

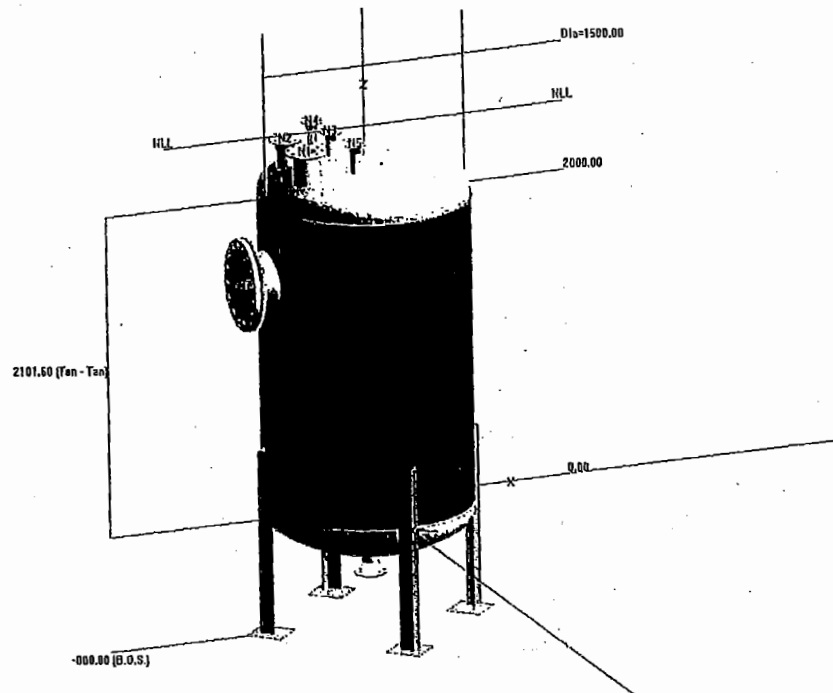
EXHIBIT V

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PERFORMANCE GROUP(USA), INC.

OAKLAND, CALIFORNIA, USA

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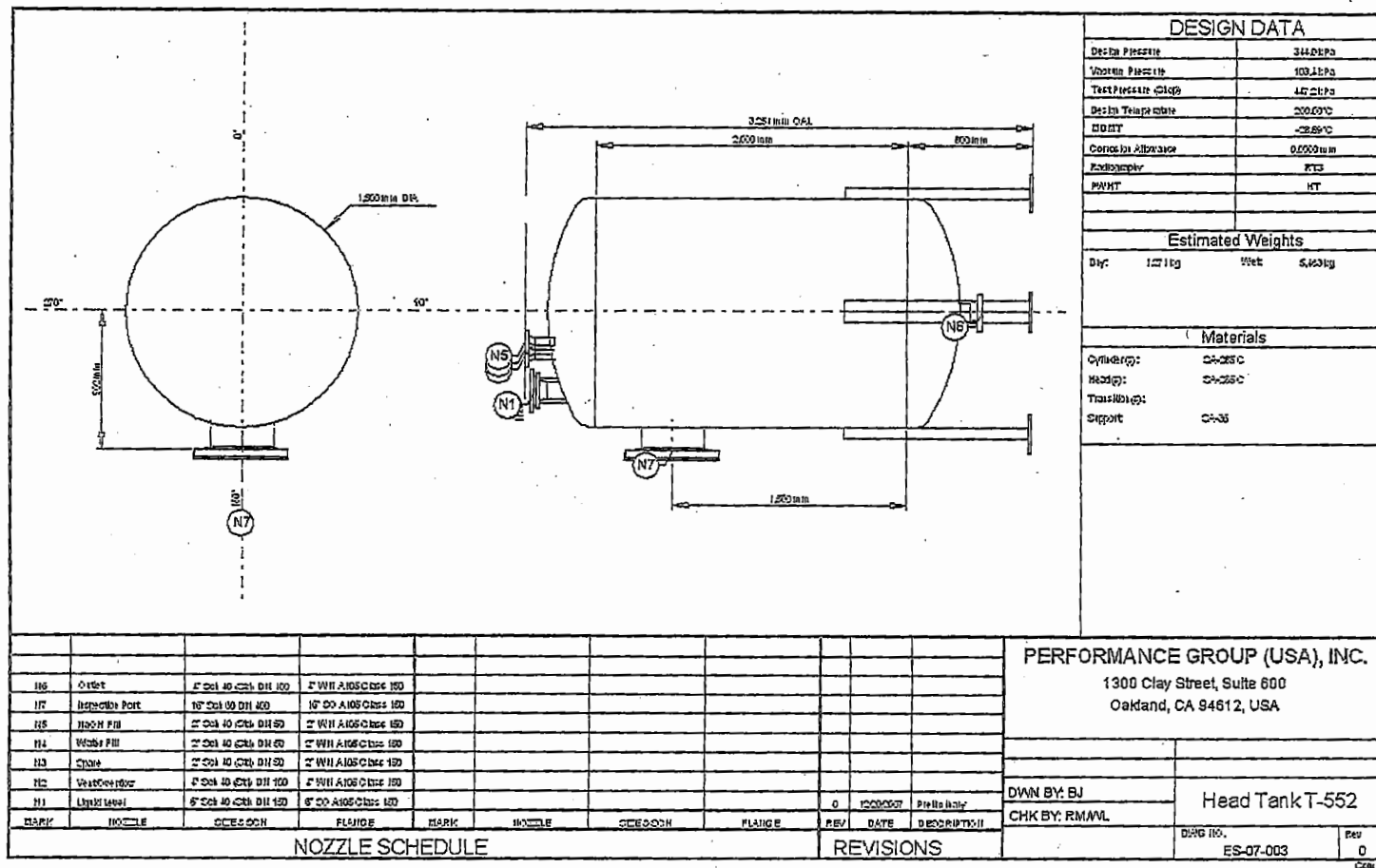
COMPRESS Pressure Vessel Design Calculations

Item: Head Tank
Vessel No: T-552
Customer: Pangang Group Jinzhou Titanium Industry, Inc.
Contract: PJTY-FEI-07-02
Designer: BJ Bhatnagar
Date: Dec. 20, 2007

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Deficiencies Summary

No deficiencies found.

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Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
<u>N1</u>	Liquid Level	6" Sch 40 (Std) DN 150	SA-106 B Smis. Pipe	No	No	No	N/A	N/A	N/A	N/A	SO A105 Class 150
<u>N2</u>	Vent/Overflow	4" Sch 40 (Std) DN 100	SA-106 B Smis. Pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
<u>N3</u>	Spare	2" Sch 40 (Std) DN 50	SA-106 B Smis. Pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
<u>N4</u>	Water Fill	2" Sch 40 (Std) DN 50	SA-106 B Smis. Pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
<u>N5</u>	NaOH Fill	2" Sch 40 (Std) DN 50	SA-106 B Smis. Pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
<u>N6</u>	Outlet	4" Sch 40 (Std) DN 100	SA-106 B Smis. Pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
<u>N7</u>	Inspection Port	16" Sch 60 DN 400	SA-106 B Smis. Pipe	No	No	No	N/A	N/A	N/A	N/A	SO A105 Class 150

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Nozzle Summary

Nozzle mark	OD (mm)	t_n (mm)	Req t_n (mm)	$A_1?$	$A_2?$	Shell			Reinforcement Pad		Corr (mm)	A/A_1 (%)
						Nom t (mm)	Design t (mm)	User t (mm)	Width (mm)	t_{pad} (mm)		
<u>N1</u>	168.27	7.11	7.11	Yes	Yes	9.00*	6.22		N/A	N/A	0.00	100.0
<u>N2</u>	114.30	6.02	6.02	Yes	Yes	9.00*	5.49		N/A	N/A	0.00	100.0
<u>N3</u>	60.33	3.91	3.91	Yes	Yes	9.00*	N/A		N/A	N/A	0.00	Exempt
<u>N4</u>	60.33	3.91	3.91	Yes	Yes	9.00*	N/A		N/A	N/A	0.00	Exempt
<u>N5</u>	60.33	3.91	3.91	Yes	Yes	9.00*	N/A		N/A	N/A	0.00	Exempt
<u>N6</u>	114.30	6.02	6.02	Yes	Yes	9.00*	6.33		N/A	N/A	0.00	100.0
<u>N7</u>	406.40	16.66	7.02	Yes	Yes	9.00	7.69		N/A	N/A	0.00	100.0

t_n : Nozzle thickness

Req t_n : Nozzle thickness required per UG-45/UG-16

Nom t : Vessel wall thickness

Design t : Required vessel wall thickness due to pressure + corrosion allowance per UG-37

User t : Local vessel wall thickness (near opening)

A_a : Area available per UG-37, governing condition

A_r : Area required per UG-37, governing condition

Corr: Corrosion allowance on nozzle wall

* Head minimum thickness after forming

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Pressure Summary

Pressure Summary for Chamber bounded by F&D Head #2 and F&D Head #1

Identifier	P Design (kPa)	T Design (°C)	MAWP (kPa)	MAP (kPa)	MAEP (kPa)	T _e external (°C)	MDMT (°C)	MDMT Exemption	Total Corrosion Allowance (mm)	Impact Test
F&D Head #1	344.0	200.0	537.26	649.45	317.46	200.0	-105.0	Note 1	1.50	No
Straight Flange on F&D Head #1	344.0	200.0	917.12	1106.91	192.62	200.0	-105.0	Note 2	1.50	No
Cylinder #1	344.0	200.0	897.53	1106.91	192.62	200.0	-105.0	Note 3	1.50	No
Straight Flange on F&D Head #2	344.0	200.0	897.03	1106.91	192.62	200.0	-105.0	Note 5	1.50	No
F&D Head #2	344.0	200.0	587.33	713.43	364.30	200.0	-105.0	Note 4	1.50	No
Legs #1	344.0	200.0	344.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Liquid Level (N1)	344.0	200.0	397.91	463.34	192.62	200.0	-48.0	Note 6	0.00	No
Vent/Overflow (N2)	344.0	200.0	702.01	815.59	192.62	200.0	-48.0	Note 7	0.00	No
Spore (N3)	344.0	200.0	1112.88	1338.99	192.62	200.0	-48.0	Note 8	0.00	No
Water Fill (N4)	344.0	200.0	1112.36	1338.99	192.62	200.0	-48.0	Note 8	0.00	No
NaOH Fill (N5)	344.0	200.0	1112.36	1338.99	192.62	200.0	-48.0	Note 8	0.00	No
Outlet (N6)	344.0	200.0	741.79	889.39	192.62	200.0	-48.0	Note 9	0.00	No
Inspection Port (N7)	344.0	200.0	658.57	799.36	120.79	200.0	-48.0	Note 10	0.00	No

Chamber design MDMT is -28.89°C

Chamber rated MDMT is -48.00°C @ 344.00 kPa

Chamber MAWP hot & corroded is 344.00 kPa @ 200.0°C

Chamber MAP cold & new is 463.34 kPa @ 21.1°C

Chamber MAEP is 120.79 kPa @ 200.0°C

Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Straight Flange governs MDMT	
2.	Material is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.32217)	
3.	Material is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.34027)	
4.	Straight Flange governs MDMT	
5.	Material is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.34073)	
6.	Flange rating governs: Flange rated MDMT = -105 °C (UCS-68(c) applies.) Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C	UCS-66(b)(3): Coincident ratio = 0.175361
7.	Flange rating governs: Flange rated MDMT = -105 °C (UCS-68(c) applies.) Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C	UCS-66(b)(3): Coincident ratio = 0.1754077
8.	Flange rating governs: Flange rated MDMT = -105 °C (UCS-68(c) applies.) Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C	UCS-66(b)(3): Coincident ratio = 0.1750631

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9.	Flange rating governs: Flange rated MDMT = -105 °C (UCS-68(c) applies.) Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C	UCS-66(b)(3): Coincident ratio = 0.189694
10.	Flange rating governs: Flange rated MDMT = -105 °C (UCS-68(c) applies.) Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C	UCS-66(b)(3): Coincident ratio = 0.1798077

Design notes are available on the Settings Summary page.

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Revision History

No.	Date	Operator	Notes
0	12/20/2007	BJ	New vessel created ASME Section VIII Division 1 [Build 6256]

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UG-22 Loadings

UG-22 (a) Internal or External Design Pressure :	Yes
UG-22 (b) Weight of the vessel and normal contents under operating or test conditions:	Yes
UG-22 (c) Superimposed static reactions from weight of attached equipment (external loads):	No
UG-22 (d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22 (f) Wind reactions:	No
UG-22 (f) Seismic reactions:	No

Note: UG-22 (b),(c) and (f) loads only considered when supports are present.

Performance Group (USA), Inc**Thickness Summary**

Component Identifier	Material	Diameter (mm)	Length (mm)	Nominal t (mm)	Design t (mm)	Joint E	Load
<u>F&D Head #1</u>	SA-285 C	1500.00 OD	284.93	9.00*	6.33	0.8500	Internal
<u>Straight Flange on F&D Head #1</u>	SA-285 C	1500.00 OD	50.80	9.00	7.33	0.8500	External
<u>Cylinder #1</u>	SA-285 C	1500.00 OD	2000.00	9.00	7.33	0.8500	External
<u>Straight Flange on F&D Head #2</u>	SA-285 C	1500.00 OD	50.80	9.00	7.33	0.8500	External
<u>F&D Head #2</u>	SA-285 C	1500.00 OD	280.61	9.00*	6.19	0.8500	Internal

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

Internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Performance Group (USA), Inc**Weight Summary**

Component	Weight (kg) Contributed by Vessel Elements						
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid
F&D Head #1	160.89	133.70	0.00	0.00	0.00	360.47	360.37
Cylinder #1	651.29	542.10	0.00	0.00	0.00	3,462.08	3,461.92
F&D Head #2	164.36	136.59	0.00	0.00	0.00	368.91	368.90
Legs #1	89.59	89.59	0.00	0.00	0.00	0.00	0.00
TOTAL:	1,066.13	901.99	0.00	0.00	0.00	4,191.47	4,191.19

* Shells with attached nozzles have weight reduced by material cut out for opening.

Component	Weight (kg) Contributed by Attachments								
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads
	New	Corroded	New	Corroded					
F&D Head #1	0.00	0.00	34.16	34.16	0.00	0.00	0.00	0.00	0.00
Cylinder #1	0.00	0.00	162.78	162.78	0.00	0.00	0.00	0.00	0.00
F&D Head #2	0.00	0.00	8.17	8.17	0.00	0.00	0.00	0.00	0.00
Legs #1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL:	0.00	0.00	205.12	205.12	0.00	0.00	0.00	0.00	0.00

Vessel operating weight, Corroded: 5,299 kg

Vessel operating weight, New: 5,463 kg

Vessel empty weight, Corroded: 1,107 kg

Vessel empty weight, New: 1,271 kg

Vessel test weight, New: 5,462 kg

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 1,271 kg

Center of Gravity: 991.95 mm

Vessel Capacity

Vessel Capacity** (New): 4,174 liters

Vessel Capacity** (Corroded): 4,174 liters

**The vessel capacity does not include volume of nozzle, piping or other attachments.

G Performance Group (USA), Inc**Hydrostatic Test**

Shop test pressure determination for Chamber bounded by F&D Head #2 and F&D Head #1 based on MAWP per UG-99(b)

Shop hydrostatic test gauge pressure is 447.2 kPa at 21.11 °C (the chamber MAWP = 344 kPa)

The shop test is performed with the vessel in the horizontal position.

Identifier	Local test pressure kPa	Test liquid static head kPa	UG-99 stress ratio	UG-99 pressure factor	Stress during test MPa	Allowable test stress MPa	Stress excessive?
F&D Head #1 (1)	461.72	14.52	1	1.30	37.194	184.5	No
Straight Flange on F&D Head #1	461.72	14.52	1	1.30	38.245	184.5	No
Cylinder #1	461.72	14.52	1	1.30	38.245	184.5	No
Straight Flange on F&D Head #2	461.72	14.52	1	1.30	38.245	184.5	No
F&D Head #2	461.72	14.52	1	1.30	34.568	184.5	No
Inspection Port (N7)	463.3	16.1	1	1.30	82.275	276.75	No
Liquid Level (N1)	460.28	13.08	1	1.30	83.643	276.75	No
NaOH Fill (N5)	456.68	9.48	1	1.30	48.87	276.75	No
Outlet (N6)	454.96	7.76	1	1.30	50.258	276.75	No
Spare (N3)	457.17	9.97	1	1.30	48.525	276.75	No
Vent/Overflow (N2)	460.03	12.83	1	1.30	62.437	276.75	No
Water Fill (N4)	457.49	10.29	1	1.30	48.957	276.75	No

Notes:

- (1) F&D Head #1 limits the UG-99 stress ratio.
- (2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
- (3) VIII-2, AD-151.1(b) used as the basis for nozzle allowable test stress.
- (4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by F&D Head #2 and F&D Head #1.

The test temperature of 21.11 °C is warmer than the minimum recommended temperature of -31 °C so the brittle fracture provision of UG-99(h) has been met.

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Vacuum Summary

Component	Line of Support	Elevation above Datum (mm)	Length Le (mm)
<u>F&D Head #1</u>	-	2315.73	N/A
-	<u>1/3 depth of F&D Head #1</u>	2136.11	N/A
<u>Straight Flange on F&D Head #1 Top</u>	-	2050.80	2277.45
<u>Straight Flange on F&D Head #1 Bottom</u>	-	2000.00	2277.45
<u>Cylinder #1 Top</u>	-	2000.00	2277.45
<u>Cylinder #1 Bottom</u>	-	0.00	2277.45
<u>Straight Flange on F&D Head #2 Top</u>	-	0.00	2277.45
<u>Straight Flange on F&D Head #2 Bottom</u>	-	-50.80	2277.45
-	<u>1/3 depth of F&D Head #2</u>	-141.34	N/A
<u>F&D Head #2</u>	-	-331.41	N/A

Note
For main components, the listed value of 'Le' is the largest unsupported length for the component.

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Engineering Notes

Note: Unit to be Externally Sand Blasted and painted with an Epoxy primer and (2) high build coats of Catalyzed Epoxy Overcoat.

Performance Group (USA), Inc**Cylinder #1****ASME Section VIII Division 1, 2007 Edition Metric**

Component: Cylinder
 Material specification: SA-285 C (II-D Metric p. 10, ln. 3)
 Material is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.34027)

Internal design pressure: $P = 344 \text{ kPa @ } 200^\circ\text{C}$
 External design pressure: $P_e = 103.421 \text{ kPa @ } 200^\circ\text{C}$

Static liquid head:

$P_s = 24.0207 \text{ kPa}$ (SG=1.0000, $H_s=2451.47 \text{ mm}$ Operating head)
 $P_{th} = 14.5213 \text{ kPa}$ (SG=1.0000, $H_s=1482.00 \text{ mm}$, Horizontal test head)

Corrosion allowance: Inner C = 0.00 mm Outer C = 1.50 mm

Design MDMT = -28.89°C No impact test performed
 Rated MDMT = -105.00°C Material is not normalized
 Material is not produced to Fine Grain Practice
 PWHT is performed

Radiography: Longitudinal joint - Spot UW-11(b) Type 1
 Top circumferential joint - Spot UW-11(b) Type 2
 Bottom circumferential joint - Spot UW-11(b) Type 1

Estimated weight: New = 660.4310 kg corr = 549.7228 kg
 Capacity: New = 3449.9780 liters corr = 3449.9780 liters
 OD = 1500.00 mm
 Length $L_c = 2000.00 \text{ mm}$
 $t = 9.00 \text{ mm}$

Design thickness, (at 200.00°C) Appendix 1-1

$$\begin{aligned} t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\ &= 368.02 \cdot 750.00 / (108000 \cdot 0.85 + 0.40 \cdot 368.02) + 1.50 \\ &= 4.5034 \text{ mm} \end{aligned}$$

Maximum allowable working pressure, (at 200.00°C) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\ &= 108000 \cdot 0.85 \cdot 7.4989 / (750.00 - 0.40 \cdot 7.4989) - 24.0207 \\ &= 897.5255 \text{ kPa} \end{aligned}$$

Maximum allowable pressure, (at 21.11°C) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) \\ &= 108000 \cdot 0.85 \cdot 9.0000 / (750.00 - 0.40 \cdot 9.0000) \\ &= 1106.9132 \text{ kPa} \end{aligned}$$

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External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 2277.4470/1500.0000 = 1.5183$$

$$D_o/t = 1500.0000/5.833334 = 257.1428$$

From table G: $A = 0.000210$
 From table CS-2 Metric: $B = 19.9455 \text{ MPa}$

$$P_a = 4*B/(3*(D_o/t))$$

$$= 4*19.9455/(3*(1500.0000/5.833334))$$

$$= 103.4212 \text{ kPa}$$

Design thickness for external pressure $P_a = 103.4212 \text{ kPa}$

$$= t + \text{Corrosion} = 5.833334 + 1.50 = 7.33 \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 2277.4470/1500.00 = 1.5183$$

$$D_o/t = 1500.00/7.4989 = 200.0304$$

From table G: $A = 0.000303$
 From table CS-2 Metric: $B = 28.8971 \text{ MPa}$

$$P_a = 4*B/(3*(D_o/t))$$

$$= 4*28.8971/(3*(1500.00/7.4989))$$

$$= 192.6183 \text{ kPa}$$

% Extreme fiber elongation - UCS-79(d)

$$= (50 * t / R_f) * (1 - R_f / R_o)$$

$$= (50 * 9.00 / 745.5001) * (1 - 745.5001 / \infty)$$

$$= 0.6036 \%$$

External Pressure + Weight Check (Bergman, ASME paper 54-A-104)

$$P_v = W / (2*\pi*R_m) + M / (\pi*R_m^2)$$

$$= 875.80 / (2*\pi*744.7495) + 1586.11 / (\pi*744.7495^2)$$

$$= 27.4568 \text{ N/cm}$$

$$\alpha = P_v / (P_a * D_o)$$

$$= 27.456818 / (103.4214 * 1500.0000)$$

$$= 0.0177$$

$$n = 5$$

$$m = 1.23 / (L/D_o)^2$$

$$= 1.23 / (2277.447021/1500.0000)^2$$

$$= 0.5336$$

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$$\begin{aligned}\text{Ratio } P_e &= (n^2 - 1 + m + m^*\alpha) / (n^2 - 1 + m) \\ &= (5^2 - 1 + 0.533570 + 0.533570*0.017699) / (5^2 - 1 + 0.533570) \\ &= 1.0004\end{aligned}$$

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight Check at Bottom Seam (Bergman, ASME paper 54-A-104)

$$\begin{aligned}P_v &= W / (2*\pi*R_m) + M / (\pi*R_m^2) \\ &= 875.80 / (2*\pi*744.7495) + 0.00 / (\pi*744.7495^2) \\ &= 18.3543 \text{ N/cm}\end{aligned}$$

$$\begin{aligned}\alpha &= P_v / (P_e * D_o) \\ &= 18.354259 / (103.4214*1500.0000) \\ &= 0.0118\end{aligned}$$

$$n = 5$$

$$\begin{aligned}m &= 1.23 / (L/D_o)^2 \\ &= 1.23 / (2277.447021/1500.0000)^2 \\ &= 0.5336\end{aligned}$$

$$\begin{aligned}\text{Ratio } P_e &= (n^2 - 1 + m + m^*\alpha) / (n^2 - 1 + m) \\ &= (5^2 - 1 + 0.533570 + 0.533570*0.011831) / (5^2 - 1 + 0.533570) \\ &= 1.0003\end{aligned}$$

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

Design thickness = 7.33 mm

The governing condition is due to external pressure.

The cylinder thickness of 9.00 mm is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (kPa)	Allowable Stress Before UG-23 Stress Increase (MPa)		Temperature (°C)	Corrosion C (mm)	Location	Load	Req'd Thk Due to Tension (mm)	Req'd Thk Due to Compression (mm)
		S _t	S _c						
<u>Operating, Hot & Corroded</u>	344.00	108.00	<u>81.47</u>	200.00	1.5000	top	Weight	<u>1.1708</u>	<u>1.1539</u>
						Bottom	Weight	<u>1.1624</u>	<u>1.1624</u>
<u>Operating, Hot & New</u>	344.00	108.00	<u>85.17</u>	200.00	0.0000	top	Weight	<u>1.1681</u>	<u>1.1513</u>
						Bottom	Weight	<u>1.1597</u>	<u>1.1597</u>
<u>Hot Shut Down, Corroded</u>	0.00	108.00	<u>81.47</u>	200.00	1.5000	top	Weight	<u>0.0114</u>	<u>0.0337</u>
						Bottom	Weight	<u>0.0225</u>	<u>0.0225</u>
<u>Hot Shut Down, New</u>	0.00	108.00	<u>85.17</u>	200.00	0.0000	top	Weight	<u>0.0142</u>	<u>0.0356</u>
						Bottom	Weight	<u>0.0249</u>	<u>0.0249</u>
<u>Empty, Corroded</u>	0.00	108.00	<u>90.27</u>	-17.78	1.5000	top	Weight	<u>0.0102</u>	<u>0.0304</u>
						Bottom	Weight	<u>0.0203</u>	<u>0.0203</u>

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<u>Empty, New</u>	0.00	108.00	<u>95.01</u>	-17.78	0.0000	top	Weight	<u>0.0128</u>	<u>0.0319</u>
						Bottom	Weight	<u>0.0223</u>	<u>0.0223</u>
<u>Vacuum</u>	-103.42	108.00	<u>81.47</u>	200.00	1.5000	top	Weight	<u>0.4816</u>	<u>0.5039</u>
						Bottom	Weight	<u>0.4927</u>	<u>0.4927</u>
<u>Hot Shut Down, Corroded, Weight & Eccentric Moments Only</u>	0.00	108.00	<u>81.47</u>	200.00	1.5000	top	Weight	<u>0.0114</u>	<u>0.0337</u>
						Bottom	Weight	<u>0.0225</u>	<u>0.0225</u>

Allowable Compressive Stress, Hot and Corroded- S_{cHC} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 7.4989) \\
 &= 0.001250 \\
 B &= 81.4695 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cHC} &= \underline{81.4695 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Hot and New- S_{cHN} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 9.0000) \\
 &= 0.001500 \\
 B &= 85.1720 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cHN} &= \underline{85.1720 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and New- S_{cCN} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 9.0000) \\
 &= 0.001500 \\
 B &= 95.0147 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cCN} &= \underline{95.0147 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and Corroded- S_{cCC} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 7.4989) \\
 &= 0.001250 \\
 B &= 90.2737 \text{ MPa} \\
 S &= 108.0000 / 1.0000
 \end{aligned}$$

Performance Group (USA), Inc

$$= 108.0000 \text{ MPa}$$

$$S_{cCC} = 90.2737 \text{ MPa}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC} (table CS-2 Metric)

$$A = 0.125 / (R_o / t)$$

$$= 0.125 / (750.0000 / 7.4989)$$

$$= 0.001250$$

$$B = 81.4695 \text{ MPa}$$

$$S = 108.0000 / 1.0000$$

$$= 108.0000 \text{ MPa}$$

$$S_{cVC} = 81.4695 \text{ MPa}$$

Operating, Hot & Corroded, Above Support Point

$$t_p = P \cdot R / (2 \cdot S_t \cdot K_s \cdot E_c + 0.40 \cdot |P|) \quad (\text{Pressure})$$

$$= 344.00 \cdot 741.0000 / (2 \cdot 108000 \cdot 1.0000 \cdot 1.00 + 0.40 \cdot |344.0000|)$$

$$= 1.18 \text{ mm}$$

$$t_m = M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{bending})$$

$$= 1586 / (\pi \cdot 744.7495^2 \cdot 108000 \cdot 1.0000 \cdot 1.00) \cdot 10^9$$

$$= 0.01 \text{ mm}$$

$$t_w = W / (2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{Weight})$$

$$= 876 / (2 \cdot \pi \cdot 744.7495 \cdot 108000 \cdot 1.0000 \cdot 1.00) \cdot 10^4$$

$$= 0.02 \text{ mm}$$

$$t_t = t_p + t_m + t_w \quad (\text{total required, tensile})$$

$$= 1.179360 + 0.008428 + (0.016995)$$

$$= 1.17 \text{ mm}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.008428 + (0.016995) - (1.179360)|$$

$$= 1.15 \text{ mm}$$

Maximum allowable working pressure, Longitudinal Stress

$$P = 2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w) / (R - 0.40 \cdot (t - t_m + t_w))$$

$$= 2 \cdot 108000 \cdot 1.0000 \cdot 1.00 \cdot (7.4989 - 0.008428 + (0.016995)) / (741.0000 - 0.40 \cdot (7.4989 - 0.008428 + (0.016995)))$$

$$= 2197.30 \text{ kPa}$$

Operating, Hot & New, Above Support Point

$$t_p = P \cdot R / (2 \cdot S_t \cdot K_s \cdot E_c + 0.40 \cdot |P|) \quad (\text{Pressure})$$

$$= 344.00 \cdot 741.0000 / (2 \cdot 108000 \cdot 1.0000 \cdot 1.00 + 0.40 \cdot |344.0000|)$$

$$= 1.18 \text{ mm}$$

$$t_m = M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{bending})$$

Performance Group (USA), Inc

$$= 1586/(\pi * 745.5001^2 * 108000 * 1.0000 * 1.00) * 10^6$$

$$= 0.01 \text{ mm}$$

$$t_w = W/(2 * \pi * R_m * S_t * K_s * E_c) * \text{MetricFactor} \quad (\text{Weight})$$

$$= 1013/(2 * \pi * 745.5001 * 108000 * 1.0000 * 1.00) * 10^4$$

$$= 0.02 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 1.179360 + 0.008411 - (0.019633)$$

$$= \underline{1.17 \text{ mm}}$$

$$t_c = |t_{mo} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.008411 + (0.019633) - (1.179360)|$$

$$= \underline{1.15 \text{ mm}}$$

Maximum allowable working pressure, Longitudinal Stress

$$P = 2 * S_t * K_s * E_c * (t - t_m + t_w) / (R - 0.40 * (t - t_m + t_w))$$

$$= 2 * 108000 * 1.0000 * 1.00 * (9.0000 - 0.008411 + (0.019633)) / (741.0000 - 0.40 * (9.0000 - 0.008411 + (0.019633)))$$

$$= 2639.59 \text{ kPa}$$

Hot Shut Down, Corroded, Above Support Point

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M/(\pi * R_m^2 * S_c * K_s) * \text{MetricFactor} \quad (\text{bending})$$

$$= 1586/(\pi * 744.7495^2 * 81469 * 1.0000) * 10^6$$

$$= 0.01 \text{ mm}$$

$$t_w = W/(2 * \pi * R_m * S_c * K_s) * \text{MetricFactor} \quad (\text{Weight})$$

$$= 876/(2 * \pi * 744.7495 * 81469 * 1.0000) * 10^4$$

$$= 0.02 \text{ mm}$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |0.000000 + 0.011173 - (0.022529)|$$

$$= \underline{0.01 \text{ mm}}$$

$$t_c = t_{mo} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0.011173 + (0.022529) - (0.000000)$$

$$= \underline{0.03 \text{ mm}}$$

Hot Shut Down, New, Above Support Point

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M/(\pi * R_m^2 * S_c * K_s) * \text{MetricFactor} \quad (\text{bending})$$

$$= 1586/(\pi * 745.5001^2 * 85172 * 1.0000) * 10^6$$

$$= 0.01 \text{ mm}$$

$$t_w = W/(2 * \pi * R_m * S_c * K_s) * \text{MetricFactor} \quad (\text{Weight})$$

$$= 1013/(2 * \pi * 745.5001 * 85172 * 1.0000) * 10^4$$

Performance Group (USA), Inc

$$= 0.02 \text{ mm}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0.000000 + 0.010666 - (0.024895)| \\ &= \underline{0.01 \text{ mm}} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0.010666 + (0.024895) - (0.000000) \\ &= \underline{0.04 \text{ mm}} \end{aligned}$$

Empty, Corroded, Above Support Point

$$\begin{aligned} t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\ t_m &= M/(\pi \cdot R_m^2 \cdot S_o \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\ &= 1586/(\pi \cdot 744.7495^2 \cdot 90274 \cdot 1.0000) \cdot 10^6 \\ &= 0.01 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_w &= W/(2 \cdot \pi \cdot R_m \cdot S_o \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\ &= 876/(2 \cdot \pi \cdot 744.7495 \cdot 90274 \cdot 1.0000) \cdot 10^4 \\ &= 0.02 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0.000000 + 0.010083 - (0.020332)| \\ &= \underline{0.01 \text{ mm}} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0.010083 + (0.020332) - (0.000000) \\ &= \underline{0.03 \text{ mm}} \end{aligned}$$

Empty, New, Above Support Point

$$\begin{aligned} t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\ t_m &= M/(\pi \cdot R_m^2 \cdot S_o \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\ &= 1586/(\pi \cdot 745.5001^2 \cdot 95015 \cdot 1.0000) \cdot 10^6 \\ &= 0.01 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_w &= W/(2 \cdot \pi \cdot R_m \cdot S_o \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\ &= 1013/(2 \cdot \pi \cdot 745.5001 \cdot 95015 \cdot 1.0000) \cdot 10^4 \\ &= 0.02 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0.000000 + 0.009561 - (0.022316)| \\ &= \underline{0.01 \text{ mm}} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0.009561 + (0.022316) - (0.000000) \\ &= \underline{0.03 \text{ mm}} \end{aligned}$$

G Performance Group (USA), Inc**Vacuum, Above Support Point**

$$\begin{aligned}
 t_p &= P \cdot R / (2 \cdot S_c \cdot K_s + 0.40 \cdot |P|) && \text{(Pressure)} \\
 &= -103.42 \cdot 741.0000 / (2 \cdot 81469 \cdot 1.0000 + 0.40 \cdot |103.4214|) \\
 &= -0.47 \text{ mm} \\
 t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\
 &= 1586 / (\pi \cdot 744.7495^2 \cdot 81469 \cdot 1.0000) \cdot 10^6 \\
 &= 0.01 \text{ mm} \\
 t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\
 &= 876 / (2 \cdot \pi \cdot 744.7495 \cdot 81469 \cdot 1.0000) \cdot 10^4 \\
 &= 0.02 \text{ mm} \\
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |-0.470212 + 0.011173 - (0.022529)| \\
 &= \underline{0.48 \text{ mm}} \\
 t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0.011173 + (0.022529) - (-0.470212) \\
 &= \underline{0.50 \text{ mm}}
 \end{aligned}$$

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Above Support Point

$$\begin{aligned}
 t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\
 t_m &= M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\
 &= 1586 / (\pi \cdot 744.7495^2 \cdot 81469 \cdot 1.0000) \cdot 10^6 \\
 &= 0.01 \text{ mm} \\
 t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\
 &= 876 / (2 \cdot \pi \cdot 744.7495 \cdot 81469 \cdot 1.0000) \cdot 10^4 \\
 &= 0.02 \text{ mm} \\
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |0.000000 + 0.011173 - (0.022529)| \\
 &= \underline{0.01 \text{ mm}} \\
 t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0.011173 + (0.022529) - (0.000000) \\
 &= \underline{0.03 \text{ mm}}
 \end{aligned}$$

Operating, Hot & Corroded, Below Support Point

$$\begin{aligned}
 t_p &= P \cdot R / (2 \cdot S_t \cdot K_s \cdot E_c + 0.40 \cdot |P|) && \text{(Pressure)} \\
 &= 344.00 \cdot 741.0000 / (2 \cdot 108000 \cdot 1.0000 \cdot 1.00 + 0.40 \cdot |344.0000|) \\
 &= 1.18 \text{ mm} \\
 t_m &= M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} && \text{(bending)} \\
 &= 0 / (\pi \cdot 744.7495^2 \cdot 108000 \cdot 1.0000 \cdot 1.00) \cdot 10^6 \\
 &= 0.00 \text{ mm}
 \end{aligned}$$

G Performance Group (USA), Inc

$$t_w = W / (2 * \pi * R_m * S_t * K_s * E_c) * \text{MetricFactor} \quad (\text{Weight})$$

$$= 876 / (2 * \pi * 744.7495 * 108000 * 1.0000 * 1.00) * 10^4$$

$$= 0.02 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 1.179360 + 0.000000 - (0.016995)$$

$$= \underline{1.16 \text{ mm}}$$

$$t_o = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.000000 + (0.016995) - (1.179360)|$$

$$= \underline{1.16 \text{ mm}}$$

Maximum allowable working pressure, Longitudinal Stress

$$P = 2 * S_t * K_s * E_c * (t - t_m + t_w) / (R - 0.40 * (t - t_m + t_w))$$

$$= 2 * 108000 * 1.0000 * 1.00 * (7.4989 - 0.000000 + (0.016995)) / (741.0000 - 0.40 * (7.4989 - 0.000000 + (0.016995)))$$

$$= 2199.78 \text{ kPa}$$

Operating, Hot & New, Below Support Point

$$t_p = P * R / (2 * S_t * K_s * E_c + 0.40 * |P|) \quad (\text{Pressure})$$

$$= 344.00 * 741.0000 / (2 * 108000 * 1.0000 * 1.00 + 0.40 * |344.0000|)$$

$$= 1.18 \text{ mm}$$

$$t_m = M / (\pi * R_m^2 * S_t * K_s * E_c) * \text{MetricFactor} \quad (\text{bending})$$

$$= 0 / (\pi * 745.5001^2 * 108000 * 1.0000 * 1.00) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W / (2 * \pi * R_m * S_t * K_s * E_c) * \text{MetricFactor} \quad (\text{Weight})$$

$$= 1013 / (2 * \pi * 745.5001 * 108000 * 1.0000 * 1.00) * 10^4$$

$$= 0.02 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 1.179360 + 0.000000 - (0.019633)$$

$$= \underline{1.16 \text{ mm}}$$

$$t_o = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.000000 + (0.019633) - (1.179360)|$$

$$= \underline{1.16 \text{ mm}}$$

Maximum allowable working pressure, Longitudinal Stress

$$P = 2 * S_t * K_s * E_c * (t - t_m + t_w) / (R - 0.40 * (t - t_m + t_w))$$

$$= 2 * 108000 * 1.0000 * 1.00 * (9.0000 - 0.000000 + (0.019633)) / (741.0000 - 0.40 * (9.0000 - 0.000000 + (0.019633)))$$

$$= 2642.07 \text{ kPa}$$

Performance Group (USA), Inc**Hot Shut Down, Corroded, Below Support Point**

$$\begin{aligned}
 t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\
 t_m &= M/(\pi \cdot R_m^2 \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\
 &= 0/(\pi \cdot 744.7495^2 \cdot 81469 \cdot 1.0000) \cdot 10^6 \\
 &= 0.00 \text{ mm} \\
 t_w &= W/(2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\
 &= 876/(2 \cdot \pi \cdot 744.7495 \cdot 81469 \cdot 1.0000) \cdot 10^4 \\
 &= 0.02 \text{ mm} \\
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |0.000000 + 0.000000 - (0.022529)| \\
 &= \underline{0.02 \text{ mm}} \\
 t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0.000000 + (0.022529) - (0.000000) \\
 &= \underline{0.02 \text{ mm}}
 \end{aligned}$$

Hot Shut Down, New, Below Support Point

$$\begin{aligned}
 t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\
 t_m &= M/(\pi \cdot R_m^2 \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\
 &= 0/(\pi \cdot 745.5001^2 \cdot 85172 \cdot 1.0000) \cdot 10^6 \\
 &= 0.00 \text{ mm} \\
 t_w &= W/(2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\
 &= 1013/(2 \cdot \pi \cdot 745.5001 \cdot 85172 \cdot 1.0000) \cdot 10^4 \\
 &= 0.02 \text{ mm} \\
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |0.000000 + 0.000000 - (0.024895)| \\
 &= \underline{0.02 \text{ mm}} \\
 t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0.000000 + (0.024895) - (0.000000) \\
 &= \underline{0.02 \text{ mm}}
 \end{aligned}$$

Empty, Corroded, Below Support Point

$$\begin{aligned}
 t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\
 t_m &= M/(\pi \cdot R_m^2 \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\
 &= 0/(\pi \cdot 744.7495^2 \cdot 90274 \cdot 1.0000) \cdot 10^6 \\
 &= 0.00 \text{ mm} \\
 t_w &= W/(2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\
 &= 876/(2 \cdot \pi \cdot 744.7495 \cdot 90274 \cdot 1.0000) \cdot 10^4 \\
 &= 0.02 \text{ mm} \\
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)}
 \end{aligned}$$

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$$= |0.000000 + 0.000000 - (0.020332)|$$

$$= \underline{0.02 \text{ mm}}$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0.000000 + (0.020332) - (0.000000)$$

$$= \underline{0.02 \text{ mm}}$$

Empty, New, Below Support Point

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M/(\pi R_m^2 S_c K_s) * \text{MetricFactor} \quad (\text{bending})$$

$$= 0/(\pi * 745.5001^2 * 95015 * 1.0000) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W/(2\pi R_m S_o K_s) * \text{MetricFactor} \quad (\text{Weight})$$

$$= 1013/(2\pi * 745.5001 * 95015 * 1.0000) * 10^4$$

$$= 0.02 \text{ mm}$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |0.000000 + 0.000000 - (0.022316)|$$

$$= \underline{0.02 \text{ mm}}$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0.000000 + (0.022316) - (0.000000)$$

$$= \underline{0.02 \text{ mm}}$$

Vacuum, Below Support Point

$$t_p = P/R/(2S_o K_s + 0.40|P|) \quad (\text{Pressure})$$

$$= -103.42 * 741.0000 / (2 * 81469 * 1.0000 + 0.40 * |103.4214|)$$

$$= -0.47 \text{ mm}$$

$$t_m = M/(\pi R_m^2 S_c K_s) * \text{MetricFactor} \quad (\text{bending})$$

$$= 0/(\pi * 744.7495^2 * 81469 * 1.0000) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W/(2\pi R_m S_o K_s) * \text{MetricFactor} \quad (\text{Weight})$$

$$= 876/(2\pi * 744.7495 * 81469 * 1.0000) * 10^4$$

$$= 0.02 \text{ mm}$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |-0.470212 + 0.000000 - (0.022529)|$$

$$= \underline{0.49 \text{ mm}}$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0.000000 + (0.022529) - (-0.470212)$$

$$= \underline{0.49 \text{ mm}}$$

Performance Group (USA), Inc**Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Below Support Point**

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M/(\pi R_m^2 S_c K_s) * \text{MetricFactor} \quad (\text{bending})$$

$$= 0/(\pi * 744.7495^2 * 81469 * 1.0000) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W/(2\pi R_m S_c K_s) * \text{MetricFactor} \quad (\text{Weight})$$

$$= 876/(2\pi * 744.7495 * 81469 * 1.0000) * 10^4$$

$$= 0.02 \text{ mm}$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |0.000000 + 0.000000 - (0.022529)|$$

$$= \underline{0.02 \text{ mm}}$$

$$t_o = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0.000000 + (0.022529) - (0.000000)$$

$$= \underline{0.02 \text{ mm}}$$

Performance Group (USA), Inc**F&D Head #1****ASME Section VIII, Division 1, 2007 Edition Metric**

Component: F&D Head
 Material Specification: SA-285 C (II-D Metric p.10, ln. 3)
Straight Flange governs MDMT

Internal design pressure: $P = 344 \text{ kPa @ } 200^\circ\text{C}$
 External design pressure: $P_e = 103.4214 \text{ kPa @ } 200^\circ\text{C}$

Static liquid head:

$P_s = 3.926 \text{ kPa (SG=1, } H_s=400.67 \text{ mm Operating head)}$
 $P_{th} = 14.5213 \text{ kPa (SG=1, } H_s=1482 \text{ mm Horizontal test head)}$

Corrosion allowance: Inner C = 0 mm Outer C = 1.5 mm

Design MDMT = -28.89°C No impact test performed
 Rated MDMT = -105°C Material is not normalized
 Material is not produced to fine grain practice
 PWHT is performed
 Do not Optimize MDMT / Find MAWP

Radiography: Category A joints - Seamless No RT
 Head to shell seam - Spot UW-11(b) Type 2

Estimated weight*: new = 160.9 kg corr. = 133.7 kg
 Capacity*: new = 355.8 liters corr. = 355.8 liters
 * Includes straight flange

Outer diameter = 1500 mm
 Crown radius L = 1450 mm
 Knuckle radius r = 90 mm
 Minimum head thickness = 9 mm
 Straight flange length L_{sf} = 50.8 mm
 Nominal straight flange thickness t_{sf} = 9 mm

Results Summary

The governing condition is internal pressure.
 Minimum thickness per UG-16 = $1.5 \text{ mm} + 1.5 \text{ mm} = 3 \text{ mm}$
 Design thickness due to internal pressure (t) = 6.33 mm
 Design thickness due to external pressure (t_e) = 5.79 mm
 Maximum allowable working pressure (MAWP) = 537.26 kPa
 Maximum allowable pressure (MAP) = 649.45 kPa

M (Corroded)

$$M = 1/4 * [3 + (L/r)^{1/2}] = 1/4 * [3 + (1,450/90)^{1/2}] = 1.753466$$

Performance Group (USA), Inc**M (New)**

$$M = 1/4 * [3 + (L/r)^{1/2}] = 1/4 * [3 + (1,450/90)^{1/2}] = 1.753466$$

Design thickness for internal pressure, (Corroded at 200 °C) Appendix 1-4(d)

$$\begin{aligned} t &= P * L_o * M / (2 * S * E + P * (M - 0.2)) + \text{Corrosion} \\ &= 347.93 * 1,457.5 * 1.7535 / (2 * 108,000 * 0.85 + 347.93 * (1.7535 - 0.2)) + 1.5 \\ &= 6.33 \text{ mm} \end{aligned}$$

The head internal pressure design thickness is 6.33 mm.

Maximum allowable working pressure, (Corroded at 200 °C) Appendix 1-4(d)

$$\begin{aligned} P &= 2 * S * E * t / (M * L_o - t * (M - 0.2)) - P_s \\ &= 2 * 108,000 * 0.85 * 7.5 / (1.7535 * 1,457.5 - 7.5 * (1.7535 - 0.2)) - 3.93 \\ &= 537.26 \text{ kPa} \end{aligned}$$

The maximum allowable working pressure (MAWP) is 537.26 kPa.

Maximum allowable pressure, (New at 21.11 °C) Appendix 1-4(d)

$$\begin{aligned} P &= 2 * S * E * t / (M * L_o - t * (M - 0.2)) - P_s \\ &= 2 * 108,000 * 0.85 * 9 / (1.7535 * 1,459 - 9 * (1.7535 - 0.2)) - 0 \\ &= 649.45 \text{ kPa} \end{aligned}$$

The maximum allowable pressure (MAP) is 649.45 kPa.

Design thickness for external pressure, (Corroded at 200 °C) UG-33(e)

Equivalent outside spherical radius (R_o)

$$\begin{aligned} &= \text{Outside crown radius} \\ &= 1,457.5 \text{ mm} \end{aligned}$$

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (1,457.5 / 4.29) \\ &= 0.000368 \end{aligned}$$

From Table CS-2 Metric: $B = 35,146.2 \text{ MPa}$

$$\begin{aligned} P_a &= B / (R_o / t) \\ &= 35,146.15 / (1,457.5 / 4.29) \\ &= 103.4213 \text{ kPa} \end{aligned}$$

$$t = 4.29 \text{ mm} + \text{Corrosion} = 4.29 \text{ mm} + 1.5 \text{ mm} = 5.79 \text{ mm}$$

Check the external pressure per UG-33(a)(1) Appendix 1-4(d)

$$\begin{aligned} t &= 1.67 * P_o * L_o * M / (2 * S * E + 1.67 * P_o * (M - 0.2)) + \text{Corrosion} \\ &= 1.67 * 103.42 * 1,457.5 * 1.7535 / (2 * 108,000 * 1 + 1.67 * 103.42 * (1.7535 - 0.2)) + 1.5 \\ &= 3.54 \text{ mm} \end{aligned}$$

The head external pressure design thickness (t_e) is 5.79 mm.

G Performance Group (USA), Inc**Maximum Allowable External Pressure, (Corroded at 200 °C) UG-33(e)**Equivalent outside spherical radius (R_o)

= Outside crown radius

= 1,457.5 mm

A = $0.125 / (R_o/t)$ = $0.125 / (1,457.5/7.5)$

= 0.000643

From Table CS-2 Metric: $B=61.7028$ MPa $P_a = B/(R_o/t)$ = $61,702.78/(1,457.5/7.5)$

= 317.462 kPa

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(d) $P = 2*S*E*t / ((M*L_o - t*(M - 0.2))*1.67) - P_{s2}$ = $2*108,000*1*7.5 / ((1.7535*1,457.5 - 7.5*(1.7535 - 0.2))*1.67) - 0$

= 381.25 kPa

The maximum allowable external pressure (MAEP) is 317.46 kPa.**% Extreme fiber elongation - UCS-79(d)**= $(75*t / R_i)*(1 - R_i / R_o)$ = $(75*9 / 94.5)*(1 - 94.5 / \infty)$

= 7.1429%

Performance Group (USA), Inc**Straight Flange on F&D Head #1****ASME Section VIII Division 1, 2007 Edition Metric**

Component: Straight Flange
 Material specification: SA-285 C (II-D Metric p. 10, ln. 3)
 Material is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.32217)

Internal design pressure: $P = 344 \text{ kPa @ } 200^\circ\text{C}$
 External design pressure: $P_e = 103.421 \text{ kPa @ } 200^\circ\text{C}$

Static liquid head:

$P_s = 4.4238 \text{ kPa}$ (SG=1.0000, $H_s=451.47 \text{ mm}$ Operating head)
 $P_{th} = 14.5213 \text{ kPa}$ (SG=1.0000, $H_s=1482.00 \text{ mm}$, Horizontal test head)

Corrosion allowance: Inner C = 0.00 mm Outer C = 1.50 mm

Design MDMT = -28.89°C No impact test performed
 Rated MDMT = -105.00°C Material is not normalized
 Material is not produced to Fine Grain Practice
 PWHT is performed

Radiography: Longitudinal joint - Seamless No RT
 Circumferential joint - Spot UW-11(b) Type 2

Estimated weight: New = 16.7749 kg corr = 13.9630 kg
 Capacity: New = 87.6294 liters corr = 87.6294 liters
 OD = 1500.00 mm
 Length $L_c = 50.80 \text{ mm}$
 $t = 9.00 \text{ mm}$

Design thickness, (at 200.00 °C) Appendix 1-1

$$\begin{aligned} t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\ &= 348.42 \cdot 750.00 / (108000 \cdot 0.85 + 0.40 \cdot 348.42) + 1.50 \\ &= 4.3459 \text{ mm} \end{aligned}$$

Maximum allowable working pressure, (at 200.00 °C) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\ &= 108000 \cdot 0.85 \cdot 7.4989 / (750.00 - 0.40 \cdot 7.4989) - 4.4238 \\ &= 917.1224 \text{ kPa} \end{aligned}$$

Maximum allowable pressure, (at 21.11 °C) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) \\ &= 108000 \cdot 0.85 \cdot 9.0000 / (750.00 - 0.40 \cdot 9.0000) \\ &= 1106.9132 \text{ kPa} \end{aligned}$$

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External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 2277.4470/1500.0000 = 1.5183$$

$$D_o/t = 1500.0000/5.833334 = 257.1428$$

From table G: $A = 0.000210$

From table CS-2 Metric: $B = 19.9455 \text{ MPa}$

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o/t)) \\ &= 4 \cdot 19.9455 / (3 \cdot (1500.0000/5.833334)) \\ &= 103.4212 \text{ kPa} \end{aligned}$$

Design thickness for external pressure $P_a = 103.4212 \text{ kPa}$

$$= t + \text{Corrosion} = 5.833334 + 1.50 = 7.33 \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 2277.4470/1500.00 = 1.5183$$

$$D_o/t = 1500.00/7.4989 = 200.0304$$

From table G: $A = 0.000303$

From table CS-2 Metric: $B = 28.8971 \text{ MPa}$

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o/t)) \\ &= 4 \cdot 28.8971 / (3 \cdot (1500.00/7.4989)) \\ &= 192.6183 \text{ kPa} \end{aligned}$$

% Extreme fiber elongation - UCS-79(d)

$$\begin{aligned} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\ &= (50 \cdot 9.00 / 745.5001) \cdot (1 - 745.5001 / \infty) \\ &= 0.6036 \% \end{aligned}$$

Design thickness = 7.33 mm

The governing condition is due to external pressure.

The cylinder thickness of 9.00 mm is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (kPa)	Allowable Stress Before UG-23 Stress Increase (MPa)		Temperature (°C)	Corrosion C (mm)	Load	Req'd Thk Due to Tension (mm)	Req'd Thk Due to Compression (mm)
		S_t	S_c					
Operating, Hot & Corroded	344.00	108.00	81.47	200.00	1.5000	Weight	1.4708	1.4689
Operating, Hot & New	344.00	108.00	85.17	200.00	0.0000	Weight	1.4701	1.4682

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Hot Shut Down, Corroded	0.00	108.00	<u>81.47</u>	200.00	1.5000	Weight	<u>0.0034</u>	<u>0.0054</u>
Hot Shut Down, New	0.00	108.00	<u>85.17</u>	200.00	0.0000	Weight	<u>0.0039</u>	<u>0.0058</u>
Empty, Corroded	0.00	108.00	<u>90.27</u>	-17.78	1.5000	Weight	<u>0.0030</u>	<u>0.0049</u>
Empty, New	0.00	108.00	<u>95.01</u>	-17.78	0.0000	Weight	<u>0.0035</u>	<u>0.0052</u>
Vacuum	-103.42	108.00	<u>81.47</u>	200.00	1.5000	Weight	<u>0.4736</u>	<u>0.4756</u>
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	108.00	<u>81.47</u>	200.00	1.5000	Weight	<u>0.0034</u>	<u>0.0054</u>

Allowable Compressive Stress, Hot and Corroded- S_{cHC} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 7.4989) \\
 &= 0.001250 \\
 B &= 81.4695 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cHC} &= \underline{81.4695 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Hot and New- S_{cHN} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 9.0000) \\
 &= 0.001500 \\
 B &= 85.1720 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cHN} &= \underline{85.1720 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and New- S_{cCN} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 9.0000) \\
 &= 0.001500 \\
 B &= 95.0147 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cCN} &= \underline{95.0147 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and Corroded- S_{cCC} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 7.4989) \\
 &= 0.001250 \\
 B &= 90.2737 \text{ MPa} \\
 S &= 108.0000 / 1.0000
 \end{aligned}$$

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$$= 108.0000 \text{ MPa}$$

$$S_{cCC} = 90.2737 \text{ MPa}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC} , (table CS-2 Metric)

$$A = 0.125 / (R_o / t)$$

$$= 0.125 / (750.0000 / 7.4989)$$

$$= 0.001250$$

$$B = 81.4695 \text{ MPa}$$

$$S = 108.0000 / 1.0000$$

$$= 108.0000 \text{ MPa}$$

$$S_{cVC} = 81.4695 \text{ MPa}$$

Operating, Hot & Corroded, Bottom Seam

$$t_p = P \cdot R / (2 \cdot S_t \cdot K_s \cdot E_c + 0.40 \cdot |P|) \quad (\text{Pressure})$$

$$= 344.00 \cdot 741.0000 / (2 \cdot 108000 \cdot 1.0000 \cdot 0.80 + 0.40 \cdot |344.0000|)$$

$$= 1.47 \text{ mm}$$

$$t_m = M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{bending})$$

$$= 146 / (\pi \cdot 744.7495^2 \cdot 108000 \cdot 1.0000 \cdot 0.80) \cdot 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W / (2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{Weight})$$

$$= 170 / (2 \cdot \pi \cdot 744.7495 \cdot 108000 \cdot 1.0000 \cdot 0.80) \cdot 10^4$$

$$= 0.00 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 1.473965 + 0.000970 - (0.004130)$$

$$= 1.47 \text{ mm}$$

$$t_c = |t_m + t_w - t_p| \quad (\text{total, net tensile})$$

$$= |0.000970 + (0.004130) - (1.473965)|$$

$$= 1.47 \text{ mm}$$

Maximum allowable working pressure, Longitudinal Stress

$$P = 2 \cdot S_t \cdot K_s \cdot E_c \cdot (t_m + t_w) / (R - 0.40 \cdot (t_m + t_w))$$

$$= 2 \cdot 108000 \cdot 1.0000 \cdot 0.80 \cdot (7.4989 - 0.000970 + (0.004130)) / (741.0000 - 0.40 \cdot (7.4989 - 0.000970 + (0.004130)))$$

$$= 1756.57 \text{ kPa}$$

Operating, Hot & New, Bottom Seam

$$t_p = P \cdot R / (2 \cdot S_t \cdot K_s \cdot E_c + 0.40 \cdot |P|) \quad (\text{Pressure})$$

$$= 344.00 \cdot 741.0000 / (2 \cdot 108000 \cdot 1.0000 \cdot 0.80 + 0.40 \cdot |344.0000|)$$

$$= 1.47 \text{ mm}$$

$$t_m = M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{bending})$$

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$$= 146/(\pi \cdot 745.5001^2 \cdot 108000 \cdot 1.0000 \cdot 0.80) \cdot 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W/(2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{Weight})$$

$$= 198/(2 \cdot \pi \cdot 745.5001 \cdot 108000 \cdot 1.0000 \cdot 0.80) \cdot 10^4$$

$$= 0.00 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 1.473965 + 0.000969 - (0.004797)$$

$$= \underline{1.47 \text{ mm}}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.000969 + (0.004797) - (1.473965)|$$

$$= \underline{1.47 \text{ mm}}$$

Maximum allowable working pressure, Longitudinal Stress

$$P = 2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w) / (R - 0.40 \cdot (t - t_m + t_w))$$

$$= 2 \cdot 108000 \cdot 1.0000 \cdot 0.80 \cdot (9.0000 - 0.000969 + (0.004797)) / (741.0000 - 0.40 \cdot (9.0000 - 0.000969 + (0.004797)))$$

$$= 2109.93 \text{ kPa}$$

Hot Shut Down, Corroded, Bottom Seam

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M/(\pi \cdot R_m^2 \cdot S_c \cdot K_s) \cdot \text{MetricFactor} \quad (\text{bending})$$

$$= 146/(\pi \cdot 744.7495^2 \cdot 81469 \cdot 1.0000) \cdot 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W/(2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) \cdot \text{MetricFactor} \quad (\text{Weight})$$

$$= 170/(2 \cdot \pi \cdot 744.7495 \cdot 81469 \cdot 1.0000) \cdot 10^4$$

$$= 0.00 \text{ mm}$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |0.000000 + 0.001029 - (0.004380)|$$

$$= \underline{0.00 \text{ mm}}$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0.001029 + (0.004380) - (0.000000)$$

$$= \underline{0.01 \text{ mm}}$$

Hot Shut Down, New, Bottom Seam

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M/(\pi \cdot R_m^2 \cdot S_c \cdot K_s) \cdot \text{MetricFactor} \quad (\text{bending})$$

$$= 146/(\pi \cdot 745.5001^2 \cdot 85172 \cdot 1.0000) \cdot 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W/(2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) \cdot \text{MetricFactor} \quad (\text{Weight})$$

$$= 198/(2 \cdot \pi \cdot 745.5001 \cdot 85172 \cdot 1.0000) \cdot 10^4$$

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$$= 0.00 \text{ mm}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0.000000 + 0.000982 - (0.004866)| \\ &= \underline{0.00 \text{ mm}} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0.000982 + (0.004866) - (0.000000) \\ &= \underline{0.01 \text{ mm}} \end{aligned}$$

Empty, Corroded, Bottom Seam

$$\begin{aligned} t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\ t_m &= M/(\pi R_m^2 S_c K_s) * \text{MetricFactor} && \text{(bending)} \\ &= 146/(\pi * 744.7495^2 * 90274 * 1.0000) * 10^6 \\ &= 0.00 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_w &= W/(2 * \pi R_m S_o K_s) * \text{MetricFactor} && \text{(Weight)} \\ &= 170/(2 * \pi * 744.7495 * 90274 * 1.0000) * 10^4 \\ &= 0.00 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0.000000 + 0.000929 - (0.003953)| \\ &= \underline{0.00 \text{ mm}} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0.000929 + (0.003953) - (0.000000) \\ &= \underline{0.00 \text{ mm}} \end{aligned}$$

Empty, New, Bottom Seam

$$\begin{aligned} t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\ t_m &= M/(\pi R_m^2 S_c K_s) * \text{MetricFactor} && \text{(bending)} \\ &= 146/(\pi * 745.5001^2 * 95015 * 1.0000) * 10^6 \\ &= 0.00 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_w &= W/(2 * \pi R_m S_o K_s) * \text{MetricFactor} && \text{(Weight)} \\ &= 198/(2 * \pi * 745.5001 * 95015 * 1.0000) * 10^4 \\ &= 0.00 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\ &= |0.000000 + 0.000881 - (0.004362)| \\ &= \underline{0.00 \text{ mm}} \end{aligned}$$

$$\begin{aligned} t_c &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\ &= 0.000881 + (0.004362) - (0.000000) \\ &= \underline{0.01 \text{ mm}} \end{aligned}$$

Performance Group (USA), Inc**Vacuum, Bottom Seam**

$$\begin{aligned}
 t_p &= P \cdot R / (2 \cdot S_o \cdot K_s + 0.40 \cdot |P|) && \text{(Pressure)} \\
 &= -103.42 \cdot 741.0000 / (2 \cdot 81469 \cdot 1.0000 + 0.40 \cdot |103.4214|) \\
 &= -0.47 \text{ mm} \\
 t_m &= M / (\pi \cdot R_m^2 \cdot S_o \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\
 &= 146 / (\pi \cdot 744.7495^2 \cdot 81469 \cdot 1.0000) \cdot 10^6 \\
 &= 0.00 \text{ mm} \\
 t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_o \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\
 &= 170 / (2 \cdot \pi \cdot 744.7495 \cdot 81469 \cdot 1.0000) \cdot 10^4 \\
 &= 0.00 \text{ mm} \\
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |-0.470212 + 0.001029 - (0.004380)| \\
 &= \underline{0.47 \text{ mm}} \\
 t_o &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0.001029 + (0.004380) - (-0.470212) \\
 &= \underline{0.48 \text{ mm}}
 \end{aligned}$$

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Bottom Seam

$$\begin{aligned}
 t_p &= 0.00 \text{ mm} && \text{(Pressure)} \\
 t_m &= M / (\pi \cdot R_m^2 \cdot S_o \cdot K_s) \cdot \text{MetricFactor} && \text{(bending)} \\
 &= 146 / (\pi \cdot 744.7495^2 \cdot 81469 \cdot 1.0000) \cdot 10^6 \\
 &= 0.00 \text{ mm} \\
 t_w &= W / (2 \cdot \pi \cdot R_m \cdot S_o \cdot K_s) \cdot \text{MetricFactor} && \text{(Weight)} \\
 &= 170 / (2 \cdot \pi \cdot 744.7495 \cdot 81469 \cdot 1.0000) \cdot 10^4 \\
 &= 0.00 \text{ mm} \\
 t_t &= |t_p + t_m - t_w| && \text{(total, net compressive)} \\
 &= |0.000000 + 0.001029 - (0.004380)| \\
 &= \underline{0.00 \text{ mm}} \\
 t_o &= t_{mc} + t_{wc} - t_{pc} && \text{(total required, compressive)} \\
 &= 0.001029 + (0.004380) - (0.000000) \\
 &= \underline{0.01 \text{ mm}}
 \end{aligned}$$

Performance Group (USA), Inc**Straight Flange on F&D Head #2****ASME Section VIII Division 1, 2007 Edition Metric**

Component: Straight Flange
 Material specification: SA-285 C (II-D Metric p. 10, ln. 3)
 Material is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.34073)

Internal design pressure: $P = 344 \text{ kPa @ } 200^\circ\text{C}$
 External design pressure: $P_e = 103.421 \text{ kPa @ } 200^\circ\text{C}$

Static liquid head:

$P_s = 24.5184 \text{ kPa}$ (SG=1.0000, $H_s=2502.27 \text{ mm}$ Operating head)
 $P_{th} = 14.5213 \text{ kPa}$ (SG=1.0000, $H_s=1482.00 \text{ mm}$, Horizontal test head)

Corrosion allowance: Inner C = 0.00 mm Outer C = 1.50 mm

Design MDMT = -28.89°C No impact test performed
 Rated MDMT = -105.00°C Material is not normalized
 Material is not produced to Fine Grain Practice
 PWHT is performed

Radiography: Longitudinal joint - Seamless No RT
 Circumferential joint - Spot UW-11(b) Type 1

Estimated weight: New = 16.7749 kg corr = 13.9630 kg
 Capacity: New = 87.6294 liters corr = 87.6294 liters
 OD = 1500.00 mm
 Length $L_c = 50.80 \text{ mm}$
 $t = 9.00 \text{ mm}$

Design thickness, (at 200.00°C) Appendix 1-1

$$\begin{aligned} t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\ &= 368.52 \cdot 750.00 / (108000 \cdot 0.85 + 0.40 \cdot 368.52) + 1.50 \\ &= 4.5085 \text{ mm} \end{aligned}$$

Maximum allowable working pressure, (at 200.00°C) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) - P_s \\ &= 108000 \cdot 0.85 \cdot 7.4989 / (750.00 - 0.40 \cdot 7.4989) - 24.5184 \\ &= 897.0277 \text{ kPa} \end{aligned}$$

Maximum allowable pressure, (at 21.11°C) Appendix 1-1

$$\begin{aligned} P &= S \cdot E \cdot t / (R_o - 0.40 \cdot t) \\ &= 108000 \cdot 0.85 \cdot 9.0000 / (750.00 - 0.40 \cdot 9.0000) \\ &= 1106.9132 \text{ kPa} \end{aligned}$$

Performance Group (USA), Inc**External Pressure, (Corroded & at 200.00°C) UG-28(c)**

$$L/D_o = 2277.4470/1500.0000 = 1.5183$$

$$D_o/t = 1500.0000/5.833334 = 257.1428$$

From table G: $A = 0.000210$

From table CS-2 Metric: $B = 19.9455 \text{ MPa}$

$$\begin{aligned} P_a &= 4*B/(3*(D_o/t)) \\ &= 4*19.9455/(3*(1500.0000/5.833334)) \\ &= 103.4212 \text{ kPa} \end{aligned}$$

Design thickness for external pressure $P_a = 103.4212 \text{ kPa}$

$$= t + \text{Corrosion} = 5.833334 + 1.50 = 7.33 \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 2277.4470/1500.00 = 1.5183$$

$$D_o/t = 1500.00/7.4989 = 200.0304$$

From table G: $A = 0.000303$

From table CS-2 Metric: $B = 28.8971 \text{ MPa}$

$$\begin{aligned} P_a &= 4*B/(3*(D_o/t)) \\ &= 4*28.8971/(3*(1500.00/7.4989)) \\ &= 192.6183 \text{ kPa} \end{aligned}$$

% Extreme fiber elongation - UCS-79(d)

$$\begin{aligned} &= (50 * t / R_f) * (1 - R_f / R_o) \\ &= (50 * 9.00 / 745.5001) * (1 - 745.5001 / \infty) \\ &= 0.6036 \% \end{aligned}$$

Design thickness = 7.33 mm

The governing condition is due to external pressure.

The cylinder thickness of 9.00 mm is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (kPa)	Allowable Stress Before UG-23 Stress Increase (MPa)		Temperature (°C)	Corrosion C (mm)	Load	Req'd Thk Due to Tension (mm)	Req'd Thk Due to Compression (mm)
		S_t	S_o					
Operating, Hot & Corroded	344.00	108.00	81.47	200.00	1.5000	Weight	1.4839	1.4839
Operating, Hot & New	344.00	108.00	85.17	200.00	0.0000	Weight	1.4844	1.4844

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<u>Hot Shut Down, Corroded</u>	0.00	108.00	<u>81.47</u>	200.00	1.5000	Weight	<u>0.0966</u>	<u>0.0966</u>
<u>Hot Shut Down, New</u>	0.00	108.00	<u>85.17</u>	200.00	0.0000	Weight	<u>0.0971</u>	<u>0.0971</u>
<u>Empty, Corroded</u>	0.00	108.00	<u>90.27</u>	-17.78	1.5000	Weight	<u>0.0033</u>	<u>0.0033</u>
<u>Empty, New</u>	0.00	108.00	<u>95.01</u>	-17.78	0.0000	Weight	<u>0.0040</u>	<u>0.0040</u>
<u>Vacuum</u>	-103.42	108.00	<u>81.47</u>	200.00	1.5000	Weight	<u>0.3614</u>	<u>0.3614</u>
<u>Hot Shut Down, Corroded, Weight & Eccentric Moments Only</u>	0.00	108.00	<u>81.47</u>	200.00	1.5000	Weight	<u>0.0966</u>	<u>0.0966</u>

Allowable Compressive Stress, Hot and Corroded- S_{cHC} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 7.4989) \\
 &= 0.001250 \\
 B &= 81.4695 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cHC} &= \underline{81.4695 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Hot and New- S_{cHN} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 9.0000) \\
 &= 0.001500 \\
 B &= 85.1720 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cHN} &= \underline{85.1720 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and New- S_{cCN} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 9.0000) \\
 &= 0.001500 \\
 B &= 95.0147 \text{ MPa} \\
 S &= 108.0000 / 1.0000 \\
 &= 108.0000 \text{ MPa} \\
 S_{cCN} &= \underline{95.0147 \text{ MPa}}
 \end{aligned}$$

Allowable Compressive Stress, Cold and Corroded- S_{cCC} , (table CS-2 Metric)

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (750.0000 / 7.4989) \\
 &= 0.001250 \\
 B &= 90.2737 \text{ MPa} \\
 S &= 108.0000 / 1.0000
 \end{aligned}$$

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$$= 108.0000 \text{ MPa}$$

$$S_{cCC} = 90.2737 \text{ MPa}$$

Allowable Compressive Stress, Vacuum and Corroded- S_{cVC} (table CS-2 Metric)

$$A = 0.125 / (R_o / t)$$

$$= 0.125 / (750.0000 / 7.4989)$$

$$= 0.001250$$

$$B = 81.4695 \text{ MPa}$$

$$S = 108.0000 / 1.0000$$

$$= 108.0000 \text{ MPa}$$

$$S_{cVC} = 81.4695 \text{ MPa}$$

Operating, Hot & Corroded, Top Seam

$$t_p = P \cdot R / (2 \cdot S_t \cdot K_s \cdot E_c + 0.40 \cdot |P|) \quad (\text{Pressure})$$

$$= 344.00 \cdot 741.0000 / (2 \cdot 108000 \cdot 1.0000 \cdot 0.85 + 0.40 \cdot |344.0000|)$$

$$= 1.39 \text{ mm}$$

$$t_m = M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{bending})$$

$$= 0 / (\pi \cdot 744.7495^2 \cdot 108000 \cdot 1.0000 \cdot 0.85) \cdot 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W / (2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{Weight})$$

$$= -4230 / (2 \cdot \pi \cdot 744.7495 \cdot 108000 \cdot 1.0000 \cdot 0.85) \cdot 10^4$$

$$= -0.10 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 1.387326 + 0.000000 - (-0.096563)$$

$$= 1.48 \text{ mm}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.000000 + (-0.096563) - (1.387326)|$$

$$= 1.48 \text{ mm}$$

Maximum allowable working pressure, Longitudinal Stress

$$P = 2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w) / (R - 0.40 \cdot (t - t_m + t_w))$$

$$= 2 \cdot 108000 \cdot 1.0000 \cdot 0.85 \cdot (7.4989 - 0.000000 + (-0.096563)) / (741.0000 - 0.40 \cdot (7.4989 - 0.000000 + (-0.096563)))$$

$$= 1841.45 \text{ kPa}$$

Operating, Hot & New, Top Seam

$$t_p = P \cdot R / (2 \cdot S_t \cdot K_s \cdot E_c + 0.40 \cdot |P|) \quad (\text{Pressure})$$

$$= 344.00 \cdot 741.0000 / (2 \cdot 108000 \cdot 1.0000 \cdot 0.85 + 0.40 \cdot |344.0000|)$$

$$= 1.39 \text{ mm}$$

$$t_m = M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{bending})$$

Performance Group (USA), Inc

$$= 0 / (\pi * 745.5001^2 * 108000 * 1.0000 * 0.85) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W / (2 * \pi * R_m * S_t * K_s * E_o) * \text{MetricFactor} \quad (\text{Weight})$$

$$= -4258 / (2 * \pi * 745.5001 * 108000 * 1.0000 * 0.85) * 10^4$$

$$= -0.10 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 1.387326 + 0.000000 - (-0.097101)$$

$$= \underline{1.48 \text{ mm}}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.000000 + (-0.097101) - (1.387326)|$$

$$= \underline{1.48 \text{ mm}}$$

Maximum allowable working pressure, Longitudinal Stress

$$P = 2 * S_t * K_s * E_o * (t - t_m + t_w) / (R - 0.40 * (t - t_m + t_w))$$

$$= 2 * 108000 * 1.0000 * 0.85 * (9.0000 - 0.000000 + (-0.097101)) / (741.0000 - 0.40 * (9.0000 - 0.000000 + (-0.097101)))$$

$$= 2216.55 \text{ kPa}$$

Hot Shut Down, Corroded, Top Seam

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M / (\pi * R_m^2 * S_t * K_s * E_o) * \text{MetricFactor} \quad (\text{bending})$$

$$= 0 / (\pi * 744.7495^2 * 108000 * 1.0000 * 0.85) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W / (2 * \pi * R_m * S_t * K_s * E_o) * \text{MetricFactor} \quad (\text{Weight})$$

$$= -4230 / (2 * \pi * 744.7495 * 108000 * 1.0000 * 0.85) * 10^4$$

$$= -0.10 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 0.000000 + 0.000000 - (-0.096563)$$

$$= \underline{0.10 \text{ mm}}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.000000 + (-0.096563) - (0.000000)|$$

$$= \underline{0.10 \text{ mm}}$$

Hot Shut Down, New, Top Seam

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M / (\pi * R_m^2 * S_t * K_s * E_o) * \text{MetricFactor} \quad (\text{bending})$$

$$= 0 / (\pi * 745.5001^2 * 108000 * 1.0000 * 0.85) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W / (2 * \pi * R_m * S_t * K_s * E_o) * \text{MetricFactor} \quad (\text{Weight})$$

Performance Group (USA), Inc

$$= -4258/(2*\pi*745.5001*108000*1.0000*0.85) * 10^4$$

$$= -0.10 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad \text{(total required, tensile)}$$

$$= 0.000000 + 0.000000 - (-0.097101)$$

$$= \underline{0.10 \text{ mm}}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad \text{(total, net tensile)}$$

$$= |0.000000 + (-0.097101) - (0.000000)|$$

$$= \underline{0.10 \text{ mm}}$$

Empty, Corroded, Top Seam

$$t_p = 0.00 \text{ mm} \quad \text{(Pressure)}$$

$$t_m = M/(\pi*R_m^2*S_t*K_s*E_c) * \text{MetricFactor} \quad \text{(bending)}$$

$$= 0/(\pi*744.7495^2*108000*1.0000*0.85) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W/(2*\pi*R_m*S_t*K_s*E_c) * \text{MetricFactor} \quad \text{(Weight)}$$

$$= -145/(2*\pi*744.7495*108000*1.0000*0.85) * 10^4$$

$$= -0.00 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad \text{(total required, tensile)}$$

$$= 0.000000 + 0.000000 - (-0.003318)$$

$$= \underline{0.00 \text{ mm}}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad \text{(total, net tensile)}$$

$$= |0.000000 + (-0.003318) - (0.000000)|$$

$$= \underline{0.00 \text{ mm}}$$

Empty, New, Top Seam

$$t_p = 0.00 \text{ mm} \quad \text{(Pressure)}$$

$$t_m = M/(\pi*R_m^2*S_t*K_s*E_c) * \text{MetricFactor} \quad \text{(bending)}$$

$$= 0/(\pi*745.5001^2*108000*1.0000*0.85) * 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W/(2*\pi*R_m*S_t*K_s*E_c) * \text{MetricFactor} \quad \text{(Weight)}$$

$$= -173/(2*\pi*745.5001*108000*1.0000*0.85) * 10^4$$

$$= -0.00 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad \text{(total required, tensile)}$$

$$= 0.000000 + 0.000000 - (-0.003951)$$

$$= \underline{0.00 \text{ mm}}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}|$$

Performance Group (USA), Inc(total, net
tensile)

$$= |0.000000 + (-0.003951) - (0.000000)|$$

$$= \underline{0.00 \text{ mm}}$$

Vacuum, Top Seam

$$t_p = P \cdot R / (2 \cdot S_c \cdot K_s + 0.40 \cdot |P|) \quad (\text{Pressure})$$

$$= -103.42 \cdot 741.0000 / (2 \cdot 81469 \cdot 1.0000 + 0.40 \cdot |103.4214|)$$

$$= -0.47 \text{ mm}$$

$$t_m = M / (\pi \cdot R_m^2 \cdot S_c \cdot K_s) \cdot \text{MetricFactor} \quad (\text{bending})$$

$$= 0 / (\pi \cdot 744.7495^2 \cdot 81469 \cdot 1.0000) \cdot 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W / (2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s) \cdot \text{MetricFactor} \quad (\text{Weight})$$

$$= -4230 / (2 \cdot \pi \cdot 744.7495 \cdot 81469 \cdot 1.0000) \cdot 10^4$$

$$= -0.11 \text{ mm}$$

$$t_t = |t_p + t_m - t_w| \quad (\text{total, net compressive})$$

$$= |-0.470212 + 0.000000 - (-0.108807)|$$

$$= \underline{0.36 \text{ mm}}$$

$$t_c = t_{mc} + t_{wc} - t_{pc} \quad (\text{total required, compressive})$$

$$= 0.000000 + (-0.108807) - (-0.470212)$$

$$= \underline{0.36 \text{ mm}}$$

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Top Seam

$$t_p = 0.00 \text{ mm} \quad (\text{Pressure})$$

$$t_m = M / (\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{bending})$$

$$= 0 / (\pi \cdot 744.7495^2 \cdot 108000 \cdot 1.0000 \cdot 0.85) \cdot 10^6$$

$$= 0.00 \text{ mm}$$

$$t_w = W / (2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c) \cdot \text{MetricFactor} \quad (\text{Weight})$$

$$= -4230 / (2 \cdot \pi \cdot 744.7495 \cdot 108000 \cdot 1.0000 \cdot 0.85) \cdot 10^4$$

$$= -0.10 \text{ mm}$$

$$t_t = t_p + t_m - t_w \quad (\text{total required, tensile})$$

$$= 0.000000 + 0.000000 - (-0.096563)$$

$$= \underline{0.10 \text{ mm}}$$

$$t_c = |t_{mc} + t_{wc} - t_{pc}| \quad (\text{total, net tensile})$$

$$= |0.000000 + (-0.096563) - (0.000000)|$$

$$= \underline{0.10 \text{ mm}}$$

Performance Group (USA), Inc**F&D Head #2****ASME Section VIII, Division 1, 2007 Edition Metric**

Component: F&D Head
 Material Specification: SA-285 C (II-D Metric p.10, ln. 3)
Straight Flange governs MDMT

Internal design pressure: $P = 344 \text{ kPa @ } 200^\circ\text{C}$
 External design pressure: $P_e = 103.4214 \text{ kPa @ } 200^\circ\text{C}$

Static liquid head:

$P_s = 27.1798 \text{ kPa (SG=1, } H_s=2773.88 \text{ mm Operating head)}$
 $P_{th} = 14.5213 \text{ kPa (SG=1, } H_s=1482 \text{ mm Horizontal test head)}$

Corrosion allowance: Inner C = 0 mm Outer C = 1.5 mm

Design MDMT = -28.89°C No impact test performed
 Rated MDMT = -105°C Material is not normalized
 Material is not produced to fine grain practice
 PWHT is performed
 Do not Optimize MDMT / Find MAWP

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

Estimated weight*: new = 164.4 kg corr = 136.6 kg
 Capacity*: new = 368.6 liters corr = 368.6 liters
 * includes straight flange

Outer diameter = 1500 mm
 Crown radius L = 1347.6 mm
 Knuckle radius r = 90 mm
 Minimum head thickness = 9 mm
 Straight flange length L_{sf} = 50.8 mm
 Nominal straight flange thickness t_{sf} = 9 mm

Results Summary

The governing condition is internal pressure.
 Minimum thickness per UG-16 = $1.5 \text{ mm} + 1.5 \text{ mm} = 3 \text{ mm}$
 Design thickness due to internal pressure (t) = 6.19 mm
 Design thickness due to external pressure (t_e) = 5.49 mm
 Maximum allowable working pressure (MAWP) = 567.33 kPa
 Maximum allowable pressure (MAP) = 713.43 kPa

M (Corroded)

$$M = 1/4 * [3 + (L/r)^{1/2}] = 1/4 * [3 + (1,347.6/90)^{1/2}] = 1.717385$$

Performance Group (USA), Inc**M (New)**

$$M = 1/4[3 + (L/r)^{1/2}] = 1/4[3 + (1,347.6/90)^{1/2}] = 1.717385$$

Design thickness for internal pressure, (Corroded at 200 °C) Appendix 1-4(d)

$$\begin{aligned} t &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) + \text{Corrosion} \\ &= 371.18 \cdot 1,355.1 \cdot 1.7174 / (2 \cdot 108,000 \cdot 0.85 + 371.18 \cdot (1.7174 - 0.2)) + 1.5 \\ &= 6.19 \text{ mm} \end{aligned}$$

The head internal pressure design thickness is 6.19 mm.**Maximum allowable working pressure, (Corroded at 200 °C) Appendix 1-4(d)**

$$\begin{aligned} P &= 2 \cdot S \cdot E \cdot t / (M \cdot L_o - t \cdot (M - 0.2)) - P_s \\ &= 2 \cdot 108,000 \cdot 0.85 \cdot 7.5 / (1.7174 \cdot 1,355.1 - 7.5 \cdot (1.7174 - 0.2)) - 27.18 \\ &= 567.33 \text{ kPa} \end{aligned}$$

The maximum allowable working pressure (MAWP) is 567.33 kPa.**Maximum allowable pressure, (New at 21.11 °C) Appendix 1-4(d)**

$$\begin{aligned} P &= 2 \cdot S \cdot E \cdot t / (M \cdot L_o - t \cdot (M - 0.2)) - P_s \\ &= 2 \cdot 108,000 \cdot 0.85 \cdot 9 / (1.7174 \cdot 1,356.6 - 9 \cdot (1.7174 - 0.2)) - 0 \\ &= 713.43 \text{ kPa} \end{aligned}$$

The maximum allowable pressure (MAP) is 713.43 kPa.**Design thickness for external pressure, (Corroded at 200 °C) UG-33(e)**Equivalent outside spherical radius (R_o)

$$\begin{aligned} &= \text{Outside crown radius} \\ &= 1,355.1 \text{ mm} \end{aligned}$$

$$\begin{aligned} A &= 0.125 / (R_o/t) \\ &= 0.125 / (1,355.1/3.99) \\ &= 0.000368 \end{aligned}$$

From Table CS-2 Metric: $B = 35.1462 \text{ MPa}$

$$\begin{aligned} P_a &= B / (R_o/t) \\ &= 35,146.16 / (1,355.1/3.99) \\ &= 103.4214 \text{ kPa} \end{aligned}$$

$$t = 3.99 \text{ mm} + \text{Corrosion} = 3.99 \text{ mm} + 1.5 \text{ mm} = 5.49 \text{ mm}$$

Check the external pressure per UG-33(a)(1) Appendix 1-4(d)

$$\begin{aligned} t &= 1.67 \cdot P_s \cdot L_o \cdot M / (2 \cdot S \cdot E + 1.67 \cdot P_s \cdot (M - 0.2)) + \text{Corrosion} \\ &= 1.67 \cdot 103.42 \cdot 1,355.1 \cdot 1.7174 / (2 \cdot 108,000 \cdot 1 + 1.67 \cdot 103.42 \cdot (1.7174 - 0.2)) + 1.5 \\ &= 3.36 \text{ mm} \end{aligned}$$

The head external pressure design thickness (t_e) is 5.49 mm.

Performance Group (USA), Inc**Maximum Allowable External Pressure, (Corroded at 200 °C) UG-33(e)**Equivalent outside spherical radius (R_o)

$$= \text{Outside crown radius}$$

$$= 1,355.1 \text{ mm}$$

$$A = 0.125 / (R_o/t)$$

$$= 0.125 / (1,355.1/7.5)$$

$$= 0.000692$$

From Table CS-2 Metric: $B=65.8325 \text{ MPa}$

$$P_a = B/(R_o/t)$$

$$= 65,832.52/(1,355.1/7.5)$$

$$= 364.3047 \text{ kPa}$$

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(d)

$$P = 2 \cdot S \cdot E \cdot t / ((M \cdot L_o - t \cdot (M - 0.2)) \cdot 1.67) - P_{s2}$$

$$= 2 \cdot 108,000 \cdot 1 \cdot 7.5 / ((1.7174 \cdot 1,355.1 - 7.5 \cdot (1.7174 - 0.2)) \cdot 1.67) - 0$$

$$= 418.82 \text{ kPa}$$

The maximum allowable external pressure (MAEP) is 364.3 kPa.**% Extreme fiber elongation - UCS-79(d)**

$$= (75 \cdot t / R_i) \cdot (1 - R_i / R_o)$$

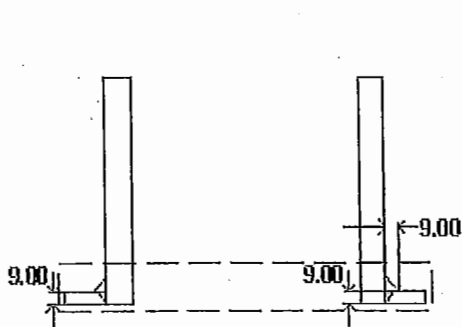
$$= (75 \cdot 9 / 94.5) \cdot (1 - 94.5 / \infty)$$

$$= 7.1429\%$$

Performance Group (USA), Inc

Inspection Port (N7)

ASME Section VIII Division 1, 2007 Edition Metric



$t_{w(lower)} = 9 \text{ mm}$
 $Leg_{41} = 9 \text{ mm}$

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

Located on:

Liquid static head included:

Nozzle material specification:

Nozzle longitudinal joint efficiency:

Nozzle description:

Flange description:

Bolt Material:

Flange rated MDMT:

(UCS-66(b)(3): Coincident ratio = 0.1798077)

(Flange rated MDMT = -105 °C (UCS-68(c) applies.)

Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C)

Liquid static head on flange:

ASME B16.5 flange rating MAWP:

ASME B16.5 flange rating MAP:

ASME B16.5 flange hydro test:

Nozzle orientation:

Local vessel minimum thickness:

Nozzle center line offset to datum line:

End of nozzle to shell center:

Nozzle inside diameter, new:

Cylinder #1

11.1509 kPa

SA-106 B Smls. Pipe
 (II-D Metric p. 14, In. 5)

1

16" Sch 60 DN 400

16 inch Class 150 SO
 A105

SA-193 B7 Bolt <= 64
 (II-D Metric p. 348, In.
 33)

-48 °C

9.3231 kPa

1395.5 kPa @ 200 °C

1965.01 kPa @

21.11 °C

3102.64 kPa @

21.11 °C

180 °

9 mm

1500 mm

902.4 mm

373.08 mm

Performance Group (USA), Inc

Nozzle nominal wall thickness:	16.66 mm
Nozzle corrosion allowance:	0 mm
Projection available outside vessel, Lpr:	135.74 mm
Projection available outside vessel to flange face, Lf:	152.4 mm

Performance Group (USA), Inc

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 669.72 kPa @ 200 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
17.3081	17.3284	10.6684	5.8497	--	--	0.8103	6.14	14.58

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	5.25	6.3	weld size is adequate

Calculations for internal pressure 669.72 kPa @ 200 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.32845).

Nozzle UCS-66 governing thk: 9 mm

Nozzle rated MDMT: -105 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 373.08 mm

Normal to the vessel wall outside: $2.5 \cdot (t - C) = 18.75$ mm

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 669.7165 \cdot 186.54 / (118,000 \cdot 1 - 0.6 \cdot 669.7165) \\
 &= 1.06 \text{ mm}
 \end{aligned}$$

Performance Group (USA), IncRequired thickness t_r from UG-37(a)

$$\begin{aligned}
 t_r &= P R_o / (S E + 0.4 P) \\
 &= 669.7165 * 750 / (108,000 * 1 + 0.4 * 669.7165) \\
 &= 4.64 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 108$ MPa f_{r1} = lesser of 1 or $S_n/S_v = 1$ f_{r2} = lesser of 1 or $S_n/S_v = 1$

$$\begin{aligned}
 A &= d * t_r * F + 2 * t_n * t_r * F * (1 - f_{r1}) \\
 &= 373.08 * 4.64 * 1 + 2 * 16.66 * 4.64 * 1 * (1 - 1) \\
 &= \underline{17.3081 \text{ cm}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1

 A_1 = larger of the following = 10.6684 cm^2

$$\begin{aligned}
 &= d * (E_1 * t - F * t_r) - 2 * t_n * (E_1 * t - F * t_r) * (1 - f_{r1}) \\
 &= 373.08 * (1 * 7.5 - 1 * 4.64) - 2 * 16.66 * (1 * 7.5 - 1 * 4.64) * (1 - 1) \\
 &= 10.6684 \text{ cm}^2 \\
 &= 2 * (t + t_n) * (E_1 * t - F * t_r) - 2 * t_n * (E_1 * t - F * t_r) * (1 - f_{r1}) \\
 &= 2 * (7.5 + 16.66) * (1 * 7.5 - 1 * 4.64) - 2 * 16.66 * (1 * 7.5 - 1 * 4.64) * (1 - 1) \\
 &= 1.3819 \text{ cm}^2
 \end{aligned}$$

 A_2 = smaller of the following = 5.8497 cm^2

$$\begin{aligned}
 &= 5 * (t_n - t_m) * f_{r2} * t \\
 &= 5 * (16.66 - 1.06) * 1 * 7.5 \\
 &= 5.8497 \text{ cm}^2 \\
 &= 5 * (t_n - t_m) * f_{r2} * t_n \\
 &= 5 * (16.66 - 1.06) * 1 * 16.66 \\
 &= 12.9974 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 * f_{r2} \\
 &= 9^2 * 1 \\
 &= \underline{0.8103 \text{ cm}^2}
 \end{aligned}$$

$$\text{Area} = A_1 + A_2 + A_{41}$$

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$$= 10.6684 + 5.8497 + 0.8103$$

$$= \underline{17.3284 \text{ cm}^2}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or $t = 7.5$ mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{5.25}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 9 = 6.3$ mm

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

Wall thickness per UG-45(a): $t_{r1} = 1.06$ mm ($E = 1$)

Wall thickness per UG-45(b)(1): $t_{r2} = 6.14$ mm

Wall thickness per UG-16(b): $t_{r3} = 1.5$ mm

Standard wall pipe per UG-45(b)(4): $t_{r4} = 8.33$ mm

The greater of t_{r2} or t_{r3} : $t_{r5} = 6.14$ mm

The lesser of t_{r4} or t_{r5} : $t_{r6} = 6.14$ mm

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Required per UG-45 is the larger of t_{r1} or $t_{r6} = 6.14$ mm

Available nozzle wall thickness new, $t_n = 0.875 \cdot 16.66 = 14.58$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 799.36 kPa @ 21.11 °C The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
20.6484	20.6651	12.9284	6.9264	--	--	0.8103	5.53	14.58

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg41)	6	6.3	weld size is adequate

Calculations for internal pressure 799.36 kPa @ 21.11 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 373.08$ mm

Normal to the vessel wall outside: $2.5 \cdot (t - C) = 22.5$ mm

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 799.3612 \cdot 186.54 / (118,000 \cdot 1 - 0.6 \cdot 799.3612) \\
 &= 1.27 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

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$$\begin{aligned} t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\ &= 799.3612 \cdot 750 / (108,000 \cdot 1 + 0.4 \cdot 799.3612) \\ &= 5.53 \text{ mm} \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 108$ MPa

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 373.08 \cdot 5.53 \cdot 1 + 2 \cdot 16.66 \cdot 5.53 \cdot 1 \cdot (1 - 1) \\ &= \underline{20.6484 \text{ cm}^2} \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{12.9284 \text{ cm}^2}$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 373.08 \cdot (1 \cdot 9 - 1 \cdot 5.53) - 2 \cdot 16.66 \cdot (1 \cdot 9 - 1 \cdot 5.53) \cdot (1 - 1) \\ &= 12.9284 \text{ cm}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (9 + 16.66) \cdot (1 \cdot 9 - 1 \cdot 5.53) - 2 \cdot 16.66 \cdot (1 \cdot 9 - 1 \cdot 5.53) \cdot (1 - 1) \\ &= 1.7787 \text{ cm}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{6.9264 \text{ cm}^2}$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (16.66 - 1.27) \cdot 1 \cdot 9 \\ &= 6.9264 \text{ cm}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (16.66 - 1.27) \cdot 1 \cdot 16.66 \\ &= 12.8238 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 9^2 \cdot 1 \\ &= \underline{0.8103 \text{ cm}^2} \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 12.9284 + 6.9264 + 0.8103 \\ &= \underline{20.6651 \text{ cm}^2} \end{aligned}$$

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As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 9 \text{ mm}$

$t_{c(min)} = \text{lesser of } 6 \text{ mm or } 0.7 * t_{min} = \underline{6} \text{ mm}$

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 9 = 6.3 \text{ mm}$

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

Wall thickness per UG-45(a): $t_{r1} = 1.27 \text{ mm (E=1)}$

Wall thickness per UG-45(b)(1): $t_{r2} = 5.53 \text{ mm}$

Wall thickness per UG-16(b): $t_{r3} = 1.5 \text{ mm}$

Standard wall pipe per UG-45(b)(4): $t_{r4} = 8.33 \text{ mm}$

The greater of t_{r2} or t_{r3} : $t_{r5} = 5.53 \text{ mm}$

The lesser of t_{r4} or t_{r5} : $t_{r6} = 5.53 \text{ mm}$

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Required per UG-45 is the larger of t_{r1} or $t_{r6} = 5.53$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 16.66 = 14.58$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm ²) For $P_e = 120.79$ kPa @ 200 °C The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
11.5519	11.5522	4.8729	5.869	--	--	0.8103	2.34	14.58

Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg 41)	5.25	6.3	weld size is adequate

Calculations for external pressure 120.79 kPa @ 200 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 373.08$ mm

Normal to the vessel wall outside: $2.5 \times (t - C) = 18.75$ mm

Nozzle required thickness per UG-28 $t_{rn} = 1.01$ mm

From UG-37(d)(1) required thickness $t_r = 6.19$ mm

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 118$, $S_v = 108$ MPa

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

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

$$\begin{aligned} A &= 0.5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= 0.5 \cdot (373.08 \cdot 6.19 \cdot 1 + 2 \cdot 16.66 \cdot 6.19 \cdot 1 \cdot (1 - 1)) \\ &= \underline{11.5519 \text{ cm}^2} \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{4.8729 \text{ cm}^2}$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 373.08 \cdot (1 \cdot 7.5 - 1 \cdot 6.19) - 2 \cdot 16.66 \cdot (1 \cdot 7.5 - 1 \cdot 6.19) \cdot (1 - 1) \\ &= 4.8729 \text{ cm}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (7.5 + 16.66) \cdot (1 \cdot 7.5 - 1 \cdot 6.19) - 2 \cdot 16.66 \cdot (1 \cdot 7.5 - 1 \cdot 6.19) \cdot (1 - 1) \\ &= 0.631 \text{ cm}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{5.869 \text{ cm}^2}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (16.66 - 1.01) \cdot 1 \cdot 7.5 \\ &= 5.869 \text{ cm}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (16.66 - 1.01) \cdot 1 \cdot 16.66 \\ &= 13.0406 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 9^2 \cdot 1 \\ &= \underline{0.8103 \text{ cm}^2} \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 4.8729 + 5.869 + 0.8103 \\ &= \underline{11.5522 \text{ cm}^2} \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or $t = 7.5$ mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{5.25}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 9 = 6.3$ mm

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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

Wall thickness per UG-45(a): $t_{r1} = 1.01$ mm

Wall thickness per UG-45(b)(2): $t_{r2} = 2.34$ mm

Wall thickness per UG-16(b): $t_{r3} = 1.5$ mm

Standard wall pipe per UG-45(b)(4): $t_{r4} = 8.33$ mm

The greater of t_{r2} or t_{r3} : $t_{r5} = 2.34$ mm

The lesser of t_{r4} or t_{r5} : $t_{r6} = 2.34$ mm

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 2.34$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 16.66 = 14.58$ mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 180.4513/406.4000 = 0.4440$$

$$D_o/t = 406.4000/1.009583 = 402.5424$$

From table G: $A = 0.000382$

From table CS-2 Metric: $B = 36.4659$ MPa

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o/t)) \\ &= 4 \cdot 36.4659 / (3 \cdot (406.4000/1.009583)) \\ &= 120.7854 \text{ kPa} \end{aligned}$$

Design thickness for external pressure $P_a = 120.7854$ kPa

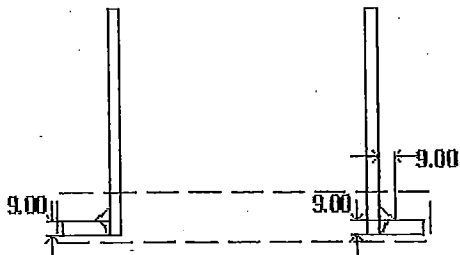
$$= t + \text{Corrosion} = 1.009583 + 0.00 = 1.01 \text{ mm}$$

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Liquid Level (N1)

ASME Section VIII Division 1, 2007 Edition Metric

$t_{w(lower)} = 9 \text{ mm}$
 $Leg_{41} = 9 \text{ mm}$



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

Located on:

Liquid static head included:

Nozzle material specification:

Nozzle longitudinal joint efficiency:

Nozzle description:

Flange description:

Bolt Material:

Flange rated MDMT:

(UCS-66(b)(3): Coincident ratio = 0.175361)

(Flange rated MDMT = -105 °C (UCS-68(c) applies.)

Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C)

Liquid static head on flange:

ASME B16.5 flange rating MAWP:

ASME B16.5 flange rating MAP:

ASME B16.5 flange hydro test:

Nozzle orientation:

Calculated as hillside:

Local vessel minimum thickness:

End of nozzle to datum line:

F&D Head #1

2.4731 kPa

SA-106 B Smls. Pipe
 (II-D Metric p. 14, ln. 5)

1

6" Sch 40 (Std) DN
 150

6 inch Class 150 SO
 A105

SA-193 B7 Bolt <= 64
 (II-D Metric p. 348, ln.
 33)

-48 °C

0.5854 kPa

1395.5 kPa @ 200 °C

1965.01 kPa @
 21.11 °C

3102.64 kPa @
 21.11 °C

160°

yes

9 mm

2391.76 mm

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Nozzle inside diameter, new:	154.05 mm
Nozzle nominal wall thickness:	7.11 mm
Nozzle corrosion allowance:	0 mm
Opening chord length:	166.5 mm
Projection available outside vessel, Lpr:	145.29 mm
Projection available outside vessel to flange face, Lf:	152.4 mm
Distance to head center, R:	550 mm

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Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 400.38 kPa @ 200 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
7.8648	7.8671	4.6206	2.4361	--	--	0.8103	6.22	6.22

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	4.98	6.3	weld size is adequate

Calculations for internal pressure 400.38 kPa @ 200 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.03641).

Nozzle UCS-66 governing thk: 6.22 mm

Nozzle rated MDMT: -105 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 166.5 mm

Normal to the vessel wall outside: $2.5 \cdot (t_n - C_n) + t_e = 17.78$ mm

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

$$\begin{aligned}
 t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 400.3837 \cdot 77.03 / (118,000 \cdot 1 - 0.6 \cdot 400.3837) \\
 &= 0.26 \text{ mm}
 \end{aligned}$$

Performance Group (USA), Inc**Required thickness t_r from UG-37(a)**

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 400.38 \cdot 1,457.5 \cdot 1.7535 / (2 \cdot 108,000 \cdot 1 + 400.38 \cdot (1.7535 - 0.2)) \\
 &= 4.72 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)Allowable stresses: $S_n = 118$, $S_v = 108$ MPa $f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$ $f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 166.5 \cdot 4.72 \cdot 1 + 2 \cdot 7.11 \cdot 4.72 \cdot 1 \cdot (1 - 1) \\
 &= \underline{7.8648 \text{ cm}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1 $A_1 = \text{larger of the following} = \underline{4.6206 \text{ cm}^2}$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 166.5 \cdot (1 \cdot 7.5 - 1 \cdot 4.72) - 2 \cdot 7.11 \cdot (1 \cdot 7.5 - 1 \cdot 4.72) \cdot (1 - 1) \\
 &= 4.6206 \text{ cm}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (7.5 + 7.11) \cdot (1 \cdot 7.5 - 1 \cdot 4.72) - 2 \cdot 7.11 \cdot (1 \cdot 7.5 - 1 \cdot 4.72) \cdot (1 - 1) \\
 &= 0.811 \text{ cm}^2
 \end{aligned}$$

 $A_2 = \text{smaller of the following} = \underline{2.4361 \text{ cm}^2}$

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (7.11 - 0.26) \cdot 1 \cdot 7.5 \\
 &= 2.5684 \text{ cm}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (7.11 - 0.26) \cdot 1 \cdot 7.11 \\
 &= 2.4361 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 9^2 \cdot 1 \\
 &= \underline{0.8103 \text{ cm}^2}
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 4.6206 + 2.4361 + 0.8103
 \end{aligned}$$

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$$= 7.8671 \text{ cm}^2$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 19 mm or t_n or $t = 7.11$ mm

$t_{c(min)}$ = lesser of 6 mm or $0.7 * t_{min} = 4.98$ mm

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 9 = 6.3$ mm

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.

Wall thickness per UG-45(a): $t_{r1} = 0.26$ mm ($E = 1$)

Wall thickness per UG-45(b)(1): $t_{r2} = 6.23$ mm

Wall thickness per UG-16(b): $t_{r3} = 1.5$ mm

Standard wall pipe per UG-45(b)(4): $t_{r4} = 6.22$ mm

The greater of t_{r2} or t_{r3} : $t_{r5} = 6.23$ mm

The lesser of t_{r4} or t_{r5} : $t_{r6} = 6.22$ mm

Performance Group (USA), Inc

Required per UG-45 is the larger of t_{r1} or $t_{r8} = 6.22$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 7.11 = 6.22$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 463.34 kPa @ 21.11 °C The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
9.1069	9.1097	5.8781	2.4213	--	--	0.8103	5.47	6.22

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	4.98	6.3	weld size is adequate

Calculations for internal pressure 463.34 kPa @ 21.11 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 166.5$ mm

Normal to the vessel wall outside: $2.5 \times (t_n - C_n) + t_e = 17.78$ mm

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 463.336 \cdot 77.03 / (118,000 \cdot 1 - 0.6 \cdot 463.336) \\
 &= 0.3 \text{ mm}
 \end{aligned}$$

Required thickness t_r from UG-37(a)

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$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 463.34 \cdot 1,459 \cdot 1.7535 / (2 \cdot 108,000 \cdot 1 + 463.34 \cdot (1.7535 - 0.2)) \\
 &= 5.47 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 108$ MPa

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

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

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 166.5 \cdot 5.47 \cdot 1 + 2 \cdot 7.11 \cdot 5.47 \cdot 1 \cdot (1 - 1) \\
 &= \underline{9.1069} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{5.8781} \text{ cm}^2$$

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 166.5 \cdot (1 \cdot 9 - 1 \cdot 5.47) - 2 \cdot 7.11 \cdot (1 \cdot 9 - 1 \cdot 5.47) \cdot (1 - 1) \\
 &= 5.8781 \text{ cm}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (9 + 7.11) \cdot (1 \cdot 9 - 1 \cdot 5.47) - 2 \cdot 7.11 \cdot (1 \cdot 9 - 1 \cdot 5.47) \cdot (1 - 1) \\
 &= 1.1374 \text{ cm}^2
 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{2.4213} \text{ cm}^2$$

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (7.11 - 0.3) \cdot 1 \cdot 9 \\
 &= 3.0645 \text{ cm}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (7.11 - 0.3) \cdot 1 \cdot 7.11 \\
 &= 2.4213 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 9^2 \cdot 1 \\
 &= \underline{0.8103} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 5.8781 + 2.4213 + 0.8103 \\
 &= \underline{9.1097} \text{ cm}^2
 \end{aligned}$$

G Performance Group (USA), Inc

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 19 mm or t_n or $t = 7.11$ mm

$t_{c(min)}$ = lesser of 6 mm or $0.7 * t_{min} = 4.98$ mm

$t_{c(actual)} = 0.7 * \text{Leg} = 0.7 * 9 = 6.3$ mm

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.

Wall thickness per UG-45(a): $t_{r1} = 0.3$ mm ($E = 1$)

Wall thickness per UG-45(b)(1): $t_{r2} = 5.47$ mm

Wall thickness per UG-16(b): $t_{r3} = 1.5$ mm

Standard wall pipe per UG-45(b)(4): $t_{r4} = 6.22$ mm

The greater of t_{r2} or t_{r3} : $t_{r5} = 5.47$ mm

The lesser of t_{r4} or t_{r5} : $t_{r6} = 5.47$ mm

Performance Group (USA), Inc

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 5.47$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 7.11 = 6.22$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm ²) For $P_e = 192.62$ kPa @ 200 °C The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
4.8716	5.8013	2.7413	2.2497	--	--	0.8103	3.78	6.22

Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg 41)	4.98	6.3	weld size is adequate

Calculations for external pressure 192.62 kPa @ 200 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 166.48$ mm

Normal to the vessel wall outside: $2.5 \times (t_n - C_n) + t_e = 17.78$ mm

Nozzle required thickness per UG-28 $t_m = 0.79$ mm

From UG-37(d)(1) required thickness $t_r = 5.85$ mm

Area required per UG-37(d)(1)

Allowable stresses: $S_n = 118$, $S_v = 108$ MPa

Performance Group (USA), Inc

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

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

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= 0.5(166.48 \cdot 5.85 \cdot 1 + 2 \cdot 7.11 \cdot 5.85 \cdot 1 \cdot (1 - 1)) \\ &= \underline{4.8716} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{2.7413} \text{ cm}^2$$

$$\begin{aligned} &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\ &= 166.48(1 \cdot 7.5 - 1 \cdot 5.85) - 2 \cdot 7.11(1 \cdot 7.5 - 1 \cdot 5.85)(1 - 1) \\ &= 2.7413 \text{ cm}^2 \\ &= 2 \cdot (t + t_n)(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\ &= 2 \cdot (7.5 + 7.11)(1 \cdot 7.5 - 1 \cdot 5.85) - 2 \cdot 7.11(1 \cdot 7.5 - 1 \cdot 5.85)(1 - 1) \\ &= 0.4813 \text{ cm}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{2.2497} \text{ cm}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (7.11 - 0.79) \cdot 1 \cdot 7.5 \\ &= 2.3723 \text{ cm}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (7.11 - 0.79) \cdot 1 \cdot 7.11 \\ &= 2.2497 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 9^2 \cdot 1 \\ &= \underline{0.8103} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 2.7413 + 2.2497 + 0.8103 \\ &= \underline{5.8013} \text{ cm}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{\min} = lesser of 19 mm or t_n or $t = 7.11$ mm

$t_{c(\min)}$ = lesser of 6 mm or $0.7 \cdot t_{\min} = \underline{4.98}$ mm

$t_{c(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 9 = 6.3$ mm

Performance Group (USA), Inc

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.

Wall thickness per UG-45(a):	$t_{r1} = 0.79 \text{ mm}$
Wall thickness per UG-45(b)(2):	$t_{r2} = 3.78 \text{ mm}$
Wall thickness per UG-16(b):	$t_{r3} = 1.5 \text{ mm}$
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 6.22 \text{ mm}$
The greater of t_{r2} or t_{r3} :	$t_{r5} = 3.78 \text{ mm}$
The lesser of t_{r4} or t_{r5} :	$t_{r6} = 3.78 \text{ mm}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.78 \text{ mm}$

Available nozzle wall thickness new, $t_n = 0.875 \times 7.11 = 6.22 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 221.0428/168.2750 = 1.3136$$

$$D_o/t = 168.2750/0.785708 = 214.1700$$

From table G: $A = 0.000324$

From table CS-2 Metric: $B = 30.9402 \text{ MPa}$

$$\begin{aligned} P_a &= 4 \cdot B / (3 \cdot (D_o/t)) \\ &= 4 \cdot 30.9402 / (3 \cdot (168.2750/0.785708)) \\ &= 192.6205 \text{ kPa} \end{aligned}$$

Design thickness for external pressure $P_a = 192.6205 \text{ kPa}$

$$= t + \text{Corrosion} = 0.785708 + 0.00 = 0.79 \text{ mm}$$

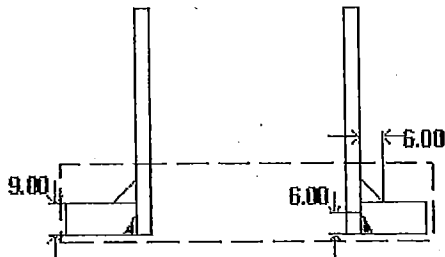
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NaOH Fill (N5)

ASME Section VIII Division 1, 2007 Edition Metric

$$t_{w(lower)} = 6 \text{ mm}$$

$$Leg_{41} = 6 \text{ mm}$$



Note: round inside edges per UG-78(c)

Located on:

Liquid static head included:

Nozzle material specification:

Nozzle longitudinal joint efficiency:

Nozzle description:

Flange description:

Bolt Material:

Flange rated MDMT:

(UCS-66(b)(3): Coincident ratio = 0.1750631)

(Flange rated MDMT = -105 °C (UCS-68(c) applies.)

Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C)

Liquid static head on flange:

ASME B16.5 flange rating MAWP:

ASME B16.5 flange rating MAP:

ASME B16.5 flange hydro test:

Nozzle orientation:

Calculated as hillside:

Local vessel minimum thickness:

End of nozzle to datum line:

Nozzle inside diameter, new:

F&D Head #1

1.9657 kPa

SA-106 B Smls. Pipe
(II-D Metric p. 14, In. 5)

1

2" Sch 40 (Std) DN 50

2 inch Class 150 WN

A105

SA-193 B7 Bolt <= 64
(II-D Metric p. 348, In. 33)

-48 °C

0 kPa

1395.5 kPa @ 200 °C

1965.01 kPa @

21.11 °C

3102.64 kPa @

21.11 °C

120 °

yes

9 mm

2451.47 mm

52.5 mm

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Nozzle nominal wall thickness:	3.91 mm
Nozzle corrosion allowance:	0 mm
Opening chord length:	54.62 mm
Projection available outside vessel, Lpr:	164.35 mm
Projection available outside vessel to flange face, Lf:	183.4 mm
Distance to head center, R:	400 mm

Performance Group (USA), Inc

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 1114.32 kPa @ 200 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

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 size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg 41)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for internal pressure 1114.32 kPa @ 200 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.02253).

Nozzle UCS-66 governing thk: 3.42 mm

Nozzle rated MDMT: -105 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 54.62 mm

Normal to the vessel wall outside: $2.5(t_n - C_n) + t_e = 9.78$ mm

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

$$t_m = \frac{P \cdot R_n}{(S_n \cdot E - 0.6 \cdot P)}$$

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$$= 1,114.322 * 26.25 / (118,000 * 1 - 0.6 * 1,114.322)$$

$$= 0.25 \text{ mm}$$

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

$$t_r = P * L_o * M / (2 * S * E + P * (M - 0.2))$$

$$= 1,114.322 * 1,459 * 1 / (2 * 108,000 * 1 + 1,114.322 * (1 - 0.2))$$

$$= 7.5 \text{ mm}$$

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

UW-16(d) Weld Check

$$t_{min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 3.91 \text{ mm}$$

$$t_{1(min)} \text{ or } t_{2(min)} = \text{lesser of } 6 \text{ mm or } 0.7 * t_{min} = 2.74 \text{ mm}$$

$$t_{1(actual)} = 0.7 * \text{Leg} = 0.7 * 6 = 4.2 \text{ mm}$$

The weld size t_1 is satisfactory.

$$t_{2(actual)} = 6 \text{ mm}$$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 10.2 \geq 1.25 * t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	$t_{r1} = 0.25 \text{ mm (E = 1)}$
Wall thickness per UG-45(b)(1):	$t_{r2} = 14.58 \text{ mm}$
Wall thickness per UG-16(b):	$t_{r3} = 1.5 \text{ mm}$
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 3.42 \text{ mm}$
The greater of t_{r2} or t_{r3} :	$t_{r5} = 14.58 \text{ mm}$
The lesser of t_{r4} or t_{r5} :	$t_{r6} = 3.42 \text{ mm}$

Performance Group (USA), Inc

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.42$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 3.91 = 3.42$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 1338.99 kPa @ 21.11 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

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 size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for internal pressure 1338.99 kPa @ 21.11 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 54.62$ mm

Normal to the vessel wall outside: $2.5 \times (t_n - C_n) + t_e = 9.78$ mm

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

$$\begin{aligned}
 t_n &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,338.99 \cdot 26.25 / (118,000 \cdot 1 - 0.6 \cdot 1,338.99) \\
 &= 0.3 \text{ mm}
 \end{aligned}$$

Performance Group (USA), Inc

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

$$\begin{aligned} t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\ &= 1,338.99 \cdot 1,459 \cdot 1 / (2 \cdot 108,000 \cdot 1 + 1,338.99 \cdot (1 - 0.2)) \\ &= 9 \text{ mm} \end{aligned}$$

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

UW-16(d) Weld Check

$$\begin{aligned} t_{min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 3.91 \text{ mm} \\ t_{1(min)} \text{ or } t_{2(min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{min} = 2.74 \text{ mm} \\ t_{1(actual)} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 6 = 4.2 \text{ mm} \\ \text{The weld size } t_1 &\text{ is satisfactory.} \\ t_{2(actual)} &= 6 \text{ mm} \\ \text{The weld size } t_2 &\text{ is satisfactory.} \end{aligned}$$

$$t_1 + t_2 = 10.2 \geq 1.25 \cdot t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	$t_{r1} = 0.3 \text{ mm (E=1)}$
Wall thickness per UG-45(b)(1):	$t_{r2} = 15.71 \text{ mm}$
Wall thickness per UG-16(b):	$t_{r3} = 1.5 \text{ mm}$
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 3.42 \text{ mm}$
The greater of t_{r2} or t_{r3} :	$t_{r5} = 15.71 \text{ mm}$
The lesser of t_{r4} or t_{r5} :	$t_{r6} = 3.42 \text{ mm}$

Performance Group (USA), Inc

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.42$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 3.91 = 3.42$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm ²) For $P_e = 192.62$ kPa @ 200 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg41)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for external pressure 192.62 kPa @ 200 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 54.61$ mm

Normal to the vessel wall outside: $2.5 \times (t_n - C_n) + t_o = 9.78$ mm

Nozzle required thickness per UG-28 $t_m = 0.42$ mm

From UG-37(d)(1) required thickness $t_r = 5.85$ mm

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

Performance Group (USA), Inc**UW-16(d) Weld Check**

t_{min} = lesser of 19 mm or t_n or $t = 3.91$ mm

$t_{1(min)}$ or $t_{2(min)}$ = lesser of 6 mm or $0.7 * t_{min} = 2.74$ mm

$t_{1(actual)} = 0.7 * Leg = 0.7 * 6 = 4.2$ mm

The weld size t_1 is satisfactory.

$t_{2(actual)} = 6$ mm

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 10.2 \geq 1.25 * t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a): $t_{r1} = 0.42$ mm

Wall thickness per UG-45(b)(2): $t_{r2} = 3.78$ mm

Wall thickness per UG-16(b): $t_{r3} = 1.5$ mm

Standard wall pipe per UG-45(b)(4): $t_{r4} = 3.42$ mm

The greater of t_{r2} or t_{r3} : $t_{r5} = 3.78$ mm

The lesser of t_{r4} or t_{r5} : $t_{r6} = 3.42$ mm

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.42$ mm

Available nozzle wall thickness new, $t_n = 0.875 * 3.91 = 3.42$ mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 200.5974/60.3250 = 3.3253$$

$$D_o/t = 60.3250/0.418315 = 144.2094$$

From table G: $A = 0.000219$

From table CS-2 Metric: $B = 20.8322$ MPa

$$P_a = 4 * B / (3 * (D_o/t))$$

$$= 4 * 20.8322 / (3 * (60.3250/0.418315))$$

$$= 192.6109 \text{ kPa}$$

Design thickness for external pressure $P_a = 192.6109$ kPa

$$= t + \text{Corrosion} = 0.418315 + 0.00 = 0.42 \text{ mm}$$

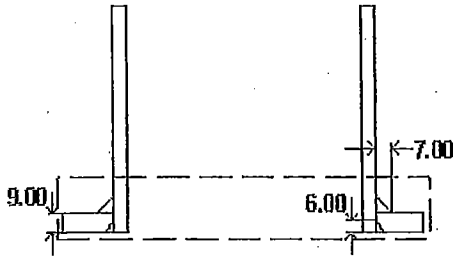
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Outlet (N6)

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$t_{w(lower)} = 6 \text{ mm}$

$Leg_{41} = 7 \text{ mm}$



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

Located on:

Liquid static head included:

Nozzle material specification:

Nozzle longitudinal joint efficiency:

Nozzle description:

Flange description:

Bolt Material:

Flange rated MDMT:

(UCS-66(b)(3): Coincident ratio = 0.189694)

(Flange rated MDMT = -105 °C (UCS-68(c) applies.)

Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C)

Liquid static head on flange:

ASME B16.5 flange rating MAWP:

ASME B16.5 flange rating MAP:

ASME B16.5 flange hydro test:

Nozzle orientation:

Calculated as hillside:

Local vessel minimum thickness:

End of nozzle to datum line:

F&D Head #2

28.6615 kPa

SA-106 B Smls. Pipe
(II-D Metric p. 14, In. 5)

1

4" Sch 40 (Std) DN
100

4 inch Class 150 WN
A105

SA-193 B7 Bolt <= 64
(II-D Metric p. 348, In.
33)

-48 °C

28.7498 kPa

1395.5 kPa @ 200 °C

1965.01 kPa @

21.11 °C

3102.64 kPa @

21.11 °C

0°

no

9 mm

-482.6 mm

Performance Group (USA), Inc

Nozzle inside diameter, new:	102.26 mm
Nozzle nominal wall thickness:	6.02 mm
Nozzle corrosion allowance:	0 mm
Projection available outside vessel, Lpr:	128.52 mm
Projection available outside vessel to flange face, Lf:	152.4 mm
Distance to head center, R:	0 mm

Performance Group (USA), Inc

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 770.45 kPa @ 200 °C The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
4.934	4.9355	2.7342	1.711	--	--	0.4903	5.27	5.27

Weld Failure Path Analysis Summary (N) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
27,235	23,774	151,082	33,524	152,604

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg 41)	4.21	4.9	weld size is adequate
Nozzle to shell groove (Lower)	4.21	6	weld size is adequate

Calculations for internal pressure 770.45 kPa @ 200 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.03071).

Nozzle UCS-66 governing thk: 5.27 mm

Nozzle rated MDMT: -105 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 102.26 mm

Normal to the vessel wall outside: $2.5 \cdot (t_n - C_n) + t_g = 15.05$ mm

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

$$t_m = P \cdot R_n / (S_n \cdot E - 0.6 \cdot P)$$

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$$= 770.4483 \times 51.13 / (118,000 \times 1 - 0.6 \times 770.4483)$$

$$= 0.34 \text{ mm}$$

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

$$t_r = P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2))$$

$$= 770.4483 \times 1,356.6 \times 1 / (2 \times 108,000 \times 1 + 770.4483 \times (1 - 0.2))$$

$$= 4.83 \text{ mm}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 108 \text{ MPa}$

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

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

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$

$$= 102.26 \times 4.83 \times 1 + 2 \times 6.02 \times 4.83 \times 1 \times (1 - 1)$$

$$= \underline{4.934 \text{ cm}^2}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{2.7342 \text{ cm}^2}$

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 102.26 \times (1 \times 7.5 - 1 \times 4.83) - 2 \times 6.02 \times (1 \times 7.5 - 1 \times 4.83) \times (1 - 1)$$

$$= 2.7342 \text{ cm}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (7.5 + 6.02) \times (1 \times 7.5 - 1 \times 4.83) - 2 \times 6.02 \times (1 \times 7.5 - 1 \times 4.83) \times (1 - 1)$$

$$= 0.7232 \text{ cm}^2$$

$A_2 = \text{smaller of the following} = \underline{1.711 \text{ cm}^2}$

$$= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (6.02 - 0.34) \times 1 \times 7.5$$

$$= 2.1316 \text{ cm}^2$$

$$= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n$$

$$= 5 \cdot (6.02 - 0.34) \times 1 \times 6.02$$

$$= 1.711 \text{ cm}^2$$

$$A_{41} = \text{Leg}^2 \cdot f_{r2}$$

$$= 7^2 \times 1$$

$$= \underline{0.4903 \text{ cm}^2}$$

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$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 2.7342 + 1.711 + 0.4903 \\
 &= \underline{4.9355 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$$\begin{aligned}
 t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 6.02 \text{ mm} \\
 t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{4.21 \text{ mm}} \\
 t_{1(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 7 = 4.9 \text{ mm} \\
 &\text{The weld size } t_1 \text{ is satisfactory.} \\
 t_{2(\text{actual})} &= 6 \text{ mm} \\
 &\text{The weld size } t_2 \text{ is satisfactory.}
 \end{aligned}$$

$$t_1 + t_2 = 10.9 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.34 \text{ mm (E=1)} \\
 \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 9.76 \text{ mm} \\
 \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 1.5 \text{ mm} \\
 \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 5.27 \text{ mm} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 9.76 \text{ mm} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 5.27 \text{ mm}
 \end{aligned}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{5.27 \text{ mm}}$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 6.02 = 5.27 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\begin{aligned}
 \text{Groove weld in tension:} & \quad 0.74 \cdot 108 = 79.92 \text{ MPa} \\
 \text{Nozzle wall in shear:} & \quad 0.7 \cdot 118 = 82.6 \text{ MPa} \\
 \text{Inner fillet weld in shear:} & \quad 0.49 \cdot 108 = 52.92 \text{ MPa}
 \end{aligned}$$

Strength of welded joints:

$$\begin{aligned}
 (1) \text{ Inner fillet weld in shear} \\
 (\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_1 &= (\pi/2) \cdot 114.3 \cdot 7 \cdot 52.92 = 66,509.55 \text{ N}
 \end{aligned}$$

(3) Nozzle wall in shear

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$$(\pi/2) * \text{Mean nozzle dia} * t_n * S_n = (\pi/2) * 108.28 * 6.02 * 82.6 = 84,572.88 \text{ N}$$

(4) Groove weld in tension

$$(\pi/2) * \text{Nozzle OD} * t_w * S_g = (\pi/2) * 114.3 * 6 * 79.92 = 86,094 \text{ N}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * f_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (493.4048 - 273.4188 + 2 * 6.02 * 1 * (1 * 7.5 - 1 * 4.83)) * 108 \\ &= \underline{27,235.27 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (171.0964 + 0 + 49.0322 + 0) * 108 \\ &= \underline{23,773.89 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (171.0964 + 0 + 49.0322 + 0 + 2 * 6.02 * 7.5 * 1) * 108 \\ &= \underline{33,524.49 \text{ N}} \end{aligned}$$

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Load for path 1-1 lesser of W or $W_{1-1} = 23773.89$ N
 Path 1-1 through (1) & (3) = $66,509.55 + 84,572.88 = 151,082.42$ N
 Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 27235.27$ N
 Path 2-2 through (1), (4) = $66,509.55 + 86,094 = 152,603.56$ N
 Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 889.39 kPa @ 21.11 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
<u>5.6933</u>	<u>5.6961</u>	<u>3.5103</u>	<u>1.6955</u>	--	--	<u>0.4903</u>	<u>5.27</u>	5.27

Weld Failure Path Analysis Summary (N)				
All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
<u>28,039</u>	<u>23,607</u>	<u>151,082</u>	<u>35,309</u>	<u>152,604</u>

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg 41)	<u>4.21</u>	4.9	weld size is adequate
Nozzle to shell groove (Lower)	<u>4.21</u>	6	weld size is adequate

Calculations for internal pressure 889.39 kPa @ 21.11 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 102.26$ mm
 Normal to the vessel wall outside: $2.5(t_n - C_n) + t_o = 15.05$ mm

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

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$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 889.3866 \cdot 51.13 / (118,000 \cdot 1 - 0.6 \cdot 889.3866) \\
 &= 0.39 \text{ mm}
 \end{aligned}$$

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

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 889.3866 \cdot 1,356.6 \cdot 1 / (2 \cdot 108,000 \cdot 1 + 889.3866 \cdot (1 - 0.2)) \\
 &= 5.57 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 108$ MPa

$$\begin{aligned}
 f_{r1} &= \text{lesser of } 1 \text{ or } S_n / S_v = 1 \\
 f_{r2} &= \text{lesser of } 1 \text{ or } S_n / S_v = 1
 \end{aligned}$$

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 102.26 \cdot 5.57 \cdot 1 + 2 \cdot 6.02 \cdot 5.57 \cdot 1 \cdot (1 - 1) \\
 &= \underline{5.6933 \text{ cm}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 3.5103 cm²

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 102.26 \cdot (1 \cdot 9 - 1 \cdot 5.57) - 2 \cdot 6.02 \cdot (1 \cdot 9 - 1 \cdot 5.57) \cdot (1 - 1) \\
 &= 3.5103 \text{ cm}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (9 + 6.02) \cdot (1 \cdot 9 - 1 \cdot 5.57) - 2 \cdot 6.02 \cdot (1 \cdot 9 - 1 \cdot 5.57) \cdot (1 - 1) \\
 &= 1.031 \text{ cm}^2
 \end{aligned}$$

A_2 = smaller of the following = 1.6955 cm²

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (6.02 - 0.39) \cdot 1 \cdot 9 \\
 &= 2.5355 \text{ cm}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (6.02 - 0.39) \cdot 1 \cdot 6.02 \\
 &= 1.6955 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 7^2 \cdot 1 \\
 &= \underline{0.4903 \text{ cm}^2}
 \end{aligned}$$

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$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 3.5103 + 1.6955 + 0.4903 \\
 &= \underline{5.6961 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$$\begin{aligned}
 t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 6.02 \text{ mm} \\
 t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{4.21 \text{ mm}} \\
 t_{1(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 7 = 4.9 \text{ mm} \\
 \text{The weld size } t_1 &\text{ is satisfactory.} \\
 t_{2(\text{actual})} &= 6 \text{ mm} \\
 \text{The weld size } t_2 &\text{ is satisfactory.}
 \end{aligned}$$

$$t_1 + t_2 = 10.9 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.39 \text{ mm (E=1)} \\
 \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 9.53 \text{ mm} \\
 \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 1.5 \text{ mm} \\
 \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 5.27 \text{ mm} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 9.53 \text{ mm} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 5.27 \text{ mm}
 \end{aligned}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{5.27 \text{ mm}}$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 6.02 = 5.27 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\begin{aligned}
 \text{Groove weld in tension:} & \quad 0.74 \cdot 108 = 79.92 \text{ MPa} \\
 \text{Nozzle wall in shear:} & \quad 0.7 \cdot 118 = 82.6 \text{ MPa} \\
 \text{Inner fillet weld in shear:} & \quad 0.49 \cdot 108 = 52.92 \text{ MPa}
 \end{aligned}$$

Strength of welded joints:

$$\begin{aligned}
 (1) \text{ Inner fillet weld in shear} \\
 (\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_1 &= (\pi/2) \cdot 114.3 \cdot 7 \cdot 52.92 = 66,509.55 \text{ N}
 \end{aligned}$$

(3) Nozzle wall in shear

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$$(\pi/2) * \text{Mean nozzle dia} * t_n * S_n = (\pi/2) * 108.28 * 6.02 * 82.6 = 84,572.88 \text{ N}$$

(4) Groove weld-in tension

$$(\pi/2) * \text{Nozzle OD} * t_w * S_g = (\pi/2) * 114.3 * 6 * 79.92 = 86,094 \text{ N}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * f_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (569.3272 - 351.0315 + 2 * 6.02 * 1 * (1 * 9 - 1 * 5.57)) * 108 \\ &= \underline{28,039.23 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (169.548 + 0 + 49.0322 + 0) * 108 \\ &= \underline{23,606.67 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * f_{r1}) * S_v \\ &= (169.548 + 0 + 49.0322 + 0 + 2 * 6.02 * 9 * 1) * 108 \\ &= \underline{35,309.16 \text{ N}} \end{aligned}$$

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Load for path 1-1 lesser of W or $W_{1-1} = 23606.67 \text{ N}$

Path 1-1 through (1) & (3) = $66,509.55 + 84,572.88 = 151,082.42 \text{ N}$

Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 28039.23 \text{ N}$

Path 2-2 through (1), (4) = $66,509.55 + 86,094 = 152,603.56 \text{ N}$

Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For $P_e = 192.62 \text{ kPa @ } 200^\circ \text{C}$ The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
2.7824	4.2445	2.1039	1.6503	--	--	0.4903	3.57	5.27

Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	4.21	4.9	weld size is adequate
Nozzle to shell groove (Lower)	4.21	6	weld size is adequate

Calculations for external pressure 192.62 kPa @ 200 °C**Limits of reinforcement per UG-40**

Parallel to the vessel wall: $d = 102.26 \text{ mm}$

Normal to the vessel wall outside: $2.5(t_n - C_n) + t_o = 15.05 \text{ mm}$

Nozzle required thickness per UG-28 $t_m = 0.54 \text{ mm}$

From UG-37(d)(1) required thickness $t_r = 5.44 \text{ mm}$

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Area required per UG-37(d)(1)

Allowable stresses: $S_n = 118$, $S_v = 108$ MPa

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

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

$$\begin{aligned} A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\ &= 0.5(102.26 \cdot 5.44 \cdot 1 + 2 \cdot 6.02 \cdot 5.44 \cdot 1 \cdot (1 - 1)) \\ &= \underline{2.7824} \text{ cm}^2 \end{aligned}$$

Area available from FIG. UG-37.1

$A_1 = \text{larger of the following} = \underline{2.1039} \text{ cm}^2$

$$\begin{aligned} &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 102.26 \cdot (1 \cdot 7.5 - 1 \cdot 5.44) - 2 \cdot 6.02 \cdot (1 \cdot 7.5 - 1 \cdot 5.44) \cdot (1 - 1) \\ &= 2.1039 \text{ cm}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (7.5 + 6.02) \cdot (1 \cdot 7.5 - 1 \cdot 5.44) - 2 \cdot 6.02 \cdot (1 \cdot 7.5 - 1 \cdot 5.44) \cdot (1 - 1) \\ &= 0.5561 \text{ cm}^2 \end{aligned}$$

$A_2 = \text{smaller of the following} = \underline{1.6503} \text{ cm}^2$

$$\begin{aligned} &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\ &= 5 \cdot (6.02 - 0.54) \cdot 1 \cdot 7.5 \\ &= 2.0555 \text{ cm}^2 \\ &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (6.02 - 0.54) \cdot 1 \cdot 6.02 \\ &= 1.6503 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 7^2 \cdot 1 \\ &= \underline{0.4903} \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 2.1039 + 1.6503 + 0.4903 \\ &= \underline{4.2445} \text{ cm}^2 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

G Performance Group (USA), Inc

$t_{min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 6.02 \text{ mm}$
 $t_{1(min)} \text{ or } t_{2(min)} = \text{lesser of } 6 \text{ mm or } 0.7 * t_{min} = \underline{4.21} \text{ mm}$
 $t_{1(actual)} = 0.7 * \text{Leg} = 0.7 * 7 = 4.9 \text{ mm}$
 The weld size t_1 is satisfactory.
 $t_{2(actual)} = 6 \text{ mm}$
 The weld size t_2 is satisfactory.

$$t_1 + t_2 = 10.9 \geq 1.25 * t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	$t_{r1} = 0.54 \text{ mm}$
Wall thickness per UG-45(b)(2):	$t_{r2} = 3.57 \text{ mm}$
Wall thickness per UG-16(b):	$t_{r3} = 1.5 \text{ mm}$
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 5.27 \text{ mm}$
The greater of t_{r2} or t_{r3} :	$t_{r5} = 3.57 \text{ mm}$
The lesser of t_{r4} or t_{r5} :	$t_{r6} = 3.57 \text{ mm}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{3.57} \text{ mm}$

Available nozzle wall thickness new, $t_n = 0.875 * 6.02 = 5.27 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200.00° C) UG-28(c)

$$L/D_o = 152.4000/114.3000 = 1.3333$$

$$D_o/t = 114.3000/0.537302 = 212.7297$$

From table G: $A = 0.000322$
 From table CS-2 Metric: $B = 30.7309 \text{ MPa}$

$$\begin{aligned}
 P_a &= 4 * B / (3 * (D_o / t)) \\
 &= 4 * 30.7309 / (3 * (114.3000 / 0.537302)) \\
 &= 192.6132 \text{ kPa}
 \end{aligned}$$

Design thickness for external pressure $P_a = 192.6132 \text{ kPa}$

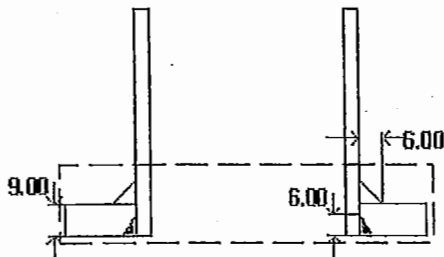
$$= t + \text{Corrosion} = 0.537302 + 0.00 = 0.54 \text{ mm}$$

G Performance Group (USA), Inc

Spare (N3)

ASME Section VIII Division 1, 2007 Edition Metric

$t_{w(lower)} = 6 \text{ mm}$
 $Leg_{41} = 6 \text{ mm}$



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

Located on:

Liquid static head included:

Nozzle material specification:

Nozzle longitudinal joint efficiency:

Nozzle description:

Flange description:

Bolt Material:

Flange rated MDMT:

(UCS-66(b)(3): Coincident ratio = 0.1750631)

(Flange rated MDMT = -105 °C (UCS-68(c) applies.)

Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C)

Liquid static head on flange:

ASME B16.5 flange rating MAWP:

ASME B16.5 flange rating MAP:

ASME B16.5 flange hydro test:

Nozzle orientation:

Calculated as hillside:

Local vessel minimum thickness:

End of nozzle to datum line:

Nozzle inside diameter, new:

F&D Head #1

1.6299 kPa

SA-106 B Smls. Pipe
 (II-D Metric p. 14, ln. 5)

1

2" Sch 40 (Std) DN 50

2 inch Class 150 WN
 A105

SA-193 B7 Bolt <= 64
 (II-D Metric p. 348, ln. 33)

-48 °C

0 kPa

1395.5 kPa @ 200 °C

1965.01 kPa @
 21.11 °C

3102.64 kPa @
 21.11 °C

180 °

yes

9 mm

2451.47 mm

52.5 mm

91/130

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Nozzle nominal wall thickness:	3.91 mm
Nozzle corrosion allowance:	0 mm
Opening chord length:	53.3 mm
Projection available outside vessel, Lpr:	133.35 mm
Projection available outside vessel to flange face, Lf:	152.4 mm
Distance to head center, R:	250 mm

Performance Group (USA), Inc

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 1114.51 kPa @ 200 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

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 size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg 41)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for internal pressure 1114.51 kPa @ 200 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.0225).

Nozzle UCS-66 governing thk: 3.42 mm

Nozzle rated MDMT: -105 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 53.3 mm

Normal to the vessel wall outside: $2.5(t_n - C_n) + t_g = 9.78$ mm

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

$$t_n = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

Performance Group (USA), Inc

$$= 1,114.51 * 26.25 / (118,000 * 1 - 0.6 * 1,114.51)$$

$$= 0.25 \text{ mm}$$

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

$$t_r = P * L_o * M / (2 * S * E + P * (M - 0.2))$$

$$= 1,114.51 * 1,459 * 1 / (2 * 108,000 * 1 + 1,114.51 * (1 - 0.2))$$

$$= 7.5 \text{ mm}$$

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

UW-16(d) Weld Check

$$t_{min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 3.91 \text{ mm}$$

$$t_{1(min)} \text{ or } t_{2(min)} = \text{lesser of } 6 \text{ mm or } 0.7 * t_{min} = \underline{2.74 \text{ mm}}$$

$$t_{1(actual)} = 0.7 * \text{Leg} = 0.7 * 6 = 4.2 \text{ mm}$$

The weld size t_1 is satisfactory.

$$t_{2(actual)} = 6 \text{ mm}$$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 10.2 \geq 1.25 * t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	$t_{r1} = 0.25 \text{ mm (E = 1)}$
Wall thickness per UG-45(b)(1):	$t_{r2} = 14.58 \text{ mm}$
Wall thickness per UG-16(b):	$t_{r3} = 1.5 \text{ mm}$
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 3.42 \text{ mm}$
The greater of t_{r2} or t_{r3} :	$t_{r5} = 14.58 \text{ mm}$
The lesser of t_{r4} or t_{r5} :	$t_{r6} = 3.42 \text{ mm}$

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Required per UG-45 is the larger of t_{r1} or $t_{r0} = 3.42$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 3.91 = 3.42$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 1338.99 kPa @ 21.11 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

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 size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for internal pressure 1338.99 kPa @ 21.11 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 53.3$ mm

Normal to the vessel wall outside: $2.5 \times (t_n - C_n) + t_o = 9.78$ mm

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,338.99 \times 26.25 / (118,000 \times 1 - 0.6 \times 1,338.99) \\
 &= 0.3 \text{ mm}
 \end{aligned}$$

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

$$\begin{aligned} t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\ &= 1,338.99 \cdot 1,459 \cdot 1 / (2 \cdot 108,000 \cdot 1 + 1,338.99 \cdot (1 - 0.2)) \\ &= 9 \text{ mm} \end{aligned}$$

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

UW-16(d) Weld Check

$$\begin{aligned} t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 3.91 \text{ mm} \\ t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = 2.74 \text{ mm} \\ t_{1(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 6 = 4.2 \text{ mm} \\ \text{The weld size } t_1 &\text{ is satisfactory.} \\ t_{2(\text{actual})} &= 6 \text{ mm} \\ \text{The weld size } t_2 &\text{ is satisfactory.} \end{aligned}$$

$$t_1 + t_2 = 10.2 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

$$\begin{aligned} \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.3 \text{ mm (E=1)} \\ \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 15.71 \text{ mm} \\ \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 1.5 \text{ mm} \\ \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 3.42 \text{ mm} \\ \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 15.71 \text{ mm} \\ \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 3.42 \text{ mm} \end{aligned}$$

Performance Group (USA), Inc

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.42$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 3.91 = 3.42$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm ²) For $P_e = 192.62$ kPa @ 200 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg 41)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for external pressure 192.62 kPa @ 200 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 53.3$ mm

Normal to the vessel wall outside: $2.5(t_n - C_n) + t_e = 9.78$ mm

Nozzle required thickness per UG-28 $t_m = 0.38$ mm

From UG-37(d)(1) required thickness $t_r = 5.85$ mm

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

G Performance Group (USA), Inc**UW-16(d) Weld Check**

$t_{\min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 3.91 \text{ mm}$
 $t_{1(\min)} \text{ or } t_{2(\min)} = \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = 2.74 \text{ mm}$
 $t_{1(\text{actual})} = 0.7 \cdot \text{Leg} = 0.7 \cdot 6 = 4.2 \text{ mm}$
 The weld size t_1 is satisfactory.
 $t_{2(\text{actual})} = 6 \text{ mm}$
 The weld size t_2 is satisfactory.

$$t_1 + t_2 = 10.2 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a): $t_{r1} = 0.38 \text{ mm}$
 Wall thickness per UG-45(b)(2): $t_{r2} = 3.78 \text{ mm}$
 Wall thickness per UG-16(b): $t_{r3} = 1.5 \text{ mm}$
 Standard wall pipe per UG-45(b)(4): $t_{r4} = 3.42 \text{ mm}$
 The greater of t_{r2} or t_{r3} : $t_{r5} = 3.78 \text{ mm}$
 The lesser of t_{r4} or t_{r5} : $t_{r6} = 3.42 \text{ mm}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.42 \text{ mm}$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 3.91 = 3.42 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 162.8943/60.3250 = 2.7003$$

$$D_o/t = 60.3250/0.381440 = 158.1506$$

From table G: $A = 0.000240$
 From table CS-2 Metric: $B = 22.8479 \text{ MPa}$

$$\begin{aligned}
 P_a &= 4 \cdot B / (3 \cdot (D_o/t)) \\
 &= 4 \cdot 22.8479 / (3 \cdot (60.3250/0.381440)) \\
 &= 192.6254 \text{ kPa}
 \end{aligned}$$

Design thickness for external pressure $P_a = 192.6254 \text{ kPa}$

$$= t + \text{Corrosion} = 0.381440 + 0.00 = 0.38 \text{ mm}$$

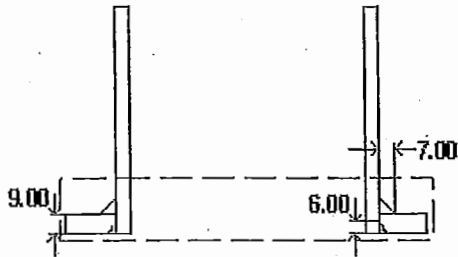
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Vent/Overflow (N2)

ASME Section VIII Division 1, 2007 Edition Metric

$$t_{w(lower)} = 6 \text{ mm}$$

$$Leg_{41} = 7 \text{ mm}$$



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

Located on:

Liquid static head included:

Nozzle material specification:

Nozzle longitudinal joint efficiency:

Nozzle description:

Flange description:

Bolt Material:

Flange rated MDMT:

(UCS-66(b)(3): Coincident ratio = 0.1754077)

(Flange rated MDMT = -105 °C (UCS-68(c) applies.)

Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C)

Liquid static head on flange:

ASME B16.5 flange rating MAWP:

ASME B16.5 flange rating MAP:

ASME B16.5 flange hydro test:

Nozzle orientation:

Calculated as hillside:

Local vessel minimum thickness:

End of nozzle to datum line:

F&D Head #1

2.4731 kPa

SA-106 B Smls. Pipe
(II-D Metric p. 14, In. 5)

1

4" Sch 40 (Std) DN
100

4 inch Class 150 WN
A105

SA-193 B7 Bolt <= 64
(II-D Metric p. 348, In.
33)

-48 °C

0.6771 kPa

1395.5 kPa @ 200 °C

1965.01 kPa @
21.11 °C

3102.64 kPa @
21.11 °C

200 °

yes

9 mm

2382.37 mm

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Nozzle inside diameter, new:	102.26 mm
Nozzle nominal wall thickness:	6.02 mm
Nozzle corrosion allowance:	0 mm
Opening chord length:	110.52 mm
Projection available outside vessel, Lpr:	128.52 mm
Projection available outside vessel to flange face, Lf:	152.4 mm
Distance to head center, R:	550 mm

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Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-37 governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 704.48 kPa @ 200 °C The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
5.2455	5.2516	3.0419	1.7194	--	--	0.4903	5.27	5.27

Weld Failure Path Analysis Summary (N) All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
27.377	23.864	151.082	33.615	152.604

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg41)	4.21	4.9	weld size is adequate
Nozzle to shell groove (Lower)	4.21	6	weld size is adequate

Calculations for internal pressure 704.48 kPa @ 200 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.02855).

Nozzle UCS-66 governing thk: 5.27 mm

Nozzle rated MDMT: -105 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 110.52 mm

Normal to the vessel wall outside: $2.5 \cdot (t_n - C_n) + t_o = 15.05$ mm

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

$$t_m = P \cdot R_n / (S_n \cdot E - 0.6 \cdot P)$$

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$$= 704.4813 \times 51.13 / (118,000 \times 1 - 0.6 \times 704.4813)$$

$$= 0.31 \text{ mm}$$

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

$$t_r = P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2))$$

$$= 704.4813 \times 1,459 \times 1 / (2 \times 108,000 \times 1 + 704.4813 \times (1 - 0.2))$$

$$= 4.75 \text{ mm}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 108 \text{ MPa}$ $f_{r1} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$ $f_{r2} = \text{lesser of } 1 \text{ or } S_n / S_v = 1$

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$

$$= 110.52 \times 4.75 \times 1 + 2 \times 6.02 \times 4.75 \times 1 \times (1 - 1)$$

$$= \underline{5.2455 \text{ cm}^2}$$

Area available from FIG. UG-37.1

 $A_1 = \text{larger of the following} = \underline{3.0419 \text{ cm}^2}$

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 110.52 \times (1 \times 7.5 - 1 \times 4.75) - 2 \times 6.02 \times (1 \times 7.5 - 1 \times 4.75) \times (1 - 1)$$

$$= 3.0419 \text{ cm}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (7.5 + 6.02) \times (1 \times 7.5 - 1 \times 4.75) - 2 \times 6.02 \times (1 \times 7.5 - 1 \times 4.75) \times (1 - 1)$$

$$= 0.7445 \text{ cm}^2$$

 $A_2 = \text{smaller of the following} = \underline{1.7194 \text{ cm}^2}$

$$= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (6.02 - 0.31) \times 1 \times 7.5$$

$$= 2.1419 \text{ cm}^2$$

$$= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n$$

$$= 5 \cdot (6.02 - 0.31) \times 1 \times 6.02$$

$$= 1.7194 \text{ cm}^2$$

$$A_{41} = \text{Leg}^2 \cdot f_{r2}$$

$$= 7^2 \times 1$$

$$= \underline{0.4903 \text{ cm}^2}$$

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$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 3.0419 + 1.7194 + 0.4903 \\
 &= \underline{5.2516 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$$\begin{aligned}
 t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 6.02 \text{ mm} \\
 t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{4.21 \text{ mm}} \\
 t_{1(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 7 = 4.9 \text{ mm} \\
 &\text{The weld size } t_1 \text{ is satisfactory.} \\
 t_{2(\text{actual})} &= 6 \text{ mm} \\
 &\text{The weld size } t_2 \text{ is satisfactory.}
 \end{aligned}$$

$$t_1 + t_2 = 10.9 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.31 \text{ mm (E=1)} \\
 \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 9.79 \text{ mm} \\
 \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 1.5 \text{ mm} \\
 \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 5.27 \text{ mm} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 9.79 \text{ mm} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 5.27 \text{ mm}
 \end{aligned}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{5.27 \text{ mm}}$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 6.02 = 5.27 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\begin{aligned}
 \text{Groove weld in tension:} & \quad 0.74 \cdot 108 = 79.92 \text{ MPa} \\
 \text{Nozzle wall in shear:} & \quad 0.7 \cdot 118 = 82.6 \text{ MPa} \\
 \text{Inner fillet weld in shear:} & \quad 0.49 \cdot 108 = 52.92 \text{ MPa}
 \end{aligned}$$

Strength of welded joints:

$$\begin{aligned}
 (1) \text{ Inner fillet weld in shear} \\
 (\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_1 &= (\pi/2) \cdot 114.3 \cdot 7 \cdot 52.92 = 66,509.55 \text{ N}
 \end{aligned}$$

(3) Nozzle wall in shear

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$$(\pi/2) * \text{Mean nozzle dia} * t_n * S_n = (\pi/2) * 108.28 * 6.02 * 82.6 = 84,572.88 \text{ N}$$

(4) Groove weld in tension

$$(\pi/2) * \text{Nozzle OD} * t_w * S_g = (\pi/2) * 114.3 * 6 * 79.92 = 86,094 \text{ N}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * t_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (524.5451 - 304.1929 + 2 * 6.02 * 1 * (1 * 7.5 - 1 * 4.75)) * 108 \\ &= \underline{27,377.2 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (171.9351 + 0 + 49.0322 + 0) * 108 \\ &= \underline{23,864.47 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t_{r1}) * S_v \\ &= (171.9351 + 0 + 49.0322 + 0 + 2 * 6.02 * 7.5 * 1) * 108 \\ &= \underline{33,615.07 \text{ N}} \end{aligned}$$

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Load for path 1-1 lesser of W or $W_{1-1} = 23864.47$ N
 Path 1-1 through (1) & (3) = $66,509.55 + 84,572.88 = 151,082.42$ N
 Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 27377.2$ N
 Path 2-2 through (1), (4) = $66,509.55 + 86,094 = 152,603.56$ N
 Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for MAP

Available reinforcement per UG-37 governs the MAP of this nozzle.

UG-37 Area Calculation Summary (cm ²)							UG-45 Nozzle Wall Thickness Summary (mm)	
For P = 815.59 kPa @ 21.11 °C The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
6.0702	6.0716	3.8761	1.7052	--	--	0.4903	5.27	5.27

Weld Failure Path Analysis Summary (N)				
All failure paths are stronger than the applicable weld loads				
Weld load W	Weld load W ₁₋₁	Path 1-1 strength	Weld load W ₂₋₂	Path 2-2 strength
28,257	23,711	151,082	35,414	152,604

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg41)	4.21	4.9	weld size is adequate
Nozzle to shell groove (Lower)	4.21	6	weld size is adequate

Calculations for internal pressure 815.59 kPa @ 21.11 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 110.52$ mm
 Normal to the vessel wall outside: $2.5 \cdot (t_n - C_n) + t_e = 15.05$ mm

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

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$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 815.5867 \cdot 51.13 / (118,000 \cdot 1 - 0.6 \cdot 815.5867) \\
 &= 0.36 \text{ mm}
 \end{aligned}$$

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

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 815.5867 \cdot 1,459 \cdot 1 / (2 \cdot 108,000 \cdot 1 + 815.5867 \cdot (1 - 0.2)) \\
 &= 5.49 \text{ mm}
 \end{aligned}$$

Area required per UG-37(c)

Allowable stresses: $S_n = 118$, $S_v = 108$ MPa

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

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

$$\begin{aligned}
 A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
 &= 110.52 \cdot 5.49 \cdot 1 + 2 \cdot 6.02 \cdot 5.49 \cdot 1 \cdot (1 - 1) \\
 &= \underline{6.0702 \text{ cm}^2}
 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following = 3.8761 cm²

$$\begin{aligned}
 &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 110.52 \cdot (1 \cdot 9 - 1 \cdot 5.49) - 2 \cdot 6.02 \cdot (1 \cdot 9 - 1 \cdot 5.49) \cdot (1 - 1) \\
 &= 3.8761 \text{ cm}^2 \\
 &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
 &= 2 \cdot (9 + 6.02) \cdot (1 \cdot 9 - 1 \cdot 5.49) - 2 \cdot 6.02 \cdot (1 \cdot 9 - 1 \cdot 5.49) \cdot (1 - 1) \\
 &= 1.0535 \text{ cm}^2
 \end{aligned}$$

A_2 = smaller of the following = 1.7052 cm²

$$\begin{aligned}
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5 \cdot (6.02 - 0.36) \cdot 1 \cdot 9 \\
 &= 2.549 \text{ cm}^2 \\
 &= 5 \cdot (t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5 \cdot (6.02 - 0.36) \cdot 1 \cdot 6.02 \\
 &= 1.7052 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 7^2 \cdot 1 \\
 &= \underline{0.4903 \text{ cm}^2}
 \end{aligned}$$

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$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 3.8761 + 1.7052 + 0.4903 \\
 &= \underline{6.0716 \text{ cm}^2}
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.

UW-16(d) Weld Check

$$\begin{aligned}
 t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 6.02 \text{ mm} \\
 t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = \underline{4.21 \text{ mm}} \\
 t_{1(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 7 = 4.9 \text{ mm} \\
 &\text{The weld size } t_1 \text{ is satisfactory.} \\
 t_{2(\text{actual})} &= 6 \text{ mm} \\
 &\text{The weld size } t_2 \text{ is satisfactory.}
 \end{aligned}$$

$$t_1 + t_2 = 10.9 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

$$\begin{aligned}
 \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.36 \text{ mm (E=1)} \\
 \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 9.6 \text{ mm} \\
 \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 1.5 \text{ mm} \\
 \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 5.27 \text{ mm} \\
 \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 9.6 \text{ mm} \\
 \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 5.27 \text{ mm}
 \end{aligned}$$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{5.27 \text{ mm}}$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 6.02 = 5.27 \text{ mm}$

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45(c) and UW-15(c)

$$\begin{aligned}
 \text{Groove weld in tension:} & \quad 0.74 \cdot 108 = 79.92 \text{ MPa} \\
 \text{Nozzle wall in shear:} & \quad 0.7 \cdot 118 = 82.6 \text{ MPa} \\
 \text{Inner fillet weld in shear:} & \quad 0.49 \cdot 108 = 52.92 \text{ MPa}
 \end{aligned}$$

Strength of welded joints:

$$\begin{aligned}
 (1) \text{ Inner fillet weld in shear,} \\
 (\pi/2) \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_1 &= (\pi/2) \cdot 114.3 \cdot 7 \cdot 52.92 = 66,509.55 \text{ N}
 \end{aligned}$$

(3) Nozzle wall in shear

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$$(\pi/2) * \text{Mean nozzle dia} * t_n * S_n = (\pi/2) * 108.28 * 6.02 * 82.6 = 84,572.88 \text{ N}$$

(4) Groove weld in tension

$$(\pi/2) * \text{Nozzle OD} * t_w * S_g = (\pi/2) * 114.3 * 6 * 79.92 = 86,094 \text{ N}$$

Loading on welds per UG-41(b)(1)

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * f_{r1} * (E_t * t - F * t_r)) * S_v \\ &= (607.0193 - 387.6121 + 2 * 6.02 * 1 * (1 * 9 - 1 * 5.49)) * 108 \\ &= \underline{28,256.71 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (170.5158 + 0 + 49.0322 + 0) * 108 \\ &= \underline{23,711.18 \text{ N}} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * f_{r1}) * S_v \\ &= (170.5158 + 0 + 49.0322 + 0 + 2 * 6.02 * 9 * 1) * 108 \\ &= \underline{35,413.67 \text{ N}} \end{aligned}$$

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Load for path 1-1 lesser of W or $W_{1-1} = 23711.18 \text{ N}$
 Path 1-1 through (1) & (3) = $66,509.55 + 84,572.88 = 151,082.42 \text{ N}$
 Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2-2} = 28256.71 \text{ N}$
 Path 2-2 through (1), (4) = $66,509.55 + 86,094 = 152,603.56 \text{ N}$
 Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm ²) For $P_e = 192.62 \text{ kPa @ } 200^\circ \text{C}$ The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (mm) The nozzle passes UG-45	
A required	A available	A ₁	A ₂	A ₃	A ₅	A welds	t _{req}	t _{min}
3.2333	3.9413	1.8194	1.6316	--	--	0.4903	3.78	5.27

Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	4.21	4.9	weld size is adequate
Nozzle to shell groove (Lower)	4.21	6	weld size is adequate

Calculations for external pressure 192.62 kPa @ 200 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 110.5 \text{ mm}$
 Normal to the vessel wall outside: $2.5 \cdot (t_n - C_n) + t_o = 15.05 \text{ mm}$

Nozzle required thickness per UG-28 $t_m = 0.6 \text{ mm}$

From UG-37(d)(1) required thickness $t_r = 5.85 \text{ mm}$

Performance Group (USA), Inc**Area required per UG-37(d)(1)**Allowable stresses: $S_n = 118$, $S_v = 108$ MPa $f_{r1} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$ $f_{r2} = \text{lesser of } 1 \text{ or } S_n/S_v = 1$

$$\begin{aligned}
 A &= 0.5(d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})) \\
 &= 0.5(110.5 \cdot 5.85 \cdot 1 + 2 \cdot 6.02 \cdot 5.85 \cdot 1 \cdot (1 - 1)) \\
 &= \underline{3.2333} \text{ cm}^2
 \end{aligned}$$

Area available from FIG. UG-37.1 $A_1 = \text{larger of the following} = \underline{1.8194} \text{ cm}^2$

$$\begin{aligned}
 &= d(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\
 &= 110.5(1 \cdot 7.5 - 1 \cdot 5.85) - 2 \cdot 6.02(1 \cdot 7.5 - 1 \cdot 5.85)(1 - 1) \\
 &= 1.8194 \text{ cm}^2 \\
 &= 2 \cdot (t + t_n)(E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n(E_1 \cdot t - F \cdot t_r)(1 - f_{r1}) \\
 &= 2 \cdot (7.5 + 6.02)(1 \cdot 7.5 - 1 \cdot 5.85) - 2 \cdot 6.02(1 \cdot 7.5 - 1 \cdot 5.85)(1 - 1) \\
 &= 0.4452 \text{ cm}^2
 \end{aligned}$$

 $A_2 = \text{smaller of the following} = \underline{1.6316} \text{ cm}^2$

$$\begin{aligned}
 &= 5(t_n - t_m) \cdot f_{r2} \cdot t \\
 &= 5(6.02 - 0.6) \cdot 1 \cdot 7.5 \\
 &= 2.0323 \text{ cm}^2 \\
 &= 5(t_n - t_m) \cdot f_{r2} \cdot t_n \\
 &= 5(6.02 - 0.6) \cdot 1 \cdot 6.02 \\
 &= 1.6316 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 A_{41} &= \text{Leg}^2 \cdot f_{r2} \\
 &= 7^2 \cdot 1 \\
 &= \underline{0.4903} \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A_1 + A_2 + A_{41} \\
 &= 1.8194 + 1.6316 + 0.4903 \\
 &= \underline{3.9413} \text{ cm}^2
 \end{aligned}$$

As Area \geq A the reinforcement is adequate.**UW-16(d) Weld Check**

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t_{min} = lesser of 19 mm or t_n or $t = 6.02$ mm
 $t_{1(min)}$ or $t_{2(min)}$ = lesser of 6 mm or $0.7 \cdot t_{min} = 4.21$ mm
 $t_{1(actual)} = 0.7 \cdot Leg = 0.7 \cdot 7 = 4.9$ mm
 The weld size t_1 is satisfactory.
 $t_{2(actual)} = 6$ mm
 The weld size t_2 is satisfactory.

$$t_1 + t_2 = 10.9 \geq 1.25 \cdot t_{min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a): $t_{r1} = 0.6$ mm
 Wall thickness per UG-45(b)(2): $t_{r2} = 3.78$ mm
 Wall thickness per UG-16(b): $t_{r3} = 1.5$ mm
 Standard wall pipe per UG-45(b)(4): $t_{r4} = 5.27$ mm
 The greater of t_{r2} or t_{r3} : $t_{r5} = 3.78$ mm
 The lesser of t_{r4} or t_{r5} : $t_{r6} = 3.78$ mm

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.78$ mm

Available nozzle wall thickness new, $t_n = 0.875 \cdot 6.02 = 5.27$ mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 198.9682/114.3000 = 1.7408$$

$$D_o/t = 114.3000/0.599356 = 190.7045$$

From table G: $A = 0.000289$
 From table CS-2 Metric: $B = 27.5504$ MPa

$$P_a = 4 \cdot B / (3 \cdot (D_o/t))$$

$$= 4 \cdot 27.5504 / (3 \cdot (114.3000/0.599356))$$

$$= 192.6221 \text{ kPa}$$

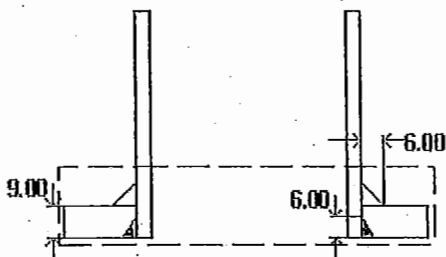
Design thickness for external pressure $P_a = 192.6221$ kPa

$$= t + \text{Corrosion} = 0.599356 + 0.00 = 0.60 \text{ mm}$$

G Performance Group (USA), Inc**Water Fill (N4)****ASME Section VIII Division 1, 2007 Edition Metric**

$$t_{w(\text{lower})} = 6 \text{ mm}$$

$$\text{Leg}_{41} = 6 \text{ mm}$$



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

Located on:

Liquid static head included:

Nozzle material specification:

Nozzle longitudinal joint efficiency:

Nozzle description:

Flange description:

Bolt Material:

Flange rated MDMT:

(UCS-66(b)(3): Coincident ratio = 0.1750631)

(Flange rated MDMT = -105 °C (UCS-68(c) applies.)

Bolts rated MDMT per Fig UCS-66 note (e) = -48 °C)

Liquid static head on flange:

ASME B16.5 flange rating MAWP:

ASME B16.5 flange rating MAP:

ASME B16.5 flange hydro test:

Nozzle orientation:

Calculated as hillside:

Local vessel minimum thickness:

End of nozzle to datum line:

Nozzle inside diameter, new:

F&D Head #1

1.9657 kPa

SA-106 B Smpls. Pipe
(II-D Metric p. 14, ln. 5)

1

2" Sch 40 (Std) DN 50

2 inch Class 150 WN
A105

SA-193 B7 Bolt <= 64
(II-D Metric p. 348, ln. 33)

-48 °C

0 kPa

1395.5 kPa @ 200 °C

1965.01 kPa @
21.11 °C

3102.64 kPa @
21.11 °C

225°

yes

9 mm

2451.47 mm

52.5 mm

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Nozzle nominal wall thickness:	3.91 mm
Nozzle corrosion allowance:	0 mm
Opening chord length:	54.62 mm
Projection available outside vessel, Lpr:	164.35 mm
Projection available outside vessel to flange face, Lf:	183.4 mm
Distance to head center, R:	400 mm

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Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 1114.32 kPa @ 200 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

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 size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg 41)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for internal pressure 1114.32 kPa @ 200 °C

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt to -105 °C per UCS-66(b)(3) (coincident ratio = 0.02253).

Nozzle UCS-66 governing thk: 3.42 mm

Nozzle rated MDMT: -105 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 54.62 mm

Normal to the vessel wall outside: $2.5(t_n - C_n) + t_o = 9.78$ mm

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

$$t_n = P \cdot R_n / (S_n \cdot E - 0.6 \cdot P)$$

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$$= 1,114.322 * 26.25 / (118,000 * 1 - 0.6 * 1,114.322)$$

$$= 0.25 \text{ mm}$$

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

$$t_r = P * L_o * M / (2 * S * E + P * (M - 0.2))$$

$$= 1,114.322 * 1,459 * 1 / (2 * 108,000 * 1 + 1,114.322 * (1 - 0.2))$$

$$= 7.5 \text{ mm}$$

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

UW-16(d) Weld Check

$$t_{\min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 3.91 \text{ mm}$$

$$t_{1(\min)} \text{ or } t_{2(\min)} = \text{lesser of } 6 \text{ mm or } 0.7 * t_{\min} = 2.74 \text{ mm}$$

$$t_{1(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 6 = 4.2 \text{ mm}$$

The weld size t_1 is satisfactory.

$$t_{2(\text{actual})} = 6 \text{ mm}$$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 10.2 \geq 1.25 * t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	$t_{r1} = 0.25 \text{ mm (E=1)}$
Wall thickness per UG-45(b)(1):	$t_{r2} = 14.58 \text{ mm}$
Wall thickness per UG-16(b):	$t_{r3} = 1.5 \text{ mm}$
Standard wall pipe per UG-45(b)(4):	$t_{r4} = 3.42 \text{ mm}$
The greater of t_{r2} or t_{r3} :	$t_{r5} = 14.58 \text{ mm}$
The lesser of t_{r4} or t_{r5} :	$t_{r6} = 3.42 \text{ mm}$

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Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.42$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 3.91 = 3.42$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (cm ²) For P = 1338.99 kPa @ 21.11 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

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 size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg 41)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for internal pressure 1338.99 kPa @ 21.11 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 54.62$ mm

Normal to the vessel wall outside: $2.5 \times (t_n - C_n) + t_o = 9.78$ mm

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 1,338.99 \times 26.25 / (118,000 \times 1 - 0.6 \times 1,338.99) \\
 &= 0.3 \text{ mm}
 \end{aligned}$$

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

$$\begin{aligned} t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\ &= 1,338.99 \cdot 1,459 \cdot 1 / (2 \cdot 108,000 \cdot 1 + 1,338.99 \cdot (1 - 0.2)) \\ &= 9 \text{ mm} \end{aligned}$$

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

UW-16(d) Weld Check

$$\begin{aligned} t_{\min} &= \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 3.91 \text{ mm} \\ t_{1(\min)} \text{ or } t_{2(\min)} &= \text{lesser of } 6 \text{ mm or } 0.7 \cdot t_{\min} = 2.74 \text{ mm} \\ t_{1(\text{actual})} &= 0.7 \cdot \text{Leg} = 0.7 \cdot 6 = 4.2 \text{ mm} \\ \text{The weld size } t_1 &\text{ is satisfactory.} \\ t_{2(\text{actual})} &= 6 \text{ mm} \\ \text{The weld size } t_2 &\text{ is satisfactory.} \end{aligned}$$

$$t_1 + t_2 = 10.2 \geq 1.25 \cdot t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

$$\begin{aligned} \text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.3 \text{ mm (E=1)} \\ \text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 15.71 \text{ mm} \\ \text{Wall thickness per UG-16(b):} & \quad t_{r3} = 1.5 \text{ mm} \\ \text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 3.42 \text{ mm} \\ \text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 15.71 \text{ mm} \\ \text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 3.42 \text{ mm} \end{aligned}$$

Performance Group (USA), Inc

Required per UG-45 is the larger of t_{r1} or $t_{r6} = 3.42$ mm

Available nozzle wall thickness new, $t_n = 0.875 \times 3.91 = 3.42$ mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm ²) For $P_e = 192.62$ kPa @ 200 °C							UG-45 Nozzle Wall Thickness Summary (mm) 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)							3.42	3.42

Weld Failure Path Analysis Summary

Weld strength calculations are not required for
external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (mm)	Actual weld size (mm)	Status
Nozzle to shell fillet (Leg ₄₁)	2.74	4.2	weld size is adequate
Nozzle to shell groove (Lower)	2.74	6	weld size is adequate

Calculations for external pressure 192.62 kPa @ 200 °C

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 54.61$ mm

Normal to the vessel wall outside: $2.5 \times (t_n - C_n) + t_e = 9.78$ mm

Nozzle required thickness per UG-28 $t_m = 0.42$ mm

From UG-37(d)(1) required thickness $t_r = 5.85$ mm

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

G Performance Group (USA), Inc**UW-16(d) Weld Check**

$t_{\min} = \text{lesser of } 19 \text{ mm or } t_n \text{ or } t = 3.91 \text{ mm}$

$t_{1(\min)} \text{ or } t_{2(\min)} = \text{lesser of } 6 \text{ mm or } 0.7 * t_{\min} = \underline{2.74} \text{ mm}$

$t_{1(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 6 = 4.2 \text{ mm}$

The weld size t_1 is satisfactory.

$t_{2(\text{actual})} = 6 \text{ mm}$

The weld size t_2 is satisfactory.

$$t_1 + t_2 = 10.2 \geq 1.25 * t_{\min}$$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a): $t_{r1} = 0.42 \text{ mm}$

Wall thickness per UG-45(b)(2): $t_{r2} = 3.78 \text{ mm}$

Wall thickness per UG-16(b): $t_{r3} = 1.5 \text{ mm}$

Standard wall pipe per UG-45(b)(4): $t_{r4} = 3.42 \text{ mm}$

The greater of t_{r2} or t_{r3} : $t_{r5} = 3.78 \text{ mm}$

The lesser of t_{r4} or t_{r5} : $t_{r6} = 3.42 \text{ mm}$

Required per UG-45 is the larger of t_{r1} or $t_{r6} = \underline{3.42} \text{ mm}$

Available nozzle wall thickness new, $t_n = 0.875 * 3.91 = 3.42 \text{ mm}$

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 200.00°C) UG-28(c)

$$L/D_o = 200.5974/60.3250 = 3.3253$$

$$D_o/t = 60.3250/0.418315 = 144.2094$$

From table G: $A = 0.000219$

From table CS-2 Metric: $B = 20.8322 \text{ MPa}$

$$P_a = 4 * B / (3 * (D_o/t))$$

$$= 4 * 20.8322 / (3 * (60.3250/0.418315))$$

$$= 192.6109 \text{ kPa}$$

Design thickness for external pressure $P_a = 192.6109 \text{ kPa}$

$$= t + \text{Corrosion} = 0.418315 + 0.00 = 0.42 \text{ mm}$$

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Legs #1

Leg material:		SA-36
Leg description:		4x4x3/8 Equal Angle (Leg in)
Number of legs:	N =	4
Overall length:		1,200 mm
Base to girth seam length:		800 mm
Bolt circle:		1,550.8 mm
Anchor bolt size:		0.5 inch series 8 threaded
Anchor bolt material:		SA-193-B
Anchor bolts/leg:		1
Anchor bolt allowable stress:	S _b =	137.895 MPa
Anchor bolt corrosion allowance:		0 mm
Anchor bolt hole clearance:		13 mm
Base plate width:		254 mm
Base plate length:		254 mm
Base plate thickness:		10 mm (<u>6.6</u> mm required)
Base plate allowable stress:		165.474 MPa
Foundation allowable bearing stress:		11.4 MPa
Effective length coefficient:	K =	1.2
Coefficient:	C _m =	0.85
Leg yield stress:	F _y =	248.211 MPa
Leg elastic modulus:	E =	199,948 MPa
Leg to shell fillet weld:		6.35 mm (<u>0.33</u> mm required)
Legs braced:		No

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Note: The support attachment point is assumed to be 25.4 mm up from the cylinder circumferential seam.

Loading	Force attack angle °	Leg position °	Axial end load N	Shear resisted N	Axial f_a MPa	Bending f_{bx} MPa	Bending f_{by} MPa	Ratio H_{1-1}	Ratio H_{1-2}
Weight operating corroded Moment = 1,586.1 N-m	0	0	11,925.7	0.0	6.463	15.405	0	0.1338	0.1374
		90	12,983.1	0.0	7.036	16.771	0	0.1459	0.1496
		180	14,040.5	0.0	7.609	18.137	0	0.1580	0.1618
		270	12,983.1	0.0	7.036	16.771	0	0.1459	0.1496

Loading	Force attack angle °	Leg position °	Axial end load N	Shear resisted N	Axial f_a MPa	Bending f_{bx} MPa	Bending f_{by} MPa	Ratio H_{1-1}	Ratio H_{1-2}
Governing Condition Weight operating new Moment = 1,586.1 N-m	0	0	12,327.6	0.0	6.681	15.924	0	0.1384	0.1421
		90	13,385.0	0.0	7.254	17.29	0	0.1505	0.1543
		180	14,442.4	0.0	7.827	18.656	0	0.1626	0.1664
		270	13,385.0	0.0	7.254	17.29	0	0.1505	0.1543

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Loading	Force attack angle °	Leg position °	Axial end load N	Shear resisted N	Axial f_a MPa	Bending f_{bx} MPa	Bending f_{by} MPa	Ratio H_{1-1}	Ratio H_{1-2}
Weight empty corroded Moment = 1,586.1 N-m	0	0	1,656.8	0.0	0.898	2.14	0	0.0184	0.0191
		90	2,714.3	0.0	1.471	3.506	0	0.0301	0.0313
		180	3,771.7	0.0	2.044	4.872	0	0.0419	0.0435
		270	2,714.3	0.0	1.471	3.506	0	0.0301	0.0313

Loading	Force attack angle °	Leg position °	Axial end load N	Shear resisted N	Axial f_a MPa	Bending f_{bx} MPa	Bending f_{by} MPa	Ratio H_{1-1}	Ratio H_{1-2}
Weight empty new Moment = 1,586.1 N-m	0	0	2,059.3	0.0	1.116	2.66	0	0.0228	0.0237
		90	3,116.7	0.0	1.689	4.026	0	0.0346	0.0359
		180	4,174.1	0.0	2.262	5.392	0	0.0464	0.0481
		270	3,116.7	0.0	1.689	4.026	0	0.0346	0.0359

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Loading	Force attack angle °	Leg position °	Axial end load N	Shear resisted N	Axial f_a MPa	Bending f_{bx} MPa	Bending f_{by} MPa	Ratio H_{1-1}	Ratio H_{1-2}
Weight vacuum corroded Moment = 1,586.1 N-m	0	0	11,925.7	0.0	6.463	15.405	0	0.1338	0.1374
		90	12,983.1	0.0	7.036	16.771	0	0.1459	0.1496
		180	14,040.5	0.0	7.609	18.137	0	0.1580	0.1618
		270	12,983.1	0.0	7.036	16.771	0	0.1459	0.1496

Leg Calculations (AISC manual ninth edition)

Axial end load, P_1 (Based on vessel total bending moment acting at leg attachment elevation)

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$$\begin{aligned}
 P_1 &= W/N + 48*M_1/(N*D) \\
 &= 53,540.15/4 + 48*1e3*132.2/(4*1,500) \\
 &= \underline{14,442.45 \text{ N}}
 \end{aligned}$$

Allowable axial compressive stress, F_a (AISC chapter E)

Local buckling check (AISC 5-99)

$$b/t = (4/0.375) < (76 / \text{Sqr}(36)) \text{ so } Q_s = 1$$

Flexural-torsional buckling (AISC 5-317)

$$\begin{aligned}
 \text{Shear center distance } w_o &= 3.4215 \\
 r_o^2 &= w_o^2 + (I_z + I_w)/A \\
 &= 3.4215^2 + (73.88 + 289.07)/18.4516 \\
 &= 31.38 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Torsional constant } J &= 5.58 \text{ cm}^4 \\
 \text{Shear modulus } G &= 76.98 \text{ GPa}
 \end{aligned}$$

$$\begin{aligned}
 F_{ej} &= G*J / (A*r_o^2) \\
 &= 76,979.96*5.58 / (18.4516*31.3767) \\
 &= 0.742 \text{ GPa}
 \end{aligned}$$

$$K*I/r_w = 1.2*749.2/39.58 = 22.714$$

$$\begin{aligned}
 F_{ew} &= \pi^2*E/(K/r_w)^2 \\
 &= \pi^2*199.948/(22.714)^2 \\
 &= 3.825 \text{ GPa}
 \end{aligned}$$

$$\begin{aligned}
 H &= 1 - (w_o^2 / r_o^2) \\
 &= 1 - (3.421^2 / 31.37674) \\
 &= 0.6269051
 \end{aligned}$$

$$\begin{aligned}
 F_e &= ((F_{ew} + F_{ej})/(2*H))*(1 - \text{Sqr}(1 - (4*F_{ew}*F_{ej}*H)/(F_{ew} + F_{ej})^2)) \\
 &= ((3.825 + 0.742)/(2*0.6269))*(1 - \text{Sqr}(1 - (4*3.825*0.742*0.6269)/(3.825 + 0.742)^2)) \\
 &= 0.686 \text{ GPa}
 \end{aligned}$$

Equivalent slenderness ratio

$$\begin{aligned}
 K/r &= \pi*\text{Sqr}(E/F_e) \\
 &= \pi*\text{Sqr}(199.948/0.686) \\
 &= 53.63401
 \end{aligned}$$

$$\begin{aligned}
 C_o &= \text{Sqr}(2*\pi^2*E/(F_y*Q_s)) \\
 &= \text{Sqr}(2*\pi^2*199,948/(248.211*1)) \\
 &= 126.0993
 \end{aligned}$$

$$K*I/r = 1.2*749.2/20.01 = 44.9308$$

$$\begin{aligned}
 F_a &= 1 * (1 - (K/r)^2/(2*C_o^2))*F_y / (5/3 + 3*(K/r)/(8*C_o) - (K/r)^3/(8*C_o^3)) \\
 &= 1 * (1 - (53.634)^2/(2*126.0993^2))*248.211 / (5/3 + 3*(53.634)/(8*126.0993) - (53.634)^3/(8*126.0993^3)) \\
 &= 124.28 \text{ MPa}
 \end{aligned}$$

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Allowable axial compression and bending (AISC chapter H)

Note: r is divided by 1.35 - See AISC 6.1.4, pg. 5-314

$$\begin{aligned} F'_{ex} &= 1*12*\pi^2*E/(23*(Kl/r)^2) \\ &= 1*12*\pi^2*199,948/(23*(60.6566)^2) \\ &= 279.843 \text{ MPa} \end{aligned}$$

$$\begin{aligned} F'_{ey} &= 1*12*\pi^2*E/(23*(Kl/r)^2) \\ &= 1*12*\pi^2*199,948/(23*(30.6639)^2) \\ &= 1,095.004 \text{ MPa} \end{aligned}$$

$$\begin{aligned} F_b &= 1*0.66*F_y \\ &= 1*0.66*248.211 \\ &= 163.819 \text{ MPa} \end{aligned}$$

Compressive axial stress

$$\begin{aligned} f_a &= P_1/A \\ &= 14,442.45/1,845.157 \\ &= \underline{7.827} \text{ MPa} \end{aligned}$$

Bending stresses

$$\begin{aligned} f_{bx} &= F*\cos(\alpha)*L/(I_x/C_x) + P_1*E_{cc}/(I_x/C_x) \\ &= 0*\cos(0)*749.2/(1e4*73.8759/30.89) + 14,442.45*30.89/(1e4*73.8759/30.89) \\ &= \underline{18.656} \text{ MPa} \end{aligned}$$

$$\begin{aligned} f_{by} &= F*\sin(\alpha)*L/(I_y/C_y) \\ &= 0*\sin(0)*749.2/(1e4*289.07/71.84) \\ &= \underline{0} \text{ MPa} \end{aligned}$$

AISC equation H₁₋₁

$$\begin{aligned} H_{1-1} &= f_a/F_a + C_{mx}*f_{bx}/((1 - f_a/F'_{ex})*F_{bx}) + C_{my}*f_{by}/((1 - f_a/F'_{ey})*F_{by}) \\ &= 7.827/124.28 + 0.85*18.656/((1 - 7.827/279.843)*163.819) + 0.85*0/((1 - 7.827/1,095.004)*163.819) \\ &= \underline{0.1626} \end{aligned}$$

AISC equation H₁₋₂

$$\begin{aligned} H_{1-2} &= f_a/(0.6*F_y) + f_{bx}/F_{bx} + f_{by}/F_{by} \\ &= 7.827/(0.6*1*248.211) + 18.656/163.819 + 0/163.819 \\ &= \underline{0.1664} \end{aligned}$$

4, 4x4x3/8 Equal Angle legs are adequate.

Anchor bolts - Weight empty corroded condition governs

Tensile loading per leg (1 bolt per leg)

$$\begin{aligned} R &= 48*M/(N*BC) - W/N \\ &= 48*132.2/(4*1.5508) - 10,857/4 \end{aligned}$$

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$$= -1,691.48 \text{ N}$$

There is no net uplift (R is negative).

0.5 inch series 8 threaded bolts are satisfactory.

Check the leg to vessel fillet weld, Bednar 10.3, Weight operating new governs

Note: continuous welding is assumed for all support leg fillet welds.

The following leg attachment weld analysis assumes the fillet weld is present on three sides (leg top closure plate is used).

$$\begin{aligned} Z_w &= (2*b*d + d^2)/3 \\ &= (2*14.3685*45.08 + 45.08^2)/3 \\ &= 1,109.224 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} J_w &= (b + 2*d)^3/12 - d^2*(b + d)^2/(b + 2*d) \\ &= (14.3685 + 2*45.08)^3/12 - 45.08^2*(14.3685 + 45.08)^2/(14.3685 + 2*45.08) \\ &= 26,465.83 \text{ cm}^3 \end{aligned}$$

$$\begin{aligned} E &= d^2/(b + 2*d) \\ &= 45.08^2/(14.3685 + 2*45.08) \\ &= 194.42 \text{ mm} \end{aligned}$$

$$\text{Governing weld load } f_x = \cos(0)*0 = 0 \text{ N}$$

$$\text{Governing weld load } f_y = \sin(0)*0 = 0 \text{ N}$$

$$\begin{aligned} f_1 &= P/L_{\text{weld}} \\ &= 14,442.45/104.5285 \\ &= 138.17 \text{ N/cm (} v_L \text{ direct shear)} \end{aligned}$$

$$\begin{aligned} f_2 &= f_y * L_{\text{leg}} * 0.5 * b / J_w \\ &= 0 * 749.2 * 0.5 * 143.69 / 2,646,583.1228 \\ &= 0 \text{ N/cm (} v_L \text{ torsion shear)} \end{aligned}$$

$$\begin{aligned} f_3 &= f_y / L_{\text{weld}} \\ &= 0 / 104.5285 \\ &= 0 \text{ N/cm (} v_c \text{ direct shear)} \end{aligned}$$

$$\begin{aligned} f_4 &= f_y * L_{\text{leg}} * E / J_w \\ &= 0 * 749.2 * 194.42 / 2,646,583.1228 \\ &= 0 \text{ N/cm (} v_c \text{ torsion shear)} \end{aligned}$$

$$\begin{aligned} f_5 &= f_x * L_{\text{leg}} / Z_w \\ &= 0 * 74.92 / 1,109.224 \\ &= 0 \text{ N/cm (} M_L \text{ bending)} \end{aligned}$$

$$\begin{aligned} f_6 &= f_x / L_{\text{weld}} \\ &= 0 / 104.5285 \\ &= 0 \text{ N/cm (Direct outward radial shear)} \end{aligned}$$

$$\begin{aligned} f &= \text{Sqr}((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2) \\ &= \text{Sqr}((138.17 + 0)^2 + (0 + 0)^2 + (0 + 0)^2) \end{aligned}$$

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= 138.17 N/cm (Resultant shear load)

Required leg to vessel fillet weld leg size (welded both sides + top)

$$\begin{aligned} t_w &= f / (0.707 * 0.55 * S_a) \\ &= 13.82 / (0.707 * 0.55 * 108) \\ &= \underline{0.33} \text{ mm} \end{aligned}$$

The 6.35 mm leg to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$$\begin{aligned} f_p &= P / (B * N) \\ &= 14,407.81 / (254 * 254) \\ &= 0.223 \text{ MPa} \end{aligned}$$

Required base plate thickness is the largest of the following: (6.6 mm)

$$\begin{aligned} t_b &= \text{Sqr}(0.5 * P / S_b) \\ &= \text{Sqr}(0.5 * 14,407.81 / 165.474) \\ &= 6.6 \text{ mm} \end{aligned}$$

$$\begin{aligned} t_b &= 0.5 * (N - d) * \text{Sqr}(3 * f_p / S_b) \\ &= 0.5 * (254 - 101.6) * \text{Sqr}(3 * 0.223 / 165.474) \\ &= 4.85 \text{ mm} \end{aligned}$$

The base plate thickness is adequate.

Check the leg to vessel attachment stresses, WRC-107 (Weight operating corroded governs)

Applied Loads

Radial load:	$P_r = 0$	N
Circumferential moment:	$M_o = 0$	N-m
Circumferential shear:	$V_o = 0$	N
Longitudinal moment:	$M_L = 433.73$	N-m
Longitudinal shear:	$V_L = 14,040.5$	N
Torsion moment:	$M_t = 0$	N-m
Internal pressure:	$P = 368.02$	kPa
Mean shell radius:	$R_m = 745.5$	mm
Local shell thickness:	$t = 7.5$	mm
Shell yield stress:	$S_y = 177$	MPa

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Maximum stresses due to the applied loads at the leg edge (includes pressure)

$$R_m/t = 99.4151$$

$$C_1 = 71.84, C_2 = 287.37 \text{ mm}$$

Note: Actual lug $C_1/C_2 < 1/4$, $C_1/C_2 = 1/4$ used as this is the minimum ratio covered by WRC 107.

$$\text{Local circumferential pressure stress} = P \cdot R_i/t = 36.404 \text{ MPa}$$

$$\text{Local longitudinal pressure stress} = P \cdot R_i/2t = 18.202 \text{ MPa}$$

$$\text{Maximum combined stress } (P_L + P_b + Q) = 42.18 \text{ MPa}$$

$$\text{Allowable combined stress } (P_L + P_b + Q) = +3 \cdot S = +324 \text{ MPa}$$

The maximum combined stress $(P_L + P_b + Q)$ is within allowable limits.

$$\text{Maximum local primary membrane stress } (P_L) = 37.76 \text{ MPa}$$

$$\text{Allowable local primary membrane } (P_L) = +1.5 \cdot S = +162 \text{ MPa}$$

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the leg edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	2.9759	0.2853	0	0	0	0	0	0	0	0
4C*	9.958	0.2313	0	0	0	0	0	0	0	0
1C	0.0602	0.1696	0	0	0	0	0	0	0	0
2C-1	0.0245	0.1696	0	0	0	0	0	0	0	0
3A*	4.0343	0.153	0	0	0	0	0	0	0	0
1A	0.0626	0.1776	0	0	0	0	0	0	0	0
3B*	6.1927	0.2428	-1.358	-1.358	1.358	1.358	0	0	0	0
1B-1	0.014	0.1968	-4.413	4.413	4.413	-4.413	0	0	0	0
Pressure stress*			36.404	36.404	36.404	36.404	36.404	36.404	36.404	36.404
Total circumferential stress			30.633	39.459	42.175	33.35	36.404	36.404	36.404	36.404
Primary membrane circumferential stress*			35.046	35.046	37.763	37.763	36.404	36.404	38.404	36.404
3C*	4.2218	0.2313	0	0	0	0	0	0	0	0
4C*	8.3789	0.2853	0	0	0	0	0	0	0	0
1C-1	0.0313	0.2409	0	0	0	0	0	0	0	0
2C	0.0324	0.2409	0	0	0	0	0	0	0	0
4A*	8.3785	0.153	0	0	0	0	0	0	0	0
2A	0.0238	0.2221	0	0	0	0	0	0	0	0
4B*	3.151	0.2428	-1.393	-1.393	1.393	1.393	0	0	0	0
2B-1	0.0141	0.2722	-3.213	3.213	3.213	-3.213	0	0	0	0
Pressure stress*			18.202	18.202	18.202	18.202	18.202	18.202	18.202	18.202

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Total longitudinal stress	13.596	20.022	22.808	16.382	18.202	18.202	18.202	18.202
Primary membrane longitudinal stress*	16.809	16.809	19.595	19.595	18.202	18.202	18.202	18.202
Shear from M_t	0	0	0	0	0	0	0	0
Circ shear from V_o	0	0	0	0	0	0	0	0
Long shear from V_L	0	0	0	0	-1.627	-1.627	1.627	1.627
Total Shear stress	0	0	0	0	-1.627	-1.627	1.627	1.627
Combined stress (P_L+P_b+Q)	30.633	38.459	42.175	33.35	36.549	36.549	36.549	36.549

Note: * denotes primary stress.

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Liquid Level bounded by F&D Head #2

Location from datum 2451.47 mm

Operating Liquid Specific Gravity 1.0000

Test liquid specific gravity 1.0000