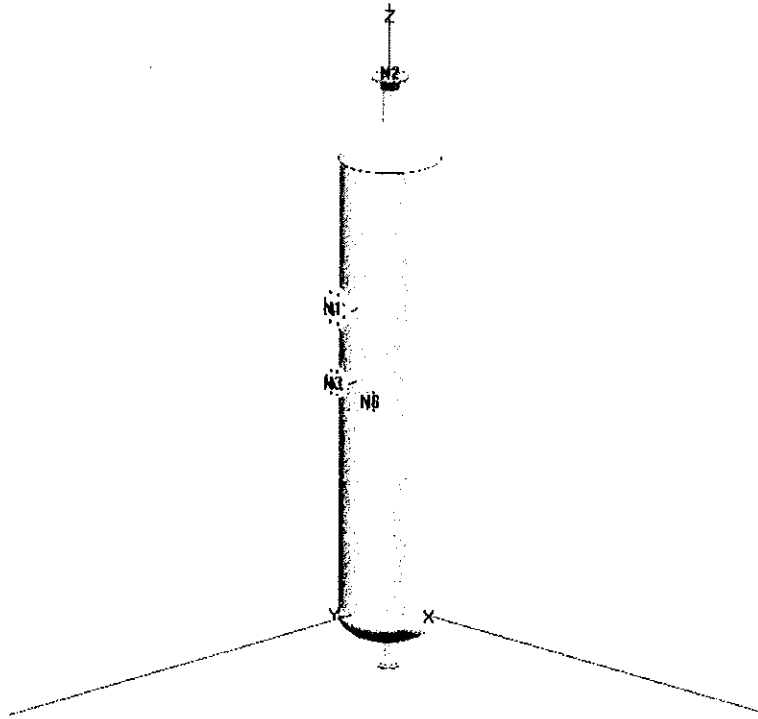


Codeware, Inc.

ASME SEC VIII, DIV I, 2010ED, 2011AD



COMPRESS Pressure Vessel Design Calculations

Item: 30" O/D x 10' S/S Separator
Vessel No: SN1667 to 1674, DWG 2013-070-300R2
Customer:
Revt: 0
Designer: Wilfred Cao
Date: Nov 08, 2013

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Ellipsoidal Head #1

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Component: Ellipsoidal Head
 Material Specification: SA-516 70 (II-D p.18, In. 19)
Straight Flange governs MDMT

Internal design pressure: P = 1,360 psi @ 194 °F

Static liquid head:

$P_s = 0$ psi (SG=1, $H_s=0$ " Operating head)
 $P_{th} = 1$ psi (SG=1, $H_s=27.72$ " Horizontal test head)

Corrosion allowance: Inner C = 0.125" Outer C = 0"

Design MDMT = -20°F No impact test performed
 Rated MDMT = -32.3°F Material is normalized
 Material is not produced to fine grain practice
 PWHT is not performed
 Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - Seamless No RT
 Head to shell seam - Full UW-11(a) Type 1

Estimated weight*: new = 374.7 lb corr = 337.4 lb
 Capacity*: new = 17.2 US gal corr = 17.7 US gal
 * includes straight flange

Outer diameter = 30"
 Minimum head thickness = 1.14"
 Head ratio D/2h = 2 (new)
 Head ratio D/2h = 1.9823 (corroded)
 Straight flange length L_{sf} = 2"
 Nominal straight flange thickness t_{sf} = 1.25"

Results Summary

The governing condition is internal pressure.
 Minimum thickness per UG-16 = $0.0625" + 0.125" = 0.1875"$
 Design thickness due to internal pressure (t) = 1.0756"
 Maximum allowable working pressure (MAWP) = 1,458.12 psi

K (Corroded)

$$K = (1/6) * [2 + (D / (2*h))^2] = (1/6) * [2 + (27.97 / (2*7.055))^2] = 0.98824$$

K (New)

$$K = (1/6) * [2 + (D / (2*h))^2] = (1/6) * [2 + (27.72 / (2*6.93))^2] = 1$$

Design thickness for internal pressure, (Corroded at 194 °F) Appendix 1-4(c)

$$\begin{aligned}
 t &= P \cdot D_o \cdot K / (2 \cdot S \cdot E + 2 \cdot P \cdot (K - 0.1)) + \text{Corrosion} \\
 &= 1,360 \cdot 30 \cdot 0.98824 / (2 \cdot 20,000 \cdot 1 + 2 \cdot 1,360 \cdot (0.98824 - 0.1)) + 0.125 \\
 &= 1.0756"
 \end{aligned}$$

The head internal pressure design thickness is 1.0756".

Maximum allowable working pressure, (Corroded at 194 °F) Appendix 1-4(c)

$$\begin{aligned}
 P &= 2 \cdot S \cdot E \cdot t / (K \cdot D_o - 2 \cdot t \cdot (K - 0.1)) - P_s \\
 &= 2 \cdot 20,000 \cdot 1 \cdot 1.015 / (0.98824 \cdot 30 - 2 \cdot 1.015 \cdot (0.98824 - 0.1)) - 0 \\
 &= 1,458.12 \text{ psi}
 \end{aligned}$$

The maximum allowable working pressure (MAWP) is 1,458.12 psi.

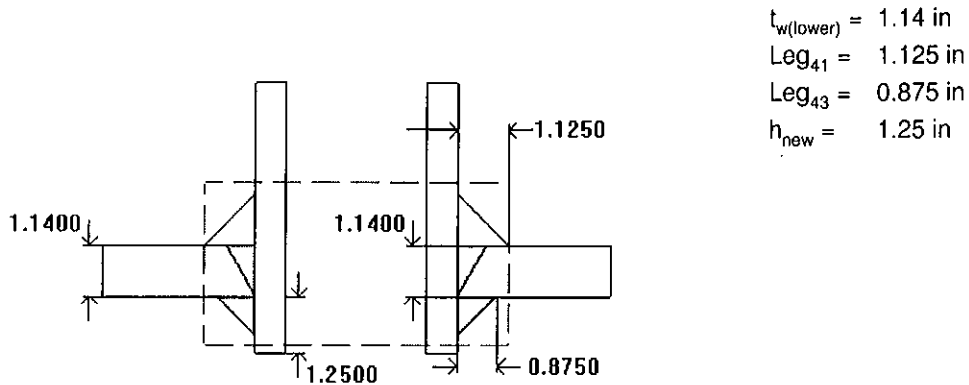
% Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 \text{EFE} &= (75 \cdot t / R_t) \cdot (1 - R_t / R_o) \\
 &= (75 \cdot 1.25 / 5.3374) \cdot (1 - 5.3374 / \infty) \\
 &= 17.5647\%
 \end{aligned}$$

The extreme fiber elongation exceeds 5 percent and the thickness exceeds 5/8 inch;. Heat treatment per UCS-56 is required if fabricated by cold forming.

Nozzle #2 (N2)

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Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	Ellipsoidal Head #1
Orientation:	0°
End of nozzle to datum line:	143 in
Calculated as hillside:	No
Distance to head center, R:	0 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Description:	NPS 4 XXS
Inside diameter, new:	3.152 in
Nominal wall thickness:	0.674 in
Corrosion allowance:	0.125 in
Projection available outside vessel, Lpr:	8.7713 in
Internal projection, h _{new} :	1.25 in
Projection available outside vessel to flange face, Lf:	13.0213 in
Local vessel minimum thickness:	1.14 in
Liquid static head included:	0 psi
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 4 Class 600 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-27.6°F per UCS-66(b)(1)(b)
Liquid static head:	0 psi

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MAWP rating:	1,367.2 psi @ 194°F
MAP rating:	1,480 psi @ 70°F
Hydrotest rating:	2,225 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Full UW-11(a) Type 1

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in²) For P = 1,367.2 psi @ 194 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
3.1706	3.6227	0.4043	0.9531	0.7685	--	1.4968	0.3324	0.5898

UG-41 Weld Failure Path Analysis Summary The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.25	0.7875	weld size is adequate

Calculations for internal pressure 1,367.2 psi @ 194 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.3074).

Nozzle UCS-66 governing thk: 0.5898 in

Nozzle rated MDMT: -155 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.402, 1.701 + (0.674 - 0.125) + (1.14 - 0.125)) \\
 &= 3.402 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_\phi) \\
 &= \text{MIN}(2.5*(1.14 - 0.125), 2.5*(0.674 - 0.125) + 0) \\
 &= 1.3725 \text{ in}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(1.14 - 0.125), 2.5*(0.674 - 0.125 - 0.125)) \\
 &= 1.06 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,367.2 \cdot 1.701 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) \\
 &= 0.1429 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned}
 t_r &= P \cdot K_1 \cdot D_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\
 &= 1,367.2 \cdot 0.892 \cdot 30 / (2 \cdot 20,000 \cdot 1 + 0.8 \cdot 1,367.2) \\
 &= 0.8903 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 17,100$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 3.402 \cdot 0.8903 \cdot 1 + 2 \cdot 0.549 \cdot 0.8903 \cdot 1 \cdot (1 - 0.855) \\
 &= \underline{3.1706} \text{ in}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.4043} \text{ in}^2$$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 3.402 \cdot (1 \cdot 1.015 - 1 \cdot 0.8903) - 2 \cdot 0.549 \cdot (1 \cdot 1.015 - 1 \cdot 0.8903) \cdot (1 - 0.855) \\
 &= 0.4043 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (1.015 + 0.549) \cdot (1 \cdot 1.015 - 1 \cdot 0.8903) - 2 \cdot 0.549 \cdot (1 \cdot 1.015 - 1 \cdot 0.8903) \cdot (1 - 0.855) \\
 &= 0.3702 \text{ in}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.9531} \text{ in}^2$$

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (0.549 - 0.1429) \cdot 0.855 \cdot 1.015 \\
 &= 1.7621 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (0.549 - 0.1429) \cdot 0.855 \cdot 0.549 \\
 &= 0.9531 \text{ in}^2
 \end{aligned}$$

$$A_3 = \text{smaller of the following} = \underline{0.7685} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot t_i \cdot f_{r2} \\ &= 5 \cdot 1.015 \cdot 0.424 \cdot 0.855 \\ &= \underline{1.8398} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot t_i \cdot f_{r2} \\ &= 5 \cdot 0.424 \cdot 0.424 \cdot 0.855 \\ &= \underline{0.7685} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot h \cdot t_i \cdot f_{r2} \\ &= 2 \cdot 1.125 \cdot 0.424 \cdot 0.855 \\ &= \underline{0.8157} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 1.125^2 \cdot 0.855 \\ &= \underline{1.0821} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{43} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.6964^2 \cdot 0.855 \\ &= \underline{0.4147} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\ &= 0.4043 + 0.9531 + 0.7685 + 1.0821 + 0.4147 \\ &= \underline{3.6227} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 0.75 or t_n or $t = 0.549$ in

$t_{c(\min)}$ = lesser of 0.25 or $0.7 \cdot t_{\min} = \underline{0.25}$ in

$t_{c(\text{actual})}$ = $0.7 \cdot \text{Leg} = 0.7 \cdot 1.125 = 0.7875$ in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned} t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\ &= 1,367.2 \cdot 1.701 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) + 0.125 \end{aligned}$$

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$$= 0.2679 \text{ in}$$

$$\begin{aligned} t_a &= \max[t_{a \text{UG-27}}, t_{a \text{UG-22}}] \\ &= \max[0.2679, 0] \\ &= 0.2679 \text{ in} \end{aligned}$$

$$t_{b1} = 1.0803 \text{ in}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{b \text{UG16}}] \\ &= \max[1.0803, 0.1875] \\ &= 1.0803 \text{ in} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[0.3324, 1.0803] \\ &= 0.3324 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[0.2679, 0.3324] \\ &= 0.3324 \text{ in} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.674 = 0.5898 \text{ in}$

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in ²) For P = 1,480 psi @ 70 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
3.248	5.2874	0.5826	1.5274	1.4407	--	1.7367	0.2074	0.5898

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.25	0.7875	weld size is adequate

Calculations for internal pressure 1,480 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.152, 1.576 + (0.674 - 0) + (1.14 - 0)) \\
 &= 3.39 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(1.14 - 0), 2.5*(0.674 - 0) + 0) \\
 &= 1.685 \text{ in}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(1.14 - 0), 2.5*(0.674 - 0 - 0)) \\
 &= 1.685 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,480 \cdot 1.576 / (17,100 \cdot 1 - 0.6 \cdot 1,480) \\
 &= 0.1439 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned} t_r &= P \cdot K_1 \cdot D_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\ &= 1,480 \cdot 0.9 \cdot 30 / (2 \cdot 20,000 \cdot 1 + 0.8 \cdot 1,480) \\ &= 0.9703 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 17,100$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.152 \cdot 0.9703 \cdot 1 + 2 \cdot 0.674 \cdot 0.9703 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{3.248} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.5826} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.152 \cdot (1 \cdot 1.14 - 1 \cdot 0.9703) - 2 \cdot 0.674 \cdot (1 \cdot 1.14 - 1 \cdot 0.9703) \cdot (1 - 0.855) \\ &= 0.5018 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (1.14 + 0.674) \cdot (1 \cdot 1.14 - 1 \cdot 0.9703) - 2 \cdot 0.674 \cdot (1 \cdot 1.14 - 1 \cdot 0.9703) \cdot (1 - 0.855) \\ &= 0.5826 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{1.5274} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.674 - 0.1439) \cdot 0.855 \cdot 1.14 \\ &= 2.5834 \text{ in}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.674 - 0.1439) \cdot 0.855 \cdot 0.674 \\ &= 1.5274 \text{ in}^2 \end{aligned}$$

$$A_3 = \text{smaller of the following} = \underline{1.4407} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot t \cdot t_i \cdot f_{r2} \\ &= 5 \cdot 1.14 \cdot 0.674 \cdot 0.855 \\ &= \underline{3.2847} \text{ in}^2 \\ &= 5 \cdot t_i \cdot t_i \cdot f_{r2} \end{aligned}$$

$$\begin{aligned}
 &= 5 * 0.674 * 0.674 * 0.855 \\
 &= \underline{1.942} \text{ in}^2 \\
 &= 2 * h * t_i * f_{r2} \\
 &= 2 * 1.25 * 0.674 * 0.855 \\
 &= \underline{1.4407} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 * f_{r2} \\
 &= 1.125^2 * 0.855 \\
 &= \underline{1.0821} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 * f_{r2} \\
 &= 0.875^2 * 0.855 \\
 &= \underline{0.6546} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0.5826 + 1.5274 + 1.4407 + 1.0821 + 0.6546 \\
 &= \underline{5.2874} \text{ in}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 0.75 or t_n or $t = 0.674$ in

$t_{c(\min)}$ = lesser of 0.25 or $0.7 * t_{\min} = \underline{0.25}$ in

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 1.125 = 0.7875$ in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P * R / (S * E - 0.6 * P) + \text{Corrosion} \\
 &= 1,480 * 1.576 / (17,100 * 1 - 0.6 * 1,480) + 0 \\
 &= 0.1439 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\
 &= \max[0.1439, 0] \\
 &= 0.1439 \text{ in}
 \end{aligned}$$

$$t_{b1} = 1.0407 \text{ in}$$

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$$\begin{aligned}t_{b1} &= \max[t_{b1} , t_{bUG16}] \\ &= \max[1.0407 , 0.0625] \\ &= 1.0407 \text{ in}\end{aligned}$$

$$\begin{aligned}t_b &= \min[t_{b3} , t_{b1}] \\ &= \min[0.2074 , 1.0407] \\ &= 0.2074 \text{ in}\end{aligned}$$

$$\begin{aligned}t_{UG-45} &= \max[t_a , t_b] \\ &= \max[0.1439 , 0.2074] \\ &= 0.2074 \text{ in}\end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.674 = 0.5898 \text{ in}$

The nozzle neck thickness is adequate.

Cylinder #1

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Component: Cylinder
 Material specification: SA-516 70 (II-D p. 18, ln. 19)
 Material impact test exemption temperature from Fig UCS-66 Curve D = -21 °F
 Fig UCS-66.1 MDMT reduction = 11.3 °F, (coincident ratio = 0.8872)
 UCS-66 governing thickness = 1.25 in

Internal design pressure: P = 1,360 psi @ 194 °F

Static liquid head:

$$P_{th} = 1 \text{ psi}_{\text{head}} \quad (\text{SG} = 1, H_s = 27.61", \text{Horizontal test})$$

Corrosion allowance Inner C = 0.125" Outer C = 0"

Design MDMT = -20 °F No impact test performed
 Rated MDMT = -32.3 °F Material is normalized
 Material is not produced to Fine Grain Practice
 PWHT is not performed

Radiography: Longitudinal joint - Full UW-11(a) Type 1
 Top circumferential joint - Full UW-11(a) Type 1
 Bottom circumferential joint - Spot UW-11(a)(5)(b) Type 1

Estimated weight New = 3,823.5 lb corr = 3,456.2 lb
 Capacity New = 308.55 US gal corr = 314.18 US gal

OD = 30"
 Length = 120"
 L_c
 t = 1.25"

Design thickness, (at 194 °F) Appendix 1-1

$$\begin{aligned} t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\ &= 1,360 \cdot 15 / (20,000 \cdot 1.00 + 0.40 \cdot 1,360) + 0.125 \\ &= 1.118" \end{aligned}$$

Maximum allowable working pressure, (at 194 °F) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\ &= 20,000 \cdot 1.00 \cdot 1.125 / (15 - 0.40 \cdot 1.125) - 0 \\ &= 1,546.39 \text{ psi} \end{aligned}$$

% Extreme fiber elongation - UCS-79(d)

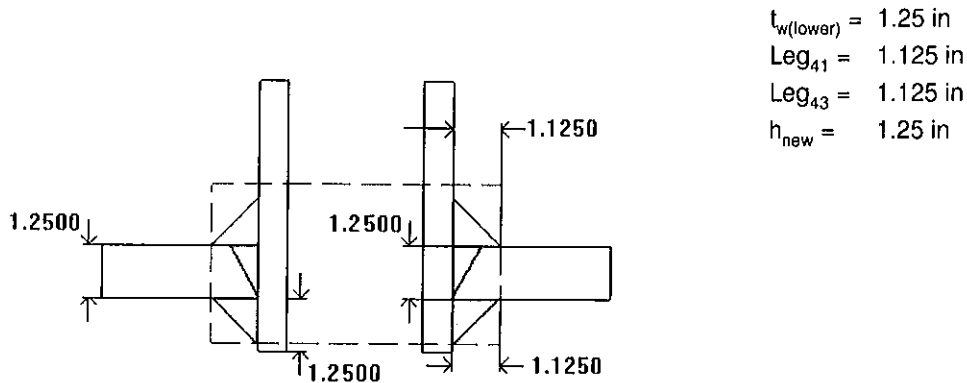
$$\begin{aligned} EFE &= (50 \cdot t / R_i) \cdot (1 - R_i / R_o) \\ &= (50 \cdot 1.25 / 14.375) \cdot (1 - 14.375 / \infty) \\ &= 4.3478\% \end{aligned}$$

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The extreme fiber elongation does not exceed 5%.

Nozzle #1 (N1)

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Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	Cylinder #1
Orientation:	90°
Nozzle center line offset to datum line:	84 in
End of nozzle to shell center:	23 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-106 B Smls pipe (II-D p. 10, In. 40)
Description:	NPS 4 XXS
Inside diameter, new:	3.152 in
Nominal wall thickness:	0.674 in
Corrosion allowance:	0.125 in
Projection available outside vessel, L _{pr} :	3.75 in
Internal projection, h _{new} :	1.25 in
Projection available outside vessel to flange face, L _f :	8 in
Local vessel minimum thickness:	1.25 in
Liquid static head included:	0 psi
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 4 Class 600 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, In. 32)
Blind included:	No
Rated MDMT:	-27.6°F per UCS-66(b)(1)(b)
Liquid static head:	0 psi
MAWP rating:	1,367.2 psi @ 194°F

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MAP rating:	1,480 psi @ 70°F
Hydrotest rating:	2,225 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Full UW-11(a) Type 1

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in²) For P = 1,367.2 psl @ 194 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
3.5545	3.981	0.4115	0.9531	0.7685	--	1.8479	0.3324	0.5898

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.25	0.7875	weld size is adequate

Calculations for internal pressure 1,367.2 psi @ 194 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.3074).

Nozzle UCS-66 governing thk: 0.5898 in

Nozzle rated MDMT: -155 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.402, 1.701 + (0.674 - 0.125) + (1.25 - 0.125)) \\
 &= 3.402 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(1.25 - 0.125), 2.5*(0.674 - 0.125) + 0) \\
 &= 1.3725 \text{ in}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(1.25 - 0.125), 2.5*(0.674 - 0.125 - 0.125)) \\
 &= 1.06 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned} t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\ &= 1,367.2 \cdot 1.701 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) \\ &= 0.1429 \text{ in} \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\ &= 1,367.2 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,367.2) \\ &= 0.9981 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 17,100$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.402 \cdot 0.9981 \cdot 1 + 2 \cdot 0.549 \cdot 0.9981 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{3.5545} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.4115} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.402 \cdot (1 \cdot 1.125 - 1 \cdot 0.9981) - 2 \cdot 0.549 \cdot (1 \cdot 1.125 - 1 \cdot 0.9981) \cdot (1 - 0.855) \\ &= 0.4115 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (1.125 + 0.549) \cdot (1 \cdot 1.125 - 1 \cdot 0.9981) - 2 \cdot 0.549 \cdot (1 \cdot 1.125 - 1 \cdot 0.9981) \cdot (1 - 0.855) \\ &= 0.4046 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.9531} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.549 - 0.1429) \cdot 0.855 \cdot 1.125 \\ &= 1.9531 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.549 - 0.1429) \cdot 0.855 \cdot 0.549 \\ &= 0.9531 \text{ in}^2 \end{aligned}$$

$$A_3 = \text{smaller of the following} = \underline{0.7685} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot t_1 \cdot t_2 \\ &= 5 \cdot 1.125 \cdot 0.424 \cdot 0.855 \\ &= \underline{2.0392} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot t_1 \cdot t_2 \\ &= 5 \cdot 0.424 \cdot 0.424 \cdot 0.855 \\ &= \underline{0.7685} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot h \cdot t_1 \cdot t_2 \\ &= 2 \cdot 1.125 \cdot 0.424 \cdot 0.855 \\ &= \underline{0.8157} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot t_2 \\ &= 1.125^2 \cdot 0.855 \\ &= \underline{1.0821} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{43} &= \text{Leg}^2 \cdot t_2 \\ &= 0.9464^2 \cdot 0.855 \\ &= \underline{0.7658} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\ &= 0.4115 + 0.9531 + 0.7685 + 1.0821 + 0.7658 \\ &= \underline{3.981} \text{ in}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 0.75 or t_n or $t = 0.549$ in

$t_{c(\min)}$ = lesser of 0.25 or $0.7 \cdot t_{\min} = \underline{0.25}$ in

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 1.125 = 0.7875$ in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned} t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\ &= 1,367.2 \cdot 1.701 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) + 0.125 \\ &= 0.2679 \text{ in} \end{aligned}$$

$$t_a = \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}]$$

$$= \max[0.2679 , 0]$$

$$= 0.2679 \text{ in}$$

$$t_{b1} = P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion}$$

$$= 1,367.2 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,367.2) + 0.125$$

$$= 1.1231 \text{ in}$$

$$t_{b1} = \max[t_{b1} , t_{bUG16}]$$

$$= \max[1.1231 , 0.1875]$$

$$= 1.1231 \text{ in}$$

$$t_b = \min[t_{b3} , t_{b1}]$$

$$= \min[0.3324 , 1.1231]$$

$$= 0.3324 \text{ in}$$

$$t_{UG-45} = \max[t_a , t_b]$$

$$= \max[0.2679 , 0.3324]$$

$$= 0.3324 \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.674 = 0.5898 \text{ in}$

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in ²) For P = 1,480 psi @ 70 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
3.6089	5.7602	0.6279	1.5274	1.4407	--	2.1642	0.2074	0.5898

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.25	0.7875	weld size is adequate

Calculations for internal pressure 1,480 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.152, 1.576 + (0.674 - 0) + (1.25 - 0)) \\
 &= 3.5 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(1.25 - 0), 2.5*(0.674 - 0) + 0) \\
 &= 1.685 \text{ in}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(1.25 - 0), 2.5*(0.674 - 0 - 0)) \\
 &= 1.685 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P * R_n / (S_n * E - 0.6 * P) \\
 &= 1,480 * 1.576 / (17,100 * 1 - 0.6 * 1,480) \\
 &= 0.1439 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\ &= 1,480 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,480) \\ &= 1.0781 \text{ in} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 17,100$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.152 \cdot 1.0781 \cdot 1 + 2 \cdot 0.674 \cdot 1.0781 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{3.6089} \text{ in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{0.6279} \text{ in}^2$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.152 \cdot (1 \cdot 1.25 - 1 \cdot 1.0781) - 2 \cdot 0.674 \cdot (1 \cdot 1.25 - 1 \cdot 1.0781) \cdot (1 - 0.855) \\ &= 0.5083 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (1.25 + 0.674) \cdot (1 \cdot 1.25 - 1 \cdot 1.0781) - 2 \cdot 0.674 \cdot (1 \cdot 1.25 - 1 \cdot 1.0781) \cdot (1 - 0.855) \\ &= 0.6279 \text{ in}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{1.5274} \text{ in}^2$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.674 - 0.1439) \cdot 0.855 \cdot 1.25 \\ &= 2.8327 \text{ in}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.674 - 0.1439) \cdot 0.855 \cdot 0.674 \\ &= 1.5274 \text{ in}^2 \end{aligned}$$

$A_3 = \text{smaller of the following} = \underline{1.4407} \text{ in}^2$

$$\begin{aligned} &= 5 \cdot t \cdot t_i \cdot f_{r2} \\ &= 5 \cdot 1.25 \cdot 0.674 \cdot 0.855 \\ &= \underline{3.6017} \text{ in}^2 \\ &= 5 \cdot t_i \cdot t_i \cdot f_{r2} \end{aligned}$$

$$\begin{aligned}
 &= 5 \cdot 0.674 \cdot 0.674 \cdot 0.855 \\
 &= \underline{1.942} \text{ in}^2 \\
 &= 2 \cdot h \cdot t_f \cdot f_{r2} \\
 &= 2 \cdot 1.25 \cdot 0.674 \cdot 0.855 \\
 &= \underline{1.4407} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 1.125^2 \cdot 0.855 \\
 &= \underline{1.0821} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 1.125^2 \cdot 0.855 \\
 &= \underline{1.0821} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0.6279 + 1.5274 + 1.4407 + 1.0821 + 1.0821 \\
 &= \underline{5.7602} \text{ in}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

$$\begin{aligned}
 \text{Fillet weld: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.674 \text{ in} \\
 t_{c(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.25} \text{ in} \\
 t_{c(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 1.125 = 0.7875 \text{ in}
 \end{aligned}$$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\
 &= 1,480 \cdot 1.576 / (17,100 \cdot 1 - 0.6 \cdot 1,480) + 0 \\
 &= 0.1439 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\
 &= \max[0.1439, 0] \\
 &= 0.1439 \text{ in}
 \end{aligned}$$

$$\begin{aligned}
 t_{b1} &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion} \\
 &= 1,480 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,480) + 0 \\
 &= 1.0781 \text{ in}
 \end{aligned}$$

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$$\begin{aligned}t_{b1} &= \max[t_{b1} , t_{bUG16}] \\ &= \max[1.0781 , 0.0625] \\ &= 1.0781 \text{ in}\end{aligned}$$

$$\begin{aligned}t_b &= \min[t_{b3} , t_{b1}] \\ &= \min[0.2074 , 1.0781] \\ &= 0.2074 \text{ in}\end{aligned}$$

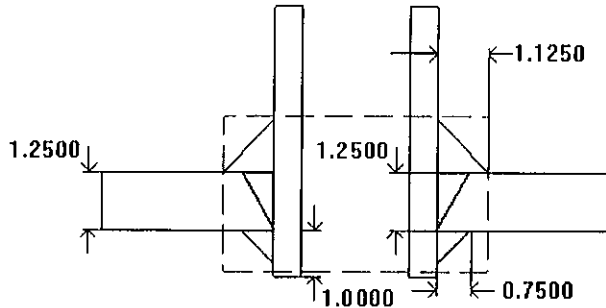
$$\begin{aligned}t_{UG-45} &= \max[t_a , t_b] \\ &= \max[0.1439 , 0.2074] \\ &= 0.2074 \text{ in}\end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.674 = 0.5898$ in

The nozzle neck thickness is adequate.

Nozzle #3 (N3)

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$t_{w(lower)} = 1.25$ in
 $Leg_{41} = 1.125$ in
 $Leg_{43} = 0.75$ in
 $h_{new} = 1$ in

Note: round inside edges per UG-76(c)

Location and Orientation

Located on: Cylinder #1
 Orientation: 90°
 Nozzle center line offset to datum line: 64 in
 End of nozzle to shell center: 23 in
 Passes through a Category A joint: No

Nozzle

Access opening: No
 Material specification: SA-106 B Smls pipe (II-D p. 10, ln. 40)
 Description: NPS 3 XXS
 Inside diameter, new: 2.3 in
 Nominal wall thickness: 0.6 in
 Corrosion allowance: 0.125 in
 Projection available outside vessel, L_{pr}: 4.5 in
 Internal projection, h_{new} : 1 in
 Projection available outside vessel to flange face, L_f: 8 in
 Local vessel minimum thickness: 1.25 in
 Liquid static head included: 0 psi
 Longitudinal joint efficiency: 1

ASME B16.5-2009 Flange

Description: NPS 3 Class 600 WN A105
 Bolt Material: SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 334, ln. 32)
 Blind included: No
 Rated MDMT: -27.6° F per UCS-66(b)(1)(b)
 Liquid static head: 0 psi
 MAWP rating: 1,367.2 psi @ 194° F

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MAP rating:	1,480 psi @ 70°F
Hydrotest rating:	2,225 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Full UW-11(a) Type 1

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in²) For P = 1,367.2 psi @ 194 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
2.6827	3.0207	0.3886	0.7471	0.5237	--	1.3613	0.314	0.525

UG-41 Weld Failure Path Analysis Summary The nozzle is exempt from weld strength calculations per UW-15(b)(1)
--

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.25	0.7875	weld size is adequate

Calculations for internal pressure 1,367.2 psi @ 194 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.2677).

Nozzle UCS-66 governing thk: 0.525 in

Nozzle rated MDMT: -155 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.55, 1.275 + (0.6 - 0.125) + (1.25 - 0.125)) \\
 &= 2.875 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(1.25 - 0.125), 2.5*(0.6 - 0.125) + 0) \\
 &= 1.1875 \text{ in}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(1.25 - 0.125), 2.5*(0.6 - 0.125 - 0.125)) \\
 &= 0.875 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,367.2 \cdot 1.275 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) \\
 &= 0.1071 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 1,367.2 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,367.2) \\
 &= 0.9981 \text{ in}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 17,100$, $S_v = 20,000$ psi

$$f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 0.855$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 2.55 \cdot 0.9981 \cdot 1 + 2 \cdot 0.475 \cdot 0.9981 \cdot 1 \cdot (1 - 0.855) \\
 &= \underline{2.6827} \text{ in}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.3886} \text{ in}^2$$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2.55 \cdot (1 \cdot 1.125 - 1 \cdot 0.9981) - 2 \cdot 0.475 \cdot (1 \cdot 1.125 - 1 \cdot 0.9981) \cdot (1 - 0.855) \\
 &= 0.3061 \text{ in}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (1.125 + 0.475) \cdot (1 \cdot 1.125 - 1 \cdot 0.9981) - 2 \cdot 0.475 \cdot (1 \cdot 1.125 - 1 \cdot 0.9981) \cdot (1 - 0.855) \\
 &= 0.3886 \text{ in}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.7471} \text{ in}^2$$

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (0.475 - 0.1071) \cdot 0.855 \cdot 1.125 \\
 &= 1.7694 \text{ in}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (0.475 - 0.1071) \cdot 0.855 \cdot 0.475 \\
 &= 0.7471 \text{ in}^2
 \end{aligned}$$

$$A_3 = \text{smaller of the following} = \underline{0.5237} \text{ in}^2$$

$$\begin{aligned}
 &= 5 * t_i * f_{r2} \\
 &= 5 * 1.125 * 0.35 * 0.855 \\
 &= \underline{1.6833} \text{ in}^2 \\
 &= 5 * t_i * t_i * f_{r2} \\
 &= 5 * 0.35 * 0.35 * 0.855 \\
 &= \underline{0.5237} \text{ in}^2 \\
 &= 2 * h * t_i * f_{r2} \\
 &= 2 * 0.875 * 0.35 * 0.855 \\
 &= \underline{0.5237} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 * f_{r2} \\
 &= 1.125^2 * 0.855 \\
 &= \underline{1.0821} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{43} &= \text{Leg}^2 * f_{r2} \\
 &= 0.5714^2 * 0.855 \\
 &= \underline{0.2792} \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
 &= 0.3886 + 0.7471 + 0.5237 + 1.0821 + 0.2792 \\
 &= \underline{3.0207} \text{ in}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 0.75 or t_n or $t = 0.475$ in

$t_{c(\min)}$ = lesser of 0.25 or $0.7 * t_{\min} = \underline{0.25}$ in

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 1.125 = 0.7875$ in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
 t_{a \text{ UG-27}} &= P * R / (S * E - 0.6 * P) + \text{Corrosion} \\
 &= 1,367.2 * 1.275 / (17,100 * 1 - 0.6 * 1,367.2) + 0.125 \\
 &= 0.2321 \text{ in}
 \end{aligned}$$

$$t_a = \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}]$$

$$= \max[0.2321 , 0]$$

$$= 0.2321 \text{ in}$$

$$t_{b1} = P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion}$$

$$= 1,367.2 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,367.2) + 0.125$$

$$= 1.1231 \text{ in}$$

$$t_{b1} = \max[t_{b1} , t_{bUG16}]$$

$$= \max[1.1231 , 0.1875]$$

$$= 1.1231 \text{ in}$$

$$t_b = \min[t_{b3} , t_{b1}]$$

$$= \min[0.314 , 1.1231]$$

$$= 0.314 \text{ in}$$

$$t_{UG-45} = \max[t_a , t_b]$$

$$= \max[0.2321 , 0.314]$$

$$= 0.314 \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.6 = 0.525 \text{ in}$

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in ²) For P = 1,480 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.189	0.525

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.25	0.7875	weld size is adequate

Calculations for internal pressure 1,480 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.3, 1.15 + (0.6 - 0) + (1.25 - 0)) \\
 &= 3 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_g) \\
 &= \text{MIN}(2.5*(1.25 - 0), 2.5*(0.6 - 0) + 0) \\
 &= 1.5 \text{ in}
 \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_I &= \text{MIN}(2.5*(t - C), 2.5*(t_i - C_n - C)) \\
 &= \text{MIN}(2.5*(1.25 - 0), 2.5*(0.6 - 0 - 0)) \\
 &= 1.5 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,480 \cdot 1.15 / (17,100 \cdot 1 - 0.6 \cdot 1,480) \\
 &= 0.105 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\ &= 1,480 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,480) \\ &= 1.0781 \text{ in} \end{aligned}$$

This opening does not require reinforcement per UG-36(c)(3)(a)

UW-16(c) Weld Check

$$\begin{aligned} \text{Fillet weld: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.6 \text{ in} \\ t_{c(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = 0.25 \text{ in} \\ t_{c(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 1.125 = 0.7875 \text{ in} \end{aligned}$$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned} t_{a \text{UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\ &= 1,480 \cdot 1.15 / (17,100 \cdot 1 - 0.6 \cdot 1,480) + 0 \\ &= 0.105 \text{ in} \end{aligned}$$

$$\begin{aligned} t_a &= \max[t_{a \text{UG-27}}, t_{a \text{UG-22}}] \\ &= \max[0.105, 0] \\ &= 0.105 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion} \\ &= 1,480 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,480) + 0 \\ &= 1.0781 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{b \text{UG16}}] \\ &= \max[1.0781, 0.0625] \\ &= 1.0781 \text{ in} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[0.189, 1.0781] \\ &= 0.189 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[0.105, 0.189] \\ &= 0.189 \text{ in} \end{aligned}$$

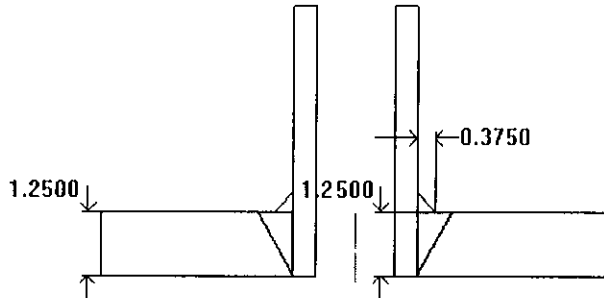
Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.6 = 0.525 \text{ in}$

The nozzle neck thickness is adequate.

Nozzle #5 (N6)

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$t_{w(lower)} = 1.25$ in
 $Leg_{41} = 0.375$ in



Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	Cylinder #1
Orientation:	60°
Nozzle center line offset to datum line:	60 in
End of nozzle to shell center:	21 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Description:	NPS 2 XXS
Inside diameter, new:	1.503 in
Nominal wall thickness:	0.436 in
Corrosion allowance:	0.125 in
Projection available outside vessel, Lpr:	2.87 in
Projection available outside vessel to flange face, Lf:	6 in
Local vessel minimum thickness:	1.25 in
Liquid static head included:	0 psi
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 2 Class 600 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-27.6°F per UCS-66(b)(1)(b)
Liquid static head:	0 psi
MAWP rating:	1,367.2 psi @ 194°F
MAP rating:	1,480 psi @ 70°F

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Hydrotest rating:	2,225 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Full UW-11(a) Type 1

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in ²) For P = 1,367.2 psi @ 194 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.2598	0.3815

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.2177	0.2625	weld size is adequate

Calculations for internal pressure 1,367.2 psi @ 194 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.287).

Nozzle UCS-66 governing thk: 0.3815 in

Nozzle rated MDMT: -155 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.753, 0.8765 + (0.436 - 0.125) + (1.25 - 0.125)) \\
 &= 2.3125 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(1.25 - 0.125), 2.5*(0.436 - 0.125) + 0) \\
 &= 0.7775 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,367.2 \cdot 0.8765 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) \\
 &= 0.0736 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\ &= 1,367.2 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,367.2) \\ &= 0.9981 \text{ in} \end{aligned}$$

This opening does not require reinforcement per UG-36(c)(3)(a)

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 0.75 or t_n or $t = 0.311$ in

$$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.2177} \text{ in}$$

$$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.375 = 0.2625 \text{ in}$$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned} t_{a \text{UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\ &= 1,367.2 \cdot 0.8765 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) + 0.125 \\ &= 0.1986 \text{ in} \end{aligned}$$

$$\begin{aligned} t_a &= \max[t_{a \text{UG-27}}, t_{a \text{UG-22}}] \\ &= \max[0.1986, 0] \\ &= 0.1986 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion} \\ &= 1,367.2 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,367.2) + 0.125 \\ &= 1.1231 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{b \text{UG16}}] \\ &= \max[1.1231, 0.1875] \\ &= 1.1231 \text{ in} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[0.2598, 1.1231] \\ &= 0.2598 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[0.1986, 0.2598] \\ &= 0.2598 \text{ in} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.436 = 0.3815$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in ²) For P = 1,480 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.3815

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (ln)	Actual weld throat size (ln)	Status
Nozzle to shell fillet (Leg ₄₁)	0.25	0.2625	weld size is adequate

Calculations for internal pressure 1,480 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.503, 0.7515 + (0.436 - 0) + (1.25 - 0)) \\
 &= 2.4375 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(1.25 - 0), 2.5*(0.436 - 0) + 0) \\
 &= 1.09 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,480 \cdot 0.7515 / (17,100 \cdot 1 - 0.6 \cdot 1,480) \\
 &= 0.0686 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 1,480 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,480) \\
 &= 1.0781 \text{ in}
 \end{aligned}$$

This opening does not require reinforcement per UG-36(c)(3)(a)

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.436 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = 0.25 \text{ in}$

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.375 = 0.2625 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

$$\begin{aligned} t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\ &= 1,480 \cdot 0.7515 / (17,100 \cdot 1 - 0.6 \cdot 1,480) + 0 \\ &= 0.0686 \text{ in} \end{aligned}$$

$$\begin{aligned} t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\ &= \max[0.0686, 0] \\ &= 0.0686 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) + \text{Corrosion} \\ &= 1,480 \cdot 15 / (20,000 \cdot 1 + 0.4 \cdot 1,480) + 0 \\ &= 1.0781 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{b \text{ UG16}}] \\ &= \max[1.0781, 0.0625] \\ &= 1.0781 \text{ in} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[0.1348, 1.0781] \\ &= 0.1348 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[0.0686, 0.1348] \\ &= 0.1348 \text{ in} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.436 = 0.3815 \text{ in}$

The nozzle neck thickness is adequate.

Ellipsoidal Head #2

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Component: Ellipsoidal Head
 Material Specification: SA-516 70 (II-D p.18, ln. 19)
Straight Flange governs MDMT

Internal design pressure: P = 1,360 psi @ 194 °F

Static liquid head:

$P_s = 0$ psi (SG=1, $H_s=0$ " Operating head)
 $P_{th} = 1$ psi (SG=1, $H_s=27.72$ " Horizontal test head)

Corrosion allowance: Inner C = 0.125" Outer C = 0"

Design MDMT = -20 °F	No impact test performed
Rated MDMT = -32.3 °F	Material is normalized
	Material is not produced to fine grain practice
	PWHT is not performed
	Do not Optimize MDMT / Find MAWP

Radiography:	Category A joints -	Seamless No RT
	Head to shell seam -	Spot UW-11(a)(5)(b) Type 1

Estimated weight*: new = 378.4 lb	corr = 340.7 lb
Capacity*: new = 17.2 US gal	corr = 17.7 US gal

* includes straight flange

Outer diameter	= 30"
Minimum head thickness	= 1.14"
Head ratio D/2h	= 2 (new)
Head ratio D/2h	= 1.9823 (corroded)
Straight flange length L_{sf}	= 2"
Nominal straight flange thickness t_{sf}	= 1.25"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	= 0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	= <u>1.0756"</u>
Maximum allowable working pressure (MAWP)	= <u>1,458.12</u> psi

K (Corroded)

$$K = (1/6) * [2 + (D / (2*h))^2] = (1/6) * [2 + (27.97 / (2*7.055))^2] = 0.98824$$

K (New)

$$K = (1/6) * [2 + (D / (2*h))^2] = (1/6) * [2 + (27.72 / (2*6.93))^2] = 1$$

Design thickness for internal pressure, (Corroded at 194 °F) Appendix 1-4(c)

$$\begin{aligned}
 t &= P \cdot D_o \cdot K / (2 \cdot S \cdot E + 2 \cdot P \cdot (K - 0.1)) + \text{Corrosion} \\
 &= 1,360 \cdot 30 \cdot 0.98824 / (2 \cdot 20,000 \cdot 1 + 2 \cdot 1,360 \cdot (0.98824 - 0.1)) + 0.125 \\
 &= 1.0756"
 \end{aligned}$$

The head internal pressure design thickness is 1.0756".

Maximum allowable working pressure, (Corroded at 194 °F) Appendix 1-4(c)

$$\begin{aligned}
 P &= 2 \cdot S \cdot E \cdot t / (K \cdot D_o - 2 \cdot t \cdot (K - 0.1)) - P_s \\
 &= 2 \cdot 20,000 \cdot 1 \cdot 1.015 / (0.98824 \cdot 30 - 2 \cdot 1.015 \cdot (0.98824 - 0.1)) - 0 \\
 &= 1,458.12 \text{ psi}
 \end{aligned}$$

The maximum allowable working pressure (MAWP) is 1,458.12 psi.

% Extreme fiber elongation - UCS-79(d)

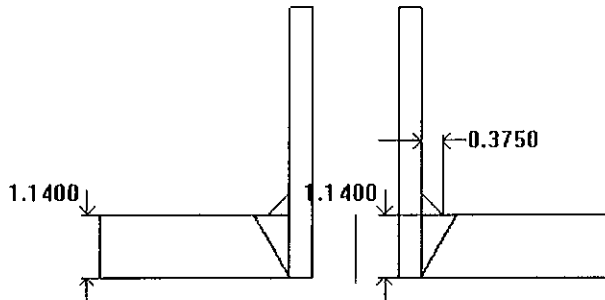
$$\begin{aligned}
 EFE &= (75 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (75 \cdot 1.25 / 5.3374) \cdot (1 - 5.3374 / \infty) \\
 &= 17.5647\%
 \end{aligned}$$

The extreme fiber elongation exceeds 5 percent and the thickness exceeds 5/8 inch;. Heat treatment per UCS-56 is required if fabricated by cold forming.

Nozzle #4 (N5)

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$t_{w(lower)} = 1.14$ in
 $Leg_{41} = 0.375$ in



Note: round inside edges per UG-76(c)

Location and Orientation

Located on:	Ellipsoidal Head #2
Orientation:	0°
End of nozzle to datum line:	-17 in
Calculated as hillside:	No
Distance to head center, R:	0 in
Passes through a Category A joint:	No

Nozzle

Access opening:	No
Material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Description:	NPS 2 XXS
Inside diameter, new:	1.503 in
Nominal wall thickness:	0.436 in
Corrosion allowance:	0.125 in
Projection available outside vessel, L _{pr} :	3.8253 in
Projection available outside vessel to flange face, L _f :	6.9553 in
Local vessel minimum thickness:	1.14 in
Liquid static head included:	0 psi
Longitudinal joint efficiency:	1

ASME B16.5-2009 Flange

Description:	NPS 2 Class 600 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Blind included:	No
Rated MDMT:	-27.6°F per UCS-66(b)(1)(b)
Liquid static head:	0 psi
MAWP rating:	1,367.2 psi @ 194°F

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MAP rating:	1,480 psi @ 70°F
Hydrotest rating:	2,225 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	Full UW-11(a) Type 1

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in ²) For P = 1,367.2 psi @ 194 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.2598	0.3815

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.2177	0.2625	weld size is adequate

Calculations for internal pressure 1,367.2 psi @ 194 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.287).

Nozzle UCS-66 governing thk: 0.3815 in

Nozzle rated MDMT: -155 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.753, 0.8765 + (0.436 - 0.125) + (1.14 - 0.125)) \\
 &= 2.2025 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_\theta) \\
 &= \text{MIN}(2.5*(1.14 - 0.125), 2.5*(0.436 - 0.125) + 0) \\
 &= 0.7775 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,367.2 \cdot 0.8765 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) \\
 &= 0.0736 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned} t_r &= P \cdot K_f \cdot D_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\ &= 1,367.2 \cdot 0.892 \cdot 30 / (2 \cdot 20,000 \cdot 1 + 0.8 \cdot 1,367.2) \\ &= 0.8903 \text{ in} \end{aligned}$$

This opening does not require reinforcement per UG-36(c)(3)(a)

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 0.75 or t_n or $t = 0.311$ in

$t_{c(\min)}$ = lesser of 0.25 or $0.7 \cdot t_{\min} = 0.2177$ in

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.375 = 0.2625$ in

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned} t_{a \text{ UG-27}} &= P \cdot R / (S \cdot E - 0.6 \cdot P) + \text{Corrosion} \\ &= 1,367.2 \cdot 0.8765 / (17,100 \cdot 1 - 0.6 \cdot 1,367.2) + 0.125 \\ &= 0.1986 \text{ in} \end{aligned}$$

$$\begin{aligned} t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\ &= \max[0.1986, 0] \\ &= 0.1986 \text{ in} \end{aligned}$$

$$t_{b1} = 1.0803 \text{ in}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{b \text{ UG16}}] \\ &= \max[1.0803, 0.1875] \\ &= 1.0803 \text{ in} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[0.2598, 1.0803] \\ &= 0.2598 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[0.1986, 0.2598] \\ &= 0.2598 \text{ in} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.436 = 0.3815$ in

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The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The attached ASME B16.5 flange limits the nozzle MAP.

UG-37 Area Calculation Summary (in ²) For P = 1,480 psi @ 70 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.3815

UG-41 Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(2)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg ₄₁)	0.25	0.2625	weld size is adequate

Calculations for internal pressure 1,480 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.503, 0.7515 + (0.436 - 0) + (1.14 - 0)) \\
 &= 2.3275 \text{ in}
 \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_o) \\
 &= \text{MIN}(2.5*(1.14 - 0), 2.5*(0.436 - 0) + 0) \\
 &= 1.09 \text{ in}
 \end{aligned}$$

Nozzle required thickness per UG-27(c)(1)

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,480 \cdot 0.7515 / (17,100 \cdot 1 - 0.6 \cdot 1,480) \\
 &= 0.0686 \text{ in}
 \end{aligned}$$

Required thickness t_r from UG-37(a)(c)

$$\begin{aligned}
 t_r &= P \cdot K_1 \cdot D_o / (2 \cdot S \cdot E + 0.8 \cdot P) \\
 &= 1,480 \cdot 0.9 \cdot 30 / (2 \cdot 20,000 \cdot 1 + 0.8 \cdot 1,480) \\
 &= 0.9703 \text{ in}
 \end{aligned}$$

This opening does not require reinforcement per UG-36(c)(3)(a)

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.436 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = 0.25 \text{ in}$

$t_{c(\text{actual})} = 0.7*\text{Leg} = 0.7*0.375 = 0.2625 \text{ in}$

The fillet weld size is satisfactory.

Weld strength calculations are not required for this detail which conforms to Fig. UW-16.1, sketch (c-e).

UG-45 Nozzle Neck Thickness Check

Interpretation VIII-1-83-66 has been applied.

$$\begin{aligned} t_{a \text{ UG-27}} &= P*R / (S*E - 0.6*P) + \text{Corrosion} \\ &= 1,480*0.7515 / (17,100*1 - 0.6*1,480) + 0 \\ &= 0.0686 \text{ in} \end{aligned}$$

$$\begin{aligned} t_a &= \max[t_{a \text{ UG-27}}, t_{a \text{ UG-22}}] \\ &= \max[0.0686, 0] \\ &= 0.0686 \text{ in} \end{aligned}$$

$$t_{b1} = 1.0407 \text{ in}$$

$$\begin{aligned} t_{b1} &= \max[t_{b1}, t_{b \text{ UG16}}] \\ &= \max[1.0407, 0.0625] \\ &= 1.0407 \text{ in} \end{aligned}$$

$$\begin{aligned} t_b &= \min[t_{b3}, t_{b1}] \\ &= \min[0.1348, 1.0407] \\ &= 0.1348 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{\text{UG-45}} &= \max[t_a, t_b] \\ &= \max[0.0686, 0.1348] \\ &= 0.1348 \text{ in} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875*0.436 = 0.3815 \text{ in}$

The nozzle neck thickness is adequate.

shell:

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$$S = \frac{P(R - 0.4t)}{Et}$$

$$= \frac{2040(15 - 0.4 \times 1.25)}{1.25}$$

$$= 23664 \text{ psi}$$

$$< 0.9 \times 38,000$$

$$= 34,200 \text{ psi}$$