\[ P_L = \text{local primary membrane stress intensity, psi (MPa).} \]

This stress intensity is derived from the average value across the solid section under consideration. It considers discontinuities but not concentrations.

\[ P_m = \text{general primary membrane stress intensity, psi (MPa).} \]

This stress intensity is derived from the average value across the solid section under consideration. It excludes discontinuities and concentrations and is produced only by pressure and other mechanical loads.

\[ S_m = \text{design stress intensity values given in Tables 2A,} \]

2B, and 4, Section II, Part D, Subpart 1, psi (MPa)

\[ S_y = \text{yield strength values given in Tables Y-1, Section II,} \]

Part D, Subpart 1, psi (MPa)

NC-3218 Upper Limits of Test Pressure

The evaluation of pressure test loadings shall be in accordance with (a) through (d) below.

(a) **Test Pressure Limit.** If the calculated pressure at any point in a vessel, including static head, exceeds the required test pressure defined in NC-6221 or for a vessel by more than 6%, the resulting stresses shall be calculated using all the loadings that may exist during the test. The stress allowances for this situation are given in (b) and (c) below.

(b) **Hydrostatically Tested Vessels.** The hydrostatic test pressure of a completed vessel shall not exceed that value which results in the following stress intensity limits:

\[ \alpha \times P_m + P_b \leq 1.35S_y \quad \text{for} \quad P_m \leq 0.67S_y \]

\[ \alpha \times P_m + P_b \leq (2.15S_y - 1.2P_m) \quad \text{for} \quad 0.67S_y < P_m \leq 0.90S_y \]

where \( S_y \) is the tabulated yield strength at test temperature. For other than rectangular sections, \( P_m + P_b \) shall not exceed a value of \( \alpha \times 0.9S_y \), where the factor \( \alpha \) is defined as the ratio of the load set producing a fully plastic section divided by the load set producing initial yielding in the extreme fibers of the section.

(c) **Pneumatically Tested Vessels.** The limits given in (b) above shall apply to pneumatically tested vessels, except that the calculated membrane stress intensity shall be limited to 80% of the yield strength at the test temperature. For other than rectangular sections, \( P_m + P_b \) shall not exceed a value of \( \alpha \times 0.8S_y \), where the factor \( \alpha \) is defined in (b)(2) above.

(d) **Multichamber Vessels.** In the case of multichamber vessels, pressure may be applied simultaneously to the appropriate adjacent chamber to maintain the stress intensity limits given in (b) and (c) above.

NC-3219 Fatigue Evaluation

When determining whether or not a fatigue analysis shall be specified, the Owner may consider experience with comparable vessels under similar conditions in accordance with the provisions of NC-3219.1. When not based upon significant applicable service experience, the need for a fatigue analysis shall be determined in accordance with the provisions of NC-3219.2 and NC-3219.3.

NC-3219.1 Service Experience. When the Owner is considering experience with comparable vessels under similar service conditions as related to the design and service contemplated, particular attention shall be given to the possible deleterious effects of the design features of (a) through (e) below:

(a) nonintegral construction, such as the use of pad type reinforcements or of fillet welded attachments, as opposed to integral construction;

(b) use of pipe threaded connections, particularly for diameters in excess of 2\(\frac{3}{4}\) in. (70 mm);

(c) stud bolted attachments;

(d) partial penetration welds;

(e) major thickness changes between adjacent members.

NC-3219.2 Rules to Determine Need for Fatigue Analysis of Integral Parts of Vessels. A fatigue analysis need not be made, provided all of Condition A or all of Condition B is met. If neither Condition A nor B is met, a detailed fatigue analysis shall be made in accordance with the rules of Appendices XIII and XIV for those parts which do not satisfy the conditions. The rules of Condition A or Condition B are applicable to all integral parts of the vessel, including integrally reinforced type nozzles. For vessels having pad-type nozzles or nonintegral attachments, the requirements of NC-3219.3 apply.

NC-3219.2.1 Condition A. Fatigue analysis is not mandatory for materials having a specified minimum tensile strength not exceeding 80.0 ksi (550 MPa) when the total of the expected number of cycles of types (a) plus (b) plus (c) plus (d), defined below, does not exceed 1,000 cycles:

(a) is the expected design number of full range pressure cycles including startup and shutdown;

(b) is the expected number of service pressure cycles in which the range of pressure variation exceeds 20% of the Design Pressure. Cycles in which the pressure variation does not exceed 20% of the Design Pressure are not limited in number. Pressure cycles caused by fluctuations in atmospheric conditions need not be considered;

(c) is the effective number of changes in metal temperature between any two adjacent points in the pressure vessel, including nozzles. The effective number of such changes is determined by multiplying the number
**NC-3224.6 Minimum Thickness of Ellipsoidal Heads.** The minimum thickness of a 2:1 ellipsoidal head shall be established using the procedures given in NC-3224.8 and the curve of Figure NC-3224.6-1, which is labeled “2:1 ellipsoidal head.” Ellipsoidal head designs which have $D/2h$ values different from 2 shall be analyzed as equivalent torispherical heads or according to Appendix II, XIII, or XIV. The cylindrical shell to which the head is attached shall be equal to or greater in thickness than the required head thickness for a distance, measured from the tangent line along the cylinder, of not less than $\sqrt{Rt}$. Transition joints to shells of thickness less than the required head thickness shall not be located within the minimum distance. Transition joints to shells greater than the required head thickness may be located within this minimum distance and shall be in accordance with NC-3361 and Figure NC-3358-1.

**NC-3224.7 Minimum Thickness of Hemispherical Heads.** For hemispherical heads, the thickness shall be as required for spherical shells, NC-3224.4. The requirements for the transition to cylindrical shells of different thickness, given in NC-3361 and Figure NC-3361-1, shall be met.

**NC-3224.8 Minimum Thickness of Torispherical Heads.** The minimum thickness of a torispherical head having $t/L \geq 0.002$ up to a $t/L$ where $P/S \leq 0.08$ (approximately $t/L = 0.04$ to 0.05) shall be established by using the curves in Figure NC-3224.6-1. Interpolation may be used for $r/D$ values which fall within the range of the curves; however, no extrapolation of the curves is permitted. For designs where $P/S > 0.08$, which is above the upper limit of Figure NC-3224.6-1, the thickness shall be set by the following equation:

$$t = \frac{D}{2} \left[ e^{P/S} - 1 \right]$$

Where $t/L < 0.002$, which is below the lower limit of Figure NC-3224.6-1, the head design must be analyzed according to Appendix II, XIII, or XIV. The cylindrical shell to which the head is attached shall be equal to or greater in thickness than the required head thickness for a distance, measured from the tangent line along the cylinder, of not less than $\sqrt{Rt}$. Transition joints to shells of thickness less than the required head thickness shall not be located within this minimum distance. Transition joints to shells of thickness greater than the required head thickness may be located within this minimum distance and shall be in accordance with NC-3361 and Figure NC-3358-1.

**NC-3224.8.1 Crown and Knuckle Radii.** In connection with the design procedures of NC-3224.8 and Figure NC-3224.6-1, the inside crown radius to which an unstayed head is formed shall not be greater than the inside diameter of the skirt of the head. The inside knuckle radius of a torispherical head shall not be less than 6% of the outside diameter of the skirt nor less than three times the head thickness.

**NC-3224.9 Minimum Thickness of Integral Head Skirts.** In addition to the requirements of NC-3224.8 or NC-3224.6, when an integral head skirt is provided, the skirt thickness shall not be less than the required thickness of a seamless shell of the same diameter. All transition joints shall be in accordance with NC-3361 and Figure NC-3358-1.

**NC-3224.10 Composite Head Shapes.** A head for a cylindrical shell may be built up of several head shapes, the thicknesses of which satisfy the requirements of the appropriate equations above. The adjoining shapes must be so formed that they have a common tangent transverse to the joint. Any taper at a joint shall be within the boundary of the shape having the thinner wall (Figure NC-3361-1).

**NC-3224.11 Loadings on Heads Other Than Pressure.** Provision shall be made for other loadings given in NC-3212. For torispherical and ellipsoidal heads, the effect of other loadings must be determined in accordance with Appendix II, XIII, or XIV. For the conical or spherical portions of heads, the effect of composite loading may be treated as in NC-3224.3, NC-3224.4, and NC-3224.13(a)(4).

**NC-3224.12 Toriconical Heads.** (In preparation.)

(a) General Requirements

(1) Applicable Equations and Rules. These rules apply to concentric reducer sections when all the longitudinal loads are transmitted wholly through the shell of the reducer. When loads are transmitted in part or as a whole by other elements, such as inner shells, stays, or tubes, these rules do not apply.

(2) Minimum Thickness of Reducer Elements. The thickness of each element of a reducer under internal pressure shall not be less than that computed by the applicable equation. In addition, provisions shall be made for any of the other loadings listed in NC-3212.

(3) Transition Section Reducers Joining Two Cylindrical Shells. A transition section reducer consisting of one or more elements may be used to join two cylindrical shell sections of different diameters but with a common axis, provided these requirements are met.

(4) Minimum Thickness of Conical Shells. The minimum thickness of conical shells shall be determined by the same equations as for cylindrical shells in which $R$ is the radius measured normal to the wall surface at the point under consideration. Subparagraphs (b) and (c) give rules for cone to cylinder junctions of the large and small end, respectively.
The weld at the junction is radiographed and meets the requirements of NC-5250.

(5) the junction is not closer than \( 2.8 \sqrt{R_{s} t_{r}} \) to another junction or discontinuity, where \( R_{s} \) is the radius of the cylinder at the small end of the cone.

(6) Reinforcement Requirements:

(a) When Inherent Reinforcement Is Adequate. The thickness of the cone and cylinder forming a junction at the small end of half apex angles up to 30 deg need not be thicker than required by NC-3224.3 if the point representing the junction lies in the Adequate region of Figure NC-3224.13(c)(6)(a)-1.

(b) Requirements for Integral Reinforcement. When the half-apex angle exceeds the maximum permitted by Figure NC-3224.13(c)(6)(a)-1, the cone and cylinder must be reinforced in the area adjacent to the junction. Figure NC-3224.13(b)(6)(b)-1 gives \( Q \) values for ratios of Design Pressure \( P \) to \( S \) and values of \( \alpha \) up to 30 deg. The junction may be reinforced by making both the cylinder and cone thickness equal to \( t_{r} \) and provided that the requirements of (1) through (3) below are met.

(1) The increased cylinder thickness extends a minimum distance of \( 2.0 \sqrt{R_{s} t_{r}} \) from the junction, where \( R_{s} \) is the radius of the cylinder at the large end of the cone.

(2) The increased cone thickness extends a minimum distance of \( 2.0 \sqrt{R_{s} t_{r}} \) from the junction.

(3) In no case shall \( t_{r} \) be less than the thickness required for the cone in accordance with NC-3224.3.

(c) Supplementary Requirements for Reducer Section’s Small End. These rules apply, provided the requirements of (1) through (6) below are met:

(1) the two parts to be joined have the same rotational axis

(2) the load is internal pressure (NC-3224.11)

(3) the joint is a butt weld having its surfaces merge smoothly, both inside and outside, with the adjacent cone and cylinder surfaces without reducing the thickness.

(4) the weld at the junction is radiographed and meets the requirements of NC-3252.2(b).

(5) the junction is not closer than \( 2.8 \sqrt{R_{s} t_{r}} \) to another junction or discontinuity, where \( R_{s} \) is the radius of the cylinder at the small end of the cone.

(6) Reinforcement Requirements:

(a) When Inherent Reinforcement Is Adequate. The thickness of the cone and cylinder forming a junction at the small end of half apex angles up to 30 deg need not be thicker than required by NC-3224.3 if the point representing the junction lies in the Adequate region of Figure NC-3224.13(c)(6)(a)-1.

(b) Requirements for Integral Reinforcement. When the half-apex angle exceeds the maximum permitted by Figure NC-3224.13(c)(6)(a)-1, the cone and cylinder must be reinforced in the area adjacent to the junction. Figure NC-3224.13(c)(6)(b)-1 gives \( Q \) values for ratios of Design Pressure \( P \) to \( S \) and values of \( \alpha \) up to 30 deg. The junction may be reinforced by making both the cylinder and cone thickness equal to \( t_{r} \) and provided that the requirements of (1) through (3) below are met.

(1) The increased cylinder thickness \( t_{r} \) extends a minimum distance \( 1.4 \sqrt{R_{s} t_{r}} \) from the junction.

(2) The increased cone thickness \( t_{r} \) extends a minimum distance \( 1.4 \sqrt{R_{s} t_{r}} \) from the junction.

(3) In no case shall \( t_{r} \) be less than the thickness required for the cone in accordance with NC-3224.3 at a distance \( 1.4 \sqrt{R_{s} t_{r}} \) from the junction.

(d) Supplementary Requirements for Reducer Sections, Small End, Treated As Openings. Cone to cylinder junctions at the small ends of reducers as shown in...
where

\[ d = \text{finished diameter of a circular opening or finished dimension (chord length) of an opening on the plane being considered for elliptical and obround openings in corroded condition} \]

\[ F = 1.00 \text{ when the plane under consideration is in the spherical portion of a head or when the given plane contains the longitudinal axis of a cylindrical shell. For other planes through a shell, use the value of } F \text{ determined from Figure NC-3332.2-1 except that, for reinforcing pads, } F = 1. \]

\[ t_r = \text{the thickness which meets the requirements of NC-3220 in the absence of the opening} \]

\( (b) \) Not less than one-half the required material shall be on each side of the center line of the opening [NC-3234.1 (c)]

**NC-3233 Required Reinforcement for Openings in Flat Heads**

\( (a) \) Flat heads that have an opening with a diameter that does not exceed one-half of the head diameter shall have a total cross-sectional area of reinforcement \( A \), not less than that given by the equation

\[ A = 0.5dt_r \]

where

\[ d = \text{the diameter of the finished opening in its corroded condition} \]

\[ t_r = \text{the thickness that meets the requirements of NC-3225.2 in the absence of the opening} \]

\( (b) \) Flat heads that have an opening with a diameter that exceeds one-half of the head diameter shall be designed according to Appendix XIX.

**NC-3234 Limits of Reinforcement**

The boundaries of the cross-sectional area in any plane normal to the vessel wall and passing through the center of the opening within which metal shall be located in order to have value as reinforcement are designated as the limits of reinforcement for that plane and are as described in the following subparagraphs.

**NC-3234.1 Limit of Reinforcement Along the Vessel Wall.** The limits of reinforcement, measured along the midsurface of the nominal wall thickness of the vessel, shall meet the following:
(a) 100% of the required reinforcement shall be within a distance on each side of the axis of the opening equal to the greater of the following:

(1) the diameter of the finished opening in the corroded condition;
(2) the radius of the finished opening in the corroded condition plus the sum of the thicknesses of the vessel wall and the nozzle wall;

(b) two-thirds of the required reinforcement shall be within a distance on each side of the axis of the opening equal to the greater of the following:

(1) \( r + 0.5\sqrt{rL} \), where \( R \) is the mean radius of shell or head, \( r \) is the nominal vessel wall thickness, \( r \) is the radius of the finished opening in the corroded condition;
(2) the radius of the finished opening in the corroded condition plus two-thirds the sum of the thicknesses of the vessel wall and the nozzle wall.

**NC-3234.2 Limit of Reinforcement Normal to Vessel Wall.** The limits of reinforcement, measured normal to the vessel wall, shall conform to the contour of the surface at a distance on each side equal to the limits given in (a), (b), and (c) below.

(a) For Figure NC-3234.2(a)-1 sketches (a) and (b), the limit is the larger of \( 0.5\sqrt{rtn} + k \) or \( 1.73x + 2.5tp + k \), but not to exceed either 2.5t or \( (L + 2.5tp) \), where

\[ k = 0.73r_2 \text{ when a transition radius (r)}_2 \text{ is used} \]
[for the smaller of two legs of the fillet when a fillet transition is used]

\[ L = \text{length along nozzle with thickness of } t_n \text{ plus transition length} \]

\[ r = \text{inside radius of nozzle} \]

\[ r_2 = \text{transition radius between nozzle and wall} \]

\[ r_m = \text{mean nozzle radius} = r + 0.5t_n \]

\[ t = \text{nominal vessel wall thickness} \]

\[ t_n = \text{nominal nozzle thickness} \]

\[ t_p = \text{nominal thickness of connecting pipe} \]

\[ x = t_n - t_p \]

(b) For Figure NC-3234.2(a)-1 sketch (c), when \( 45 \leq \theta \leq 30 \text{ deg} \), the limit is the larger of \( 0.5\sqrt{rtn}t_n \) or \( (L' + 2.5tp) \), but not to exceed 2.5t; when \( \theta < 30 \text{ deg} \), the limit is the larger \( 0.5\sqrt{rtn}t_n \) or \( (1.73x + 2.5tp) \), but not to exceed 2.5t, where

\[ L' = \text{length of tapered section along nozzle} \]

\[ r_m = r + 0.5tp' \]

\[ t_n' = tp' + 0.667x \]

\[ x = \text{slope offset distance} \]

\[ \theta = \text{angle between vertical and slope} \]

Other terms are defined in (a) above.

(c) For Figure NC-3234.2(a)-1 sketch (d), when reinforcing pads or insert plates are used, the limit is the larger of \( 0.5\sqrt{rtn}t_n \) or \( (2.5t_n + t_c) \), but not to exceed 2.5t. In no case can the thickness \( t_c \) be used to establish the limit normal to the shell, exceed 1.5t or 1.73W, where \( t_c = \text{thickness of added reinforcing element} \)

\[ W = \text{width of added reinforcing element} \]

Other terms are defined in (a) above.

**NC-3234.3 Nozzle Piping Transitions.** The stress limits of NC-3200 shall apply to all portions of nozzles which lie within the limits of reinforcement given in NC-3234, except as noted in NC-3234.4. Stresses in the extension of any nozzle beyond the limits of reinforcement shall meet the stress limits of NC-3600.

**NC-3234.4 Consideration of Standard Reinforcement.** Where a nozzle-to-shell juncture is reinforced in accordance with the rules of NC-3234, the stresses in this region due to internal pressure may be considered to satisfy the limits of NC-3217. Under these conditions, no analysis is required for demonstration compliance for pressure induced stresses in the nozzle region. Where external piping loads are to be designed for, membrane plus bending stresses shall be calculated in the nozzle, and membrane stresses shall be calculated in the local nozzle-to-shell region. These stresses, in conjunction with pressure induced stresses, shall meet the limits of NC-3217 for \( P_m \) or \( P_l \). In this case, the pressure induced stresses in the \( P_m \) or \( P_l \) category may be assumed to be no greater than the limit specified for \( P_m \) in NC-3217 for a given condition.

**NC-3235 Metal Available for Reinforcement**

Metal may be counted as contributing to the area of reinforcement called for in NC-3232.2 and NC-3233, provided it lies within the area of reinforcement specified in NC-3234 and shall be limited to material which meets the requirements of (a) through (e) below:

(a) metal forming a part of the vessel wall which is in excess of that required on the basis of primary stress intensity (NC-3221 through NC-3224 and NC-3225.2) and is exclusive of corrosion allowance;

(b) similar excess metal in the nozzle wall, provided the nozzle is integral with the vessel wall or is joined to it by a full penetration weld;

(c) weld metal which is fully continuous with the vessel wall;

(d) metal not fully continuous with the shell, such as a pad continuously welded around its periphery, may be counted as reinforcement, provided the requirements of (a) through (e) are met;

(e) the mean coefficient of thermal expansion of metal to be included as reinforcement under (b), (c), and (d) above shall be within 15% of the value for the metal in the vessel wall.
**NC-3235.1** Metal Not Available for Reinforcement. Metal not fully continuous with the shell, as that in nozzles attached by partial penetration welds, shall not be counted as reinforcement.

**NC-3235.2** Reinforcement Metal Limited to One Opening. Metal available for reinforcement shall not be considered as applying to more than one opening.

**NC-3236** Strength of Reinforcement Material

Material used for reinforcement shall preferably have the same design stress intensity value as that of the vessel wall. In no case shall material with an allowable design stress intensity value less than 80% of the value of the vessel wall material at the Design Temperature be used in determining area available for reinforcement. If the material of the nozzle wall or reinforcement has a lower design stress intensity value $S_m$ than that for the vessel material, the amount of area provided by the nozzle wall or reinforcement in satisfying the requirements of NC-3232 shall be taken as the actual area provided multiplied by the ratio of the nozzle or reinforcement design stress intensity value to the vessel material design stress intensity value. No reduction in the reinforcement requirement may be made if the reinforcing material or weld metal has a design stress intensity value higher than that of the material of the vessel wall. The strength of the material at the point under consideration shall be used in fatigue analyses.

**NC-3237** Requirements for Nozzles With Separate Reinforcing Plates

Except for nozzles at small ends of cones reinforced in accordance with the requirements of NC-3224.11(c), added reinforcement in the form of separate reinforcing plates may be used, provided the vessel and the nozzles meet all the conditions of (a) through (d) below.

(a) The specified minimum tensile strengths of the materials do not exceed 80 ksi (550 MPa).

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

(c) The thickness of the added reinforcement does not exceed $1\frac{1}{2}$ times the shell thickness.

(d) The requirements of NC-3219 for pads in cyclic service are met.

**NC-3239** Alternative Rules for Opening Reinforcement

The requirements of this paragraph constitute an acceptable alternative to the rules of NC-3231 through NC-3237 and XIII-2000.

**NC-3239.1** Limitations. These rules are applicable only to openings utilizing nozzles in vessels within the limitations of (a) through (f) below.

(a) The nozzle is circular in cross section and its axis is perpendicular to the vessel or head.

(b) The nozzle and required reinforcing are welded integrally into the vessel with full penetration welds between all parts. Details such as those shown in Figures NC-4266(a)-1, NC-4266(b)-1 sketches (a), (b), and (c), and NC-4266(c)-1 are acceptable. However, fillet welds must be ground to a radius in accordance with Figure NC-3239.1(b)-1.

(c) In the case of spherical shells and formed heads, at least 40% of the total nozzle reinforcement area shall be located beyond the outside surface of the minimum required vessel wall thickness.

(d) The spacing between the edge of the opening and the nearest edge of any other opening is not less than the smaller of 1.25 $(d_1 + d_2)$ and $2.5\sqrt{R_t}$, but in any case, not less than 1.0 $(d_1 + d_2)$, where $d_1$ and $d_2$ are the inside diameters of the openings.

(e) The materials used in the nozzle reinforcement and vessel wall adjacent to the nozzle shall have a ratio of $UTS/YS$ of not less than 1.5, where

\[
UTS = \text{specified minimum ultimate tensile strength}
\]

\[
YS = \text{specified minimum yield strength}
\]

(f) The following dimensional limitations are met:

<table>
<thead>
<tr>
<th>NC-3244.13(d)</th>
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<tr>
<td><strong>Nozzles in</strong></td>
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<tr>
<td><strong>Cylindrical Vessels</strong></td>
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<tr>
<td>$D/t$</td>
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<td>$d/D$</td>
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<tr>
<td>$d/\sqrt{dt}$</td>
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<td>$d/\sqrt{d_0t_2}$</td>
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**NC-3239.2** Nomenclature.

- $A_a$ = available reinforcing area
- $A_r$ = required minimum reinforcing area
- $D$ = inside diameter, in corroded condition, of cylindrical vessel, spherical vessel, or spherical head
- $d$ = inside diameter of the nozzle in its corroded condition
- $R$ = inside radius, in corroded condition, of cylindrical vessel, spherical vessel, or spherical head
- $r$ = inside radius of the nozzle in its corroded condition
- $t$ = nominal wall thickness of vessel or head, less corrosion allowance
- $t_n$ = nominal wall thickness of nozzle, less corrosion allowance
- $t_r$ = wall thickness of vessel or head, computed by the equation given in NC-3224.3 for cylindrical vessels; by NC-3224.4 for spherical vessels or spherical heads
- $t_{rn}$ = wall thickness of nozzle, computed by the equation given in NC-3224.3
will be no thermal stresses greater than in the vessel itself. Such attachments shall satisfy the rules for reinforcement of openings, except that no material in the neck shall be used for reinforcement in the attachment. The inside diameter of such openings shall not exceed 4 in. (100 mm). The minimum dimensions of Figure NC-4266(d)-1 shall be met where:

\[ C = \text{maximum diametral clearance between nozzle and vessel penetration, in. (mm)} \]
\[ = 0.010 \text{ in. for } d \leq 1 \text{ in. (0.25 mm for } d \leq 25 \text{ mm)} \]
\[ = 0.020 \text{ in. for } 1 \text{ in. } < d \leq 4 \text{ in. (0.50 mm for } 25 \text{ mm } < d \leq 100 \text{ mm)} \]
\[ = 0.030 \text{ in. for } d > 4 \text{ in. (0.75 mm for } d > 100 \text{ mm)} \]

except that the above limits on maximum clearance need not be met for the full length of the opening, provided there is a region at the weld preparation and a region near the end of the opening opposite the weld that does meet the above limit on maximum clearance and the latter region is extensive enough (not necessarily continuous) to provide a positive stop for nozzle deflection.

\[ d = \text{outside diameter of nozzle} \]
\[ r_t = 1/4 t_n \text{ or } 1/2 t_n \text{ in (19 mm), whichever is less} \]
\[ t = \text{nominal thickness of vessel} \]
\[ t_c = 0.7 t \text{ or } 1/4 \text{ in. (6 mm), whichever is less} \]
\[ t_n = \text{nominal thickness of neck} \]
\[ t_w = \text{depth of weld penetration, not less than } 1/4 t_n, \text{ in. (mm)} \]

**NC-3254 Structural Attachment Welds**

Welds for structural attachments shall meet the requirements of NC-4267.

**NC-3255 Welding Grooves**

The dimensions and shape of the edges to be joined shall be such as to permit complete fusion and complete joint penetration, except as otherwise permitted in NC-3252.4.

**NC-3257 Welded Joints Subject to Bending Stress**

The requirements of NC-3257 shall be met.

**NC-3258 Design Requirements for Head Attachments**

**NC-3258.1 Skirt Length of Formed Heads.**

(a) Ellipsoidal and other types of formed heads, concave or convex to the pressure, shall have a skirt length not less than that shown in Fig. NC-3358-1.

(b) A tapered transition having a length not less than three times the offset between the adjacent surfaces of abutting sections as shown in Fig. NC-3358-3 shall be provided at joints between formed heads and shells that differ in thickness by more than one-fourth the thickness of the thinner section or by more than 1/8 in., whichever is less. When a taper is required on any formed head thicker than the shell and intended for butt welded attachment (Fig. NC-3358-1), the skirt shall be long enough so that the required length of taper does not extend beyond the tangent line.

**NC-3258.2 Unstayed Flat Head Welded to Shells.**

The requirements of welded unstayed flat heads to shells are given in NC-3225, NC-3258.3, and NC-3258.4.

**NC-3258.3 Head Attachments Using Corner Joints.**

When shells, heads, or other pressure parts are welded to a forged or rolled plate to form a corner joint, the welds shall meet the requirements given in (a) through (d) below.

(a) On the cross section through the welded joint, the line between the weld metal and the forged or rolled plate being attached shall be projected on planes both parallel to and perpendicular to the surface of the plate being attached, in order to determine the dimensions \(a\) and \(b\), respectively.

(b) For flange rings of bolted flanged connections and for flat heads and supported and unsupported tubesheets without a projection for a bolted connection, the sum of \(a\) and \(b\) shall be not less than three times the nominal wall thickness of the abutting pressure parts.

(c) For other parts, the sum of \(a\) and \(b\) shall be not less than two times the nominal wall thickness of the abutting pressure parts. Examples of such parts are flat heads and supported and unsupported tubesheets without a projection for a bolted connection and the side plates of a rectangular vessel.

(d) Joint details that have a dimension through the joint less than the thickness of the shell, head, or other pressure part or that provide eccentric attachment are not permitted.

(e) The minimum dimensions in Figures NC-4265-1 and NC-4265-2 are as follows:

(1) **Figure NC-4265-1**

Sketch (a)

\[ a + b \text{ not less than } 2 t_s \]

\[ b + c \text{ not less than } t_s \]

\[ t_p \text{ not less than } t_s \]

Sketch (b)

\[ a + b \text{ not less than } 2 t_s \]

Sketch (c)

\[ a + b \text{ not less than } 3 t_s \]

\[ b + c \text{ not less than } t_s \]

Sketches (d) and (e)

(a) For forged tubesheets, forged flat heads, and forged flanges with the weld preparation bevel angle not greater than 45 deg measured from the face:

\[ b = \text{the lesser of } t_s/2 \text{ or } T/4 \]

\[ c = 0.7 t_s \text{ or } 1/4 \text{ in. (6 mm), whichever is less} \]

\[ T, t_s = \text{nominal thickness of welded parts} \]
(-b) For all other material forms and for forged tubesheets, forged flat heads, and forged flanges with the weld preparation bevel angle greater than 45 deg measured from the face:

\[ b = \text{the lesser of } t_c \text{ or } T/2 \]
\[ c = 0.7t_c \text{ or } \frac{1}{4} \text{ in. (6 mm), whichever is less} \]
\[ T, t_n = \text{nominal thickness of welded parts sketches (f) and (g)} \]

(2) Figure NC-4265-2

Sketch (a)

(-a) For forged tubesheets, forged flat heads, and forged flanges with the weld preparation bevel angle not greater than 45 deg measured from the face:

\[ t, t_n = \text{nominal thickness of welded parts} \]
\[ t_c = 0.7t_n \text{ or } \frac{1}{4} \text{ in. (6 mm), whichever is less} \]
\[ t_w = \text{the lesser of } t_n/2 \text{ or } t/4 \]

(-b) For all other material forms and for forged tubesheets, forged flat heads, and forged flanges with the weld preparation bevel angle greater than 45 deg measured from the face:

\[ t, t_n = \text{nominal thicknesses of welded parts} \]
\[ t_c = 0.7t_n \text{ or } \frac{1}{4} \text{ in. (6 mm), whichever is less} \]
\[ t_w = \text{the lesser of } t_n/2 \text{ or } t/4 \]

NC-3259 Design Requirements for Nozzle Attachment Welds and Other Connections

The minimum design requirements for nozzle attachment welds and other connections are set forth in (a) through (c) below.

(a) Permitted Types of Nozzles and Other Connections. Nozzles and other connections may be any of the types for which rules are given in this Subarticle, provided the requirements of (1) through (7) below are met.

(1) Nozzles shall meet requirements regarding location.

(2) The attachment weld shall meet the requirements of NC-3252.4.

(3) The requirements of NC-3230 shall be met.

(4) Type No. 1 full penetration joints shall be used when the openings are in shells 21/2 in. (64 mm) or more in thickness.

(5) The welded joints shall be examined by the methods stipulated in NC-5250.

(6) Studded connections shall meet the requirements of NC-3262.4.

(7) Threaded connections shall meet the requirements of NC-3266.

(b) Provision of Telltale Holes for Air Testing. Reinforcing plates and saddles attached to the outside of a vessel shall be provided with at least one telltale hole, of maximum size 1/4 in. (6 mm) pipe tap, that may be tapped for a preliminary compressed air and soap solution or equivalent test for tightness of welds that seal off the inside of the vessel. These telltale holes may be left open or may be plugged when the vessel is in service. If the holes are plugged, the plugging material used shall not be capable of sustaining pressure between the reinforcing plate and the vessel wall. Telltale holes shall not be plugged during heat treatment.

(c) Attachments. Typical attachments are shown in Figure NC-4267-1. The minimum dimensions in this figure are as follows:

\[ a \geq t/4; \quad b \geq t/2; \quad C \geq t \]

where

\[ c = \text{minimum thickness of weld metal from the root to the face of the weld} \]
\[ t = \text{thickness of attached member} \]

NC-3260 SPECIAL VESSEL REQUIREMENTS

NC-3261 Transition Joints Between Sections of Unequal Thickness

Unless the requirements of Appendix XIII, XIV, or II are shown to be satisfied, a tapered transition as shown in Figs. NC-3358-3 and NC-3361-1 shall be 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 1/8 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 Appendix XIII, XIV, or 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 NC-3361-1 shall apply to all joints of Categories A and B except joints connecting formed heads to main shells, for which case Fig. [NC-3350-1] 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.

NC-3262 Bolted Flanged Connections

NC-3262.1 Flanges and Flanged Fittings Conforming to ASME B16.5. Except as provided in NC-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.

NC-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 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 NC-3219.3, is applied to the design.

NC-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, Appendix XI, or by the rules of Appendices II, XIII, and XIV.

NC-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

\[
0.75d_2 \times \frac{\text{Design stress intensity value of stud material at Design Temperature}}{\text{Design stress intensity value of tapped material at Design Temperature}}
\]

in which $d$ is the root diameter of the stud, except that the thread engagement need not exceed 1 1/2 $d_2$.

NC-3263 Access and Inspection Openings

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

NC-3264 Attachments and Supports

NC-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 Appendices XIII and XIV unless the conditions of NC-3219 are met. Attachments shall conform reasonably to the curvature of the shell to which they are to be attached. The fabrication requirements of NC-4267 and the examination requirements of NC-5250 shall be met.

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

NC-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 NC-3135.

NC-3264.4 Design of Supports.

(a) All vessels shall be so supported and the supporting members so arranged and attached to the vessel as to provide for the maximum imposed loadings. Wind and earthquake loads need not be assumed to occur simultaneously.

(b) All supports should be designed to prevent excessive localized stresses due to temperature changes in the vessel or deformations produced by the internal pressure.

(c) Horizontal vessels supported by saddles shall provide bearing extending over at least one-third of the shell circumference.

(d) Additional requirements for the design of supports are given in NCA-3240 and Subsection NF.

NC-3264.5 Types of Attachment Welds. Welds attaching nonpressure parts or stiffeners to pressure parts shall meet the requirements of NC-4267.

NC-3264.6 Stress Values for Weld Material. Attachment weld strength shall be based on the nominal weld area and the design stress intensity values in Tables 2A, 2B, and 4, Section II, Part D, Subpart 1 and stress criteria.