**ND-NCD-3800 Design of Atmospheric Storage Tanks**

**ND-NCD-3810 General Requirements**

**ND-NCD-3811 Acceptability**

The requirements for acceptability of atmospheric storage tanks are given in the following subparagraphs.

**ND-NCD-3811.1 Scope.**

The design rules for atmospheric storage tanks cover vertical cylindrical flat bottom above ground welded tanks at atmospheric pressure. These tanks may contain liquids such as refueling water, condensate, borated reactor coolant, or liquid radioactive waste. Such tanks may be within building structures, depending upon the liquid to be contained, or they may be above grade exposed to atmospheric conditions.

Note: These rules do not limit storage tanks from being installed below grade or below ground, provided the tanks are not subject to external pressure resulting from earth or fill.

**ND-NCD-3811.2 Design Requirements.**

The design rules for atmospheric storage tanks shall conform to the design requirements of ND-NCD-3100 and ND-NCD-3300, except as they may be modified by the requirements of this subarticle. As an alternative for Class 2 construction, the design rules of NCD-3200 may be used as a replacement for the requirements of NCD-3800. For Class 2 construction, joint efficiency $E$ shall always be taken as 1. For Class 3 storage tanks, the joint efficiency $E$ shall be based on the requirements of ND-NCD-3352. The specific design requirements shall be stipulated in the Design Specifications.

**ND-NCD-3812 Design Report**

The manufacturer Certificate Holder manufacturing of a storage tank conforming to the design requirements of this subarticle is required to provide a Design Report as part of his-their responsibility of achieving structural integrity of the tank. The Design Report shall be certified when required by NCA-3550.

**ND-NCD-3820 Design Considerations**

**ND-NCD-3821 Design and Service Conditions**

(a) Conditions Loadings shall be identified as Design or Service, and if Service they shall have Level A, B, C, or D Service Limits designated. (NCA-2142)
(b) The provisions of ND-NCD-3110 shall apply.

(c) The stress limits given in ND-NCD-3821.5 shall be met.

**ND-NCD-3821.1 Design Pressure.**
The Design Pressure shall be atmospheric.

The limitation of the Design Pressure to atmospheric is not intended to preclude the use of these tanks at vapor pressure slightly above or below atmospheric within the range normally required to operate vent valves. If these pressures or vacuums exceed 0.03 psig (0.2 kPa gage), especially in combination with large diameter tanks, the forces involved may require special consideration in the design.

**ND-NCD-3821.2 Design Temperature.**
The Design Temperature shall be not greater than 200°F (90°C).

**ND-NCD-3821.3 Loadings.**
The requirements of ND-NCD-3111 shall be met.

**ND-NCD-3821.4 Welded Joint Restrictions.**
The restrictions given in (a) through (c) below on type and size of joints or welds shall apply.

(a) Tack welds shall not be considered as having any strength value in the finished structure.

(b) The minimum size of fillet welds shall be in accordance with ND-NCD-4246.6.

(c) All nozzle welds shall be in accordance with ND-NCD-4246.5.

**ND-NCD-3821.5 Limits of Calculated Stresses for Design and Service Loadings.**
Stress limits for Design and Service Loadings are specified in Table ND-NCD-3821.5-1. The symbols used in Table ND-NCD-3821.5-1 are defined as follows:

\[ \sigma_m = \text{general membrane stress, psi (MPa). This stress is equal to the average stress across the solid section under consideration. It excludes discontinuities and concentrations, and is produced only by pressure and other mechanical loads.} \]

\[ \sigma_L = \text{local membrane stress, psi (MPa). This stress is the same as } \sigma_m, \text{ except that it includes the effect of discontinuities.} \]

\[ \sigma_b = \text{bending stress, psi (MPa). This stress is equal to the linear varying portion of the stress across the solid section under consideration. It excludes discontinuities and concentrations, and is produced only by pressure and other mechanical loads.} \]

\[ S = \text{allowable stress value given in Section II, Part D, Subpart 1, Tables 1A, 1B, and 3, psi (MPa). The allowable stress shall correspond to the highest metal temperature at the section under consideration during the loading under consideration.} \]
Typical examples of locations and loadings for which \( \sigma_m, \sigma_L, \) and \( \sigma_b \) are applicable are shown in Section III Appendices, Mandatory Appendix XIII, Table XIII-2600-1, with \( \sigma \) considered as equivalent to \( P \) in Section III Appendices, Mandatory Appendix XIII, Table XIII-2600-1.

<table>
<thead>
<tr>
<th>Service Limit</th>
<th>Stress Limits [Note (1)] and [Note (2)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design and Level A</td>
<td>( \sigma_m \leq 1.0S ) ( (\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.5S )</td>
</tr>
<tr>
<td>Level B</td>
<td>( \sigma_m \leq 1.10S ) ( (\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.65S )</td>
</tr>
<tr>
<td>Level C</td>
<td>( \sigma_m \leq 1.5S ) ( (\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 1.8S )</td>
</tr>
<tr>
<td>Level D</td>
<td>( \sigma_m \leq 2.0S ) ( (\sigma_m \text{ or } \sigma_L) + \sigma_b \leq 2.4S )</td>
</tr>
</tbody>
</table>

NOTES:
(1) See \texttt{ND-NCD-3821.5} for definitions of symbols.
(2) These limits do not take into account either local or general buckling which might occur in thin wall vessels.

**\texttt{ND-NCD-3830 Bottom Design}**

**\texttt{ND-NCD-3831 Plate Sizes}**

(a) All bottom plates shall have a minimum nominal thickness of \( \frac{1}{4} \text{ in.} \) (6 mm) exclusive of any corrosion allowance required by the Design Specifications.

(b) Bottom plates shall be ordered of sufficient size so that, when trimmed, at least a 1 in. (25 mm) width will project beyond the outside edge of the weld attaching the bottom to the shell plate.

(c) The type of foundation used for supporting the tank shall be taken into account in the design of the bottom plates and welds. For recommended practice for construction of foundations, see API-650, Appendix B.

**\texttt{ND-NCD-3832 Methods of Construction}**

Bottoms shall be built to either one of the alternative methods of construction given in \texttt{ND-NCD-4246.1}.
**ND-NCD-3833 Shell-to-Bottom Attachment**

The requirements for shell-to-bottom attachments are given in ND-NCD-4246.2.

**ND-NCD-3840 Shell Design**

**ND-NCD-3841 Loads**

(a) Thicknesses shall be computed on the basis of the specific gravity of the stored material, but in no case shall the specific gravity be less than 1.00. The tension in each ring shall be computed 12 in. (300 mm) above the centerline of the lower horizontal joint of the course in question. In computing these stresses, the tank diameter shall be taken as the nominal diameter of the bottom course.

(b) Isolated radial loads on tank shells, such as caused by heavy loads on platforms and elevated walkways between tanks, shall be distributed by rolled structural sections, plate ribs, or built-up members, preferably in a horizontal position.

**ND-NCD-3842 Diameters and Thicknesses of Shell Plates**

(a) For method of determining minimum thicknesses of shell plates, see ND-NCD-3324.3 (and ND-NCD-3121). See ND-NCD-2121 for pressure-retaining material.

(b) In no case shall the nominal thickness of shell plates be less than the following:

<table>
<thead>
<tr>
<th>Ferrous Material</th>
<th>Aluminum Material (Class 3 only)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nominal Tank Diameter, ft (m)</strong></td>
<td><strong>Nominal Thickness, in. (mm)</strong></td>
</tr>
<tr>
<td>[Note (1)]</td>
<td>[Note (1)]</td>
</tr>
<tr>
<td>Smaller than 60-50 (18-15)</td>
<td>3/16 (5)</td>
</tr>
<tr>
<td>60-50 to 120 (18-37), incl.</td>
<td>1/4 (6)</td>
</tr>
</tbody>
</table>

**NOTE:** Nominal tank diameter shall be the centerline diameter of the shell plates, unless otherwise stipulated in the Design Specifications.

(c) The maximum nominal thickness of tank shell plates shall be 1 1/2 in. (38 mm).

**ND-NCD-3843 Arrangement of Members**

(a) The tank shell shall be designed to have all courses vertical. Unless otherwise specified, abutting shell plates at horizontal joints shall have a common vertical center line of thickness. Vertical joints in adjacent shell courses shall not be in alignment but shall be offset from each other a minimum distance of 6 in. (150 mm).
(b) Except as specified for self-supporting roofs and for tanks having the flanged roof-to-shell detail described in (c) below, tank shells shall be supplied with top angles of not less than the following sizes: tanks 35 ft (11 m) and smaller in diameter, 2\(\frac{1}{2}\) in. \(\times\) 2\(\frac{1}{2}\) in. \(\times\) \(\frac{1}{4}\) in. (64 mm \(\times\) 64 mm \(\times\) 6 mm); tanks of more than 35 ft to 60 ft (11 m to 18 m), inclusive, in diameter, 2\(\frac{1}{2}\) in. \(\times\) 2\(\frac{1}{2}\) in. \(\times\) \(\frac{5}{16}\) in. (64 mm \(\times\) 64 mm \(\times\) 8 mm); tanks larger than 60 ft (18 m) in diameter, 3 in. \(\times\) 3 in. \(\times\) \(\frac{3}{8}\) in. (75 mm \(\times\) 75 mm \(\times\) 10 mm). The outstanding leg of the top angle may extend inside or outside the tank shell.

(c) See (1) and (2) below.

(1) For tanks not exceeding 35 ft (11 m) in diameter and having supported cone roofs, the top edge of the shell may be flanged in lieu of installing a top angle. The radius of bend and the width of the flanged edge shall conform to the details of Figure ND-NCD-4246.3-1 sketch (c).

(2) This construction may be used for any tank having a self-supporting roof if the total cross-sectional area of the junction fulfills the stated area requirements for the top angle construction. No additional member, such as an angle or bar, shall be added to the flanged roof-to-shell detail.

(d) For tanks not exceeding 35 ft (11 m) in diameter and having a supported flat roof, the roof plates may be flanged and butt welded to the shell. The flanged tank roof plates shall be butt welded. The inside radius of the knuckle shall not be less than 1.75\(t\) nor more than 8\(t\).

**ND-NCD-3850 Roof Design**

**ND-NCD-3851 Types of Roofs**

The types of roofs are defined in the following subparagraphs.

**ND-NCD-3851.1 Supported Cone Roof.**

A supported cone roof is a roof formed to approximately the surface of a right cone, with its principal support provided by either rafters on girders and columns or rafters on trusses with or without columns.

**ND-NCD-3851.2 Supported Flat Roof.**

A supported flat roof is a roof that is essentially flat, with its principal support provided by either rafters supported by the shell without columns or by rafters in conjunction with girders and trusses with or without columns.

**ND-NCD-3851.3 Self-Supporting Cone Roof.**

A self-supporting cone roof is a roof formed to approximately the surface of a right cone, supported only at its periphery.
**ND-NCD-3851.4 Self-Supporting Dome Roof.**

A self-supporting dome roof is a roof formed to approximately a spherical surface, supported only at its periphery.

**ND-NCD-3851.5 Self-Supporting Umbrella Roof.**

A self-supporting umbrella roof is a modified dome roof so formed that any horizontal section is a regular polygon with as many sides as there are roof plates, supported only at its periphery.

**ND-NCD-3852 General Roof Design Requirements**

**ND-NCD-3852.1 Loading Requirements.**

All roofs and supporting structures shall be designed to support dead load, plus a uniform live load of not less than 25 lb/ft² (1.2 kPa) of projected area unless otherwise specified, except that tanks installed in an enclosed area, not exposed to the elements, shall be designed to support the dead load plus a uniform live load of not less than 10 lb/ft² (0.5 kPa).

**ND-NCD-3852.2 Minimum Plate Thickness.**

Roof plates shall have a minimum nominal thickness of 3/16 in. (5 mm). A greater thickness may be required for self-supporting roofs. Any specified corrosion allowance for the plates of self-supporting roofs shall be added to calculated thickness. Any specified corrosion allowance for plates of supported roofs shall be added to the minimum nominal thickness.

**ND-NCD-3852.3 Minimum Thickness of Supporting Members.**

All internal and external structural members shall have a minimum nominal thickness, in any component, of 0.17 in. (4 mm).

**ND-NCD-3852.4 Attachment of Roof Plates.**

Roof plates shall be attached to the top angle of the tank in accordance with ND-NCD-4246.3. Roof plates of supported roofs shall not be attached to internal supporting members.

**ND-NCD-3852.5 Welding of Roof Plates.**

(a) If the continuous fillet weld between the roof plates and the top angle does not exceed 3/16 in. (5 mm) and the slope of the roof at the top angle attachment does not exceed 2 in./ft (167 mm/m) (16.7%), the joint may be considered to serve as an emergency venting device which, in case of excessive internal pressure, will fail before failure occurs in the tank shell joints or the shell-to-bottom joint. Failure of the roof-to-shell joint may be accompanied by buckling of the top angle.

(b) Where the weld size exceeds 3/16 in. (5 mm) or where the slope of the roof at the top angle attachment is greater than 2 in./ft (167 mm/m) (16.7%), emergency venting devices conforming to the specifications noted in API Standard 200015 shall be provided. The Certificate Holder shall provide a suitable tank connection for the device.

(c) Roof plates shall be welded in accordance with ND-NCD-4246.4.
Allowable Stresses for Ferrous Steel Structures.

All parts of the structure shall be so proportioned that the sum of the static stresses shall not exceed the values given in (a) through (d) below. The decrease in yield stress at Design Temperature shall be taken into account.

(a) Tension

(1) in rolled steel, on net section, 20.0 ksi (138 MPa);

(2) in full penetration groove welds on the thinner plate area, 18.0 ksi (124 MPa).

(b) Compression

(1) in rolled steel, where lateral deflection is prevented, 20.0 ksi (138 MPa);

(2) in full penetration groove welds on the thinner plate area, 20.0 ksi (138 MPa);

(3) in columns, on cross-sectional area, ksi (MPa)

For \( L/r \) not over 120

\[
\frac{1}{1 - \left(\frac{L}{r}\right)^2} \frac{C_Y}{34,700} \frac{FS}{1 - \left(\frac{L/R}{r}\right)^2} \frac{C_Y}{34,700} \frac{DF}{1.6 - L/200r}
\]

where

\( C \) 33 for U.S. Customary calculations

228 for SI calculations

For \( L/r \) over 120 to 131.7, inclusive

\[
\frac{1}{1 - \left(\frac{L}{r}\right)^2} \frac{C_Y}{34,700} \frac{FS}{1 - \left(\frac{L}{200r}\right)^2} \frac{C_Y}{34,700} \frac{DF}{1.6 - L/200r}
\]

where

\( C \) 33 for U.S. Customary calculations

228 for SI calculations

For \( L/r \) over 131.7
Where

\[
\frac{(CY)}{(L/r)^2(1.6 - L/200r)}
\]

\[
C = \begin{cases} 149,000 & \text{for U.S. Customary calculations} \\ 1.03 \times 10^6 & \text{for SI calculations} \end{cases}
\]

\[
FS = \text{factor of safety} \quad DF = \text{design factor}
\]

\[
FS = \frac{5}{7} + \left[ \frac{t/R}{350} \right] - \frac{[t/R]^3}{18,300,000}
\]

\[
L = \text{unbraced length of column, in. (mm)}
\]

\[
R = \text{outside radius of tubular section, in. (mm)}
\]

\[
r = \text{least radius of gyration of column, in. (mm)}
\]

\[
t = \text{thickness of tubular section, in. (mm); } 1/4 \text{ in. (6 mm) minimum for main}
\]

\[
t = \text{compression members, } 3/16 \text{ in. (5 mm) minimum for bracing and other}
\]

\[
t = \text{secondary members}
\]

\[
Y = \begin{cases} 1.0 & \text{for structural sections or tubular sections having } t/R \text{ values equal to} \\
& \text{or exceeding } 0.015 \\
= (200/3)(t/R)[2 - (200/3)(t/R)] & \text{for tubular sections having } t/R \text{ values less}
\]

\[
& \text{than } 0.015
\]

For main compression members, the ratio \(L/r\) shall not exceed 180. For bracing and other secondary members, the ratio \(L/r\) shall not exceed 200.

(c) Bending

(1) in tension and compression on extreme fibers of rolled shapes and built-up members with an axis of symmetry in the plane of loading, where the laterally unsupported length of compression flange is no greater than 13 times its width, the compression flange width–thickness ratio does not exceed 17, and the web depth–thickness ratio does not exceed 70, 22.0 ksi (152 MPa);

(2) in tension and compression on extreme fibers of unsymmetrical members, where the member is supported laterally at intervals no greater than 13 times its compression flange width, 20.0 ksi (138 MPa);

(3) in tension on extreme fibers of other rolled shapes, built-up members, and plate girders, 20.0 ksi (138 MPa);
(4) in compression on extreme fibers of other rolled shapes, plate girders, and built-up members having an axis of symmetry in the plane of loading, the larger value computed by the following, ksi (MPa)

(U.S. Customary Units)

\[
20.0 - \frac{0.571}{1,000} \left( \frac{l}{r} \right)^2
\]

(SI Units)

\[
138 - \frac{3.94}{1,000} \left( \frac{l}{r} \right)^2
\]

Or

(U.S. Customary Units)

\[
\frac{12,000}{(ld/A_f)} \leq 20.0
\]

(SI Units)

\[
\frac{83,000}{(ld/A_f)} \leq 138
\]

where

\[A_f = \text{area of compression flange, in}^2 (\text{mm}^2)\]
\[d = \text{depth of section, in. (mm)}\]
\[l = \text{unbraced length of compression flange, in. (mm)}\]
\[r = \text{radius of gyration of section about an axis in the plane of loading, in. (mm)}\]

Compression on extreme fibers of other unsymmetrical sections, ksi (MPa)

(U.S. Customary Units)

\[
\frac{12,000}{(ld/A_f)} \leq 20.0
\]
\[ \frac{83000}{(ld/A_f)} \leq 138 \]

(d) Shearing

(1) in fillet, plug, slot, and partial penetration groove welds across throat area, 13.6 ksi (93.8 MPa)

(2) on the gross area of the webs of beams and girders, when \( t \) is the thickness of the web, in. (mm), and \( h \), the clear distance between web flanges, in. (mm), is not more than 60\( t \), or when the web is adequately stiffened, 13.0 ksi (89.6 MPa)

(3) on the gross area of the webs of beams and girders, if the web is not stiffened so that \( h \) is more than 60\( t \), the greatest average shear \( V/A \), ksi (MPa), shall not exceed

\[ \frac{19.5}{1 + \frac{h^2}{7,200t^2}} \]  

\[ \frac{134}{1 + \frac{h^2}{7,200t^2}} \]

where

\( A \) = the gross area of the web, in.\(^2\) (mm\(^2\))

\( V \) = the total shear, kips (N)

**ND-NCD-3852.7 Allowable Stresses for Aluminum Structures (Class 3 storage tanks only).**

All parts of the structure shall be so proportioned that the sum of the static stresses shall not exceed the allowable stresses given in Tables **ND-NCD-3852.7-1** through **ND-NCD-3852.7-6**.
**Table ND-NCD-3852.7-1** — Allowable Tensile Stresses for Roof Supports
tension on net section *(For Class 3 aluminum storage tanks only)*

<table>
<thead>
<tr>
<th>Alloy and Temper</th>
<th>Maximum Temperature, °F (°C)</th>
<th>Allowable Stress, ksi (MPa)</th>
<th>Cross Sections Farther Than 1 in. (25 mm) From Any Weld</th>
<th>Cross Sections Within 1 in. (25 mm) of a Weld</th>
</tr>
</thead>
<tbody>
<tr>
<td>6061-T6</td>
<td>To 100 (38)</td>
<td>19 (131)</td>
<td>11 (76) [Note (1)]</td>
<td>150 (65) 19 (131) 11 (76)</td>
</tr>
<tr>
<td></td>
<td>150 (65)</td>
<td>19 (131)</td>
<td>11 (76) [Note (1)]</td>
<td>200 (95) 18 (124) 11.5 (76) [Note (1)]</td>
</tr>
<tr>
<td>6063-T6</td>
<td>To 100 (38)</td>
<td>15 (103)</td>
<td>6.5 (45)</td>
<td>150 (65) 14.5 (100) 6.5 (45)</td>
</tr>
<tr>
<td></td>
<td>200 (95)</td>
<td>14 (97)</td>
<td>6 (41)</td>
<td>6063-T6 6061-T6</td>
</tr>
</tbody>
</table>

**NOTE:**

(1) These allowable stresses apply to all material welded with 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), and to material 3/8 in. (10 mm) or less in thickness welded with 4043 or 5554 filler alloy. For thicker material welded with 4043 or 5554 filler alloy, these allowable stresses shall be reduced by multiplying them by 0.8.

**Table ND-NCD-3852.7-2** — Allowable Axial Compression Stresses for Roof Supports
Axial Compression *(For Class 3 aluminum storage tanks only)*

<table>
<thead>
<tr>
<th>Alloy and Temper</th>
<th>Maximum Temp., °F (°C)</th>
<th>Cross Sections Farther Than 1.0 in. (25 mm) From Any Weld</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Allowable Stress for Slenderness Less Than S₁, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S₁ Limit, S₁</td>
</tr>
<tr>
<td>6061-T6</td>
<td>To 100 (38)</td>
<td>19 (131)</td>
</tr>
<tr>
<td></td>
<td>150 (65)</td>
<td>19 (131)</td>
</tr>
<tr>
<td></td>
<td>200 (95)</td>
<td>18 (124)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13.5 (93)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alloy and Temper</td>
<td>Maximum Temp., °F (°C)</td>
<td>Cross Sections Farther Than 1.0 in. (25 mm) From Any Weld</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------</td>
<td>---------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Allowable Stress for Slenderness Less Than $S_1$, ksi (MPa)</td>
</tr>
<tr>
<td>6063-T6</td>
<td>To 100 (38)</td>
<td>$\frac{L}{r} = 11$</td>
</tr>
<tr>
<td></td>
<td>150 (65)</td>
<td>$13.8 - 0.076\frac{L}{r}$</td>
</tr>
<tr>
<td></td>
<td>200 (95)</td>
<td>$13.3 - 0.073\frac{L}{r}$</td>
</tr>
<tr>
<td>6061-T6</td>
<td>To 100 (38)</td>
<td>$\frac{L}{r} = 67$ [Note (1)]</td>
</tr>
<tr>
<td></td>
<td>150 (65)</td>
<td>$11 (76)$ [Note (1)]</td>
</tr>
<tr>
<td></td>
<td>200 (95)</td>
<td>$11 (76)$ [Note (1)]</td>
</tr>
<tr>
<td>6063-T6</td>
<td>To 100 (38)</td>
<td>$6.5 (45)$</td>
</tr>
<tr>
<td></td>
<td>150 (65)</td>
<td>$6.5 (45)$</td>
</tr>
<tr>
<td></td>
<td>200 (95)</td>
<td>$6 (41)$</td>
</tr>
</tbody>
</table>

**GENERAL NOTES:**
(a) $L =$ length of column between points of lateral support or twice the length of a cantilever column, except where analysis shows that a shorter length can be used, in. (mm)
(b) $r =$ least radius of gyration of column, in. (mm)
NOTES:
(1) The allowable stresses apply to all material welded with 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), and to material 3/8 in. (10 mm) or less in thickness welded with 4043 or 5554 filler alloy. For thicker material welded with 4043 or 5554 filler alloy, these allowable stresses shall be reduced by multiplying them by 0.8. Allowable stresses not marked with a number in parentheses apply to material welded with either 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), or either 4043 or 5554 filler alloy.
(2) These slenderness limits apply to all material welded with 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), and to material 3/8 in. (10 mm) or less in thickness welded with 4043 or 5554 filler alloy. For thicker material welded with 4043 or 5554 filler alloy, these slenderness limits must be adjusted to correspond to the reduced values of maximum allowable stresses indicated in [Note (1)] above.
### Table ND-NCD-3852.7-3 — Allowable Bending Stresses for Roof Supports *(For Class 3 aluminum storage tanks only)*

Compression in Extreme Fibers of Shapes, Girders, and Built-Up Members, Subjected to Bending Compression in Extreme Fibers of Shapes, Girders, and Built-Up Members, Subjected to Bending

<table>
<thead>
<tr>
<th>Alloy and Temp</th>
<th>Cross Sections Farther Than 1.0 in. (25 mm) From Any Weld</th>
<th>Cross Sections Within 1.0 in. (25 mm) of a Weld</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Allowable Stress for Slenderness Less Than $S_1$, ksi (MPa)</td>
<td>Slenderness Limit $S_1$</td>
</tr>
<tr>
<td>6061-T6</td>
<td>To 100 (40)</td>
<td>19 (131)</td>
</tr>
<tr>
<td></td>
<td>150 (70)</td>
<td>19 (131)</td>
</tr>
<tr>
<td></td>
<td>200 (90)</td>
<td>18 (124)</td>
</tr>
<tr>
<td>6063-T6</td>
<td>To 100 (40)</td>
<td>13.5 (93)</td>
</tr>
</tbody>
</table>
|               | 13 (90)    | $\frac{t_b}{r_y} = 13$ | $13.8 - 0.064\frac{t_b}{r_y} = 97$ | $\frac{72,000}{(t_b/r_y)^2}$ | $6.5 (45)$ | $6.5 (45)$ | $\frac{t_b}{r_y} = 107$

*Note (1)*: Additional notes or conditions for the use of these values should be consulted in the corresponding standard or code.

*Note (2)*: Additional notes or conditions for the use of these values should be consulted in the corresponding standard or code.
<table>
<thead>
<tr>
<th>Alloy and Temp er</th>
<th>Maximum Temp., °F (°C)</th>
<th>Cross Sections Farther Than 1.0 in. (25 mm) From Any Weld</th>
<th>Cross Sections Within 1.0 in. (25 mm) of a Weld</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Allowable Stress for Slenderness Less Than $S_1$, ksi (MPa)</td>
<td>Allowable Stress for Slenderness Less Than $S_1$, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slenderness Limit $S_1$</td>
<td>Slenderness Limit $S_1$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Allowable Stress for Slenderness Between $S_1$ and $S_2$, ksi (MPa)</td>
<td>Allowable Stress for Slenderness Greater Than $S_2$, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slenderness Limit $S_2$</td>
<td>Slenderness Limit $S_2$</td>
</tr>
<tr>
<td>150 (70)</td>
<td></td>
<td>$\frac{L_b}{r_f} = 13$</td>
<td>$\frac{L_b}{r_f} = 109$</td>
</tr>
<tr>
<td></td>
<td>12.5 (86)</td>
<td>$13.3 - 0.061 \frac{L_b}{r_f}$</td>
<td>$6 (41)$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$91.6 - 0.420 \frac{L_b}{r_f}$</td>
<td></td>
</tr>
</tbody>
</table>

**GENERAL NOTES:**
(a) $L_b = \text{length of beam between points at which the compression flange is supported against movement or length of cantilever beam from free end to point at which the compression flange is supported against lateral movement, in. (mm).}$
(b) $r_f = \text{radius of gyration of beam about axis parallel to web, in. (mm). For beams that are unsymmetrical about the horizontal axis, } r_f \text{ should be calculated as though both flanges were the same as the compression flange.}$
(c) Rafters with compression flanges in direct contact with the roof plates which they support may be considered to have adequate and continuous lateral support; therefore, allowable stresses for zero length may be used.

**NOTES:**
(1) These allowable stresses apply to all material welded with 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), and to material $\frac{3}{8}$ in. (10 mm) or less in thickness welded with 4043 or 5554 filler alloy. For thicker material welded with 4043 or 5554 filler alloy, these allowable stresses shall be reduced by multiplying them by 0.8. Allowable stresses not marked with a number in parentheses apply to material welded with either 5556 or 5356 filler alloy for temperatures not exceeding 150°F (66°C), or either 4043 or 5554 alloy.
(2) These slenderness limits apply to all material welded with 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), and to material $\frac{3}{8}$ in. (10 mm) or less in thickness welded with 4043 or 5554 filler alloy. For thicker material welded with 4043 or 5554 filler alloy, these slenderness limits must be adjusted to correspond to the reduced values of maximum allowable stresses indicated in [Note (1)] above.
Table **ND-NCD-3852.7-4** — Allowable Shear Stresses for Roof Supports *(For Class 3 aluminum storage tanks only)*
Shear in Webs of Beams and Girders

<table>
<thead>
<tr>
<th>Alloy and Temper</th>
<th>Maximum Temp., °F (°C)</th>
<th>Cross Sections Farther Than 1.0 in. (25 mm) From Any Weld</th>
<th>Cross Sections Within 1.0 in. (25 mm) of a Weld</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Slenderness Limit, ( S_1 )</td>
<td>Allowable Stress for Slenderness Less Than ( S_1 ), ksi (MPa)</td>
</tr>
<tr>
<td>6061-T6</td>
<td>To 100 (38)</td>
<td>( h_t = 12 ) (83)</td>
<td>13.7 - 0.092( h_t ) ((94.5 - 0.634( h_t )) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( h_t = 15 ) (65)</td>
<td>13.5 - 0.093( h_t ) ((93.5 - 0.641( h_t )) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( h_t = 20 ) (95)</td>
<td>13.3 - 0.092( h_t ) ((91.6 - 0.634( h_t )) )</td>
</tr>
<tr>
<td>6063-T6</td>
<td>To 100 (38)</td>
<td>( h_t = 8.5 ) (59)</td>
<td>9.5 - 0.054( h_t ) ((65.5 - 0.372( h_t )) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( h_t = 13 ) (65)</td>
<td>9.2 - 0.052( h_t ) ((63.4 - 0.38( h_t )) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( h_t = 16 ) (55)</td>
<td>8.8 - 0.049( h_t ) ((61.8 - 0.338( h_t )) )</td>
</tr>
<tr>
<td>Alloy and Temper</td>
<td>Maximum Temp., °F (°C)</td>
<td>Cross Sections Farther Than 1.0 in. (25 mm) From Any Weld</td>
<td>Cross Sections Within 1.0 in. (25 mm) of a Weld</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------</td>
<td>----------------------------------------------------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Allowable Stress for Slenderness Less Than S₁, ksi (MPa)</td>
<td>Allowable Stress for Slenderness Less Than S₁, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slenderness Limit, S₁</td>
<td>Slenderness Limit, S₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Allowable Stress for Slenderness Greater Than S₂, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Allowable Stress for Slenderness Greater Than S₂, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₁, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₂, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₁, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₂, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₁, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₂, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₁, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₂, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₁, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₂, ksi (MPa)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S₁, ksi (MPa)</td>
</tr>
</tbody>
</table>

GENERAL NOTES:
(a) \( h \) = clear height of web, in. (mm)
(b) \( t \) = thickness of web, in. (mm)

NOTES:
(1) These allowable stresses apply to all material welded with 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), and to material \( \frac{3}{8} \) in. (10 mm) or less in thickness welded with 4043 or 5554 filler alloy. For thicker material welded with 4043 or 5554 filler alloy, these allowable stresses shall be reduced by multiplying them by 0.8. Allowable stresses not marked with a number in parentheses apply to material welded with either 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), or either 4043 or 5554 alloy.
(2) These slenderness limits apply to all material welded with 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), and to material \( \frac{3}{8} \) in. (10 mm) or less in thickness welded with 4043 or 5554 filler alloy. For thicker material welded with 4043 or 5554 filler alloy, these slenderness limits must be adjusted to correspond to the reduced values of maximum allowable stresses indicated in [Note (1)] above.
### Table ND-NCD-3852.7-5 — Allowable Shear and Tension Stresses for Bolts for Roof Supports (For Class 3 aluminum storage tanks only)

<table>
<thead>
<tr>
<th>Description of Bolt</th>
<th>Maximum Temperature, °F (°C), for Allowable Stress, ksi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To 100 (38)</td>
</tr>
<tr>
<td>Shear</td>
<td></td>
</tr>
<tr>
<td>2024-T4 bolts</td>
<td>16 (110)</td>
</tr>
<tr>
<td>Tension</td>
<td></td>
</tr>
<tr>
<td>2024-T4 bolts</td>
<td>26 (179)</td>
</tr>
<tr>
<td>6061-T6 bolts</td>
<td>18 (124)</td>
</tr>
</tbody>
</table>

**GENERAL NOTE:**
Bolts shall not be welded.

### Table ND-NCD-3852.7-6 — Allowable Bearing Stresses for Bolts for Roof Supports (For Class 3 aluminum storage tanks only)

<table>
<thead>
<tr>
<th>Alloy and Temper</th>
<th>Maximum Temperature, °F (°C)</th>
<th>Allowable Stress, ksi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cross Sections Farther Than 1 in. (25 mm) From Any Weld</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bolts [Note (1)]</td>
</tr>
<tr>
<td>6061-T6</td>
<td>To 100 (38)</td>
<td>34 (234)</td>
</tr>
<tr>
<td></td>
<td>150 (65)</td>
<td>33 (228)</td>
</tr>
<tr>
<td></td>
<td>200 (95)</td>
<td>32 (221)</td>
</tr>
<tr>
<td>6063-T6</td>
<td>To 100 (38)</td>
<td>24 (165)</td>
</tr>
<tr>
<td></td>
<td>150 (65)</td>
<td>23 (159)</td>
</tr>
<tr>
<td></td>
<td>200 (95)</td>
<td>22 (152)</td>
</tr>
</tbody>
</table>

**GENERAL NOTE:**
Bolts shall not be welded.

**NOTES:**
(1) These values apply for a ratio of edge distance to bolt diameter of 2 or more. For smaller ratios, multiply these allowable stresses by the ratio (edge distance)/(twice the bolt diameter).
(2) These allowable stresses apply to all material welded with 5556 or 5356 filler alloy for temperatures not exceeding 150°F (65°C), and to material $\frac{3}{8}$ in. (10 mm) or less in thickness welded with 4043 or 5554 filler alloy. For thicker material welded with 4043 or 5554 filler alloy, these allowable stresses shall be reduced by multiplying them by 0.8.
**ND-NCD-3853 Supported Cone Roofs — General Requirements**

**ND-NCD-3853.1 Slope of Roof.**
The slope of the roof shall be 3/4 in./ft (62 mm/m) (6.25%) or greater. If the rafters are set directly on chord girders, producing slightly varying rafter slopes, the slope of the flattest rafter shall conform to the specified roof slope.

**ND-NCD-3853.2 Main Supporting Members.**
Main supporting members, including those supporting the rafters, may be rolled or fabricated sections or trusses. Although these members may be in contact with the roof plates, the compression flange of a member or the top chord of a truss shall be considered to receive no lateral support from the roof plates and shall be laterally braced, if necessary, by other acceptable methods. The allowable stresses in these members shall be governed by **ND-NCD-3852.6**.

**ND-NCD-3853.3 Design of Rafters.**
Structural members, serving as rafters, may be rolled or fabricated sections but in all cases shall conform with the rules of **ND-NCD-3852** through **ND-NCD-3853**. Rafters in direct contact with the roof plates applying the loading to the rafters may be considered to receive adequate lateral support from the friction between the roof plates and the compression flanges of the rafters, with the following exceptions:

(a) trusses and open web joints used as rafters;

(b) rafters having a nominal depth greater than 15 in. (375 mm);

(c) rafters having a slope greater than 2 in./ft (167 mm/m) (16.7%).

**ND-NCD-3853.4 Spacing of Rafters.**
Rafters shall be spaced so that, in the outer ring, their centers shall not be more than 6.28 ft (1.9 m) apart, measured along the circumference of the tank. Spacing on inner rings shall not be greater than 5 1/2 ft (1.7 m).

**ND-NCD-3853.5 Roof Columns.**
Roof columns shall be made from structural shapes or pipe.

**ND-NCD-3853.6 Attachment of Rafter Clips and Column Base Clip Guides.**
Rafter clips for the outer row of rafters shall be welded to the tank shell. Column base clip guides shall be welded to the tank bottom to prevent lateral movement of column bases. All other structural attachments shall be either bolted or welded.

**ND-NCD-3853.7 Welding of Roof Plates.**
Roof plates shall be welded in accordance with **ND-NCD-4246.4**. The size of the roof-to-top angle weld shall be 3/16 in. (5 mm) or smaller.
ND-NCD-3854 Supported Flat Roofs

ND-NCD-3854.1 General Requirements.
The use of supported flat roofs shall be limited to tanks having diameters not greater than 35 ft (11 m). The design of supported flat roofs shall be in accordance with ND-NCD-3853 except as noted below in ND-NCD-3854.2.

ND-NCD-3854.2 Main Supporting Members.
(a) Requirements of ND-NCD-3853.1 do not apply.
(b) Supporting structural members may be either internal or external to the roof plate.
(c) External rafters shall not be welded to the top angle or attached to the shell plate.
(d) External rafters shall be welded to the roof plate. The weld shall be sized to carry the combined dead and live loads on the roof plate.

ND-NCD-3855 Self-Supporting Cone Roofs

ND-NCD-3855.1 Nomenclature.
The symbols used are defined as follows:
- \( A_t \): combined cross-sectional area of roof plate, shell plate, and top shell angle, in.\(^2\) (mm\(^2\))
- \( D \): nominal diameter of tank shell, ft (m)
- \( f \): tensile working stress for the material of the roof plates, shell plates, or top shell angle, whichever is the least value, at the service temperature, psi (MPa)
- \( P \): dead load of roof, plus the live load, lb/ft\(^2\) (kPa)
- \( R \): radius of curvature of roof, ft (m)
- \( t_r \): nominal thickness of roof plates, in. (mm)
- \( \theta \): angle of cone elements with the horizontal, deg

ND-NCD-3855.2 Design Requirements for Ferrous Material.
Self-supporting cone roofs shall conform to the requirements of (a) through (c) below:

Note: The equations applying to self-supporting roofs provide for a uniform live load of 25 lb/ft\(^2\) (1.2 kPa)

(a) Slope

Maximum \( \theta = 37 \) deg (tangent=9:12)

Minimum \( \sin \theta = 0.165 \) [slope 2 in./ft (167 mm/m) (16.7\%)]

(b) Plate Thickness
(1) Minimum/Maximum

(U.S. Customary Units)

\[ \text{Minimum } t_r = \frac{D}{400 \sin \theta}, \text{ but not less than } \frac{3}{16} \text{ in.} \]
\[ \text{Maximum } t_r = \frac{1}{2} \text{ in.} \]

(SI Units)

\[ \text{Minimum } t_r = \frac{D}{4.8 \sin \theta}, \text{ but not less than } 5 \text{ mm.} \]
\[ \text{Maximum } t_r = 13 \text{ mm.} \]

(2) Self-supporting roofs having the roof plates stiffened by sections welded to the plates need not conform to the minimum thickness requirements but shall be not less than \(3/16\) in. (5 mm).

(c) Top Angle to Roof-to-Shell Joint. The cross-sectional area of the top angle, \(\text{in}^2\) square inches (mm\(^2\)), plus the cross-sectional areas of the shell and roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed

(U.S. Customary Units)

\[ \frac{D^2}{3000 \sin \theta} \]

(SI Units)

\[ \frac{D^2}{0.43 \sin \theta} \]

**ND-NCD-3855.3 Design Requirements for Aluminum Material (Class 3 storage tanks only).**

Self-supporting cone roofs shall conform to the requirements of (a) through (c) below:

(a) Slope

(1) Minimum \(\sin \theta = 0.165\) [slope 2 in./ft (167 mm/m) (16.7\%)]

(2) Maximum \(\theta = 37\) deg (tangent = 9:12)
(b) Plate Thickness

(U.S. Customary Units)

\[ t_r = \frac{D}{1414 \sin \theta} \sqrt{b} \]

(SI Units)

\[ t_r = \frac{D}{3.71 \sin \theta} \sqrt{b} \]

but not less than 3/16 in. (5 mm) nominal.

(c) *Top Angle to Roof-to-Shell Joint*. The cross-sectional area of the top angle, \( \text{square inches} (\text{mm}^2) \), plus the cross-sectional areas of the shell and roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed

(U.S. Customary Units)

\[ \text{Minimum } A_t = \frac{PD^2}{8f \sin \theta} \]

(SI Units)

\[ \text{Minimum } A_t = \frac{125PD^2}{f \sin \theta} \]

**ND-NCD-3856 Self-Supporting Dome and Umbrella Roofs**

**ND-NCD-3856.1 Nomenclature.**
See **ND-NCD-3855.1** for nomenclature.

**ND-NCD-3856.2 Design Requirements for Ferrous Material.**
Self-supporting dome and umbrella roofs shall conform to the requirements of (a) through (c) below.

Note: The equations applying to self-supporting roofs provide for a uniform live load of 25 lb/ft\(^2\) (1.2 kPa)

(a) *Radius of Curvature*
\[ R = D \] unless otherwise specified

Minimum \( R = 0.80D \)

Maximum \( R = 1.2D \)

(b) *Plate Thickness*

(1) Minimum/Maximum

(U.S. Customary Units)

- Minimum \( t = \frac{R}{200} \), but not less than \( \frac{3}{16} \) in.
- Maximum \( t = \frac{1}{2} \) in.

(SI Units)

- Minimum \( t = \frac{R}{2.4} \), but not less than 5 mm
- Maximum \( t = 13 \) mm

(2) Self-supporting roofs having the roof plates stiffened by sections welded to the plates need not conform to the minimum thickness requirements but shall be not less than \( \frac{3}{16} \) in. (5 mm).

(c) *Top Angle to Roof-to-Shell Joint.* The cross-sectional area of the top angle, in square inches\( \text{in}^2 \) (mm\(^2\)), plus the cross-sectional areas of the shell and roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top angle, shall equal or exceed

(U.S. Customary Units)

\[
\frac{DR}{1, 500}
\]

(SI Units)

\[
\frac{DR}{0.216}
\]
**ND-NCD-3856.3 Design Requirements for Aluminum Material (Class 3 storage tanks only).**

Self-supporting dome and umbrella roofs shall conform to the requirements of (a) through (c) below:

(a) *Radius of Curvature*

Minimum \( R = 0.80D \)

Maximum \( R = 1.2D \)

(b) *Plate Thickness*
(U.S. Customary Units)

\[
 t_r = \frac{R}{707} \sqrt{P}
\]

(SI Units)

\[
 t_r = \frac{R}{1.86} \sqrt{P}
\]

but not less than \( \frac{3}{16} \) in. (5 mm) nominal.

(c) *Top Angle to Roof-to-Shell Joint.* The cross-sectional area of the top shell angle, in square inches\(\text{in}^2\), plus the cross-sectional areas of shell and roof plates within a distance of 16 times their thicknesses, measured from their most remote point of attachment to the top shell angle, shall equal or exceed
(U.S. Customary Units)

\[
 \text{Minimum } A_t = \frac{PRD}{4f}
\]

(SI Units)

\[
 \text{Minimum } A_t = \frac{250PRD}{f}
\]

**ND-NCD-3856.4 Top Angle Attachment for Self-Supporting Roofs.**

(a) The top angle sections for self-supporting roofs shall meet the requirements of **ND-NCD-4246.6(d)4**. Joint efficiency factors need not be applied.
(b) For self-supporting roofs, the edges of the roof plates may be flanged horizontally to rest flat against the top angle to improve welding conditions.

**ND-NCD-3860 Tank Connections and Appurtenances**

**ND-NCD-3861 Roof Manholes**

Roof manholes shall conform to Figure **ND-NCD-3861-1** and Table **ND-NCD-3861-1**, except that alternative designs that provide equivalent strength are permissible if agreed to by the Owner or his designee.

**Figure ND-NCD-3861-1 — Roof Manholes**

GENERAL NOTE:
See Table **ND-NCD-3861-1**.
Table **ND-NCD-3861-1** — Roof Manholes

<table>
<thead>
<tr>
<th>Size of Manhole, in. (mm)</th>
<th>Diameter of Neck I.D., in. (mm)</th>
<th>Diameter of Cover Plate $D_C$, in. (mm)</th>
<th>Diameter of Bolt Circle $D_B$, in. (mm)</th>
<th>Number of Bolts</th>
<th>Diameter of Gasket I.D., in. (mm)</th>
<th>O.D., in. (mm)</th>
<th>Diameter of Hole in Roof Plate or Reinforcing Plate $D_P$, in. (mm)</th>
<th>O.D. of Reinforcing Plate $D$, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 (500)</td>
<td>20 (500)</td>
<td>26 (650)</td>
<td>23$^{1/2}$ (589)</td>
<td>16</td>
<td>21$^{1/2}$ (538)</td>
<td>26 (650)</td>
<td>20$^{5/8}$ (516)</td>
<td>42 (1 050)</td>
</tr>
<tr>
<td>24 (600)</td>
<td>24 (600)</td>
<td>30 (750)</td>
<td>27$^{1/2}$ (689)</td>
<td>20</td>
<td>25$^{1/2}$ (638)</td>
<td>30 (750)</td>
<td>24$^{5/8}$ (616)</td>
<td>46 (1 150)</td>
</tr>
</tbody>
</table>

**GENERAL NOTE:**
See Figure **ND-NCD-3861-1**.

**ND-NCD-3862 Roof Nozzles**

(a) Flanged roof nozzles shall conform to Figure **ND-NCD-3862(a)-1** and Table **ND-NCD-3862(a)-1**. Threaded nozzles shall conform to Figure **ND-NCD-3862(a)-2** and Table **ND-NCD-3862(a)-2**. Alternative designs for flanged roof nozzles and threaded nozzles can be used, provided they are of equivalent strength and are agreed to by the Owner or his designee.

(b) Roof nozzles are not intended to take loads from pipe reactions. Earthquake loadings need not be considered.

**Figure **ND-NCD-3862(a)-1** — Flanged Roof Nozzles**

**GENERAL NOTES:**
(a) See Table **ND-NCD-3862(a)-1**.
(b) Slip-on welding and welding neck flanges shall conform to the requirements for 150 lb forged carbon steel raised face flanges as given in ASME B16.5.
(c) Plate ring flanges shall conform to all dimensional requirements for slip-on welding flanges, except that the extended hub on the back of the flange may be omitted.
### Table ND-NCD-3862(a)-1 — Flanged Roof Nozzles

<table>
<thead>
<tr>
<th>Nominal Size of Nozzle, in. (mm)</th>
<th>O.D. of Pipe Neck, in. (mm)</th>
<th>Diameter of Hole in Roof Plate or Reinforcing Plate, ( D_P ), in. (mm)</th>
<th>Height of Nozzle, ( H ), in. (mm)</th>
<th>O.D. of Reinforcing Plate, ( D_R ), in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(1/2) (DN 40)</td>
<td>1.900 (48)</td>
<td>2 (50)</td>
<td>6 (150)</td>
<td>5 (125) [Note (1)]</td>
</tr>
<tr>
<td>2 (DN 50)</td>
<td>2(3/8) (60)</td>
<td>2(1/2) (64)</td>
<td>6 (150)</td>
<td>7 (175) [Note (1)]</td>
</tr>
<tr>
<td>3 (DN 80)</td>
<td>3(1/2) (89)</td>
<td>3(3/8) (91)</td>
<td>6 (150)</td>
<td>9 (225) [Note (1)]</td>
</tr>
<tr>
<td>4 (DN 100)</td>
<td>4(1/2) (114)</td>
<td>4(3/8) (116)</td>
<td>6 (150)</td>
<td>11 (275) [Note (1)]</td>
</tr>
<tr>
<td>6 (DN 150)</td>
<td>6(3/8) (168)</td>
<td>6(3/4) (169)</td>
<td>6 (150)</td>
<td>15 (375) [Note (1)]</td>
</tr>
<tr>
<td>8 (DN 200)</td>
<td>8(3/8) (219)</td>
<td>8(7/8) (222)</td>
<td>6 (150)</td>
<td>18 (450)</td>
</tr>
<tr>
<td>10 (DN 250)</td>
<td>10(3/4) (273)</td>
<td>11 (275)</td>
<td>8 (200)</td>
<td>22 (550)</td>
</tr>
<tr>
<td>12 (DN 300)</td>
<td>12(3/4) (324)</td>
<td>13 (325)</td>
<td>8 (200)</td>
<td>24 (600)</td>
</tr>
</tbody>
</table>

**General Note:**
See Figure ND-NCD-3862(a)-1.

**Note:**
(1) Reinforcing plates are not required on 6 in. (150 mm) or smaller nozzles, but may be used if desired.

### Figure ND-NCD-3862(a)-2 — Screwed or Socket Weld Roof Nozzles

**General Note:**
See Table ND-NCD-3862(a)-2 and ND-NCD-3864.

### Table ND-NCD-3862(a)-2 — Screwed or Socket Weld Roof Nozzles

<table>
<thead>
<tr>
<th>Nominal Size of Nozzle, in. (mm)</th>
<th>Nominal Size of Coupling, in. (mm)</th>
<th>Diameter of Hole in Roof Plate or Reinforcing Plate, ( D_P ), in. (mm)</th>
<th>O.D. of Reinforcing Plate, ( D_R ), in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3/4) (DN 20)</td>
<td>(3/4) (DN 20)</td>
<td>1(7/16) (37)</td>
<td>4 (100) [Note (1)]</td>
</tr>
</tbody>
</table>
### Nominal Size of Nozzle, in. (mm)  
Nominal Size of Coupling, in. (mm)  
Diameter of Hole in Roof Plate or Reinforcing Plate, \( D_P \), in. (mm)  
O.D. of Reinforcing Plate, \( D_R \), in. (mm)

<table>
<thead>
<tr>
<th>Nominal Size of Nozzle, in. (mm)</th>
<th>Nominal Size of Coupling, in. (mm)</th>
<th>Diameter of Hole in Roof Plate or Reinforcing Plate, ( D_P ), in. (mm)</th>
<th>O.D. of Reinforcing Plate, ( D_R ), in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (DN 25)</td>
<td>1 (DN 25)</td>
<td>1(\frac{23}{32}) (44)</td>
<td>4(\frac{1}{2}) (113) [Note (1)]</td>
</tr>
<tr>
<td>1(\frac{1}{2}) (DN 40)</td>
<td>1(\frac{1}{2}) (DN 40)</td>
<td>2(\frac{11}{32}) (60)</td>
<td>5 (125) [Note (1)]</td>
</tr>
<tr>
<td>2 (DN 50)</td>
<td>2 (DN 50)</td>
<td>3 (75)</td>
<td>7 (175) [Note (1)]</td>
</tr>
<tr>
<td>3 (DN 75)</td>
<td>3 (DN 75)</td>
<td>4(\frac{3}{8}) (105)</td>
<td>9 (225) [Note (1)]</td>
</tr>
<tr>
<td>4 (DN 100)</td>
<td>4 (DN 100)</td>
<td>5(\frac{1}{32}) (136)</td>
<td>11 (275) [Note (1)]</td>
</tr>
<tr>
<td>6 (DN 150)</td>
<td>6 (DN 150)</td>
<td>7(\frac{17}{32}) (191)</td>
<td>15 (375) [Note (1)]</td>
</tr>
<tr>
<td>8 (DN 200)</td>
<td>8 (DN 200)</td>
<td>9(\frac{7}{8}) (251)</td>
<td>18 (450)</td>
</tr>
<tr>
<td>10 (DN 250)</td>
<td>10 (DN 250)</td>
<td>12 (300)</td>
<td>22 (550)</td>
</tr>
<tr>
<td>12 (DN 300)</td>
<td>12 (DN 300)</td>
<td>14(\frac{3}{4}) (362)</td>
<td>24 (600)</td>
</tr>
</tbody>
</table>

**GENERAL NOTE:**  
See Figure [ND-NCD-3862(a)-2](#).

**NOTE:**  
(1) Reinforcing plates are not required on 6 in. (150 mm) or smaller nozzles, but may be used if desired.

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**ND-NCD-3863 Bottom Outlet Elbows**

Bottom outlet elbows shall conform to Figure [ND-NCD-3863-1](#) and Table [ND-NCD-3863-1](#).

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**Figure [ND-NCD-3863-1](#) — Welded Bottom Outlet Elbow**

**GENERAL NOTES:**  
(a) See Table [ND-NCD-3863-1](#).
(b) Slip-on welding and welding neck flanges shall conform to the requirements for 150 lb forged carbon steel raised face flanges as given in ASME B16.5.
(c) Plate ring flanges shall conform to all dimensional requirements for slip-on welding flanges, except that the extended hub on the back of the flange may be omitted.

<table>
<thead>
<tr>
<th>Table ND-NCD-3863-1 — Welded Bottom Outlet Elbow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Pipe Size, in. (mm) [Note (1)]</td>
</tr>
<tr>
<td>2 (DN 50)</td>
</tr>
<tr>
<td>3 (DN 80)</td>
</tr>
<tr>
<td>4 (DN 100)</td>
</tr>
<tr>
<td>6 (DN 150)</td>
</tr>
<tr>
<td>8 (DN 200)</td>
</tr>
</tbody>
</table>

GENERAL NOTE:
See Figure ND-NCD-3863-1.

NOTE:
(1) Extra-strong pipe, refer to ASME B36.10M.

**ND-NCD-3864 Threaded Connections**

Threaded piping connections shall be female and shall be tapered. The threads shall conform to the requirements for taper pipe threads included in ANSI/ASME B1.20.1.

**ND-NCD-3865 Platforms, Walkways, and Stairways**

Platforms, walkways, and stairways shall be in accordance with Tables ND-NCD-3865-1 through ND-NCD-3865-3.

<table>
<thead>
<tr>
<th>Table ND-NCD-3865-1 — Platforms and Walkways</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. All parts to be made of metal.</td>
</tr>
<tr>
<td>2. Width of floor level (min.): 24 in. (600 mm).</td>
</tr>
<tr>
<td>3. Flooring to be made of grating or nonslip material.</td>
</tr>
<tr>
<td>4. Height of top railing above floor: 42 in. (1 050 mm) [Note (1)].</td>
</tr>
<tr>
<td>5. Height of toeboard (min.): 3 in. (75 mm).</td>
</tr>
<tr>
<td>6. Space between top of floor and bottom of toeboard (max.): 1/4 in. (6 mm).</td>
</tr>
</tbody>
</table>
7. Height of midrail: approximately one-half the distance from top of walkway to top of railing.

8. Distance between railing posts (max.): 96 in. (2 400 mm).

9. The completed structure shall be capable of supporting a moving concentrated load of 1,000 lb (4 450 N), and the handrail structure shall be capable of withstanding a load of 200 lb (890 N) applied in any direction at any point on the top rail.

10. Handrails to be on both sides of platform, discontinuing where necessary for access.

11. At handrail openings, any space between tank and platform wider than 6 in. (150 mm) should be floored.

12. Tank runways, which extend from one part of a tank to any part of an adjacent tank, or to ground or other structure, shall be so supported as to permit free relative movement of the structures joined by the runway. This may be accomplished by firm attachment of runway to one tank, but with a slip joint at point of contact between runway and other tank. This is to permit either tank to settle or be disrupted by an explosion without endangering the other.

NOTE:
(1) Handrail height as required by ANSI specifications. This height is mandatory in some states.

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**Table ND-NCD-3865-2 — Stairways**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All parts to be made of metal.</td>
</tr>
<tr>
<td>2</td>
<td>Width of stairs (min.): 24 in. (600 mm).</td>
</tr>
<tr>
<td>3</td>
<td>Angle of stairway with a horizontal line (max.): 50 deg [Note (1)].</td>
</tr>
<tr>
<td>4</td>
<td>Width of stair treads (min.): 8 in. (200 mm). [The run (defined as the horizontal distance between the noses of successive tread pieces) and the rise of stair treads shall be such that the sum of twice the rise, plus the run, shall be not less than 24 in. (600 mm) nor more than 26 in. (650 mm). Rises shall be uniform throughout the height of the stairway.]</td>
</tr>
<tr>
<td>5</td>
<td>Treads to be made of grating or nonslip material.</td>
</tr>
<tr>
<td>6</td>
<td>Top railing shall join platform handrail without offset, and the height measured vertically from tread level at nose of tread shall be 30 to 34 in. (750 to 850 mm).</td>
</tr>
<tr>
<td>7</td>
<td>Distance between railing posts (max.) measured along slope of railing: 96 in. (2 400 mm).</td>
</tr>
<tr>
<td>8</td>
<td>The completed structure shall be capable of supporting a moving concentrated load of 1,000 lb (4 450 N), and the handrail structure shall be capable of withstanding a load of 200 lb (890 N) applied in any direction at any point on the top rail.</td>
</tr>
<tr>
<td>9</td>
<td>Handrails shall be on both sides of straight stairs; also, handrails shall be on both sides of circular stairs when the clearance between tank shell and stair stringer exceeds 8 in. (200 mm).</td>
</tr>
</tbody>
</table>
10. Circumferential stairways should be completely supported on the shell of the tank, and ends of the stringers should be clear of the ground.

NOTE:
(1) It is recommended that the same angle be employed for all stairways in a tank group or plant area.

<table>
<thead>
<tr>
<th>Height of Rise, ( R ), in. (mm)</th>
<th>Width of Run, ( r ), in. (mm)</th>
<th>Angle deg min</th>
<th>Width of Run, ( r ), in. (mm)</th>
<th>Angle deg min</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 5\frac{1}{4} ) (131)</td>
<td>( 13\frac{1}{2} ) (338)</td>
<td>21 15</td>
<td>( 15 ) (375)</td>
<td>20 9</td>
</tr>
<tr>
<td>( 5\frac{1}{2} ) (138)</td>
<td>13 (325)</td>
<td>22 56</td>
<td>14 (350)</td>
<td>23 12</td>
</tr>
<tr>
<td>( 5\frac{3}{4} ) (144)</td>
<td>12(\frac{1}{2} ) (313)</td>
<td>24 43</td>
<td>( 14\frac{1}{4} ) (356)</td>
<td>21 38</td>
</tr>
<tr>
<td>6 (150)</td>
<td>12 (300)</td>
<td>26 34</td>
<td>14 (350)</td>
<td>23 12</td>
</tr>
<tr>
<td>( 6\frac{1}{4} ) (156)</td>
<td>11(\frac{1}{2} ) (288)</td>
<td>28 30</td>
<td>13(\frac{1}{2} ) (338)</td>
<td>24 53</td>
</tr>
<tr>
<td>( 6\frac{1}{2} ) (163)</td>
<td>11 (275)</td>
<td>30 35</td>
<td>13 (325)</td>
<td>26 34</td>
</tr>
<tr>
<td>( 6\frac{3}{4} ) (169)</td>
<td>10(\frac{1}{2} ) (263)</td>
<td>32 45</td>
<td>12(\frac{1}{2} ) (313)</td>
<td>28 23</td>
</tr>
<tr>
<td>7 (175)</td>
<td>10 (250)</td>
<td>35 0</td>
<td>12 (300)</td>
<td>30 15</td>
</tr>
<tr>
<td>( 7\frac{1}{4} ) (181)</td>
<td>9(\frac{1}{2} ) (238)</td>
<td>38 20</td>
<td>11(\frac{1}{2} ) (288)</td>
<td>32 13</td>
</tr>
<tr>
<td>( 7\frac{1}{2} ) (188)</td>
<td>9 (225)</td>
<td>39 50</td>
<td>11 (275)</td>
<td>34 18</td>
</tr>
<tr>
<td>( 7\frac{3}{4} ) (194)</td>
<td>8(\frac{1}{2} ) (213)</td>
<td>42 22</td>
<td>10(\frac{1}{2} ) (263)</td>
<td>36 26</td>
</tr>
<tr>
<td>8 (200)</td>
<td>8 (200)</td>
<td>45 0</td>
<td>10 (250)</td>
<td>38 40</td>
</tr>
<tr>
<td>( 8\frac{1}{4} ) (206)</td>
<td>7(\frac{1}{2} ) (188)</td>
<td>47 43</td>
<td>( 9\frac{1}{2} ) (238)</td>
<td>41 0</td>
</tr>
<tr>
<td>( 8\frac{1}{2} ) (213)</td>
<td></td>
<td></td>
<td>( 9 ) (225)</td>
<td>43 23</td>
</tr>
<tr>
<td>( 8\frac{3}{4} ) (219)</td>
<td></td>
<td></td>
<td>( 8\frac{1}{2} ) (213)</td>
<td>45 49</td>
</tr>
<tr>
<td>9 (225)</td>
<td></td>
<td></td>
<td>8 (200)</td>
<td>48 22</td>
</tr>
</tbody>
</table>

**ND-NCD-3866 Nozzle Piping Transitions**

The stress limits of Table ND-NCD-3821.5-1 shall apply to all portions of nozzles that lie within the limits of reinforcement given in ND-NCD-3334, except as provided in ND-NCD-3867. Stresses in the extension of any nozzle beyond the limits of reinforcement shall be subject to the stress limits of ND-NCD-3600.

**ND-NCD-3867 Consideration of Standard Reinforcement**

(a) Where a nozzle-to-shell junction is reinforced in accordance with the rules of ND-NCD-3334, the stresses in this region due to internal pressure may be considered to satisfy the
limits of Table ND-NCD-3821.5-1. Under these conditions, no analysis is required to demonstrate compliance for pressure-induced stresses in the nozzle region.

(b) Where external piping loads are to be designed for, membrane plus bending stresses due to these loads 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 Table ND-NCD-3821.5-1 for \((σ_m + σ_b)\). In this case, the pressure-induced stresses in the \((σ_m + σ_b)\) category may be assumed to be no greater than the limit specified for \(σ_m\) in Table ND-NCD-3821.5-1, for a given loading.