(e) Other dimensions of the joint shall be in accordance with details shown in Figures NC-4243-1 and NC-4243-2 where:

(1) Figure NC-4243-1

Sketches (a), (b), and (c)

(-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:

\( t, t_n = \) nominal thickness of welded parts
\( t_e = 0.7t_n \text{ or } \frac{1}{4} \text{ in. (6 mm)}, \) whichever is less
\( t_w = \) 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:

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

Sketch (d)

\( t, t_n = \) nominal thickness of welded parts, in., either leg of fillet weld = 0.25 \( t_n \) but not less than \( \frac{1}{4} \text{ in. (6 mm)} \)

Sketches (e) and (f)

\( t, t_n = \) nominal thickness of welded parts
\( t_e = 0.7t_n \text{ or } \frac{1}{4} \text{ in. (6 mm)}, \) whichever is less

(2) Figure NC-4243-2

Sketch (a)

\( a + b \text{ not less than } 2t_e \)
\( t_w \text{ not less than } t_e \)
\( t_e = \) actual thickness of shell
\( t_r = \) required thickness of shell

Sketch (b)

\( a + b \text{ not less than } 2t_e \)
\( t_e = \) actual thickness of shell

Sketch (c)

\( t_e = \) actual thickness of shell
\( t_r = \) required thickness of shell

Sketch (d)

\( a + b \text{ not less than } 2t_e \)
\( t_e = \) actual thickness of shell
\( t_r = \) required thickness of shell
\( a + b \text{ not less than } 3t_e \)

Sketch (e)

\( t_e \text{ not less than } 2t_e \)
\( r \text{ not less than } 3t_e \)

NC-3359 Design Requirements for Nozzle Attachment Welds

In addition to the requirements of NC-3352.4, the minimum design requirements for nozzle attachment welds are given in (a) and (b) below.

(a) Required Weld Strength. Sufficient welding shall be provided on either side of the line through the center of the opening parallel to the longitudinal axis of the shell to develop the strength of the reinforcing parts as required in NC-3336, through shear or tension in the weld, whichever is applicable. The strength of groove welds shall be based on the area subjected to shear or to tension. The strength of fillet welds shall be based on the area subjected to shear, computed on the minimum leg dimension. The inside diameter of a fillet weld shall be used in figuring its length. Calculations are not required when full penetration welds are used.

(b) Allowable Stress Values for Welds. The allowable stress values for groove and fillet welds and for shear in nozzles, in percentage of stress values for the vessel material, are as follows:

(1) nozzle wall shear, 70%
(2) groove weld tension, 74%
(3) groove weld shear, 60%
(4) fillet weld shear, 49%
(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-3358.1(a)-1, 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 $\frac{1}{6}$ in. (3 mm), 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(a)-1], the skirt shall be long enough so that the required length of taper does not extend beyond the tangent line.

NC-3358.2 Unstayed Flat Heads Welded to Shells. The requirements for the attachment of unstayed flat heads welded to shells are given in NC-3325, NC-3358.3, and NC-3358.4.

NC-3358.3 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, as in Figs. NC-4243-1 and NC-4243-2, the joint shall meet the applicable requirements of (a) through (f) below.

(a) On the cross section through the welded joint, the line of fusion 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 flange heads and unsupported tubeshells with a projection having holes for a bolted connection, the sum of $a$ and $b$ shall be not less than three times the nominal thickness of the abutting pressure part.

(c) For supported tubeshells with a projection having holes for a bolted connection, the sum of $a$ and $b$ shall not be less than two times the nominal wall thickness of the abutting pressure part. A supported tubeshell is defined as one in which not less than 80% of the pressure load on the tubeshell is carried by tubes, stays, or braces.

(d) For other components, the sum of $a$ and $b$ shall be not less than two times the nominal wall thickness of the abutting pressure part. Examples of such components are flat heads and supported and unsupported tubeshells without a projection having holes for a bolted connection.

(e) Other dimensions of the joint shall be in accordance with details shown in Figs. NC-4243-1 and NC-4243-2 where:

(1) Fig. NC-4243-1

Sketches (a), (b), and (c)

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

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

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

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

Sketch (d)

$$t, t_n = \text{nominal thickness of welded parts, in., either leg of fillet weld } = 0.25 \ t_n$$
$$t_w \text{ not less than } \frac{1}{4} \text{ in. (6 mm)}$$

Sketches (e) and (f)

$$t, t_n = \text{nominal thickness of welded parts}$$
$$t_c = 0.7 \ t_n \text{ or } \frac{1}{4} \text{ in. (6 mm), whichever is less}$$

(2) Fig. NC-4243-2

Sketch (a)

$$a + b \text{ not less than } 2t_s$$
$$t_n \text{ not less than } t_s$$
$$t_c = \text{actual thickness of shell}$$
$$t_p \text{ not less than } t_s$$

Sketch (b)

$$a + b \text{ not less than } 2t_s$$
$$t_c = \text{actual thickness of shell}$$

Sketch (c)

$$t_s = \text{actual thickness of shell}$$
$$t_r = \text{required thickness of shell for supported tubeshells:}$$
$$c \text{ not less than } 0.7t_s \text{ or } 1.4t_s$$
$$a + b \text{ not less than } 2t_s$$
$$t_w \text{ for flange rings, flat heads, and unsupported tubeshells:}$$
$$c \text{ not less than } t_s \text{ or } 2t_n$$
$$a + b \text{ not less than } 3t_s$$

Sketch (d)

$$t_s = \text{actual thickness of shell}$$
$$t_r = \text{required thickness of shell for } a + b \text{ not less than } 3t_s$$
$$c \text{ not less than } t_s$$

(3) In Fig. NC-4243-1,

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

(4) 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 permissible.

NC-3358.4 Flat Heads and Tubeshells With Hubs. Hubs for butt welding to the adjacent shell, head, or other pressure part, as in Fig. NC-4243.1-1, shall not be
for supported tubesheets:
c not less than 0.7t_e or 1.4t_r, whichever is less
a + b not less than 2t_e
for flange rings, flat heads, and unsupported tubesheets:
c not less than t_e or 2t_r, whichever is less
a + b not less than 3t_e
Sketch (d)
t_e = actual thickness of shell
t_r = required thickness of shell
a + b not less than 3t_e
c not less than t_e
(j) In Fig. NC-4243-1, t_r = nominal thicknesses
t_e = 0.7t_r or 1/6 in. (6 mm), whichever is less
t_w = the lesser of t_r or t/2

(j) 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 permissible.

NC-3358.4 Flat Heads and Tubesheets With Hubs. Hubs for butt welding to the adjacent shell, head, or other pressure part, as in Fig. NC-4243-1, shall not be machined from rolled plate. The component having the hub shall be forged in such a manner as to provide in the hub the full minimum tensile strength and elongation specified for the material, in a direction parallel to the axis of the vessel. Proof of this shall be furnished by a tension test specimen (subsize if necessary) taken in this direction and as close to the hub as is practical. In Fig. NC-4243-1, the minimum dimensions are as follows:

Sketch (a)
r not less than 1.5t_e
Sketch (b)
r not less than 1.5t_e
h not less than 1.5t_e
Sketch (c)
l not less than 1.5t_e
Sketch (d)

NC-3359 Design Requirements for Nozzle Attachment Welds

In addition to the requirements of NC-3352.4, the minimum design requirements for nozzle attachment welds are given in (a) and (b) below.

(a) Required Weld Strength. Sufficient welding shall be provided on either side of the line through the center of the opening parallel to the longitudinal axis of the shell to develop the strength of the reinforcing parts as required in NC-3336, through shear or tension in the weld, whichever is applicable. The strength of groove welds shall be based on the area subjected to shear or to tension. The strength of fillet welds shall be based on the area subjected to shear, computed on the minimum leg dimension. The inside diameter of a fillet weld shall be used in figuring its length. Calculations are not required when full penetration welds are used.

(b) Allowable Stress Values for Welds. The allowable stress values for groove and fillet welds and for shear in nozzles, in percentage of stress values for the vessel material, are as follows:

(1) nozzle wall shear, 70%
(2) groove weld tension, 74%
(3) groove weld shear, 60%
(4) fillet weld shear, 49%

NC-3360 SPECIAL VESSEL REQUIREMENTS

NC-3361 Tapered Transitions

A tapered transition having a length not less than three times the offset between the adjacent surfaces of abutting sections (Fig. NC-3361-1) shall be provided at joints between sections that differ in thickness by more than one-fourth of the thickness of the thinner section or by more than 1/6 in. (3 mm), whichever is less. The transition may be formed by any process that will provide a uniform taper. The weld may be in the tapered section or adjacent to it. This also applies when there is a reduction in thickness within a spherical shell or cylindrical shell course and to a taper at a Category A joint within a formed head. Provisions for tapers at circumferential butt welded joints connecting formed heads to main shells are contained in NC-3358.1(b).

NC-3362 Bolted Flange and Studed Connections

(a) It is recommended that the dimensional requirements of bolted flange connections to external piping conform to ASME B16.5, Steel Pipe Flanges and Flanged Fittings; MSS SP-42, 150 lb. Corrosion Resistant Cast Flanged Valves; or ASME B16.47, Large Diameter Steel Flanges. Such flanges and flanged fittings may be used for the pressure-temperature ratings given in the appropriate standard. Flanges and flanged fittings to other standards may be used, provided they have been designed in accordance with the rules of Appendix XI for the vessel design loads and are used within the pressure-temperature ratings so determined.

(b) 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 \( d_s \) or

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

in which \( d_s \) is the diameter of the stud. The thread engagement need not exceed \( \frac{1}{2} d_s \).
of $R$ equal to $R''$ in connection with the thickness determined from Step 3, eq. (21). If both such thickness-radius ratios are greater than 0.0175, the larger of the two thicknesses calculated in Step 3 will be the required thickness for the condition under consideration. Otherwise, proceed with Step 5.

**Step 5.** If one or more of the thickness-radius ratios determined in Steps 2 and 4 fall between 0.00667 and 0.0175 and the thickness involved was calculated by Step 1, eq. (18) or Step 3, eq. (20), find a thickness which satisfies the following equation:

$$\frac{10,150(e - e') + 277,400(e - e')^2}{R} + 0.87'' = T'' \quad (22)$$

or, if the thickness involved was calculated by Step 1, eq. (19) or Step 3, eq. (21), find a thickness which satisfies the following equation:

$$\frac{5,650(e - e') + 154,200(e - e')^2}{R''} = T'' \quad (23)$$

**Step 6.** Make a selection of thickness from the values calculated. Calculate the values of $S_{cc}$ for both $T_1$ and $T_2$ and check that values of $S_{cc}$ satisfy the requirements of ND-3922.3(c).

**NOTE:** The procedure described in [4] is predicated on the assumption that the problem is one in which biaxial compression with unit forces of unequal magnitude is the governing condition. In many cases, however, a tentative thickness will have been established previously by other design considerations and only needs to be checked for the external pressure or partial vacuum condition. In such cases, the problem is greatly simplified because the designer has only to compute the values of $S_{cc}$ for both $T_1$ and $T_2$ and then check to see if these values satisfy the requirements of ND-3922.3(c), as specified in Step 6 (see Section F.5 of Appendix F of API Standard 620, Feb. 1970 Edition, for examples illustrating the application of [a]).

**ND-3932.4 Least Permissible Thickness.** In no event shall the net thickness after fabrication of any plate subject to pressure imposed membrane stresses be less than $\frac{3}{16}$ in. (5 mm), exclusive of corrosion allowance. For tanks having cylindrical sidewalls with diameters from 60 ft (18.3 m) up to but not including 120 ft (36.6 m), such thickness for sidewall plates shall not be less than $\frac{1}{4}$ in. (6 mm) exclusive of corrosion allowance.

**ND-3932.5 External Pressure Limitations.** The thickness computed by the equations and procedures specified in ND-3932, using a negative value of $P_0$ equal to the partial vacuum for which the tank is to be designed, will ensure stability against collapse for tank surfaces of double curvature in which the meridional radius $R_1$ is equal to or less than $R_2$ or does not exceed $R_2$ by more than a very small amount. Data on the stability of sidewall surfaces of prolate spheroids are lacking, and it is not intended that the equations and procedures be used for evaluating the stability of such surfaces or of cylindrical surfaces against

---

**Equation should be on one line. See example from 2007 Edition:**

$$\frac{10,150(e - e') + 277,400(e - e')^2}{R} + 0.87'' = T'' \quad (22)$$

---

**ND-3932.6 Special Considerations Applicable to Bottoms Resting Directly on Foundations.**

(a) **Uplift Considerations.** In the case of tanks with cylindrical sidewalls and flat bottoms, the uplift\(^6\) from the pressure acting on the underside of the roof must not exceed the weight of the sidewalls plus the weight of that portion of the roof that is carried by the sidewalls when no uplift exists, unless such excess is counteracted by increasing the magnitude of the downward acting forces. This shall be a matter of agreement between the Certificate Holder and Owner. Similar precautions must be taken with flat bottom tanks of other shapes. All weights used in such calculations shall be based on net thicknesses of the materials, exclusive of corrosion allowance.

(b) **Foundation Considerations.** The type of foundation used for supporting the tank shall be taken into account in the design of bottom plates and welds. For recommended practice for construction of foundations, see API Standard 620, Feb. 1970 Edition, Appendix C.

**ND-3933 Design of Roof and Bottom Knuckle Regions, and Compression Ring**

**ND-3933.1 Nomenclature.** The symbols used are defined as follows:

- $A_c =$ net area, in.\(^2\) (mm\(^2\)), of the vertical cross section of metal required in the compression ring region, exclusive of all corrosion allowances
- $E =$ efficiency, expressed as a decimal, of meridional joints in the compression ring region in the event that $Q$ should have a positive value, indicating tension
- $Q =$ total circumferential force, lb (N) acting on a vertical cross section through the compression ring region
- $R_c =$ horizontal radius, in. (mm), of the cylindrical sidewall at its juncture with the roof or bottom
- $R_z =$ length, in. (mm), of the normal to the roof or bottom at the juncture between the roof or bottom and the sidewalls, measured from the roof or bottom to the tank's vertical axis of revolution
- $S_{ctk} =$ maximum allowable stress value for simple tension, psi (MPa) (Tables 1A, 1B, and 3, Section II, Part D, Subpart 1)
- $t_c =$ corresponding thickness, in. (mm), of the cylindrical sidewalls at and near such juncture
from Step 3, eq. (21). If both such thickness-radius ratios are greater than 0.0175, the larger of the two thicknesses calculated in Step 3 will be the required thickness for the condition under consideration. Otherwise, proceed with Step 5.

Step 5. If one or more of the thickness-radius ratios determined in Steps 2 and 4 fall between 0.00667 and 0.0175 and the thickness involved was calculated by Step 1, eq. (18) or Step 3, eq. (20), find a thickness which satisfies the following equation:

$$\frac{10,150(t - c) + 277,400(t - c)^2}{R} = T' + 0.87T''$$  \hspace{1cm} (22)

or, if the thickness involved was calculated by Step 1, eq. (19) or Step 3, eq. (21), find a thickness which satisfies the following equation:

$$\frac{5,650(t - c) + 154,200(t - c)^2}{R''} = T''$$  \hspace{1cm} (23)

Step 6. Make a selection of thickness from the values calculated. Calculate the values of $S_{ce}$ for both $T_1$ and $T_2$ and check that values of $S_{ce}$ satisfy the requirements of ND-3922.3(c).

NOTE: The procedure described in (d) is predicated on the assumption that the problem is one in which biaxial compression with unit force of unequal magnitude is the governing condition. In many cases, however, a tentative thickness will have been established previously by other design considerations and only needs to be checked for the external pressure or partial vacuum condition. In such cases, the problem is generally simplified because the designer has only to compute the values of $S_{ce}$ for both $T_1$ and $T_2$ and then check to see that these values satisfy the requirements of ND-3922.3(c), as specified in Step 6 [see Section E.3 of Appendix F of API Standard 620, Feb. 1970 Edition, for examples illustrating the application of (a)].

ND-3932.4 Least Permissible Thickness. In no event shall the net thickness after fabrication of any plate subject to pressure imposed membrane stresses be less than $\frac{3}{16}$ in. (5 mm), exclusive of corrosion allowance. For tanks having cylindrical sidewalls with diameters from 60 ft (18.3 m) up to but not including 120 ft (36.6 m), such thickness for sidewall plates shall not be less than $\frac{3}{8}$ in. (6 mm) exclusive of corrosion allowance.

ND-3932.5 External Pressure Limitations. The thickness computed by the equations and procedures specified in ND-3932, using a negative value of $P_e$ equal to the partial vacuum for which the tank is to be designed, will ensure stability against collapse for tank surfaces of double curvature in which the meridional radius $R_1$ is equal to or less than $R_2$ or does not exceed $R_2$ by more than a very small amount. Data on the stability of sidewall surfaces of prolate spheroids are lacking, and it is not intended that the formulas and procedures be used for evaluating the stability of such surfaces or of cylindrical surfaces against external pressure. However, cylindrical sidewalls of vertical tanks designed in accordance with these rules for storage of liquids with the thickness of upper courses not less than specified in ND-3932.4 for the size of tank involved and with increasing thicknesses from top to bottom as required for the combined gas and liquid loadings may safely be subjected to a partial vacuum in the gas or vapor space not exceeding 1 oz/sq in. (0.4 kPa) with the operating liquid level in the tank at any stage of its history.

This shall be a matter of agreement between the Certificate Holder and Owner. Similar precautions must be taken with flat bottom tanks of other shapes. All weights used in such calculations shall be based on net thicknesses of the materials, exclusive of corrosion allowance.

(b) Foundation Considerations. The type of foundation used for supporting the tank shall be taken into account in the design of bottom plates and welds. For recommended practice for construction of foundations, see API Standard 620, Feb. 1970 Edition, Appendix C.

ND-3933 Design of Roof and Bottom Knuckle Regions, and Compression Ring

ND-3933.1 Nomenclature. The symbols used are defined as follows:

$A_e =$ net area, in.$^2$ (mm$^2$), of the vertical cross section of metal required in the compression ring region, exclusive of all corrosion allowances

$E =$ efficiency, expressed as a decimal, of meridional joints in the compression ring region in the event that $Q$ should have a positive value, indicating tension

$Q =$ total circumferential force, lb (N) acting on a vertical cross section through the compression ring region

$R_c =$ horizontal radius, in. (mm), of the cylindrical sidewall at its juncture with the roof or bottom

$R_s =$ length, in. (mm), of the normal to the roof or bottom at the juncture between the roof or bottom and the sidewalls, measured from the roof or bottom to the tank's vertical axis of revolution

$S_{ts} =$ maximum allowable stress value for simple tension, psi (MPa) (Tables 1A, 1B, and 3, Section II, Part D, Subpart 1)

$t_c =$ corresponding thickness, in. (mm), of the cylindrical sidewalls at and near such juncture
<table>
<thead>
<tr>
<th>Vessel Component</th>
<th>Location</th>
<th>Origin of Stress</th>
<th>Type of Stress</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle (XIII-1170)</td>
<td>Within the limits of reinforcement defined by NC-3334 or WC-3230</td>
<td>Pressure and external loads and moments, including those attributable to restrained free end displacements of the attached piping</td>
<td>General membrane</td>
<td>$P_m$</td>
</tr>
<tr>
<td></td>
<td>Outside the limits of reinforcement defined by NC-3334 or WC-3230</td>
<td>Pressure and external axial, shear, and torsional loads other than those attributable to restrained free end displacements of the attached piping</td>
<td>General membrane stresses</td>
<td>$P_m$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pressure and external loads and moments other than those attributable to restrained free end displacements of the attached piping</td>
<td>Membrane</td>
<td>$P_b$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bending</td>
<td></td>
<td>$P_b$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pressure and all external loads and moments</td>
<td>Membrane</td>
<td>$P_b$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bending</td>
<td></td>
<td>$Q$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak</td>
<td></td>
<td>$F$</td>
</tr>
<tr>
<td>Nozzle wall</td>
<td>Gross structural discontinuities</td>
<td>Local membrane</td>
<td></td>
<td>$P_b$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bending</td>
<td></td>
<td>$Q$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peak</td>
<td></td>
<td>$F$</td>
</tr>
<tr>
<td>Cladding</td>
<td>Any</td>
<td>Differential expansion</td>
<td>Membrane</td>
<td>$F$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bending</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any</td>
<td>Any</td>
<td>Radial temperature distribution [Note (4)]</td>
<td>Equivalent linear stress [Note (3)]</td>
<td>$Q$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nonlinear portion of stress distribution</td>
<td></td>
<td>$F$</td>
</tr>
<tr>
<td>Any</td>
<td>Any</td>
<td>Stress concentration (notch effect)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTES:

1. If the bending moment at the edge is required to maintain the bending stress in the middle to acceptable limits, the edge bending is classified as $P_b$. Otherwise, it is classified as $Q$.
2. Consideration shall also be given to the possibility of wrinkling and excessive deformation in vessels with a large diameter-thickness ratio.
3. Consider possibility of thermal stress ratcheting.
4. Equivalent linear stress is defined as the linear stress distribution that has the same net bending moment as the actual stress distribution.
### Table XIII-1130-1

**CLASSIFICATION OF STRESS INTENSITY IN VESSELS FOR SOME TYPICAL CASES**

<table>
<thead>
<tr>
<th>Vessel Component</th>
<th>Location</th>
<th>Origin of Stress</th>
<th>Type of Stress</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle (XIII-1170)</td>
<td>Within the limits of reinforcement defined by NC-3334</td>
<td>Pressure and external loads and moments, including those attributable to restrained free end displacements of the attached piping</td>
<td>General membrane</td>
<td>$P_m$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bending (other than gross structural discontinuity stresses) averaged through nozzle thickness</td>
<td>$P_m$</td>
</tr>
<tr>
<td>Outside the limits of reinforcement defined by NC-3334</td>
<td>Pressure and external axial, shear, and torsional loads other than those attributable to restrained free end displacements of the attached piping</td>
<td>General membrane stresses</td>
<td>$P_m$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure and external loads and moments other than those attributable to restrained free end displacements of the attached piping</td>
<td>Membrane</td>
<td>$P_L$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure and all external loads and moments</td>
<td>Bending</td>
<td>$P_0$</td>
<td></td>
</tr>
<tr>
<td>Nozzle wall</td>
<td>Gross structural discontinuities</td>
<td>Local membrane</td>
<td>$P_s$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Differential expansion</td>
<td>Bending</td>
<td>$Q$</td>
<td></td>
</tr>
<tr>
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<td>Differential expansion</td>
<td>Peak</td>
<td>$F$</td>
<td></td>
</tr>
<tr>
<td>Cladding</td>
<td>Any</td>
<td>Membrane</td>
<td>$F$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Differential expansion</td>
<td>Bending</td>
<td>$F$</td>
<td></td>
</tr>
<tr>
<td>Any</td>
<td>Any</td>
<td>Radial temperature distribution [Note (2)]</td>
<td>Equivalent linear-stress [Note (3)]</td>
<td>$Q$</td>
</tr>
<tr>
<td></td>
<td>Any</td>
<td>Nonlinear portion of stress distribution</td>
<td>$F$</td>
<td></td>
</tr>
<tr>
<td>Any</td>
<td>Any</td>
<td>Stress concentration (notch effect)</td>
<td>$F$</td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

1. Consideration shall also be given to the possibility of wrinkling and excessive deformation in vessels with a large diameter-thickness ratio.
2. Consider possibility of thermal stress ratcheting.
3. Equivalent linear stress is defined as the linear stress distribution which has the same net bending moment as the actual stress distribution.
4. If the bending moment at the edge is required to maintain the bending stress in the middle to acceptable limits, the edge bending is classified as $P_s$. Otherwise, it is classified as $Q$. 


Figure NB-3643.3(a)-3
Typical Reinforced Extruded Outlet

Metal available for reinforcement
Weld metal

reinforcement