) Class 2 items only. The required thickness of a conical head under external pressure shall not be less than that determined by the rules of (1a), (2b), and (3e) below.
Note to Editors: Markups are based on 2019 Edition of NC-3000. Changes are shown in red. Cross references to paragraphs within this sub-article shall be updated based on this proposal’s markups.

(1a) When one-half of the included apex angle of the cone is equal to or less than $22\frac{1}{2}$ deg, the thickness of the cone shall be the same as the required thickness of a cylindrical shell, the length of which equals the axial length of the cone or the axial distance center to center of stiffening rings, if used, and the outside diameter of which is equal to the outside diameter at the large end of the cone or section between stiffening rings.

(2b) When one-half of the included apex angle of the cone is greater than $22\frac{1}{2}$ deg and not more than 60 deg, the thickness of the cone shall be the same as the required thickness of a cylindrical shell, the outside diameter of which equals the largest inside diameter of the cone measured perpendicularly to the cone axis, and the length of which equals an axial length that is the lesser of either the distance center to center of stiffening rings, if used, or the largest inside diameter of the section of the cone considered.

(3e) When one-half of the included apex angle of the cone is greater than 60 deg, the thickness of the cone shall be the same as the required thickness for a flat head under external pressure, the diameter of which equals the largest inside diameter of the cone (NCD-3325).

(b) Class 3 items only. The required thickness of a conical head or section under pressure on the convex side, either seamless or of built-up construction with butt joints, shall be determined in accordance with the following:

(1) When $\alpha$ is equal to or less than 60 deg

(-a) Cones having $D_L/T_e$ values greater than or equal to 10

Step 1. Assume a value for $T_e$ and determine the ratios $L_e/D_L$ and $D_L/T_e$.

Step 2. Enter Section II, Part D, Subpart 3, Figure G at a value of $L/D_o$ equivalent to the value of $L_e/D_L$ determined in Step 1. For values of $L_e/D_L$ greater than 50, enter the chart at a value of $L_e/D_L = 50$.

Step 3. Move horizontally to the line for the value of $D_o/T$ equivalent to the value of $D_L/T_e$ determined in Step 1. Interpolation may be for intermediate values of $D_L/T_e$. From the point of intersection move vertically downward to determine the value of factor A.

Step 4. Using the value of A calculated in Step 3, enter the material chart in Section II, Part D, Subpart 3 for the material under consideration. Move vertically to an intersection with material/temperature line for the design temperature (see NCD-3112.2). Interpolation may be made between lines for intermediate temperatures. In cases where the value of A falls to the right of the end of the material/temperature line, assume an intersection with the horizontal projection of the upper end of the material/temperature line. For values of A falling to the left of the material/temperature line, see Step 7.
Step 5. From the intersection obtained in Step 4, move horizontally to the right and read the value of factor B.

Step 6. Using this value of B, calculate the values of the maximum allowable external pressure $P_a$ using the following equation:

$$P_a = \frac{4B}{3(D_L/T_e)}$$

Step 7. For values of $A$ falling to the left of the applicable material/temperature line, the value of $P_a$ can be calculated using the following equation:

$$P_a = \frac{2AE}{3(D_L/T_e)}$$

Step 8. Compare the calculated value of $P_a$ obtained in Step 6 or 7 with $P$. If $P_a$ is smaller than $P$, select a larger value for $T$ and repeat the design procedure until a value of $P_a$ is obtained that is equal to or greater than $P$.

Step 9. Provide adequate reinforcement of the cone-to-cylinder juncture according to Section III Appendices, Mandatory Appendix XXII.

(-b) Cones having $D_L/T_e$ values less than 10

Step 1. Using the same procedure as given in (-a) above, obtain the value for $B$. For values of $D_L/T_e$ less than 4, the value of factor $A$ can be calculated using the following equation:

$$A = \frac{1.1}{(D_L/T_e)^2}$$

For values of $A$ greater than 0.10, use a value of 0.10.

Step 2. Using the values of $B$ obtained in Step 1, calculate the value $P_{a1}$ using the following equation:

$$P_{a1} = \left[\frac{2.167}{D_L/T_e} - 0.0833\right]B$$

Step 3. Calculate the value of $P_{a2}$ using the following equation:

$$P_{a2} = \frac{2S}{(D_L/T_e)} \left[1 - \frac{1}{(D_L/T_e)}\right]$$
Step 4. The smaller of the values of $P_{a1}$ calculated in Step 2, or $P_{a2}$ calculated in Step 3 shall be used for the maximum allowable external pressure $P_a$. Compare the calculated value of $P_a$ with $P$. If $P_a$ is smaller than $P$, select a larger value for $T$ and repeat the design procedure until a value of $P_a$ is obtained that is equal to or greater than $P$.

Step 5. Provide adequate reinforcement of the cone-to-cylinder juncture according to Section III Appendices, Mandatory Appendix XXII.

(2) When $\alpha$ of the cone is greater than 60 deg, the thickness of the cone shall be the same as the required thickness for a flat head under external pressure, the diameter of which equals the largest diameter of the cone (see NCD-3325).

(3) The thickness of an eccentric cone shall be taken as the greater of two thicknesses obtained using both the smallest and largest $\alpha$ in the calculations.

**NCD-3133.8 Tubes and Pipes When Used as Tubes.**

The required wall thickness for tubes and pipes under external pressure shall be determined in accordance with Figure NCD-3133.8-1.
Note to Editors: Markups are based on 2019 Edition of NC-3000. Changes are shown in red. Cross references to paragraphs within this sub-article shall be updated based on this proposal’s markups.

Figure NCD-3133.8-1 — Chart for Determining Wall Thickness of Tubes Under External Pressure

GENERAL NOTE: For welded tubes or pipes, use the design stress for seamless material.

NCD-3135 Attachments

(a) Except as in (c) and (d) below, attachments and connecting welds within the jurisdictional boundary of the component as defined in NCD-1130 shall meet the stress limits of the component.
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(b) The design of the component shall include consideration of the interaction effects and loads transmitted through the attachment to and from the pressure-retaining portion of the component. For Class 2 vessels designed to NCD-3200, thermal stresses, stress concentrations, and restraint of the pressure-retaining portion of the component shall be considered.

(c) Beyond $2t$ from the pressure-retaining portion of the component, where $t$ is the nominal thickness of the pressure-retaining material, the appropriate design rules of Article NF-3000 may be used as a substitute for the design rules of Article NCD-3000 for portions of attachments which are in the component support load path.

(d) Nonstructural attachments shall meet the requirements of NCD-4435.