ALTERATION PLAN
NBIC PART 3/
ASME SECTION VIII DIV.1

Addition of a larger nozzle to a pressure vessel

NB members Meeting  October 2019- R Ferrell
Reinforced Opening
Welded Nozzle Design Plan

Remove an NPS 10 nozzle and replace with an NPS 12 nozzle
Nozzle Alteration Plan

• Replace a NPS 10 outlet nozzle with a NPS 12 outlet nozzle on a pressure vessel.

• This ASME Section VIII pressure vessel requires postweld heat treatment. We will use NBIC Part 3 paragraph 2.5.2 local PWHT or Welding Method 1.

• Contact your Repair Inspector to authorize this alteration and discuss the alteration plan before quoting the job.
Nozzle NPS 12 SCH 60 Pipe
SA-106 Gr. C

Outlet Nozzle Connection

Quantity (1) - 1.025 inch minimum thickness plate by 159-3/4 inch long by 113-1/2 inch wide of SA-316 Gr. 70 material. Mill normalized, McQuaid-Ehn Test (see SA-20) and Mill test report required.

Quantity (1) - NPS 12 SCH 60 Pipe of SA-106 Gr. C material 17-1/2" long with square cut ends.
Nozzle Alteration Plan

• Reinforcing calculations need to be done to determine nozzle thickness or the need for a reinforcing element. (UG-37)
  – This is done because the cylindrical shell is designed to carry hoop stress (circumferential stress) caused by internal pressure. Removing metal by placing a hole in the cylinder disrupts the uniform distribution of this membrane stress. Therefore, that metal must be put back (compensation) to absorb its share of the stress load.

• The shell thickness calculation needs to be done to determine the required shell thickness before calculating available area.

• This shell is made up of one piece of plate. The nozzle is on the top of the shell.
Nozzle Alteration Plan
(known information)

• P=MAWP = 700 psi
• Shell material is SA-516-70 (S= 20,000 psi) with a maximum design temperature of 500°F and MDMT of 40°F. (see UCS-66)
• The Manufacturer’s Data Report from the National Board shows a shell thickness of 1.625 inches, but there is general corrosion pits 0.125 inches deep near the nozzle reinforcement area. The original inside diameter was 48 inches.
Nozzle Alteration Plan
(known information)

- The new nozzle is NPS 12 (12.75 inch outside diameter), SA-106 Gr C, 0.562 inch nominal wall (SCH 60), 
  $S = 20,000$ psi, design temperature is $500^\circ F$

- Note:
  - when pipe is ordered and received using nominal wall thickness, a 12.5% under tolerance must be deducted from the wall for design calculations.
  - For example, $0.562 \text{ nominal } \times 0.875 \text{ (subtracts 12.5\%)} = 0.492 \text{ inches}$
Design Calculations

• Both the shell and nozzle are cylindrical components under internal pressure.
• Therefore, we will use UG-27 (c) 1 to calculate the minimum required wall thickness for both.
holes in layered construction. When telltale holes are provided, they shall have a diameter of \( \frac{1}{16} \) in. to \( \frac{3}{16} \) in. (1.5 mm to 5 mm) and have a depth not less than 80% of the thickness required for a seamless shell of like dimensions. These holes shall be provided in the opposite surface to that where deterioration is expected. [For telltale holes in clad or lined vessels, see UCL-25(b).]

(f) Openings for Drain. Vessels subject to corrosion shall be supplied with a suitable drain opening at the lowest point practicable in the vessel; or a pipe may be used extending inward from any other location to within \( \frac{1}{4} \) in. (6 mm) of the lowest point.

**UG-26 LININGS**

Corrosion resistant or abrasion resistant linings, whether or not attached to the wall of a vessel, shall not be considered as contributing to the strength of the wall except as permitted in Part UCL (see Nonmandatory Appendix T).

**UG-27 THICKNESS OF SHELLS UNDER INTERNAL PRESSURE**

(a) The minimum required thickness of shells under internal pressure shall not be less than that computed by the following formulas,\(^19\) except as permitted by Mandatory Appendix 1 or Mandatory Appendix 32. In addition, provision shall be made for any of the loadings listed in UG-22, when such loadings are expected. The provided thickness of the shells shall also meet the requirements of UG-16, except as permitted in Mandatory Appendix 32.

(b) The symbols defined below are used in the formulas of this paragraph.

- \( E \) = joint efficiency for, or the efficiency of, appropriate joint in cylindrical or spherical shells, or the efficiency of ligaments between openings, whichever is less.
- For welded vessels, use the efficiency specified in UW-12.
- For ligaments between openings, use the efficiency calculated by the rules given in UG-53.
- \( P \) = internal design pressure (see UG-21)
- \( R \) = inside radius of the shell course under consideration.\(^19\)
- \( S \) = maximum allowable stress value (see UG-23 and the stress limitations specified in UG-24)
- \( t \) = minimum required thickness of shell

(c) Cylindrical Shells. The minimum thickness or maximum allowable working pressure of cylindrical shells shall be the greater thickness or lesser pressure as given by (1) or (2) below.

\[
(1) \text{Circumferential Stress (Longitudinal Joints)}
\]

When the thickness does not exceed one-half of the inside radius, or \( P \) does not exceed 0.385\(SE\), the following formulas shall apply:

\[
t = \frac{P R}{2SE - 0.6P} \quad \text{or} \quad P = \frac{5SE}{R + 0.6t}
\]

(d) Longitudinal Stress (Circumferential Joints)\(^20\)

When the thickness does not exceed one-half of the inside radius, or \( P \) does not exceed 1.25\(SE\), the following formulas shall apply:

\[
t = \frac{P R}{2SE - 0.2P} \quad \text{or} \quad P = \frac{2SE}{R + 0.2t}
\]

(e) When necessary, vessels shall be provided with stiffeners or other additional means of support to prevent overstress or large distortions under the external loadings listed in UG-22 other than pressure and temperature.

(f) A stayed jacket shell that extends completely around a cylindrical or spherical vessel shall also meet the requirements of UG-47(c).

(g) Any reduction in thickness within a shell course or spherical shell shall be in accordance with UW-9.

**UG-28 THICKNESS OF SHELLS AND TUBES UNDER EXTERNAL PRESSURE**

(a) Rules for the design of shells and tubes under external pressure given in this Division are limited to cylindrical shells, with or without stiffening rings, tubes, and spherical shells. Three typical forms of cylindrical shells are shown in Figure UG-20. Charts used in determining minimum required thicknesses of these components are given in Section II, Part D, Subpart 3.

(b) The symbols defined below are used in the procedures of this paragraph:

- \( A \) = factor determined from Section II, Part D, Subpart 3, Figure G and used to enter the applicable material chart in Section II, Part D, Subpart 3. For the case of cylinders having \( D_0/t \) values less than 10, see [c](2).
- \( B \) = factor determined from the applicable material chart or table in Section II, Part D, Subpart 3 for maximum design metal temperature [see UG-20(c)]
- \( D_0 \) = outside diameter of cylindrical shell course or tube

20 These formulas will govern only when the circumferential joint efficiency is less than one-half the longitudinal joint efficiency, or when the effect of supplementary loadings (UG-22) causing longitudinal bending or tension in conjunction with internal pressure is being investigated.
UG-27  Shell Calculation

\[ t_{\text{shell}} = \frac{PR}{SE - (0.6)P} \]

\[ t_{\text{shell}} = \frac{700 \times 24.125}{20000 \times 1 - (0.6)700} \]

\[ t_{\text{shell}} = \frac{16887.5}{19580} \]

\[ t_{\text{shell}} = 0.863'' \]

- \( P = 700 \text{ psi} \)
- \( R = 24.125'' \)
- \( S = 20,000 \text{ psi} \)
- \( E = 1 \text{ full radiography} \)
- \( C = 0 \text{ no additive thickness} \)
UG-27 Nozzle Calculation

\[ t = \frac{PR}{SE - 0.6P} \]

\[ t = \frac{700 \times (5.88325)}{20000 \times 1 - 0.6 \times 700} \]

\[ t = \frac{4706.6}{16620} \]

\[ t_{rn} = 0.283" \]

- \( P = 700 \) psi
- \( R = 5.88325 \) (subtracted 12 \( \frac{1}{2} \)%)
- \( S = 20,000 \) psi
- \( E = 1 \) (seamless pipe)
- \( C = 0 \) no additive thickness
The minimum nozzle wall thickness, other than access and inspection openings, shall be not less than the following:

This will result in the prevention of the usage of thin wall nozzles. To join a thin wall item to a vessel, an intermediate fitting will be necessary.

### Table UG-45
Nozzle Minimum Thickness Requirements

<table>
<thead>
<tr>
<th>Nominal Size</th>
<th>Minimum Wall Thickness [see UG-16(d)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in.</td>
</tr>
<tr>
<td>NPS 1/8 (DN 6)</td>
<td>0.060</td>
</tr>
<tr>
<td>NPS 1/4 (DN 8)</td>
<td>0.077</td>
</tr>
<tr>
<td>NPS 3/8 (DN 10)</td>
<td>0.080</td>
</tr>
<tr>
<td>NPS 1/2 (DN 15)</td>
<td>0.095</td>
</tr>
<tr>
<td>NPS 3/4 (DN 20)</td>
<td>0.099</td>
</tr>
<tr>
<td>NPS 1 (DN 25)</td>
<td>0.116</td>
</tr>
<tr>
<td>NPS 1 1/4 (DN 32)</td>
<td>0.123</td>
</tr>
<tr>
<td>NPS 1 1/2 (DN 40)</td>
<td>0.127</td>
</tr>
<tr>
<td>NPS 2 (DN 50)</td>
<td>0.135</td>
</tr>
<tr>
<td>NPS 2 1/2 (DN 65)</td>
<td>0.178</td>
</tr>
<tr>
<td>NPS 3 (DN 80)</td>
<td>0.189</td>
</tr>
<tr>
<td>NPS 3 1/2 (DN 90)</td>
<td>0.198</td>
</tr>
<tr>
<td>NPS 4 (DN 100)</td>
<td>0.207</td>
</tr>
<tr>
<td>NPS 5 (DN 125)</td>
<td>0.226</td>
</tr>
<tr>
<td>NPS 6 (DN 150)</td>
<td>0.245</td>
</tr>
<tr>
<td>NPS 8 (DN 200)</td>
<td>0.282</td>
</tr>
<tr>
<td>NPS 10 (DN 250)</td>
<td>0.319</td>
</tr>
<tr>
<td>NPS 12 (DN 300)</td>
<td>0.328</td>
</tr>
</tbody>
</table>

**GENERAL NOTE:** For nozzles having a specified outside diameter not equal to the outside diameter of an equivalent standard NPS (DN) size, the NPS (DN) size chosen from the table shall be one having an equivalent outside diameter larger than the nozzle outside diameter.
Necks abutting a vessel wall shall be attached by full penetration groove weld [see (b) above]

Necks inserted through the vessel wall may be attached by full penetration groove weld [see (e) above]

Special rule controlling weld placement. In most cases it will result with a weld being placed at two points, the intersection of the nozzle on the outside of the vessel shell and at the intersection of the nozzle with the inside of the shell. It is to eliminate an exposed crevice on the inside of the pressure vessel.
Minimum Nozzle Weld Sizing Defined In UW-16 and Fig. UW-16.1

Typical Example:
Solve minimum weld sizes (UW-16.2 (b))
also see UW-15 for minimum strength
t_{min} = the smaller of ¾ in. or the thickness
of the thinner parts joined by a fillet,
single bevel, or single j weld

t_c =not less than the smaller of ¼ in. or 0.7
t_{min} (this is the throat dimension not leg)

The nozzle is thinner than the shell so:
t_n = 0.562 inch= t_{min}
t_c=0.7(t_{min})=0.393 inch
Therefore the minimum leg is .556 inch (9/16 inch)

This is an important step in verification of the nozzle. Should this be done incorrectly, the nozzle could fail. t minimum is a function of the two items being joined. Where reinforcing elements are involved, there will be more than one value of t minimum based on the weld being considered.
Fillet Weld Throat Versus Leg Dimensions

Right Angle Triangle (typical fillet weld shape)

\[ c = \sqrt{a^2 + b^2} \]
\[ a = \sqrt{c^2 - b^2} \]
\[ b = \sqrt{c^2 - a^2} \]

Weld leg = Weld throat x 1.4142
Weld throat = weld leg/1.4142
Section VIII

Figure UG-37.1
Nomenclature and Formulas for Reinforced Openings

GENERAL NOTE:
Includes consideration of these areas if 
$S_n/S_V < 1.0$ (both sides of $C$)

2.5$t$ or $2.5t_n + t_e$
Use smaller value

$h$, 2.5$t$, 2.5$t_i$
Use smallest value

$d$ or $R_n + t_n + t$
Use larger value

$D_p$

For nozzle wall inserted through the vessel wall — For nozzle wall abutting the vessel wall

See UG-40 for limits of reinforcement
Section I

Figure PG-33.1
Nomenclature and Equations for Reinforced Openings

Area required: $A = (d + 2t_n)t_F$

Area available in shell; use larger value: $A_1 = \begin{cases} (d - 2t_n)(t - F t) - 2w_1(t - F t)(1 - t_r) \\ 2(t - F t_r) - 2w_1(t - F t)(1 - t_r) \end{cases}$

Area available in nozzle projecting outward; use: $A_2 = \begin{cases} 2(t_n - t_m)(2^{1/2}t_F t_r) \end{cases}$

Notes:
- For nozzle wall inserted through the vessel wall
- For nozzle wall abutting the vessel wall
- Notes for set through nozzles, $A$ extends to the nozzle O.D. [Note (1)]

$A = d t_F$

$A_1 = \begin{cases} d t - F t_r \\ 2(t + t_m)(t - F t_r) \end{cases}$

$A_2 = \begin{cases} 2(t_n - t_m)(2^{1/2}t_F t_r) \end{cases}$
Section IV

Figure HG-326.2
Nomenclature and Formulas for Reinforced Openings

Without Reinforcing Element

- \( A = \frac{d_f F + 2d_p F(1 - f_1)}{2} \) Area required
- \( A_1 = 2(f_1 f_2 f_3 - f_1 f_2 (1 - f_1) \) Area available in shell; use larger value
- \( A_2 = 2(f_1 f_2 f_3) \) Area available in nozzle projecting outward; use smaller value
- \( A_3 = f_1 f_2 f_3 \) Area available in inward nozzle
- \( A_{21} = \) outward nozzle weld = \( \text{deg} f_2 f_3 \) Area available in outward weld
- \( A_{22} = \) inward nozzle weld = \( \text{deg} f_3 f_1 \) Area available in inward weld

\[ \begin{align*}
\text{If } A_1 + A_2 + A_3 + A_{21} + A_{22} &> A \\
\text{Opening is adequately reinforced} \\
\text{If } A_1 + A_2 + A_3 + A_{21} + A_{22} &< A \\
\text{Opening is not adequately reinforced so reinforcing elements must be added and/or thickness must be increased}
\end{align*} \]

With Reinforcing Element Added

- \( A = \) same as \( A \) above Area required
- \( A_1 = \) same as \( A_1 \) above Area available
- \( A_2 = \frac{2(f_1 f_2 f_3 - f_1 f_2 (1 - f_1)) + \delta}{2} \) Area available in nozzle projecting outward; use smaller area
- \( A_3 = \) same as \( A_3 \) above Area available in inward nozzle
- \( A_{21} = \) outward nozzle weld = \( \text{deg} f_2 f_3 \) Area available in outward weld
- \( A_{22} = \) inward nozzle weld = \( \text{deg} f_3 f_1 \) Area available in inward weld
- \( A_5 = (d_p - 2d_f) f_1 f_2 f_3 \) Area available in element

\[ \begin{align*}
\text{If } A_1 + A_2 + A_3 + A_{21} + A_{22} + A_5 &> A \\
\text{Opening is adequately reinforced}
\end{align*} \]

GENERAL NOTE: This figure illustrates a common nozzle configuration and is not intended to prohibit other configurations permitted by the code.

NOTE:
(1) This formula is applicable for a rectangular cross-sectional element that falls within the limits of reinforcement.
FIG. UG-37.1

Area of Reinforcement Required

\[ t_n = 0.562 \text{ in.} \]
\[ d = 11.626 \text{ in.} \]
\[ t = 1.625 \text{ in.} \]
\[ t_r = 0.863 \text{ in.} \]
\[ F = 1.0 \]
\[ f_{r_1} = 1 \]

\[ A = dt_r F + 2t nt_r F(1-f_{r_1}) \]

\[ A = 11.625 \times 0.863 \times 1 + 0 \]
\[ = 10.032 + 0 \]
\[ = 10.032 \text{ in.}^2 \]

If Nozzle \( S_n = 17,100 \) (Sa -106-B)
Then \( f_{r_1} = 0.855 \) and \( A \) would be over 12”.
FIG. UG-37.1

Area of Reinforcement Available in Vessel

\[ t_n = 0.562 \text{ in.} \]
\[ d = 11.625 \text{ in.} \]
\[ t = 1.625 \text{ in.} \]
\[ t_r = 0.863 \text{ in.} \]
\[ F = 1.0 \]
\[ f_{r1} = 1 \]
\[ E_1 = 1 \]

\[ A_1 = d(E_1 t - F t_r) - 2 t_n(E_1 t - F t_r)(1 - f_{r1}) \]

Or

\[ A_1 = 2(t + t_n)(E_1 t - F t_r)(1 - f_{r1}) \]

USE LARGER VALUE

\[ A_1 = 8.85 \text{ in.}^2 \]
UG-37.1
Area of Reinforcement Available in Nozzle External of Vessel

\[ A_2 = 5(t_n - t_{rn}) f_{r2} t_n \]

Use the smaller value

\[ A_2 = 0.784 \text{ in.}^2 \]

\[ t_n = 0.562 \text{ in.} \]
\[ d = 11.625 \text{ in.} \]
\[ t_{rn} = 0.2985 \text{ in.} \]
\[ F = 1.0 \]
\[ f_{r2} = 0.855 \]
Area available in nozzle welds

\[ t_n = 0.562 \text{ in.} \]
\[ t_c = 0.398 \text{ in.} \]
\[ f_{r2} = 0.855 \]
Weld leg = 0.5625 in.

\[ A_{41} = (\text{leg})^2 f_{r2} \]

\[ A_{41} = 0.270 \text{ in.}^2 \]
UG-37.1

Area of reinforcement available on inside nozzle

\[ F_{r2} = \frac{s_n}{s_s} = 1 \]

Use smaller value

\[ A_3 = 2ht_i f_{r2} \]
\[ A_3 = 2 \times 1.405 \times 0.562 \times 1 \]

\[ A_3 = 1.58 \text{ in}^2 \]

h, 2.5 t, 2.5t_i
3.875, 4.0625, 1.405
Total Area of reinforcement available

\[ t_n \quad d \]

\[ A_1 + A_2 + A_3 + A_{41} \geq A \]

11.484 versus 10.032
Figure UG-37.1
Nomenclature and Formulas for Reinforced Openings

GENERAL NOTE:
Includes consideration of these areas if $S_n/S_y < 1.0$ (both sides of $C$)

2.5t or 2.5$t_n + t_e$
Use smaller value

$h, 2.5t, 2.5t_i$
Use smallest value

$d$ or $R_n + t_n + t$
Use larger value

$d$ or $R_n + t_n + t$
Use larger value

For nozzle wall inserted through the vessel wall  ——  For nozzle wall abutting the vessel wall

See UG-40 for limits of reinforcement
Without Reinforcing Element

\[ A = d \left( F + 2t_{n1} F (1 - f_{r1}) \right) \]

Area required

\[ A_1 = \frac{d(E_t - F r_t)}{2} - 2t_{n1} (E_t - F r_t) \left( 1 - f_{r1} \right) \]

Area available in shell; use larger value

\[ A_2 = \frac{5(t_{n1} - t_{m1}) f_r 2t}{5t_{n1} t_{f2}} + 2h t_{f2} \]

Area available in nozzle projecting outward; use smaller value

\[ A_3 = 5t_{m1} t_{f2} \]

Area available in inward nozzle; use smallest value

\[ A_{41} = \text{outward nozzle weld} = (\text{leg}) f_r 2t \]

Area available in outward weld

\[ A_{43} = \text{inward nozzle weld} = (\text{leg}) f_r 2t \]

Area available in inward weld

If \[ A_1 + A_2 + A_3 + A_{41} + A_{43} > A \]

Opening is adequately reinforced

If \[ A_1 + A_2 + A_3 + A_{41} + A_{43} < A \]

Opening is not adequately reinforced so reinforcing elements must be added and/or thicknesses must be increased

With Reinforcing Element Added

\[ A = \text{same as } A, \text{ above} \]

Area required

\[ A_1 = \text{same as } A_1, \text{ above} \]

Area available

\[ A_2 = \frac{5t_{n1} - t_{m1}}{f_r 2t} \]

Area available in nozzle projecting outward; use smaller area

\[ A_3 = \text{same as } A_3, \text{ above} \]

Area available in inward nozzle

\[ A_{41} = \text{outward nozzle weld} = (\text{leg}) f_r 3 \]

Area available in outward weld

\[ A_{42} = \text{outer element weld} = (\text{leg}) f_r 4 \]

Area available in outer weld

\[ A_{43} = \text{inward nozzle weld} = (\text{leg}) f_r 2 \]

Area available in inward weld

\[ A_5 = (d - 2t_{n1}) t_{e} f_r 4 \] \[ \text{[Note (1)]} \]

Area available in element

Opening is adequately reinforced

GENERAL NOTE: This figure illustrates a common nozzle configuration and is not intended to prohibit other configurations permitted by the Code.

NOTE:
(1) This formula is applicable for a rectangular cross-sectional element that falls within the limits of reinforcement.
\[A_3 = \text{area available for reinforcement when the nozzle extends inside the vessel wall (see Figure UG-37.1)}\]

\[A_n = \text{cross-sectional area of material added as reinforcement (see Figure UG-37.1)}\]

\[A_{41}, A_{42} = \text{cross-sectional area of various welds available for reinforcement (see Figure UG-37.1)}\]

\[c = \text{corrosion allowance}\]

\[D = \text{inside shell diameter}\]

\[D_p = \text{outside diameter of reinforcing element (actual size of reinforcing element may exceed the limits of reinforcement established by UG-41; however, credit cannot be taken for any material outside these limits)}\]

\[d = \text{finished diameter of circular opening or finished dimension (chord length at mid-surface of thickness excluding excess thickness available for reinforcement) of nonradial opening in the plane under consideration, in. (mm) (see Figures UG-37.1 and UG-40)}\]

\[E = 1 \text{ when an opening is in the solid plate or in a Category H butt joint; or } 0.85 \text{ when an opening is located in an ERW or autogenously welded pipe or tube. If the ERW or autogenously welded joint is clearly identifiable and it can be shown that the opening does not pass through this weld joint, then } E = 1 \text{ may be determined using the other rules of this paragraph; or }\]

\[F = \text{joint efficiency obtained from Table UW-12 when any part of the opening passes through any other welded joint}\]

\[F_p = \text{correction factor that compensates for the variation in internal pressure stresses on different planes with respect to the axis of a vessel. A value of } 1.00 \text{ shall be used for all configurations except that Figure UG-37 may be used for integrally reinforced openings in cylindrical shells and cones. (See UG-41(a))}\]

\[f_{or} = \text{strength reduction factor, not greater than 1.0 (see UG-41(a))}\]

\[f_{st} = S_n/S_s \text{ for nozzle wall inserted through the vessel wall}\]

\[f_{iz} = 1.0 \text{ for nozzle wall abutting the vessel wall and for nozzles shown in Figure UG-40, sketch (i), (k), (l), (m) and (o)}\]

\[f_{sz} = S_s/S_n \text{ for nozzle of } S_n \text{ or } S_s \text{ (lessor of } S_n \text{ or } S_s)\]

\[f_{sz} = S_s/S_n \text{ for lessor of } S_n \text{ or } S_s\]

\[h = \text{distance nozzle projects beyond the inner surface of the vessel wall. (Extension of the nozzle beyond the inner surface of the vessel wall is not limited; however, for reinforcement calculations, credit shall not be taken for material outside the limits of reinforcement established by UG-40.})\]

\[K = \text{spherical radius factor (see definition of } r, \text{ and Table UG-37)}\]

\[L = \text{length of projection defining the thickened portion of integral reinforcement of a nozzle neck beyond the outside surface of the vessel wall (see Figure UG-40 sketch (e))}\]

\[P = \text{internal design pressure (see UG-21), psi (MPa)}\]

\[R = \text{inside radius of the shell course under consideration}\]

\[R_n = \text{inside radius of the nozzle under consideration}\]

\[S = \text{allowable stress value in tension (see UG-23), psi (MPa)}\]

\[S_n = \text{allowable stresses in nozzle, psi (MPa) (see } S \text{ above)}\]

\[S_{pl} = \text{allowable stress in reinforcing element (plate), psi (MPa) (see } S \text{ above)}\]

\[S_r = \text{allowable stress in vessel, psi (MPa) (see } S \text{ above)}\]

\[t = \text{specified vessel wall thickness, } t_0 \text{ (not including forming allowances). For pipe it is the nominal thickness less manufacturing under-tolerance allowed in the pipe specification.}\]

\[t_n = \text{thickness or height of reinforcing element (see Figure UG-40)}\]

\[t_i = \text{nominal thickness of internal projection of nozzle wall}\]

\[t_a = \text{nozzle wall thickness. Except for pipe, this is the wall thickness not including forming allowances. For pipe, use the nominal thickness (see UG-16(0)).}\]

\[t_r = \text{required thickness of a seamless shell based on the circumferential stress, or of a formed head, computed by the rules of this Division for the designated pressure, using } F = 1, \text{ except that:}\]

\(a\) when the opening and its reinforcement are entirely within the spherical portion of a torispherical head, \(t_r\) is the thickness required by 1-4(d), using \(M = 1;\)

\(b\) when the opening is in a cone, \(t_r\) is the thickness required for a seamless cone of diameter \(D\) measured where the nozzle axis pierces the inside wall of the cone;

\(c\) when the opening and its reinforcement are in an ellipsoidal head and are located entirely within a circle the center of which coincides with the center of the head and the diameter of which is equal to 80% of the shell diameter, \(t_r\) is the thickness required for a seamless sphere of radius \(K_r D\), where \(D\) is the shell diameter and \(K_r\) is given by Table UG-37.
Evaluate Weld Strength

UG-41(b)

Verify strength of Compensation

• UG-37, UG-41,
• UW-15 b) 1 exempts sketches in UW-16.1
• Our nozzle installation is equal to figure UW-16.1 c)
  • No further analysis required for weld loading as per UG-41
Figure UW-16.1
Some Acceptable Types of Welded Nozzles and Other Connections to Shells, Heads, etc.

(a) Full Penetration Weld
With Integral Reinforcement
[See UW-16 (c)(1) and Note (1)]

(b) Backing strip if used may be removed after welding

(a - 1) 1/2 t_{min} max. = t_{p}

Separate Reinforcement Plates Added [See UW-16 (c)(2)]

(a - 2) 1/2 t_{min} max. = t_{p}

(e) t_{c}

(a - 3) max. = t_{p}

(a - 4) t_{p}

(b) t_{n}

(d) t_{n}

Notes follow on last page of this Figure
\( W \) is the required weld strength to attach elements that are not an integral part of the vessel wall.
Exempt Openings

Reinforcement Calculation Exception

– UG-36 exempts small openings in vessels not subject to rapid fluctuations in pressure

• 3-1/2 in. (89 mm) diameter—in vessel shells or heads with a required minimum thickness of 3/8 in. (10 mm) or less;

• 2-3/8 in. (60 mm) diameter—in vessel shells or heads over a required minimum thickness of 3/8 in. (10 mm);
Exempt Openings (cont.)

• threaded, studded, or expanded connections in which the hole cut in the shell or head is not greater than 2-3/8 in. (60 mm) diameter

• no two isolated unreinforced openings, in accordance with above, shall have their centers closer to each other than the sum of their diameters
No centers closer to each other than the sum of their diameters

3 inch dia.

2 inch dia.

Less than or equal to 5 inches
Caution - the pwht process as well as the nozzle to shell weld may heat the shell enough to relax the shell and cause it to sink in. Additional support should be considered until the heat in the nozzle area has cooled.
2.5.3.1-Welding Method 1
Limited to:

- P-No. 1 (groups 1,2,3), P-No. 3 (Gr 1,2) no Mn-Mo steels
- SMAW, GMAW, FCAW, GTAW
- Welders and procedures qualified w/o PWHT
- Preheat required to 300°F measure 4" or 4 thicknesses from joint
- 450°F maximum interpass temperature

One principle reason for preheating and interpass heating is to prevent hydrogen cracking in the weld metal and /or HAZ. It drives off moisture, reduces the cooling rate and increases the rate of hydrogen diffusion. *WRC Bulletin 452*
Purchase Order Information

• Nozzle material
  – NPS 12 Sch 60 pipe (0.562 inch nominal wall)
    • SA-106 Gr C
    • Cut to an overall length of 29-1/2 inches, square cut ends (12 inches for welder qualification)
    • Mill Test Report required (not required by Section VIII)
    • Material marked in accordance with ASME Section II
      – SA-530 Specification for general requirements for specialized carbon and alloy steel pipe
      – SA-106 Specification for seamless carbon steel pipe for high-temperature service
Summary

• Always try to have an alteration plan consistent with the original code

• NBIC - Part 3 provides acceptable options if the alteration can not follow the manufacturing practice used to meet the original code. Make sure the Owner, Repair Inspector and Jurisdiction accept the options in the alteration plan.

• QUESTIONS?