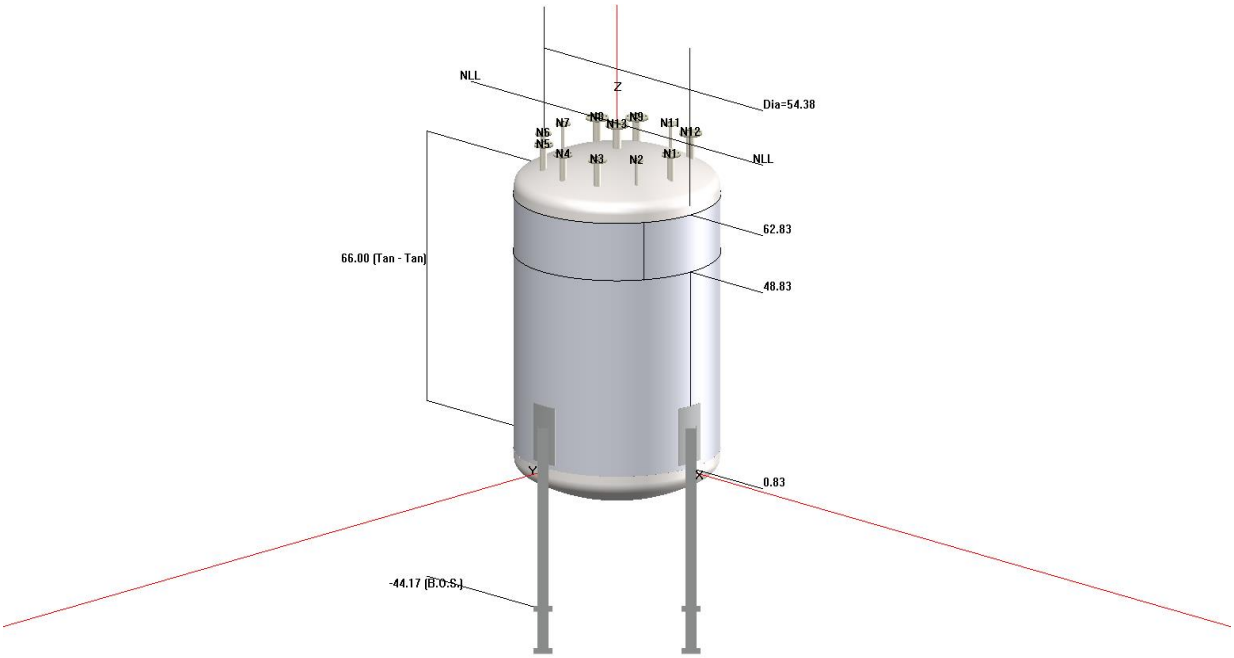
SAVANNAH TANK AND EQUIPMENT CORP.

1517 TELFAIR RD

SAVANNAH.GA 31415



COMPRESS Pressure Vessel Design Calculations

Vessel No: V-0201

Customer: EPIC

Designer: MEC/HP

Date: Wednesday, September 03, 2025

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Deficiencies Summary

No deficiencies found.

Nozzle Schedule

Specifications									
Nozzle mark	Identifier	Size	Materials		Impact Tested	Normalized	Fine Grain	Flange	Blind
N1	Nozzle #1	NPS 1.5 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 1 1/2 Class 150 SO A182 F316	No
N11	Nozzle #10	NPS 0.75 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 3/4 Class 150 SO A182 F316	No
N12	Nozzle #11	NPS 2 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 150 SO A182 F316	No
N13	Nozzle #12	NPS 2 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 150 SO A182 F316	No
N2	Nozzle #2	NPS 0.5 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 1/2 Class 150 SO A182 F316	No
N3	Nozzle #3	NPS 1.5 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 1 1/2 Class 150 SO A182 F316	No
N4	Nozzle #4	NPS 1.5 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 1 1/2 Class 150 SO A182 F316	No
N5	Nozzle #5	NPS 1.5 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 1 1/2 Class 150 SO A182 F316	No
N6	Nozzle #6	NPS 1 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 1 Class 150 SO A182 F316	No
N7	Nozzle #7	NPS 0.75 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 3/4 Class 150 SO A182 F316	No
N8	Nozzle #8	NPS 2 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 150 SO A182 F316	No
N9	Nozzle #9	NPS 2 Sch 40S (Std)	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 150 SO A182 F316	No

Nozzle Summary

Dimensions												
Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
N1	1.9	0.145	0.145	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N11	1.05	0.113	0.113	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N12	2.375	0.154	0.154	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N13	2.375	0.154	0.154	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N2	0.84	0.109	0.109	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N3	1.9	0.145	0.145	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N4	1.9	0.145	0.145	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N5	1.9	0.145	0.145	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N6	1.315	0.133	0.133	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N7	1.05	0.113	0.113	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N8	2.375	0.154	0.154	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt
N9	2.375	0.154	0.154	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt

*Head minimum thickness after forming

Definitions	
tn	Nozzle thickness
Req tn	Nozzle thickness required per UG-45/UG-16 Increased for pipe to account for 12.5% pipe thickness tolerance
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

Pressure Summary

Component Summary							
Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MDMT (°F)	MDMT Exemption	Impact Tested
TOP DISH	10	175	36.07	36.69	-320	Note 1	No
Straight Flange on TOP DISH	10	175	128.21	128.91	-320	Note 2	No
SHELL 2	10	175	95.54	96.82	-320	Note 3	No
SHELL 1	10	175	93.59	96.82	-320	Note 4	No
Straight Flange on BOTTOM DISH	10	175	125.6	128.91	-320	Note 6	No
BOTTOM DISH	10	175	33.01	36.69	-320	Note 5	No
Legs #1	10	175	10	N/A	N/A	N/A	N/A
Nozzle #1 (N1)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #10 (N11)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #11 (N12)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #12 (N13)	10	175	92.3	92.55	-55	Note 7	No
Nozzle #2 (N2)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #3 (N3)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #4 (N4)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #5 (N5)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #6 (N6)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #7 (N7)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #8 (N8)	10	175	92.14	92.55	-55	Note 7	No
Nozzle #9 (N9)	10	175	92.14	92.55	-55	Note 7	No

Chamber Summary	
Design MDMT	-20 °F
Rated MDMT	-20 °F @ 10 psi
MAWP hot & corroded	10 psi @ 175 °F
MAP cold & new	36.69 psi @ 70 °F

(1) The rated MDMT is limited to the design MDMT based on the setting in the Calculations tab of the Set Mode dialog.
(2) This pressure chamber is not designed for external pressure.

Notes for MDMT Rating		
Note #	**Exemption**	**Details**
1.	Impact test exempt per UHA-51(g) (coincident ratio = 0.1311)	
2.	Impact test exempt per UHA-51(g) (coincident ratio = 0.0661)	
3.	Impact test exempt per UHA-51(g) (coincident ratio = 0.0928)	
4.	Impact test exempt per UHA-51(g) (coincident ratio = 0.1089)	
5.	Impact test exempt per UHA-51(g) (coincident ratio = 0.169)	
6.	Impact test exempt per UHA-51(g) (coincident ratio = 0.0822)	
7.	Flange rating governs: Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

Settings Summary

COMPRESS 2025 Build 8510	
ASME Section VIII Division 1, 2023 Edition	
Units	U.S. Customary
Datum Line Location	-0.83" from bottom seam
Vessel Design Mode	Design Mode
Minimum thickness	0.0625" per UG-16(b)
Design for cold shut down only	No
Design for lethal service (full radiography required)	No
Design nozzles for	Design P only
Corrosion weight loss	100% of theoretical loss
UG-23 Stress Increase	1.20
Skirt/legs stress increase	1.0
Minimum nozzle projection	6"
Juncture calculations for $\alpha > 30$ only	Yes
Preheat P-No 1 Materials > 1.25" and <= 1.50" thick	No
UG-37(a) shell tr calculation considers longitudinal stress	No
Cylindrical shells made from pipe are entered as minimum thickness	No
Nozzles made from pipe are entered as minimum thickness	No
ASME B16.9 fittings are entered as minimum thickness	No
Butt welds	Tapered per Figure UCS-66.3(a)
Disallow Appendix 1-5, 1-8 calculations under 15 psi	No
Hydro/Pneumatic Test	
Shop Hydrotest Pressure	1.3 times vessel MAWP [UG-99(b)]
Test liquid specific gravity	1.00
Maximum stress during test	90% of yield
Required Marking - UG-116	
UG-116(e) Radiography	None
UG-116(f) Postweld heat treatment	None
Code Cases\Interpretations	
Use Appendix 46	No
Use UG-44(b)	No
Use Code Case 2901-1	No
Use Code Case 3035	No

Apply interpretation VIII-1-83-66	Yes
Apply interpretation VIII-1-86-175	Yes
Apply interpretation VIII-1-01-37	Yes
Apply interpretation VIII-1-01-150	Yes
Apply interpretation VIII-1-07-50	Yes
Apply interpretation VIII-1-16-85	Yes
No UCS-66.1 MDMT reduction	No
No UCS-68(c) MDMT reduction	No
Disallow UG-20(f) exemptions	No
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	Yes
UG-22(f) Seismic reactions	Yes
UG-22(j) Test pressure and coincident static head acting during the test:	No
Note: UG-22(b),(c) and (f) loads only considered when supports are present.	
Note 2: UG-22(d)(1),(e),(f)-snow,(g),(h),(i) are not considered. If these loads are present, additional calculations must be performed.	

License Information	
Company Name	Savannah Tank & Equipment
License	Commercial
License Key ID	23758
Support Expires	February 23, 2026
Account Number	830277377451711

Radiography Summary

UG-116 Radiography							
Component	Longitudinal Seam		Top Circumferential Seam		Bottom Circumferential Seam		Mark
	Category (Fig UW-3)	Radiography / Joint Type	Category (Fig UW-3)	Radiography / Joint Type	Category (Fig UW-3)	Radiography / Joint Type	
TOP DISH	A	None UW-11(c) / Type 1	N/A	N/A	B	None UW-11(c) / Type 1	None
SHELL 2	A	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	None
SHELL 1	A	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	None
BOTTOM DISH	A	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	N/A	N/A	None
Nozzle	**Longitudinal Seam**		**Nozzle to Vessel Circumferential Seam**		**Nozzle free end Circumferential Seam**		
Nozzle #1 (N1)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #2 (N2)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #3 (N3)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #4 (N4)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #5 (N5)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #6 (N6)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #7 (N7)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #8 (N8)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #9 (N9)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #10 (N11)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #11 (N12)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle #12 (N13)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
Nozzle Flange	**Longitudinal Seam**		**Flange Face**		**Nozzle to Flange Circumferential Seam**		
ASME B16.5/16.47 flange attached to Nozzle #1 (N1)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #2 (N2)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #3 (N3)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #4 (N4)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #5 (N5)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #6 (N6)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #7 (N7)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #8 (N8)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #9 (N9)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #10 (N11)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #11 (N12)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A
ASME B16.5/16.47 flange attached to Nozzle #12 (N13)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A / Type 4	N/A

Interpretation VIII-1 01-150 has been applied.
UG-116(e) Required Marking: **None**

Thickness Summary

Component Data								
Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
TOP DISH	SA-240 316	54 ID	9.2873	0.125*	0.0362	0	0.70	Internal
Straight Flange on TOP DISH	SA-240 316	54 ID	2	0.25	0.0207	0	0.70	Internal
SHELL 2	SA-240 316	54 ID	14	0.1875	0.0218	0	0.70	Internal
SHELL 1	SA-240 316	54 ID	48	0.1875	0.0256	0	0.70	Internal
Straight Flange on BOTTOM DISH	SA-240 316	54 ID	2	0.25	0.0257	0	0.70	Internal
BOTTOM DISH	SA-240 316	54 ID	9.2873	0.125*	0.0467	0	0.70	Internal
*Head minimum thickness after forming								

Definitions	
Nominal t	Vessel wall nominal thickness
Design t	Required vessel thickness due to governing loading + corrosion
Joint E	Longitudinal seam joint efficiency
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

Material Summary

Material Data					
Identifier	Material	Impact Tested	Normalized	Fine Grain	PWHT
TOP DISH	SA-240 316	No	No	No	No
SHELL 2	SA-240 316	No	No	No	No
SHELL 1	SA-240 316	No	No	No	No
BOTTOM DISH	SA-240 316	No	No	No	No
Nozzle #1 (N1)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #10 (N11)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #11 (N12)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #12 (N13)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #2 (N2)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #3 (N3)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #4 (N4)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #5 (N5)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #6 (N6)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #7 (N7)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #8 (N8)	SA-312 TP316 Wld pipe	No	No	No	No
Nozzle #9 (N9)	SA-312 TP316 Wld pipe	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #1 (N1)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #2 (N2)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #3 (N3)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #4 (N4)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #5 (N5)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #6 (N6)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #7 (N7)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #8 (N8)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #9 (N9)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #10 (N11)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #11 (N12)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #12 (N13)	A182 F316	No	No	No	No

Vessel Summary	
Components impact tested	None
Impact Test Temperature	(-50 °F)
Post weld heat treatment	None

Weight Summary

Weight (lb) Contributed by Vessel Elements											
Component	Metal New*	Metal Corroded	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid		Surface Area ft²
							New	Corroded	New	Corroded	
TOP DISH	122.6	122.6	36.7	0	0	0	714.8	714.8	632.5	632.5	22
SHELL 2	129.6	129.6	26.9	0	0	0	1,307.8	1,307.8	1,157.4	1,157.4	17
SHELL 1	444.3	444.3	92.1	0	0	0	4,484	4,484	3,968.2	3,968.2	57
BOTTOM DISH	123.8	123.8	36.7	0	0	0	708.7	708.7	627.2	627.2	22
Legs #1	120.5	120.5	0	0	0	0	0	0	0	0	18
TOTAL:	**940.8**	**940.8**	**192.4**	**0**	**0**	**0**	**7,215.4**	**7,215.4**	**6,385.2**	**6,385.2**	**136**
*Shells with attached nozzles have weight reduced by material cut out for opening.											

Weight (lb) Contributed by Attachments											
Component	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays	Tray Supports	Rings & Clips	Vertical Loads	Surface Area ft²
	New	Corroded	New	Corroded							
TOP DISH	0	0	58.7	58.7	0	0	0	0	0	0	4
SHELL 2	0	0	0	0	0	0	0	0	0	0	0
SHELL 1	0	0	0	0	0	0	0	0	0	0	0
BOTTOM DISH	0	0	0	0	0	0	0	0	0	0	0
Legs #1	0	0	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**58.7**	**58.7**	**0**	**0**	**0**	**0**	**0**	**0**	**4**

Vessel Totals		
	New	Corroded
Operating Weight (lb)	8,407	8,407
Empty Weight (lb)	1,192	1,192
Test Weight (lb)	7,577	7,577
Surface Area (ft²)	140	-
Capacity** (US gal)	765	765
**The vessel capacity does not include volume of nozzle, piping or other attachments.		

Vessel Lift Condition	
Vessel Lift Weight, New (lb)	1,000
Center of Gravity from Datum (in)	28.2442
Note: Vessel lift weight includes weight of insulation supports as they are assumed to be shop installed.	

Hydrostatic Test

Horizontal shop hydrostatic test based on MAWP per UG-99(b)

Gauge pressure at 70°F = 1.3*MAWP*LSR
= 1.3*10*1
= 13 psi

Horizontal shop hydrostatic test				
Identifier	**Local test pressure (psi)**	**Test liquid static head (psi)**	**UG-99(b) stress ratio**	**UG-99(b) pressure factor**
TOP DISH (1)	14.949	1.949	1	1.30
Straight Flange on TOP DISH	14.949	1.949	1	1.30
SHELL 2	14.949	1.949	1	1.30
SHELL 1	14.949	1.949	1	1.30
Straight Flange on BOTTOM DISH	14.949	1.949	1	1.30
BOTTOM DISH	14.949	1.949	1	1.30
Nozzle #1 (N1)	13.282	0.282	1	1.30
Nozzle #10 (N11)	13.99	0.99	1	1.30
Nozzle #11 (N12)	13.651	0.651	1	1.30
Nozzle #12 (N13)	14.012	1.012	1	1.30
Nozzle #2 (N2)	13.361	0.361	1	1.30
Nozzle #3 (N3)	13.643	0.643	1	1.30
Nozzle #4 (N4)	14.004	1.004	1	1.30
Nozzle #5 (N5)	14.365	1.365	1	1.30
Nozzle #6 (N6)	14.619	1.619	1	1.30
Nozzle #7 (N7)	14.711	1.711	1	1.30
Nozzle #8 (N8)	14.637	1.637	1	1.30
Nozzle #9 (N9)	14.373	1.373	1	1.30
(1) TOP DISH limits the UG-99(b) stress ratio. (2) 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.

The test temperature of 70 °F is warmer than the minimum recommended temperature of 10 °F so the brittle fracture provision of UG-99(h) has been met.

Horizontal shop hydrostatic test - Minimum test temperature		
Identifier	**Rated MDMT (°F)**	**Minimum Test Temperature (°F)**
TOP DISH	-320	-290
Straight Flange on TOP DISH	-320	-290
SHELL 2	-320	-290
SHELL 1	-320	-290
Straight Flange on BOTTOM DISH	-320	-290
BOTTOM DISH	-320	-290
Nozzle #1 (N1)	-320	-290
Nozzle #10 (N11)	-320	-290
Nozzle #11 (N12)	-320	-290
Nozzle #12 (N13)	-320	-290
Nozzle #2 (N2)	-320	-290
Nozzle #3 (N3)	-320	-290
Nozzle #4 (N4)	-320	-290
Nozzle #5 (N5)	-320	-290
Nozzle #6 (N6)	-320	-290
Nozzle #7 (N7)	-320	-290
Nozzle #8 (N8)	-320	-290
Nozzle #9 (N9)	-320	-290
Chamber Rated MDMT	-20	**10**
Limit chamber rated MDMT to Design MDMT option is active.		

Legs #1

Inputs	
Leg material	SS 316
Leg description	3x3x1/4 Equal Angle (Leg in)
Number of legs, N	4
Overall length	55"
Base to girth seam length	45"
User defined leg eccentricity	1.1"
Effective length coefficient, K	1.5
Coefficient, C_m	0.85
Leg yield stress, F_y	26,700 psi
Leg elastic modulus, E	27,653,846 psi
Angular Position	0°
Anchor Bolts	
Anchor bolt size	0.625" coarse threaded
Anchor bolt material	SA 193 GR B7
Bolt circle, BC	52.375"
Anchor bolts/leg, n	1
Anchor bolt allowable stress, S_b	20,000 psi
Anchor bolt corrosion allowance	0"
Anchor bolt hole clearance	0.375"
Reinforcing Pad	
Pad length	14"
Pad width	8"
Pad thickness	0.1875"
Base Plate	
Base plate length	5"
Base plate width	5"
Base plate thickness	0.25" (0.2305" required)
Base plate allowable stress	24,000 psi
Foundation allowable bearing stress	1,658 psi
Welds	
Leg to pad fillet weld	0.1875" (0.0215" required)
Pad to shell fillet weld	0.1875" (0.0085" required)

Legs braced	No

Note: The support attachment point is assumed to be 1 in up from the cylinder circumferential seam.

Governing Condition : Wind operating corroded, Moment = 791.0 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	1,069.7	31.4	743	4,553	0	0.3329	0.3047
	90	2,071.7	124.4	1,439	3,586	6,158	0.7046	0.6428
	180	2,245.1	31.4	1,559	6,588	0	0.6068	0.4712
	270	2,071.7	124.4	1,439	3,586	6,158	0.7046	0.6428
45	0	1,069.7	77.9	743	6,587	2,727	0.5819	0.5749
	90	1,069.7	77.9	743	6,587	2,727	0.5819	0.5749
	180	2,245.1	77.9	1,559	8,622	2,727	0.8837	0.7414
	270	2,245.1	77.9	1,559	8,622	2,727	0.8837	0.7414

Wind empty corroded, Moment = 791.0 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	-12.7	31.4	-9	2,723	0	0.1302	0.1540
	90	267.9	124.4	186	464	6,158	0.3427	0.3874
	180	441.2	31.4	306	3,465	0	0.2098	0.2158
	270	267.9	124.4	186	464	6,158	0.3427	0.3874
45	0	-12.7	77.9	-9	4,757	2,727	0.3597	0.4242
	90	-12.7	77.9	-9	4,757	2,727	0.3597	0.4242
	180	441.2	77.9	306	5,499	2,727	0.4469	0.4860
	270	441.2	77.9	306	5,499	2,727	0.4469	0.4860

Seismic operating corroded, Moment = 190.7 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	1,174.2	5.9	815	2,543	0	0.2312	0.1952
	90	2,098.8	23.5	1,457	3,633	1,163	0.4532	0.3631
	180	2,140.6	5.9	1,487	4,216	0	0.4361	0.3320
	270	2,098.8	23.5	1,457	3,633	1,163	0.4532	0.3631
45	0	1,174.2	14.7	815	2,927	515	0.2786	0.2462
	90	1,174.2	14.7	815	2,927	515	0.2786	0.2462
	180	2,140.6	14.7	1,487	4,600	515	0.4878	0.3830
	270	2,140.6	14.7	1,487	4,600	515	0.4878	0.3830

Seismic empty corroded, Moment = 38.6 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	148.8	0.8	103	330	0	0.0273	0.0252
	90	271.4	3.3	188	470	165	0.0518	0.0478
	180	279.8	0.8	194	557	0	0.0488	0.0437
	270	271.4	3.3	188	470	165	0.0518	0.0478
45	0	148.8	2.1	103	384	73	0.0336	0.0324
	90	148.8	2.1	103	384	73	0.0336	0.0324
	180	279.8	2.1	194	611	73	0.0550	0.0510
	270	279.8	2.1	194	611	73	0.0550	0.0510

Leg Calculations (AISC manual ninth edition)

Axial end load, P_1 (Based on vessel total bending moment acting at leg attachment elevation)

$P_1 = W_t / N + 48*M_t / (N*D)$
$= 8,286.86 / 4 + 48*791 / (4*54.75)$
$= 2,245.09$ lb_f

Allowable axial compressive stress, F_a (AISC chapter E)

Local buckling check (AISC 5-99)

$b / t = (3 / 0.25) < (76 / Sqr(27))$ so $Q_s = 1$

Flexural-torsional buckling (AISC 5-317)

Shear center distance $w_o = 1.014$
$r_o^2 = w_o^2 + (I_z + I_w) / A$
$= 1.014^2 + (0.5 + 1.98) / 1.44$
$= 2.75$ in^2

Torsional constant $J = 0.03$ in^4

Shear modulus G = 10,647 ksi

$F_{ej} = G*J / (A*r_o^2)$
$= 10.65E+06*0.03 / (1.44*2.7504)$
$= 81$ ksi

$K*l / r_w = 1.5*46.1875 / 1.1725 = 59.0864$

$F_{ew} = \pi^2*E / (K*l / r_w)^2$
$= \pi^2*27,654 / (59.0864)^2$
$= 78$ ksi

$H = 1 - (w_o^2 / r_o^2)$
$= 1 - (1.014^2 / 2.7504)$
$= 0.6262$

$F_e = ((F_{ew} + F_{ej}) / (2*H))*(1 - Sqr(1 - (4*F_{ew}*F_{ej}*H) / (F_{ew} + F_{ej})^2))$
$= ((78 + 81) / (2*0.6262))*(1 - Sqr(1 - (4*78*81*0.6262) / (78 + 81)^2))$
$= 49$ ksi

Equivalent slenderness ratio

$K*l / r = \pi*Sqr(E / F_e)$
$= \pi*Sqr(27,654 / 49)$
$= 74.4318$

$C_c = Sqr(2*\pi^2*E / (F_y*Q_s))$
$= Sqr(2*\pi^2*27,653,846 / (26,700*1))$
$= 142.9839$

$K*l / r = 1.5*46.1875 / 0.5894 = 117.5546$

$F_a = 1 * (1 - (K*l / r)^2 / (2*C_c^2))*F_y / (5 / 3 + 3*(K*l / r) / (8*C_c)-(K*l / r)^3 / (8*C_c^3))$
$= 1 * (1 - (117.5546)^2 / (2*142.9839^2))*26,700 / (5 / 3 + 3*(117.5546) / (8*142.9839)-(117.5546)^3 / (8*142.9839^3))$
$= 9,276$ psi

Allowable axial compression and bending (AISC chapter H)

Note: r is divided by 1.35 - See AISC 6.1.4, pg. 5-314

$F'_{ex} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*27,653,846 / (23*(158.6987)^2)$
$= 5,654$ psi

$F'_{ey} = 1*12*\pi^2*E / (23*(K*l / r)^2)$
$= 1*12*\pi^2*27,653,846 / (23*(79.7667)^2)$
$= 22,380$ psi

$F_b = 1*0.66*F_y$
$= 1*0.66*26,700$
$= 17,622$ psi

Compressive axial stress

$f_a = P_1 / A$
$= 2,245.09 / 1.44$
$= 1.559$ psi

Bending stresses

$f_{bx} = F*\cos(\alpha)*L / (I_x / C_x) + P_1*E_{cc} / (I_x / C_x)$
$= 77.94*\cos(45)*46.1875 / (0.5002 / 0.9305) + 2,245.09*0.9305 / (0.5002 / 0.9305)$
$= 8.622$ psi

$f_{by} = F*\sin(\alpha)*L / (I_y / C_y)$
$= 77.94*\sin(45)*46.1875 / (1.98 / 2.12)$
$= 2.727$ psi

AISC equation H_{1-1}

$H_{1-1} = f_a / F_a + C_{mx}*f_{bx} / ((1 - f_a / F'_{ex})*F_{bx}) + C_{my}*f_{by} / ((1 - f_a / F'_{ey})*F_{by})$
$= 1,559 / 9,276 + 0.85*8,622 / ((1 - 1,559 / 5,654)*17,622) + 0.85*2,727 / ((1 - 1,559 / 22,380)*17,622)$
$= 0.8837$

AISC equation H_{1-2}

$H_{1-2} = f_a / (0.6*1*F_y) + f_{bx} / F_{bx} + f_{by} / F_{by}$
$= 1,559 / (0.6*1*26,700) + 8,622 / 17,622 + 2,727 / 17,622$
$= 0.7414$

4, 3x3x1/4 Equal Angle legs are adequate.

Anchor bolts - Wind empty corroded condition governs

Tensile loading per leg (1 bolt per leg)

$R = 48*M / (N*BC) - 0.6*W / N$
$= 48*1,960.1 / (4*52.375) - 0.6*1,191.98 / 4$
$= 270.29$ lb_f

Required area per bolt

$A_b = R / (S_b*n)$
$= 270.29 / (20,000*1)$
$= 0.0135$ in^2

Area of a 0.625" coarse threaded bolt (corroded) = 0.202 in^2

0.625" coarse threaded bolts are satisfactory.

Check the leg to pad fillet weld, Bednar 10.3, Wind operating corroded 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).

$Z_w = (2*b*d + d^2) / 3$
$= (2*4.2426*8.8125 + 8.8125^2) / 3$
$= 50.812$ in^2

$J_w = (b + 2*d)^3 / 12 - d^2*(b + d)^2 / (b + 2*d)$
$= (4.2426 + 2*8.8125)^3 / 12 - 8.8125^2*(4.2426 + 8.8125)^2 / (4.2426 + 2*8.8125)$
$= 266.1275$ in^3

$E = d^2 / (b + 2*d)$

= 8.8125^2 / (4.2426 + 2*8.8125)
= 3.55138 in

Governing weld load f_x = Cos(90)*124.44 = 0 lb_f
Governing weld load f_y = Sin(90)*124.44 = 124.44 lb_f

$f_1 = P_1 / L_{weld}$
= 2,071.71 / 21.8676
= 94.74 lb_f/in (V_L direct shear)

$f_2 = f_y * L_{leg} * 0.5 * b / J_w$
= 124.44*46.1875*0.5*4.2426 / 266.1275
= 45.81 lb_f/in (V_L torsion shear)

$f_3 = f_y / L_{weld}$
= 124.44 / 21.8676
= 5.69 lb_f/in (V_c direct shear)

$f_4 = f_y * L_{leg} * E / J_w$
= 124.44*46.1875*3.5514 / 266.1275
= 76.7 lb_f/in (V_c torsion shear)

$f_5 = (f_x * L_{leg} + P_1 * E_{cc}) / Z_w$
= (0*46.1875 + 2,071.71*0.9305) / 50.812
= 37.94 lb_f/in (M_L bending)

$f_6 = f_x / L_{weld}$
= 0 / 21.8676
= 0 lb_f/in (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
= $Sqr((94.74 + 45.81)^2 + (5.69 + 76.7)^2 + (37.94 + 0)^2)$
= 167.28 lb_f/in (Resultant shear load)

Required leg to pad fillet weld leg size (welded both sides + top)

$t_w = f / (0.707*0.55*S_a)$
= 167.28 / (0.707*0.55*20,000)
= 0.0215 in

The 0.1875 in leg to pad attachment fillet weld size is adequate.

Check the pad to vessel fillet weld, Bednar 10.3, Wind operating corroded governs

$Z_w = b*d + d^2 / 3$
= $8*14 + 14^2 / 3$
= 177.3333 in^2

$J_w = (b + d)^3 / 6$
= $(8 + 14)^3 / 6$
= 1,774.6667 in^3

$f_1 = P_1 / L_{weld}$
= 2,071.71 / 44
= 47.08 lb_f/in (V_L direct shear)

$f_2 = f_y * L_{leg} * 0.5 * b / J_w$
= 124.44*46.1875*0.5*8 / 1,774.6667

= 12.95 lb_f/in (V_L torsion shear)

$f_3 = f_y / L_{weld}$
= 124.44 / 44
= 2.83 lb_f/in (V_c direct shear)

$f_4 = f_y * L_{leg} * 0.5 * d / J_w$
= 124.44*46.1875*0.5*14 / 1,774.6667
= 22.67 lb_f/in (V_c torsion shear)

$f_5 = (f_x * L_{leg} + P_1 * E_{cc}) / Z_w$
= (0*46.1875 + 2,071.71*0.9305) / 177.3333
= 10.87 lb_f/in (M_L bending)

$f_6 = f_x / L_{weld}$
= 0 / 44
= 0 lb_f/in (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
= $Sqr((47.08 + 12.95)^2 + (2.83 + 22.67)^2 + (10.87 + 0)^2)$
= 66.13 lb_f/in (Resultant shear load)

Required pad to vessel fillet weld leg size (welded all around the pad edge)

$t_w = f / (0.707 * 0.55 * S_a)$
= 66.13 / (0.707*0.55*20,000)
= 0.0085 in

0.1875 in pad to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$f_p = P / (B * N)$
= 2,550.93 / (5*5)
= 102 psi

Required base plate thickness is the largest of the following: (0.2305 in)

$t_b = Sqr(0.5 * P / S_b)$
= Sqr(0.5*2,550.93 / 24,000)
= 0.2305 in

$t_b = 0.5 * (N - d) * Sqr(3 * f_p / S_b)$
= 0.5*(5 - 3)*Sqr(3*102 / 24,000)
= 0.1129 in

$t_b = Sqr(3 * P_t * 0.5 * Abs(OD - BC) / S_b)$
= Sqr(3*270.29*0.5*Abs(54.375 - 52.375) / 24,000)
= 0.1838 in

The base plate thickness is adequate.

Check the leg to vessel attachment stresses, WRC 537 (Wind operating corroded governs)

Applied Loads	
Radial load, P_r	-55.11 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	4,634.4 lb_f-in
Longitudinal shear, V_L	2,245.09 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	13.23 psi
Mean shell radius, R_m	27.0938"
Local shell thickness, T	0.1875"
Design factor	3

Maximum stresses due to the applied loads at the pad edge (includes pressure)

$\gamma = R_m / T = 27.0938 / 0.1875 = 144.5$

$C_1 = 4$, $C_2 = 11.1118$ in

Local circumferential pressure stress = $P*R_i / T$ =1,906 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =953 psi

Maximum combined stress (P_L+P_b+Q) = 3,562 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 2,446 psi
Allowable local primary membrane stress (P_L) = ±1.5*S = ±30,000 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the pad edge per WRC Bulletin 537										
Figure	**Y**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	2.1494	0.3469	0	0	0	0	23	23	23	23
4C*	8.4398	0.2881	92	92	92	92	0	0	0	0
1C	0.05	0.2209	0	0	0	0	470	-470	470	-470
2C-1	0.0106	0.2209	100	-100	100	-100	0	0	0	0
3A*	3.9512	0.2075	0	0	0	0	0	0	0	0
1A	0.0561	0.2254	0	0	0	0	0	0	0	0
3B*	5.6406	0.2918	-448	-448	448	448	0	0	0	0
1B-1	0.0084	0.2426	-1,016	1,016	1,016	-1,016	0	0	0	0
Pressure stress*			1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906
Total circumferential stress			634	2,466	3,562	1,330	2,399	1,459	2,399	1,459
Primary membrane circumferential stress*			1,550	1,550	2,446	2,446	1,929	1,929	1,929	1,929
3C*	2.9567	0.2881	32	32	32	32	0	0	0	0
4C*	6.9714	0.3469	0	0	0	0	76	76	76	76
1C-1	0.0188	0.2986	177	-177	177	-177	0	0	0	0
2C	0.03	0.2986	0	0	0	0	282	-282	282	-282
4A*	9.2188	0.2075	0	0	0	0	0	0	0	0
2A	0.0209	0.2739	0	0	0	0	0	0	0	0
4B*	2.8775	0.2918	-391	-391	391	391	0	0	0	0
2B-1	0.0112	0.3044	-1,074	1,074	1,074	-1,074	0	0	0	0
Pressure stress*			953	953	953	953	953	953	953	953
Total longitudinal stress			-303	1,491	2,627	125	1,311	747	1,311	747
Primary membrane longitudinal stress*			594	594	1,376	1,376	1,029	1,029	1,029	1,029
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	-269	-269	269	269
Total Shear stress			0	0	0	0	-269	-269	269	269
Combined stress (P_L+P_b+Q)			-937	2,466	3,562	1,330	2,462	1,549	2,462	1,549
* denotes primary stress.										

Maximum stresses due to the applied loads at the leg edge (includes pressure)

$\gamma = R_m / T = 27.0938 / 0.375 = 72.25$

$C_1 = 2.1213$, $C_2 = 6.9945$ in

Local circumferential pressure stress = $P*R_i / T$ =1,906 psi

Local longitudinal pressure stress = $P*R_i / (2*T)$ =953 psi

Maximum combined stress (P_L+P_b+Q) = 3,795 psi
Allowable combined stress (P_L+P_b+Q) = ±3*S = ±60,000 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 2,421 psi

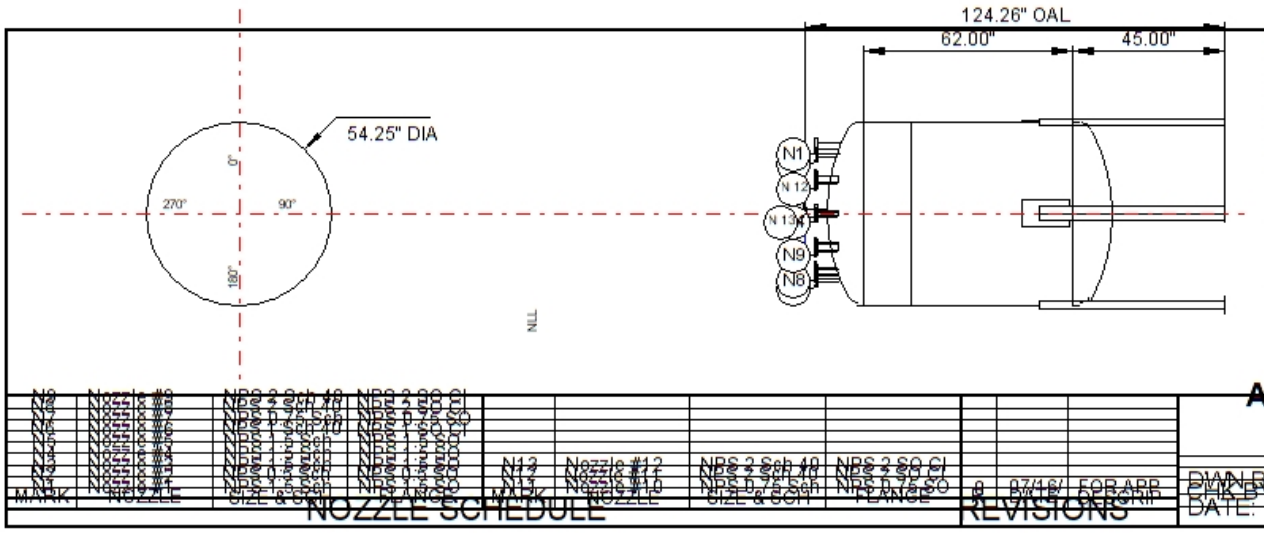
Allowable local primary membrane stress (P_L) = ±1.5*S = ±30,000 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the leg edge per WRC Bulletin 537										
Figure	**Y**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	5.0284	0.2056	0	0	0	0	27	27	27	27
4C*	10.1046	0.1686	55	55	55	55	0	0	0	0
1C	0.0809	0.1263	0	0	0	0	190	-190	190	-190
2C-1	0.0495	0.1263	116	-116	116	-116	0	0	0	0
3A*	2.8441	0.1165	0	0	0	0	0	0	0	0
1A	0.0744	0.1368	0	0	0	0	0	0	0	0
3B*	7.2079	0.1735	-460	-460	460	460	0	0	0	0
1B-1	0.0258	0.1495	-1,258	1,258	1,258	-1,258	0	0	0	0
Pressure stress*			1,906	1,906	1,906	1,906	1,906	1,906	1,906	1,906
Total circumferential stress			359	2,643	3,795	1,047	2,123	1,743	2,123	1,743
Primary membrane circumferential stress*			1,501	1,501	2,421	2,421	1,933	1,933	1,933	1,933
3C*	6.6598	0.1686	36	36	36	36	0	0	0	0
4C*	8.9961	0.2056	0	0	0	0	49	49	49	49
1C-1	0.0579	0.1752	136	-136	136	-136	0	0	0	0
2C	0.0332	0.1752	0	0	0	0	78	-78	78	-78
4A*	4.5987	0.1165	0	0	0	0	0	0	0	0
2A	0.0334	0.1736	0	0	0	0	0	0	0	0
4B*	3.0256	0.1735	-330	-330	330	330	0	0	0	0
2B-1	0.0255	0.1966	-948	948	948	-948	0	0	0	0
Pressure stress*			953	953	953	953	953	953	953	953
Total longitudinal stress			-153	1,471	2,403	235	1,080	924	1,080	924
Primary membrane longitudinal stress*			659	659	1,319	1,319	1,002	1,002	1,002	1,002
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	-214	-214	214	214
Total Shear stress			0	0	0	0	-214	-214	214	214
Combined stress (P_L+P_b+Q)			-512	2,643	3,795	1,047	2,165	1,796	2,165	1,796
* denotes primary stress.										

Liquid Level bounded by BOTTOM DISH

ASME Section VIII Division 1, 2023 Edition	
Location from Datum (in)	80.0912
Operating Liquid Specific Gravity	1.13



DESIGN DATA

Design Pressure	10 psi
Vacuum Pressure	0 psi
Test Pressure (Sho	13 psi
Design Temperatu	120 °F
MDMT	-28 °F
Corrosion Allowan	None
Radiography	None
PWHT	None

Estimated Weights

Dry: 1,102 lb Wet: 8,487 lb

Materials

Cylinder(s):	SA-240 316
Head(s):	SA-240 316
Transition(s):	
Support:	SS 316

NOZZLE SCHEDULE

MARK	NOZZLE	SIZE & SCH	FLANGE	MARK	NOZZLE	SIZE & SCH	FLANGE
N9	Nozzle #9	NPS 2 Sch 40	NPS 2 SO CL	N13	Nozzle #13	NPS 2 Sch 40	NPS 2 SO CL
N8	Nozzle #8	NPS 2 Sch 40	NPS 2 SO CL	N12	Nozzle #12	NPS 2 Sch 40	NPS 2 SO CL
N7	Nozzle #7	NPS 0.75 Sch	NPS 0.75 SO	N11	Nozzle #11	NPS 0.75 Sch	NPS 0.75 SO
N6	Nozzle #6	NPS 1 Sch 10	NPS 1 SO CL	N10	Nozzle #10	NPS 1 Sch 10	NPS 1 SO CL
N5	Nozzle #5	NPS 1 Sch	NPS 1 SO				
N4	Nozzle #4	NPS 0.75 Sch	NPS 0.75 SO				
N3	Nozzle #3	NPS 1 Sch	NPS 1 SO				
N2	Nozzle #2	NPS 0.75 Sch	NPS 0.75 SO				
N1	Nozzle #1	NPS 1.5 Sch	NPS 1.5 SO				

REVISIONS

0	07/18/	FOR APP	

ABC Fabricators Inc.
2600 Washington Blvd.
Dallas, TX, 75204

DWN BY:
CHK BY:
DATE:

General Arrang

DWG NO: 145685-1 Rev 0

Q9344 V-0201

Revision History

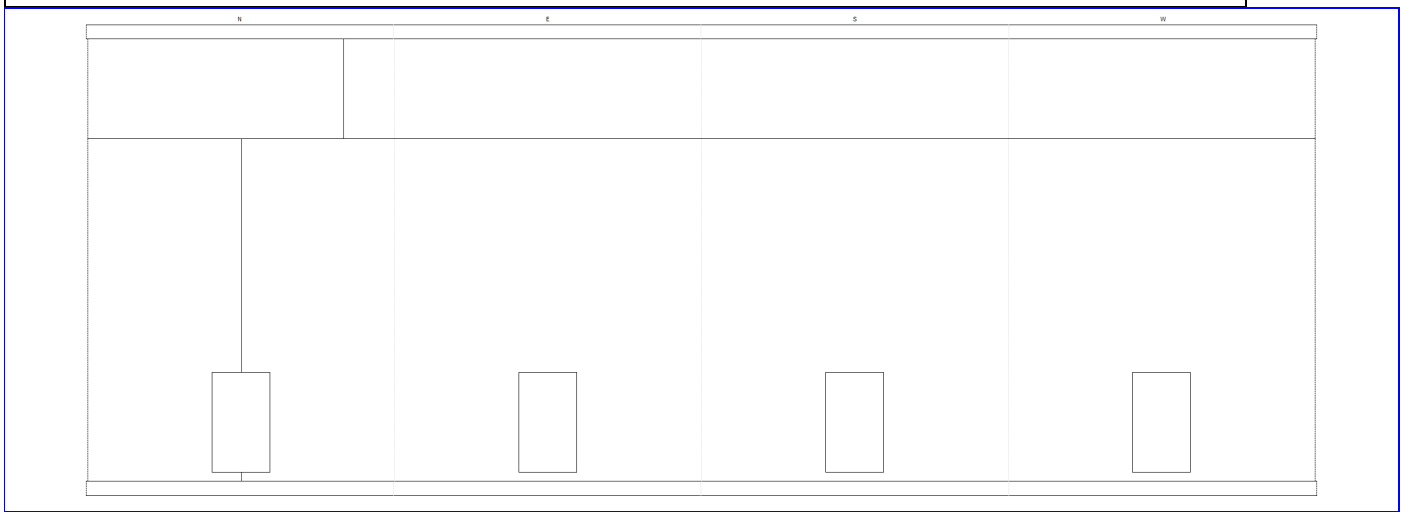
Revisions			
No.	**Date**	**Operator**	**Notes**
0	7/16/2024	melior	New vessel created ASME Section VIII Division 1 [COMPRESS 2024 Build 8400]

Long Seam Summary

Shell Long Seam Angles	
Component	**Seam 1**
SHELL 2	30°
SHELL 1	0°

Shell Plate Lengths		
Component	**Starting Angle**	**Plate 1**
SHELL 2	30°	170.235"
SHELL 1	0°	170.235"

Notes
1) Plate Lengths use the circumference of the vessel based on the mid diameter of the components. 2) North is located at 0°



Shell Rollout

Foundation Load Summary

Legs #1: Total Loading at Base				
Load	**Vessel Condition**	**Base Shear (lb_f)**	**Base Moment (lb_f-ft)**	**Vertical Force (lb_f)**
Weight Only (D)	Operating, Corroded	0	12	8,407
Weight Only (D)	Operating, New	0	12	8,407
Weight Only (D)	Empty, Corroded	0	12	1,192
Weight Only (D)	Empty, New	0	12	1,192
Weight Only (D)	Shop Hydrotest, New	0	12	7,577
Wind Only (0.6 * W)	Operating, Corroded	312	1,948	0
Wind Only (0.6 * W)	Operating, New	312	1,948	0
Wind Only (0.6 * W)	Empty, Corroded	312	1,948	0
Wind Only (0.6 * W)	Empty, New	312	1,948	0
Seismic Only (0.7 * E)	Operating, Corroded	59	399	0
Seismic Only (0.7 * E)	Operating, New	59	399	0
Seismic Only (0.7 * E)	Empty, Corroded	8	58	0
Seismic Only (0.7 * E)	Empty, New	8	58	0

All values reported are service loads for Allowable Stress Design (ASD).

Vertical Force values in the Seismic case represent the 0.7 * 0.2 * S_{DS} dead load factor (compressive) as described in the Seismic Code report. The 0.7 term is the ASD load combination factor.

Support Information	
Support Type	Legs
Number of Support Elements (Base Plates)	4
Base Plate Length	5"
Base Plate Width	5"
Base Plate Thickness	0.25"
Number of Anchor Bolts Per Base Plate	1
Bolt Circle Diameter	52.375"
Bolt Size and Type	5/8" coarse bolt
Bolt Hole Clearance	0.375"
Center of Gravity (Distance from Support Base)	72.4092"

Bill of Materials

Heads						
Item #	**Type**	**Material**	**Thk [in]**	**Dia. [in]**	**Wt. [lb] (ea.)**	**Qty**
H1	F&D Head	SA-240 316	0.125 (min.)	54 ID	123.8	2

Shells							
Item #	**Type**	**Material**	**Thk [in]**	**Dia. [in]**	**Length [in]**	**Wt. [lb] (ea.)**	**Qty**
S1	Cylinder	SA-240 316	0.1875	54 ID	14	129.6	1
S2	Cylinder	SA-240 316	0.1875	54 ID	48	444.3	1

Legs						
Item #	**Type**	**Material**	**Thk [in]**	**Length [in]**	**Wt. [lb]**	**Qty**
L1	3x3x1/4 Equal Angle	SS 316	0.25	55	30.1	4

Nozzles							
Item #	**Type**	**Material**	**NPS**	**Thk [in]**	**Dia. [in]**	**Length [in]**	**Wt. [lb]**
Noz1	Nozzle	SA-312 TP316 Wld pipe	NPS 1.5 Sch 40S (Std)	0.145	1.9 OD	30.9	7.2
Noz2	Nozzle	SA-312 TP316 Wld pipe	NPS 0.5 Sch 40S (Std)	0.109	0.84 OD	7.3	0.5
Noz3	Nozzle	SA-312 TP316 Wld pipe	NPS 1 Sch 40S (Std)	0.133	1.315 OD	7.5	1.1
Noz4	Nozzle	SA-312 TP316 Wld pipe	NPS 0.75 Sch 40S (Std)	0.113	1.05 OD	14.8	1.4
Noz5	Nozzle	SA-312 TP316 Wld pipe	NPS 2 Sch 40S (Std)	0.154	2.375 OD	30.6	9.5

Flanges						
Item #	**Type**	**Material**	**NPS**	**Dia. [in]**	**Wt. [lb] (ea.)**	**Qty**
AF1	ASME B16.5 Slip On - Class 150	A182 F316	1 1/2	5 x 1.95	3	4
AF2	ASME B16.5 Slip On - Class 150	A182 F316	1/2	3.5 x 0.88	1	1
AF3	ASME B16.5 Slip On - Class 150	A182 F316	1	4.25 x 1.36	2	1
AF4	ASME B16.5 Slip On - Class 150	A182 F316	3/4	3.88 x 1.09	2	2
AF5	ASME B16.5 Slip On - Class 150	A182 F316	2	6 x 2.44	5	4

Fasteners				
Item #	**Description**	**Material**	**Length [in]**	**Qty**
FB1	1/2" coarse bolt	SA-193 B7 Bolt <= 2 1/2	2.5	16
FB2	1/2" coarse bolt	SA-193 B7 Bolt <= 2 1/2	2	12
FB3	1/2" coarse bolt	SA-193 B7 Bolt <= 2 1/2	2.3	4
FB4	5/8" coarse bolt	SA-193 B7 Bolt <= 2 1/2	2.8	16
SB1	5/8" coarse bolt	SA 193 GR B7	-	4
All listed flange bolts require associated nuts and washers in accordance with Division 1, UCS-11.				

Insulation				
Item #	**Thk [in]**	**Density [lb/cu ft]**	**Wt. [lb]**	**Qty [ft²]**
IN1	2	9.36	192.4	123.35

Plates				
Item #	**Material**	**Thk [in]**	**Wt. [lb]**	**Qty [ft²]**
Plate1	SS 316	0.1875	23.8	3.11
Plate1 - Note: Applies to support leg plates				
Plate2	SS 316	0.25	7.1	0.69
Plate2 - Note: Applies to support leg base plates				

Building Code: ASCE 7-22 ground supported		
Risk Category (Table 1.5-1)		II
Site Class		B
Importance Factor, I_e		1.0000
Spectral Response Acceleration at short periods (% g), S_S		11.00%
Adjusted Spectral Response Acceleration at short periods (% g), S_{MS}		14.00%
Spectral Response Acceleration at 1 second period (% g), S_1		4.90%
Adjusted Spectral Response Acceleration at 1 second period (% g), S_{M1}		10.00%
Response Modification Coefficient from Table 15.4-2, R		3.0000
Long-period Transition Period, T_L		12.0000
Redundancy factor, ρ		1.0000
User Defined Vertical Accelerations Considered		No
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height		9.8573 ft
Weight	Operating, Corroded	8,407 lb
	Empty, Corroded	1,192 lb
Period of Vibration Calculation		
Fundamental Period, T	Operating, Corroded	0.433 sec (f = 2.3 Hz)
	Empty, Corroded	0.156 sec (f = 6.4 Hz)

The fundamental period of vibration T (above) is calculated using the Rayleigh method of approximation

$T = 2 * PI * Sqr(\{Sum(W_i * y_i^2)\} / \{g * Sum(W_i * y_i)\})$, where

W_i is the weight of the i^{th} lumped mass, and
y_i is its deflection when the system is treated as a cantilever beam.

2.4 Combining Nominal Loads Using Allowable Stress Design	
Load combinations considered in accordance with ASCE section 2.4.5)2.4.1:	
8.	$D + P + P_s + 0.7E$
10.	$0.6D + P + P_s + 0.7E$
Parameter description	
D	= Dead load
P	= Internal or external pressure load
P_s	= Static head load
E	= Seismic load

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Base Shear Calculations

Seismic Shear Report: Operating, Corroded					
Component	**Elevation of Bottom above Base (in)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Seismic Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**
TOP DISH	107	27.7	*	10	15
SHELL 2	93	27.7	0.5650	23	35
SHELL 1 (top)	45	27.7	0.5650	54	193
Legs #1	0	27.7	0.0002	59	411
SHELL 1 (bottom)	45	27.7	0.5650	4	2
BOTTOM DISH	45	27.7	*	4	2
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Empty, Corroded					
Component	Elevation of Bottom above Base (in)	Elastic Modulus E (10^6 psi)	Inertia I (ft^4)	Seismic Shear at Bottom (lb_f)	Bending Moment at Bottom (lb_f-ft)
TOP DISH	107	28.3	*	2	13
SHELL 2	93	28.3	0.5650	4	17
SHELL 1 (top)	45	28.3	0.5650	7	39
Legs #1	0	27.7	0.0002	8	69
SHELL 1 (bottom)	45	28.3	0.5650	1	0
BOTTOM DISH	45	28.3	*	1	0
*Moment of Inertia I varies over the length of the component					

11.4.4: Design spectral response acceleration parameters

Design earthquake spectral response acceleration at short period, S_{DS}
S_{DS} = 2 / 3 * S_{MS} / 100 = 2 / 3 * 14.00 / 100 = 0.0933
Design earthquake spectral response acceleration at 1 s period, S_{D1}
S_{D1} = 2 / 3 * S_{M1} / 100 = 2 / 3 * 10.00 / 100 = 0.0667

11.6 Seismic Design Category

The Risk Category is II.
From Table 11.6-1, the Seismic Design Category based on S_{DS} = 0.0933 is A.
From Table 11.6-2, the Seismic Design Category based on S_{D1} = 0.0667 is A.
This vessel is assigned to Seismic Design Category A.

Note: This vessel is assigned to Seismic Design Category A, and seismic design is per Section 11.7. The V_{Accel} Term is not applicable.

Base Shear Calculations

Operating, Corroded
Empty, Corroded

Base Shear Calculations: Operating, Corroded

Per ASCE Section 11.6, this vessel is assigned to Seismic Design Category A, as (S_{D1} = 0.0667) < 0.067, and (S_{DS} = 0.0933) < 0.167.
In accordance with ASCE Section 11.7, seismic load is determined with Equation 1.4-1.

V = 0.01 * W * 0.7 (Only 70% of seismic load considered as per Section 2.4.1)
= 0.01 * 8,407.3604 * 0.7
= 58.85 lb

Base Shear Calculations: Empty, Corroded

Per ASCE Section 11.6, this vessel is assigned to Seismic Design Category A, as (S_{D1} = 0.0667) < 0.067, and (S_{DS} = 0.0933) < 0.167.
In accordance with ASCE Section 11.7, seismic load is determined with Equation 1.4-1.

V = 0.01 * W * 0.7 (Only 70% of seismic load considered as per Section 2.4.1)
= 0.01 * 1,191.9786 * 0.7
= 8.34 lb

Building Code: ASCE 7-22		
Elevation of base above grade		0.00 ft
Increase effective outer diameter by		0.00 ft
Wind Force Coefficient, Cf		0.5200
Risk Category (Table 1.5-1)		II
Basic Wind Speed, V		110.00 mph
Exposure Category		B
Wind Directionality Factor, Kd		0.9500
Ground Elevation Factor, Ke		1.0000
Topographic Factor, Kzt		1.0000
Enforce min. loading of 16 psf		Yes
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height, h		9.8573 ft
Effective Width, b	Operating, Corroded	4.6343 ft
	Empty, Corroded	4.6343 ft
Fundamental Frequency, n_1	Operating, Corroded	2.3073 Hz
	Empty, Corroded	6.3970 Hz
Damping coefficient, β	Operating, Corroded	0.0260
	Empty, Corroded	0.0210

Table Lookup Values

2.4.1 Basic Load Combinations for Allowable Stress Design	
Load combinations considered in accordance with ASCE section 2.4.1:	
5.	$D + P + P_s + 0.6W$
7.	$0.6D + P + P_s + 0.6W$
Parameter Description	
D	= Dead load
P	= Internal or external pressure load
P_s	= Static head load
W	= Wind load

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Wind Pressure Calculations

Wind Deflection Report: Operating, Corroded								
Component	**Elevation of Bottom above Base (in)**	**Effective OD (ft)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Platform Wind Shear at Bottom (lb_f)**	**Total Wind Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**	**Deflection at Top (in)**
TOP DISH	107	4.86	27.7	*	0	35	26	0.0691
SHELL 2	93	4.86	27.7	0.565	0	90	99	0.0691
SHELL 1 (top)	45	4.86	27.7	0.565	0	273	808	0.0691
Legs #1	0	0	27.7	0.0002392	0	312	1,960	0.069
SHELL 1 (bottom)	45	4.86	27.7	0.565	0	39	17	0.069
BOTTOM DISH	45	4.86	27.7	*	0	35	14	0.069
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Empty, Corroded								
Component	**Elevation of Bottom above Base (in)**	**Effective OD (ft)**	**Elastic Modulus E (10^6 psi)**	**Inertia I (ft^4)**	**Platform Wind Shear at Bottom (lb_f)**	**Total Wind Shear at Bottom (lb_f)**	**Bending Moment at Bottom (lb_f-ft)**	**Deflection at Top (in)**
TOP DISH	107	4.86	28.3	*	0	35	26	0.0691
SHELL 2	93	4.86	28.3	0.565	0	90	99	0.0691
SHELL 1 (top)	45	4.86	28.3	0.565	0	273	808	0.0691
Legs #1	0	0	27.7	0.0002392	0	312	1,960	0.069
SHELL 1 (bottom)	45	4.86	28.3	0.565	0	39	17	0.069
BOTTOM DISH	45	4.86	28.3	*	0	35	14	0.069
*Moment of Inertia I varies over the length of the component								

Wind Pressure (WP) Calculations

Gust Factor (G) Calculations

Kz = $2.41 * (Z/Zg)^{2/\alpha}$
= $2.41 * (Z/3{,}280.00)^{0.2667}$

qz = $0.00256 * Kz * Kzt * Ke * V^2$
= $0.00256 * Kz * 1.0000 * 1.0000 * 110.0000^2$
= $30.9760 * Kz$

WP = $0.6 * \max[qz * Kd * G * Cf, 16\ lb/ft^2]$
= $0.6 * \max[qz * 0.9500 * G * 0.5200, 16\ lb/ft^2]$

Design Wind Pressures							
Height Z (')	Kz	qz (psf)	WP (psf)				
			Operating	Empty	Hydrotest New	Hydrotest Corroded	Vacuum
15.0	0.5729	17.75	9.60	9.60	N.A.	N.A.	N.A.
Design Wind Force determined from: F = Pressure * Af , where Af is the projected area.							

Gust Factor Calculations

Operating, Corroded
Empty, Corroded

Gust Factor Calculations: Operating, Corroded

Vessel is considered a rigid structure as n_1 = 2.3073 Hz ≥ 1 Hz.

z^- = max[0.60 * h , z_{min}]
= max[0.60 * 9.8573 , 30.0000]
= 30.0000
I_{z^-} = c * $(33 / z^-)^{1/6}$
= 0.3000 * $(33 / 30.0000)^{1/6}$
= 0.3048
L_{z^-} = l * $(z^- / 33)^{ep}$
= 320.0000 * $(30.0000 / 33)^{0.3333}$
= 309.9934
Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((4.6343 + 9.8573) / 309.9934)$^{0.63}$))
= 0.9572
G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})
= 0.925 * (1 + 1.7 * 3.40* 0.3048 * 0.9572) / (1 + 1.7 * 3.40 * 0.3048)
= 0.8997

Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as n_1 = 6.3970 Hz ≥ 1 Hz.

z^- = max[0.60 * h , z_{min}]
= max[0.60 * 9.8573 , 30.0000]
= 30.0000
I_{z^-} = c * $(33 / z^-)^{1/6}$
= 0.3000 * $(33 / 30.0000)^{1/6}$
= 0.3048
L_{z^-} = l * $(z^- / 33)^{ep}$
= 320.0000 * $(30.0000 / 33)^{0.3333}$
= 309.9934
Q = Sqr(1 / (1 + 0.63 * ((b + h) / L_{z^-})$^{0.63}$))
= Sqr(1 / (1 + 0.63 * ((4.6343 + 9.8573) / 309.9934)$^{0.63}$))

= 0.9572

G = 0.925 * (1 + 1.7 * g_Q * I_{z^-} * Q) / (1 + 1.7 * g_v * I_{z^-})

= 0.925 * (1 + 1.7 * 3.40* 0.3048 * 0.9572) / (1 + 1.7 * 3.40 * 0.3048)

= 0.8997

Table Lookup Values	
α = 7.5000, z_g = 3,280.00 ft	[Table 26.11-1, page 278]
c = 0.3000, l = 320.0000, ep = 0.3333	[Table 26.11-1, page 278]
a^- = 0.2222, b^- = 0.4700	[Table 26.11-1, page 278]
z_{min} = 30.0000 ft	[Table 26.11-1, page 278]
g_Q = 3.40	[26.11.4 page 278]
g_v = 3.40	[26.11.4 page 278]

TOP DISH

ASME Section VIII Division 1, 2023 Edition				
Component		F&D Head		
Material		SA-240 316 (II-D p. 76, ln. 21)		
Attached To		SHELL 2		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		10	175	-20
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		0.62	15.2562	1.13
Test horizontal		1.95	54	1
Dimensions				
Inner Diameter		54"		
Crown Radius L		54"		
Knuckle Radius r		3.27"		
Minimum Thickness		0.125"		
Corrosion	**Inner**	0"		
	Outer	0"		
Length L_{sf}		2"		
Nominal Thickness t_{sf}		0.25"		
Weight and Capacity				
		Weight (lb)[1]		**Capacity (US gal)[1]**
New		122.61		75.21
Corroded		122.61		75.21
Insulation				
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**
Insulation		2	9.36	36.73
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**
Insulation Supports		0	0	0
Radiography				
Category A joints		None UW-11(c) Type 1		

Head to shell seam	None UW-11(c) Type 1

[1] includes straight flange

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0362"
Maximum allowable working pressure (MAWP)	36.07 psi
Maximum allowable pressure (MAP)	36.69 psi
Rated MDMT	-320°F

Note: Endnote 66 used to determine allowable stress.

UHA-51 Material Toughness Requirements	
t_r = 10.62*54*1 / (2*20,000*0.7 - 0.2*10.62) =	0.0205"
Stress ratio = t_r*E* / (t_n - c) = 0.0205*0.8 / (0.125 - 0) =	0.1311
Impact test exempt per UHA-51(g) (coincident ratio = 0.1311)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Factor M		
M = 1/4*[3 + (L / r)$^{1/2}$]		
Corroded	M = 1/4*[3 + (54 / 3.27)$^{1/2}$]	1.7659
New	M = 1/4*[3 + (54 / 3.27)$^{1/2}$]	1.7659

Design thickness for internal pressure, (Corroded at 175 °F) Appendix 1-4(d)

t = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.62*54*1.7659 / (2*20,000*0.7 - 0.2*10.62) + 0
= 0.0362"

Maximum allowable working pressure, (Corroded at 175 °F) Appendix 1-4(d)

P = 2*S*E*t / (L*M + 0.2*t) - P_s
= 2*20,000*0.7*0.125 / (54*1.7659 + 0.2*0.125) - 0.62
= 36.07 psi

Maximum allowable pressure, (New at 70 °F) Appendix 1-4(d)

P = 2*S*E*t / (L*M + 0.2*t) - P_s
= 2*20,000*0.7*0.125 / (54*1.7659 + 0.2*0.125) - 0
= 36.69 psi

% Forming strain - UHA-44(a)(2)

$$EFE = (75*t / R_f)*(1 - R_f / R_o)$$
$$= (75*0.25 / 3.395)*(1 - 3.395 / \infty)$$
$$= 5.5228\%$$

ASME Section VIII Division 1 UG-81(a) Out-of-Roundness
Inside surface shall not deviate outside the shape by more than 1.25% of D
Inside surface shall not deviate inside the shape by more than 0.625% of D

Straight Flange on TOP DISH

ASME Section VIII Division 1, 2023 Edition				
Component		Cylinder		
Material		SA-240 316 (II-D p. 76, ln. 21)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		10	175	-20
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		0.7	17.2562	1.13
Test horizontal		1.95	54	1
Dimensions				
Inner Diameter		54"		
Length		2"		
Nominal Thickness		0.25"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		24.71		19.83
Corroded		24.71		19.83
Insulation				
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**
Insulation		2	9.36	0
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**
Insulation Supports		0	0	0
Radiography				
Longitudinal seam		None UW-11(c) Type 1		
Bottom Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0207"
Design thickness due to combined loadings + corrosion	0.008"
Maximum allowable working pressure (MAWP)	128.21 psi
Maximum allowable pressure (MAP)	128.91 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
t_r = 10.7*27 / (20,000*0.7 - 0.6*10.7) =	0.0207"
Stress ratio = t_r*E^* / (t_n - c) = 0.0207*0.8 / (0.25 - 0) =	0.0661
Stress ratio longitudinal = 446*0.8 / (20,000*0.7) =	0.0255
Impact test exempt per UHA-51(g) (coincident ratio = 0.0661)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 175 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 10.7*27 / (20,000*0.70 - 0.60*10.7) + 0
= 0.0207"

Maximum allowable working pressure, (at 175 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 20,000*0.70*0.25 / (27 + 0.60*0.25) - 0.7
= 128.21 psi

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 20,000*0.70*0.25 / (27 + 0.60*0.25)
= 128.91 psi

% Forming strain - UHA-44(a)(2)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*0.25 / 27.125)*(1 - 27.125 / ∞)
= 0.4608%

Thickness Required Due to Pressure + External Loads								
Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	10	20,000	9,909	175	0	Wind	0.008	0.008
						Seismic	0.008	0.008
Operating, Hot & New	10	20,000	9,909	175	0	Wind	0.008	0.008
						Seismic	0.008	0.008
Hot Shut Down, Corroded	0	20,000	9,909	175	0	Wind	0.0001	0.0001
						Seismic	0.0001	0.0001
Hot Shut Down, New	0	20,000	9,909	175	0	Wind	0.0001	0.0001
						Seismic	0.0001	0.0001
Empty, Corroded	0	20,000	10,222	70	0	Wind	0.0001	0.0001
						Seismic	0.0001	0.0001
Empty, New	0	20,000	10,222	70	0	Wind	0.0001	0.0001
						Seismic	0.0001	0.0001
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	9,909	175	0	Weight	0.0001	0.0001

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

A = $0.125 / (R_o / t)$
= $0.125 / (27.25 / 0.25)$
= 0.001147

B = 9,909 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cHC} = min(B, S) = 9,909 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

S_{cHN} = S_{cHC}
= 9,909 psi

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

A = $0.125 / (R_o / t)$
= $0.125 / (27.25 / 0.25)$
= 0.001147

B = 10,222 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cCN} = min(B, S) = 10,222 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

S_{cCC} = S_{cCN}
= 10,222 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (27.25 / 0.25)
= 0.001147

B = 10,222 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cVC} = min(B, S) = 10,222 psi

Operating, Hot & Corroded, Wind, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 309 / (π*27.125^2*20,000*1.20*0.70)
= 0"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*218.1 / (2*π*27.125*20,000*1.20*0.70)
= 0"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.008 + 0 - (0)
= 0.008"

t_{wc} = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 218.1 / (2*π*27.125*20,000*1.20*0.70)
= 0.0001"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0001) - (0.008)|
= 0.008"

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*20,000*1.20*0.70*(0.25 - 0 + (0)) / (27 - 0.40*(0.25 - 0 + (0)))
= 312.31 psi

Operating, Hot & New, Wind, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 309 / (π*27.125^2*20,000*1.20*0.70)
= 0"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*218.1 / (2*π*27.125*20,000*1.20*0.70)
= 0"

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.008 + 0 - (0)$
$=$ 0.008"

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 218.1 / (2*\pi*27.125*20{,}000*1.20*0.70)$
$= 0.0001"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (0.0001) - (0.008)|$
$=$ 0.008"

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*0.70*(0.25 - 0 + (0)) / (27 - 0.40*(0.25 - 0 + (0)))$
$= 312.31$ psi

Hot Shut Down, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 309 / (\pi*27.125^2*9{,}908.72*1.20)$
$= 0"$

$t_w = 0.6*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.60*218.1 / (2*\pi*27.125*9{,}908.72*1.20)$
$= 0.0001"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0001)|$
$=$ 0.0001"

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 218.1 / (2*\pi*27.125*9{,}908.72*1.20)$
$= 0.0001"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0001) - (0)$
$=$ 0.0001"

Hot Shut Down, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 309 / (\pi*27.125^2*9{,}908.72*1.20)$
$= 0"$

$t_w = 0.6*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.60*218.1 / (2*\pi*27.125*9{,}908.72*1.20)$
$= 0.0001"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0001)|$
$=$ 0.0001"

t_{wc} = W / (2*π*R_m*S_c*K_s) (Weight)
= 218.1 / (2*π*27.125*9,908.72*1.20)
= 0.0001"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0001) - (0)
= 0.0001"

Empty, Corroded, Wind, Bottom Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 309 / (π*27.125^2*10,221.85*1.20)
= 0"

t_w = 0.6*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.60*218.1 / (2*π*27.125*10,221.85*1.20)
= 0.0001"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_{wc} = W / (2*π*R_m*S_c*K_s) (Weight)
= 218.1 / (2*π*27.125*10,221.85*1.20)
= 0.0001"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0001) - (0)
= 0.0001"

Empty, New, Wind, Bottom Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 309 / (π*27.125^2*10,221.85*1.20)
= 0"

t_w = 0.6*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.60*218.1 / (2*π*27.125*10,221.85*1.20)
= 0.0001"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_{wc} = W / (2*π*R_m*S_c*K_s) (Weight)
= 218.1 / (2*π*27.125*10,221.85*1.20)
= 0.0001"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0001) - (0)
= 0.0001"

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

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 139 / (π*27.125^2*9,908.72*1.00)
= 0"

t_w = W / (2*π*R_m*S_c*K_s) (Weight)
= 218.1 / (2*π*27.125*9,908.72*1.00)
= 0.0001"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0001) - (0)
= 0.0001"

Operating, Hot & Corroded, Seismic, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 186 / (π*27.125^2*20,000*1.20*0.70)
= 0"

t_w = (0.6 - 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.59*218.1 / (2*π*27.125*20,000*1.20*0.70)
= 0"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.008 + 0 - (0)
= 0.008"

t_{wc} = (1 + 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1.01*218.1 / (2*π*27.125*20,000*1.20*0.70)
= 0.0001"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0001) - (0.008)|
= 0.008"

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*20,000*1.20*0.70*(0.25 - 0 + (0)) / (27 - 0.40*(0.25 - 0 + (0)))
= 312.32 psi

Operating, Hot & New, Seismic, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 186 / (π*27.125^2*20,000*1.20*0.70)
= 0"

t_w = (0.6 - 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.59*218.1 / (2*π*27.125*20,000*1.20*0.70)
= 0"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.008 + 0 - (0)
= 0.008"

t_{wc} = (1 + 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1.01*218.1 / (2*π*27.125*20,000*1.20*0.70)
= 0.0001"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0001) - (0.008)|
= 0.008"

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*20,000*1.20*0.70*(0.25 - 0 + (0)) / (27 - 0.40*(0.25 - 0 + (0)))
= 312.32 psi

Hot Shut Down, Corroded, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 186 / (π*27.125^2*9,908.72*1.20)
= 0"

t_w = (0.6 - 0.14*S_{DS})*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.59*218.1 / (2*π*27.125*9,908.72*1.20)
= 0.0001"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_{wc} = (1 + 0.14*S_{DS})*W / (2*π*R_m*S_c*K_s) (Weight)
= 1.01*218.1 / (2*π*27.125*9,908.72*1.20)
= 0.0001"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0001) - (0)
= 0.0001"

Hot Shut Down, New, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 186 / (π*27.125^2*9,908.72*1.20)
= 0"

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.59*218.1 / (2*\pi*27.125*9{,}908.72*1.20)$
$= 0.0001"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0001)|$
$= 0.0001"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.01*218.1 / (2*\pi*27.125*9{,}908.72*1.20)$
$= 0.0001"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0001) - (0)$
$= 0.0001"$

Empty, Corroded, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 156 / (\pi*27.125^2*10{,}221.85*1.20)$
$= 0"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.59*218.1 / (2*\pi*27.125*10{,}221.85*1.20)$
$= 0.0001"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0001)|$
$= 0.0001"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.01*218.1 / (2*\pi*27.125*10{,}221.85*1.20)$
$= 0.0001"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0001) - (0)$
$= 0.0001"$

Empty, New, Seismic, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 156 / (\pi*27.125^2*10{,}221.85*1.20)$
$= 0"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.59*218.1 / (2*\pi*27.125*10{,}221.85*1.20)$
$= 0.0001"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0001)|$
$= 0.0001"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.01*218.1 / (2*\pi*27.125*10{,}221.85*1.20)$

= 0.0001"

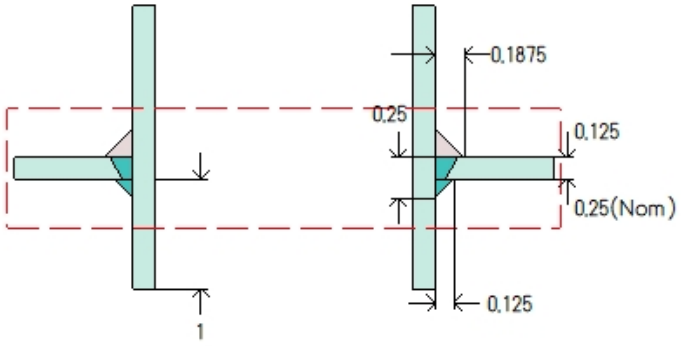
t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)

= 0 + (0.0001) - (0)

= 0.0001"

ASME Section VIII Division 1 UG-80(a) Out-of-Roundness
($D_{max} - D_{min}$) shall not exceed 1% of D
When the cross section passes through an opening or within 1 I.D. of the opening, ($D_{max} - D_{min}$) shall not exceed 1% of D + 2% of the inside diameter of the opening

Nozzle #1 (N1)

ASME Section VIII Division 1, 2023 Edition

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

Location and Orientation	
Located on	TOP DISH
Orientation	0°
End of nozzle to datum line	76.641"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 1.5 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	1.61"
Pipe nominal wall thickness	0.145"
Pipe minimum wall thickness[1]	0.1269"
Corrosion allowance	0"
Opening chord length	1.7333"
Projection available outside vessel, Lpr	5.8369"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 1.5 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.14 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.203" (0.203" min)
Internal fillet weld leg (UW-21)	0.145" (0.145" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
X_{min} = min[1.4*t_n , g_0] = [1.4*0.145 , 0.305] =	0.203"
External Leg_{min} = X_{min} + C_o / 0.7 = 0.203 + 0 / 0.7 =	0.203"
Internal Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.145 , 0.25 + 0 / 0.7] =	0.145"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*54*1 / (2*20,000*1 - 0.2*10.4) =	0.0141"
Stress ratio = t_r*E^* / (t_n - c) = 0.0141*1 / (0.125 - 0) =	0.1124
Impact test exempt per UHA-51(g) (coincident ratio = 0.1124)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1269

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1015	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0))
= 1.7333 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*0.805 / (20,000*1 - 0.6*10.4048)
= 0.0004 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.145 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1015 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*0.805 / (17,000*1 - 0.6*10.4048) + 0
= 0.0005 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0005 , 0]
= 0.0005 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0005 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.1269

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1015	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0)) \\ &= 1.7333 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*0.805 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0037 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.145 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1015 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*0.805 / (17,000*1 - 0.6*92.5484) + 0
= 0.0044 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0044 , 0]
= 0.0044 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.2207]
= 0.1269 in

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

= max[0.0044 , 0.1269]
= 0.1269 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.1269

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0))
= 1.7333 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*0.805 / (20,000*1 - 0.6*92.5532)
= 0.0037 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*0.805 / (17,000*1 - 0.6*92.5532) + 0
= 0.0044 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0044 , 0]
= 0.0044 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.2207]
= 0.1269 in

t_{UG-45} = max[t_a , t_b]
= max[0.0044 , 0.1269]
= 0.1269 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

The nozzle neck thickness is adequate.

Nozzle #2 (N2)

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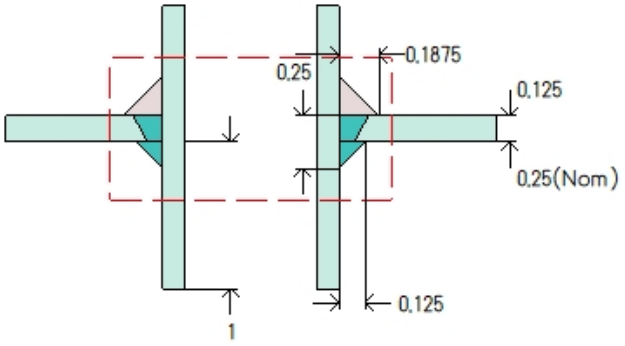
Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	TOP DISH
Orientation	30°
End of nozzle to datum line	76.4385"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 0.5 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	0.622"
Pipe nominal wall thickness	0.109"
Pipe minimum wall thickness[1]	0.0954"
Corrosion allowance	0"
Opening chord length	0.6696"
Projection available outside vessel, Lpr	5.8729"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 0.5 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.15 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.155" (0.1526" min)
Internal fillet weld leg (UW-21)	0.109" (0.109" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{min} = min[1.4*t_n , g_0] = [1.4*0.109 , 0.155] =$	0.1526"
$External\ Leg_{min} = X_{min} + C_o / 0.7 = 0.1526 + 0 / 0.7 =$	0.1526"
$Internal\ Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.109 , 0.25 + 0 / 0.7] =$	0.109"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*0.311 / (17,000*1 - 0.6*10.4) =	0.0002"
Stress ratio = t_r*E^* / (t_n - c) = 0.0002*1 / (0.0954 - 0) =	0.002
Impact test exempt per UHA-51(g) (coincident ratio = 0.002)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.0954

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0763	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(0.6696, 0.3348 + (0.109 - 0) + (0.125 - 0))
= 0.6696 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.109 - 0) + 0)
= 0.2725 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.109 - 0 - 0))
= 0.2725 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*0.311 / (20,000*1 - 0.6*10.4048)
= 0.0002 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.109 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0763 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*0.311 / (17,000*1 - 0.6*10.4048) + 0
= 0.0002 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0002 , 0]
= 0.0002 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0954 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0002 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.109 = 0.0954 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0954	0.0954

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0763	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = $MAX(d, R_n + (t_n - C_n) + (t - C))$
= $MAX(0.6696, 0.3348 + (0.109 - 0) + (0.125 - 0))$
= 0.6696 in

Outer Normal Limit of reinforcement per UG-40

L_H = $MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$
= $MIN(2.5*(0.125 - 0), 2.5*(0.109 - 0) + 0)$
= 0.2725 in

Inner Normal Limit of reinforcement per UG-40

L_I = $MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))$
= $MIN(1, 2.5*(0.125 - 0), 2.5*(0.109 - 0 - 0))$
= 0.2725 in

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$
= $92.5484*0.311 / (20{,}000*1 - 0.6*92.5484)$
= 0.0014 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.109 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0763 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*0.311 / (17,000*1 - 0.6*92.5484) + 0
= 0.0017 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0017 , 0]
= 0.0017 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0954 , 0.2207]
= 0.0954 in

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

= max[0.0017 , 0.0954]
= 0.0954 in

Available nozzle wall thickness new, t_n = 0.875*0.109 = 0.0954 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0954	0.0954

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(0.6696, 0.3348 + (0.109 - 0) + (0.125 - 0))
= 0.6696 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.109 - 0) + 0)
= 0.2725 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.109 - 0 - 0))
= 0.2725 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*0.311 / (20,000*1 - 0.6*92.5532)
= 0.0014 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*0.311 / (17,000*1 - 0.6*92.5532) + 0
= 0.0017 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0017 , 0]
= 0.0017 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0954 , 0.2207]
= 0.0954 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0017 , 0.0954]
= 0.0954 in

Available nozzle wall thickness new, t_n = 0.875*0.109 = 0.0954 in

The nozzle neck thickness is adequate.

Nozzle #3 (N3)

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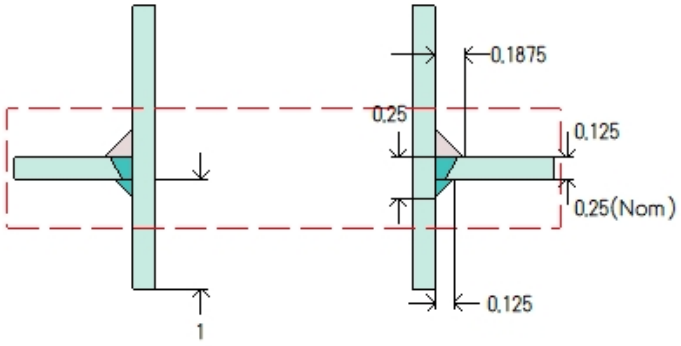

Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	TOP DISH
Orientation	60°
End of nozzle to datum line	76.641"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No

Nozzle	
Description	NPS 1.5 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	1.61"
Pipe nominal wall thickness	0.145"
Pipe minimum wall thickness[1]	0.1269"
Corrosion allowance	0"
Opening chord length	1.7333"
Projection available outside vessel, Lpr	5.8369"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi

Welds

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 1.5 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.14 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.203" (0.203" min)
Internal fillet weld leg (UW-21)	0.145" (0.145" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
X_{min} = min[1.4*t_n , g_0] = [1.4*0.145 , 0.305] =	0.203"
External Leg_{min} = X_{min} + C_o / 0.7 = 0.203 + 0 / 0.7 =	0.203"
Internal Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.145 , 0.25 + 0 / 0.7] =	0.145"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*54*1 / (2*20,000*1 - 0.2*10.4) =	0.0141"
Stress ratio = t_r*E^* / (t_n - c) = 0.0141*1 / (0.125 - 0) =	0.1124
Impact test exempt per UHA-51(g) (coincident ratio = 0.1124)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1269

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1015	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0))
= 1.7333 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0))
= 0.3125 in

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

t_{rn} = $P*R_n$ / (S_n*E - 0.6*P)
= 10.4048*0.805 / (20,000*1 - 0.6*10.4048)
= 0.0004 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.145 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1015 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*0.805 / (17,000*1 - 0.6*10.4048) + 0
= 0.0005 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0005 , 0]
= 0.0005 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0005 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.1269

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1015	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0)) \\ &= 1.7333 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*0.805 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0037 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.145 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1015 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*0.805 / (17,000*1 - 0.6*92.5484) + 0
= 0.0044 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0044 , 0]
= 0.0044 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.2207]
= 0.1269 in

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

= max[0.0044 , 0.1269]
= 0.1269 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.1269

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0))
= 1.7333 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*0.805 / (20,000*1 - 0.6*92.5532)
= 0.0037 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*0.805 / (17,000*1 - 0.6*92.5532) + 0
= 0.0044 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0044 , 0]
= 0.0044 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

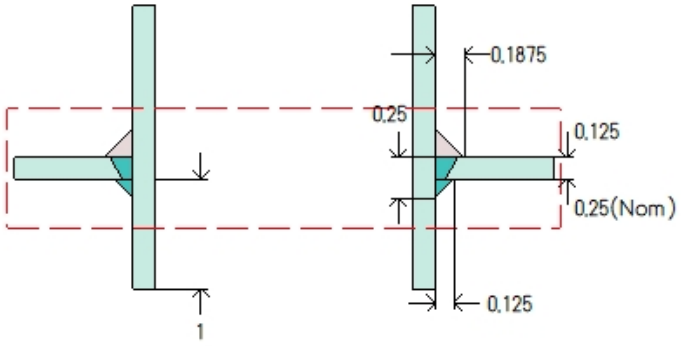
t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.2207]
= 0.1269 in

t_{UG-45} = max[t_a , t_b]
= max[0.0044 , 0.1269]
= 0.1269 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

The nozzle neck thickness is adequate.

Nozzle #4 (N4)

ASME Section VIII Division 1, 2023 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	TOP DISH
Orientation	90°
End of nozzle to datum line	76.641"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 1.5 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	1.61"
Pipe nominal wall thickness	0.145"
Pipe minimum wall thickness[1]	0.1269"
Corrosion allowance	0"
Opening chord length	1.7333"
Projection available outside vessel, Lpr	5.8369"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 1.5 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.14 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.203" (0.203" min)
Internal fillet weld leg (UW-21)	0.145" (0.145" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{min} = \min[1.4*t_n , g_0] = [1.4*0.145 , 0.305] =$	0.203"
External $Leg_{min} = X_{min} + C_o / 0.7 = 0.203 + 0 / 0.7 =$	0.203"
Internal $Leg_{min} = \min[t_n , 0.25" + C_i / 0.7] = \min[0.145 , 0.25 + 0 / 0.7] =$	0.145"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*54*1 / (2*20,000*1 - 0.2*10.4) =	0.0141"
Stress ratio = t_r*E^* / (t_n - c) = 0.0141*1 / (0.125 - 0) =	0.1124
Impact test exempt per UHA-51(g) (coincident ratio = 0.1124)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1269

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1015	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0))
= 1.7333 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*0.805 / (20,000*1 - 0.6*10.4048)
= 0.0004 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.145 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1015 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*0.805 / (17,000*1 - 0.6*10.4048) + 0
= 0.0005 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0005 , 0]
= 0.0005 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0005 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.1269

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1015	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0)) \\ &= 1.7333 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*0.805 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0037 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.145 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1015 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*0.805 / (17,000*1 - 0.6*92.5484) + 0
= 0.0044 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0044 , 0]
= 0.0044 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.2207]
= 0.1269 in

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

= max[0.0044 , 0.1269]
= 0.1269 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.1269

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0))
= 1.7333 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*0.805 / (20,000*1 - 0.6*92.5532)
= 0.0037 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*0.805 / (17,000*1 - 0.6*92.5532) + 0
= 0.0044 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0044 , 0]
= 0.0044 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.2207]
= 0.1269 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0044 , 0.1269]
= 0.1269 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

The nozzle neck thickness is adequate.

Nozzle #5 (N5)

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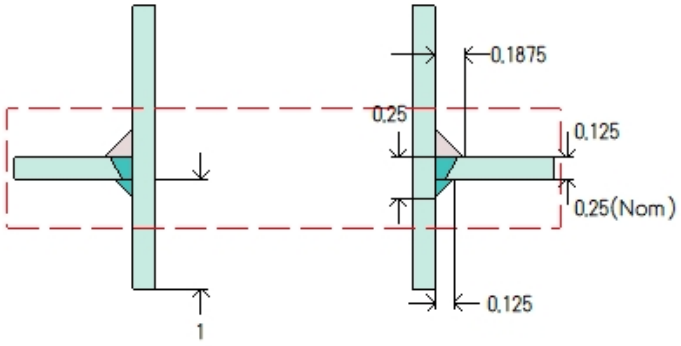	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	TOP DISH
Orientation	120°
End of nozzle to datum line	76.641"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 1.5 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	1.61"
Pipe nominal wall thickness	0.145"
Pipe minimum wall thickness[1]	0.1269"
Corrosion allowance	0"
Opening chord length	1.7333"
Projection available outside vessel, Lpr	5.8369"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 1.5 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.14 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.203" (0.203" min)
Internal fillet weld leg (UW-21)	0.145" (0.145" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
X_{min} = min[1.4*t_n , g_0] = [1.4*0.145 , 0.305] =	0.203"
External Leg_{min} = X_{min} + C_o / 0.7 = 0.203 + 0 / 0.7 =	0.203"
Internal Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.145 , 0.25 + 0 / 0.7] =	0.145"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*54*1 / (2*20,000*1 - 0.2*10.4) =	0.0141"
Stress ratio = t_r*E^* / (t_n - c) = 0.0141*1 / (0.125 - 0) =	0.1124
Impact test exempt per UHA-51(g) (coincident ratio = 0.1124)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1269

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1015	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0))
= 1.7333 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*0.805 / (20,000*1 - 0.6*10.4048)
= 0.0004 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.145 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1015 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*0.805 / (17,000*1 - 0.6*10.4048) + 0
= 0.0005 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0005 , 0]
= 0.0005 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0005 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.1269

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1015	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0)) \\ &= 1.7333 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*0.805 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0037 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.145 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1015 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*0.805 / (17,000*1 - 0.6*92.5484) + 0
= 0.0044 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0044 , 0]
= 0.0044 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.2207]
= 0.1269 in

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

= max[0.0044 , 0.1269]
= 0.1269 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1269	0.1269

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.7333, 0.8667 + (0.145 - 0) + (0.125 - 0))
= 1.7333 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.145 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.145 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*0.805 / (20,000*1 - 0.6*92.5532)
= 0.0037 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*0.805 / (17,000*1 - 0.6*92.5532) + 0
= 0.0044 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0044 , 0]
= 0.0044 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1269 , 0.2207]
= 0.1269 in

t_{UG-45} = max[t_a , t_b]
= max[0.0044 , 0.1269]
= 0.1269 in

Available nozzle wall thickness new, t_n = 0.875*0.145 = 0.1269 in

The nozzle neck thickness is adequate.

Nozzle #6 (N6)

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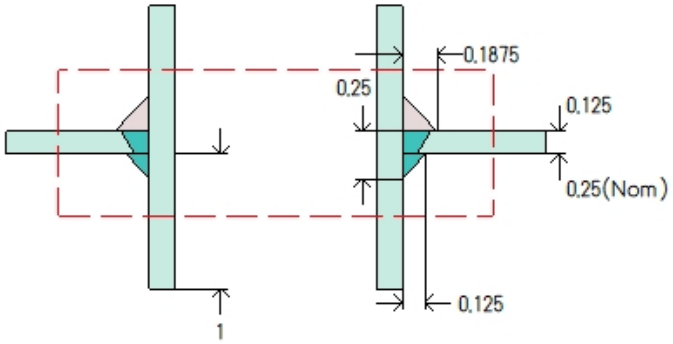	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	TOP DISH
Orientation	150°
End of nozzle to datum line	76.53"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 1 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	1.049"
Pipe nominal wall thickness	0.133"
Pipe minimum wall thickness[1]	0.1164"
Corrosion allowance	0"
Opening chord length	1.1293"
Projection available outside vessel, Lpr	5.8489"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 1 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.15 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.203" (0.1862" min)
Internal fillet weld leg (UW-21)	0.133" (0.133" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{min} = min[1.4*t_n , g_0] = [1.4*0.133 , 0.29] =$	0.1862"
$External\ Leg_{min} = X_{min} + C_o / 0.7 = 0.1862 + 0 / 0.7 =$	0.1862"
$Internal\ Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.133 , 0.25 + 0 / 0.7] =$	0.133"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*0.5245 / (17,000*1 - 0.6*10.4) =	0.0003"
Stress ratio = t_r*E^* / (t_n - c) = 0.0003*1 / (0.1164 - 0) =	0.0028
Impact test exempt per UHA-51(g) (coincident ratio = 0.0028)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1164

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0931	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.1293, 0.5647 + (0.133 - 0) + (0.125 - 0))
= 1.1293 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.133 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.133 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*0.5245 / (20,000*1 - 0.6*10.4048)
= 0.0003 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.133 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0931 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*0.5245 / (17,000*1 - 0.6*10.4048) + 0
= 0.0003 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0003 , 0]
= 0.0003 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1164 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0003 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.133 = 0.1164 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1164	0.1164

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0931	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(1.1293, 0.5647 + (0.133 - 0) + (0.125 - 0)) \\ &= 1.1293 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.133 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.133 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*0.5245 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0024 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.133 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0931 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*0.5245 / (17,000*1 - 0.6*92.5484) + 0
= 0.0029 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0029 , 0]
= 0.0029 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1164 , 0.2207]
= 0.1164 in

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

= max[0.0029 , 0.1164]
= 0.1164 in

Available nozzle wall thickness new, t_n = 0.875*0.133 = 0.1164 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1164	0.1164

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(1.1293, 0.5647 + (0.133 - 0) + (0.125 - 0))
= 1.1293 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.133 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.133 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*0.5245 / (20,000*1 - 0.6*92.5532)
= 0.0024 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*0.5245 / (17,000*1 - 0.6*92.5532) + 0
= 0.0029 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0029 , 0]
= 0.0029 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1164 , 0.2207]
= 0.1164 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0029 , 0.1164]
= 0.1164 in

Available nozzle wall thickness new, t_n = 0.875*0.133 = 0.1164 in

The nozzle neck thickness is adequate.

Nozzle #7 (N7)

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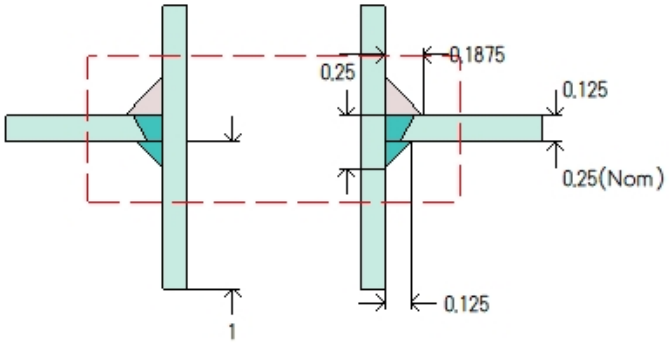
Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	TOP DISH
Orientation	180°
End of nozzle to datum line	76.4791"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 0.75 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	0.824"
Pipe nominal wall thickness	0.113"
Pipe minimum wall thickness[1]	0.0989"
Corrosion allowance	0"
Opening chord length	0.8871"
Projection available outside vessel, Lpr	5.8689"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 0.75 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.15 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.203" (0.1582" min)
Internal fillet weld leg (UW-21)	0.113" (0.113" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{min} = min[1.4*t_n , g_0] = [1.4*0.113 , 0.205] =$	0.1582"
$External\ Leg_{min} = X_{min} + C_o / 0.7 = 0.1582 + 0 / 0.7 =$	0.1582"
$Internal\ Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.113 , 0.25 + 0 / 0.7] =$	0.113"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*0.412 / (17,000*1 - 0.6*10.4) =	0.0003"
Stress ratio = t_r*E^* / (t_n - c) = 0.0003*1 / (0.0989 - 0) =	0.0026
Impact test exempt per UHA-51(g) (coincident ratio = 0.0026)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.0989

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0791	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(0.8871, 0.4436 + (0.113 - 0) + (0.125 - 0))
= 0.8871 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.113 - 0) + 0)
= 0.2825 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.113 - 0 - 0))
= 0.2825 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*0.412 / (20,000*1 - 0.6*10.4048)
= 0.0002 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.113 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0791 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*0.412 / (17,000*1 - 0.6*10.4048) + 0
= 0.0003 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0003 , 0]
= 0.0003 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0989 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0003 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.113 = 0.0989 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0989	0.0989

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0791	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = $MAX(d, R_n + (t_n - C_n) + (t - C))$
= $MAX(0.8871, 0.4436 + (0.113 - 0) + (0.125 - 0))$
= 0.8871 in

Outer Normal Limit of reinforcement per UG-40

L_H = $MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$
= $MIN(2.5*(0.125 - 0), 2.5*(0.113 - 0) + 0)$
= 0.2825 in

Inner Normal Limit of reinforcement per UG-40

L_I = $MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))$
= $MIN(1, 2.5*(0.125 - 0), 2.5*(0.113 - 0 - 0))$
= 0.2825 in

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$
= $92.5484*0.412 / (20{,}000*1 - 0.6*92.5484)$
= 0.0019 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.113 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0791 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*0.412 / (17,000*1 - 0.6*92.5484) + 0
= 0.0023 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0023 , 0]
= 0.0023 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0989 , 0.2207]
= 0.0989 in

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

= max[0.0023 , 0.0989]
= 0.0989 in

Available nozzle wall thickness new, t_n = 0.875*0.113 = 0.0989 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0989	0.0989

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(0.8871, 0.4436 + (0.113 - 0) + (0.125 - 0))
= 0.8871 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.113 - 0) + 0)
= 0.2825 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.113 - 0 - 0))
= 0.2825 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*0.412 / (20,000*1 - 0.6*92.5532)
= 0.0019 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*0.412 / (17,000*1 - 0.6*92.5532) + 0
= 0.0023 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0023 , 0]
= 0.0023 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0989 , 0.2207]
= 0.0989 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0023 , 0.0989]
= 0.0989 in

Available nozzle wall thickness new, t_n = 0.875*0.113 = 0.0989 in

The nozzle neck thickness is adequate.

Nozzle #8 (N8)

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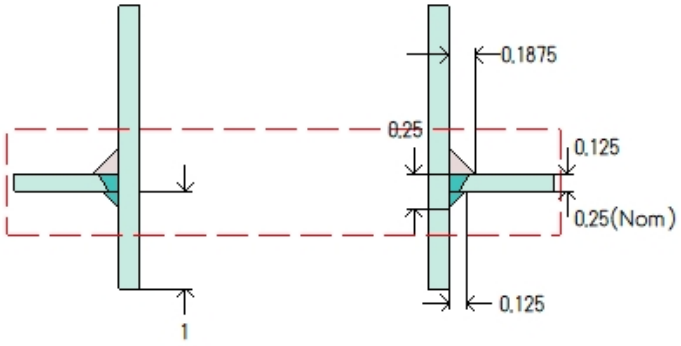

Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	TOP DISH
Orientation	210°
End of nozzle to datum line	76.7296"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 2 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	2.067"
Pipe nominal wall thickness	0.154"
Pipe minimum wall thickness[1]	0.1348"
Corrosion allowance	0"
Opening chord length	2.2253"
Projection available outside vessel, Lpr	5.8279"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 2 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.14 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.2156" (0.2156" min)
Internal fillet weld leg (UW-21)	0.154" (0.154" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{min} = \min[1.4*t_n , g_0] = [1.4*0.154 , 0.31] =$	0.2156"
$\text{External Leg}_{min} = X_{min} + C_o / 0.7 = 0.2156 + 0 / 0.7 =$	0.2156"
$\text{Internal Leg}_{min} = \min[t_n , 0.25" + C_i / 0.7] = \min[0.154 , 0.25 + 0 / 0.7] =$	0.154"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*54*1 / (2*20,000*1 - 0.2*10.4) =	0.0141"
Stress ratio = t_r*E^* / (t_n - c) = 0.0141*1 / (0.125 - 0) =	0.1124
Impact test exempt per UHA-51(g) (coincident ratio = 0.1124)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1348

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1078	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0))
= 2.2253 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*1.0335 / (20,000*1 - 0.6*10.4048)
= 0.0005 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.154 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1078 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*1.0335 / (17,000*1 - 0.6*10.4048) + 0
= 0.0006 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0006 , 0]
= 0.0006 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0006 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1348

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1078	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0)) \\ &= 2.2253 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*1.0335 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0048 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.154 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1078 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*1.0335 / (17,000*1 - 0.6*92.5484) + 0
= 0.0056 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0056 , 0]
= 0.0056 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.2207]
= 0.1348 in

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

= max[0.0056 , 0.1348]
= 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1348

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0))
= 2.2253 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*1.0335 / (20,000*1 - 0.6*92.5532)
= 0.0048 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG\text{-}27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*1.0335 / (17,000*1 - 0.6*92.5532) + 0
= 0.0056 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0056 , 0]
= 0.0056 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

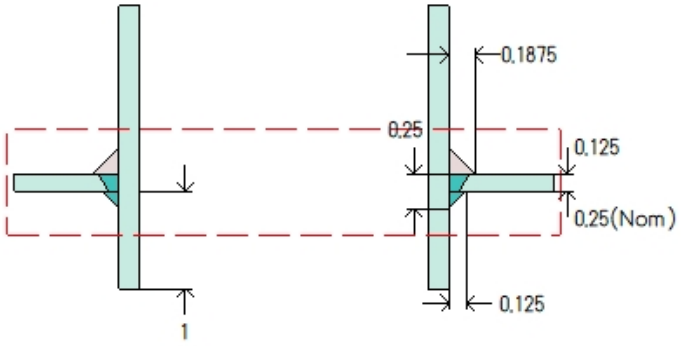
t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.2207]
= 0.1348 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0056 , 0.1348]
= 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

The nozzle neck thickness is adequate.

Nozzle #9 (N9)

ASME Section VIII Division 1, 2023 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	TOP DISH
Orientation	240°
End of nozzle to datum line	76.7296"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 2 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	2.067"
Pipe nominal wall thickness	0.154"
Pipe minimum wall thickness[1]	0.1348"
Corrosion allowance	0"
Opening chord length	2.2253"
Projection available outside vessel, Lpr	5.8279"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 2 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.14 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.2156" (0.2156" min)
Internal fillet weld leg (UW-21)	0.154" (0.154" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{min} = \min[1.4*t_n , g_0] = [1.4*0.154 , 0.31] =$	0.2156"
External $Leg_{min} = X_{min} + C_o / 0.7 = 0.2156 + 0 / 0.7 =$	0.2156"
Internal $Leg_{min} = \min[t_n , 0.25" + C_i / 0.7] = \min[0.154 , 0.25 + 0 / 0.7] =$	0.154"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*54*1 / (2*20,000*1 - 0.2*10.4) =	0.0141"
Stress ratio = t_r*E^* / (t_n - c) = 0.0141*1 / (0.125 - 0) =	0.1124
Impact test exempt per UHA-51(g) (coincident ratio = 0.1124)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1348

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1078	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0))
= 2.2253 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*1.0335 / (20,000*1 - 0.6*10.4048)
= 0.0005 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.154 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1078 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*1.0335 / (17,000*1 - 0.6*10.4048) + 0
= 0.0006 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0006 , 0]
= 0.0006 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0006 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1348

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1078	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0)) \\ &= 2.2253 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*1.0335 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0048 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.154 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1078 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*1.0335 / (17,000*1 - 0.6*92.5484) + 0
= 0.0056 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0056 , 0]
= 0.0056 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.2207]
= 0.1348 in

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

= max[0.0056 , 0.1348]
= 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1348

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0))
= 2.2253 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*1.0335 / (20,000*1 - 0.6*92.5532)
= 0.0048 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*1.0335 / (17,000*1 - 0.6*92.5532) + 0
= 0.0056 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0056 , 0]
= 0.0056 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.2207]
= 0.1348 in

t_{UG-45} = max[t_a , t_b]
= max[0.0056 , 0.1348]
= 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

The nozzle neck thickness is adequate.

Nozzle #10 (N11)

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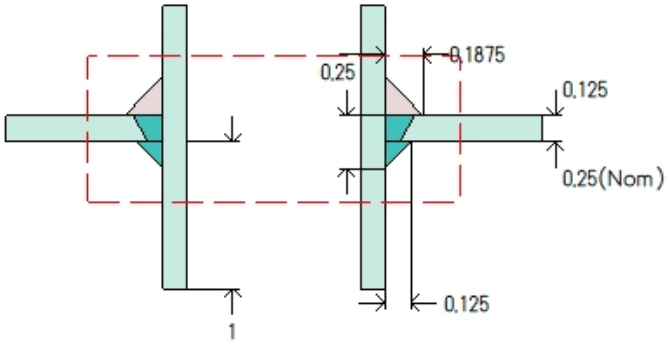	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	TOP DISH
Orientation	270°
End of nozzle to datum line	76.4791"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 0.75 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	0.824"
Pipe nominal wall thickness	0.113"
Pipe minimum wall thickness[1]	0.0989"
Corrosion allowance	0"
Opening chord length	0.8871"
Projection available outside vessel, Lpr	5.8689"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 0.75 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.15 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.203" (0.1582" min)
Internal fillet weld leg (UW-21)	0.113" (0.113" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{min} = min[1.4*t_n , g_0] = [1.4*0.113 , 0.205] =$	0.1582"
$External\ Leg_{min} = X_{min} + C_o / 0.7 = 0.1582 + 0 / 0.7 =$	0.1582"
$Internal\ Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.113 , 0.25 + 0 / 0.7] =$	0.113"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*0.412 / (17,000*1 - 0.6*10.4) =	0.0003"
Stress ratio = t_r*E^* / (t_n - c) = 0.0003*1 / (0.0989 - 0) =	0.0026
Impact test exempt per UHA-51(g) (coincident ratio = 0.0026)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.0989

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0791	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(0.8871, 0.4436 + (0.113 - 0) + (0.125 - 0))
= 0.8871 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.113 - 0) + 0)
= 0.2825 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.113 - 0 - 0))
= 0.2825 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*0.412 / (20,000*1 - 0.6*10.4048)
= 0.0002 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.113 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0791 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*0.412 / (17,000*1 - 0.6*10.4048) + 0
= 0.0003 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0003 , 0]
= 0.0003 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0989 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0003 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.113 = 0.0989 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0989	0.0989

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0791	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(0.8871, 0.4436 + (0.113 - 0) + (0.125 - 0)) \\ &= 0.8871 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.113 - 0) + 0) \\ &= 0.2825 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.113 - 0 - 0)) \\ &= 0.2825 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*0.412 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0019 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.113 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.0791 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*0.412 / (17,000*1 - 0.6*92.5484) + 0
= 0.0023 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0023 , 0]
= 0.0023 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0989 , 0.2207]
= 0.0989 in

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

= max[0.0023 , 0.0989]
= 0.0989 in

Available nozzle wall thickness new, t_n = 0.875*0.113 = 0.0989 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0989	0.0989

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = $MAX(d, R_n + (t_n - C_n) + (t - C))$
= $MAX(0.8871, 0.4436 + (0.113 - 0) + (0.125 - 0))$
= 0.8871 in

Outer Normal Limit of reinforcement per UG-40

L_H = $MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$
= $MIN(2.5*(0.125 - 0), 2.5*(0.113 - 0) + 0)$
= 0.2825 in

Inner Normal Limit of reinforcement per UG-40

L_I = $MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))$
= $MIN(1, 2.5*(0.125 - 0), 2.5*(0.113 - 0 - 0))$
= 0.2825 in

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$
= $92.5532*0.412 / (20{,}000*1 - 0.6*92.5532)$
= 0.0019 in

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

t_r = $P*L*M / (2*S*E - 0.2*P)$
= $92.5532*54*1 / (2*20{,}000*1 - 0.2*92.5532)$
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*0.412 / (17,000*1 - 0.6*92.5532) + 0
= 0.0023 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0023 , 0]
= 0.0023 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.0989 , 0.2207]
= 0.0989 in

t_{UG-45} = max[t_a , t_b]
= max[0.0023 , 0.0989]
= 0.0989 in

Available nozzle wall thickness new, t_n = 0.875*0.113 = 0.0989 in

The nozzle neck thickness is adequate.

Nozzle #11 (N12)

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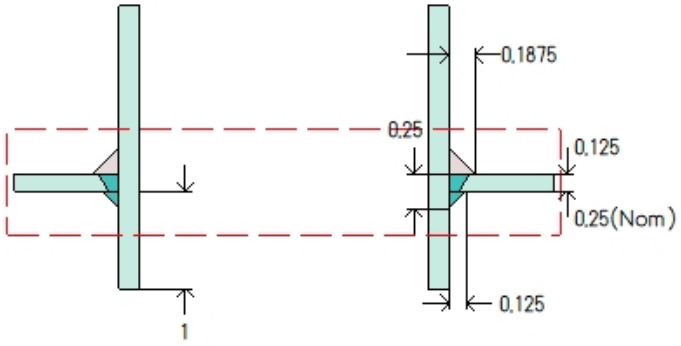

Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	TOP DISH
Orientation	300°
End of nozzle to datum line	76.7296"
Calculated as hillside	Yes
Distance to head center, R	20"
Passes through a Category A joint	No
Nozzle	
Description	NPS 2 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	2.067"
Pipe nominal wall thickness	0.154"
Pipe minimum wall thickness[1]	0.1348"
Corrosion allowance	0"
Opening chord length	2.2253"
Projection available outside vessel, Lpr	5.8279"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.4 psi
Welds	

Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1] Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 2 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.14 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.2156" (0.2156" min)
Internal fillet weld leg (UW-21)	0.154" (0.154" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
X_{min} = min[1.4*t_n , g_0] = [1.4*0.154 , 0.31] =	0.2156"
External Leg_{min} = X_{min} + C_o / 0.7 = 0.2156 + 0 / 0.7 =	0.2156"
Internal Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.154 , 0.25 + 0 / 0.7] =	0.154"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.4*54*1 / (2*20,000*1 - 0.2*10.4) =	0.0141"
Stress ratio = t_r*E^* / (t_n - c) = 0.0141*1 / (0.125 - 0) =	0.1124
Impact test exempt per UHA-51(g) (coincident ratio = 0.1124)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.4 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1348

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1078	0.1313	weld size is adequate

Calculations for internal pressure 10.4 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0))
= 2.2253 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.4048*1.0335 / (20,000*1 - 0.6*10.4048)
= 0.0005 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.4048*54*1 / (2*20,000*1 - 0.2*10.4048)
= 0.0141 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.4*54*1.7659 / (2*20,000*0.7 - 0.2*10.4)
= 0.0354 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.154 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1078 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.4048*1.0335 / (17,000*1 - 0.6*10.4048) + 0
= 0.0006 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0006 , 0]
= 0.0006 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.4*54*1.7659 / (2*20,000*1 - 0.2*10.4) + 0
= 0.0248 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0248 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0006 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1348

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1078	0.1313	weld size is adequate

Calculations for internal pressure 92.55 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0)) \\ &= 2.2253 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5484*1.0335 / (20{,}000*1 - 0.6*92.5484) \\ &= 0.0048 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5484*54*1 / (2*20,000*1 - 0.2*92.5484)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.154 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1078 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5484*1.0335 / (17,000*1 - 0.6*92.5484) + 0
= 0.0056 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0056 , 0]
= 0.0056 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.2207]
= 0.1348 in

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

= max[0.0056 , 0.1348]
= 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1348

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.2253, 1.1127 + (0.154 - 0) + (0.125 - 0))
= 2.2253 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*1.0335 / (20,000*1 - 0.6*92.5532)
= 0.0048 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*1.0335 / (17,000*1 - 0.6*92.5532) + 0
= 0.0056 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0056 , 0]
= 0.0056 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

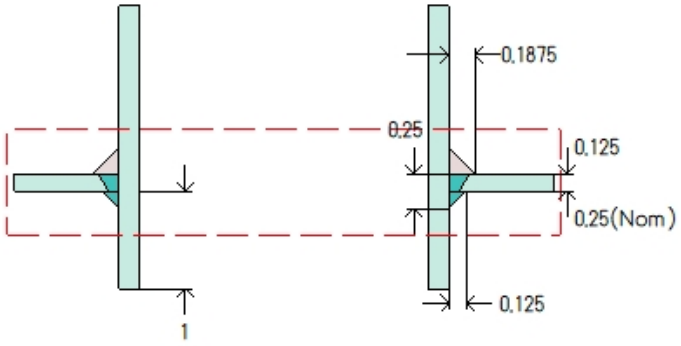
t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.2207]
= 0.1348 in

t_{UG-45} = max[t_a , t_b]
= max[0.0056 , 0.1348]
= 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

The nozzle neck thickness is adequate.

Nozzle #12 (N13)

ASME Section VIII Division 1, 2023 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	TOP DISH
Orientation	0°
End of nozzle to datum line	80.0912"
Calculated as hillside	No
Distance to head center, R	0"
Passes through a Category A joint	No
Nozzle	
Description	NPS 2 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	2.067"
Pipe nominal wall thickness	0.154"
Pipe minimum wall thickness[1]	0.1348"
Corrosion allowance	0"
Projection available outside vessel, Lpr	5.8279"
Internal projection, h_{new}	1"
Projection available outside vessel to flange face, Lf	5.9819"
Local vessel minimum thickness	0.125"
Liquid static head included	0.25 psi
Welds	
Inner fillet, Leg_{41}	0.1875"

Lower fillet, Leg_{43}	0.125"
Nozzle to vessel groove weld	0.25"
Radiography	
Longitudinal seam	Welded pipe

[1]Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-2020 Flange	
Description	NPS 2 Class 150 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	245 psi @ 175°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.2156" (0.2156" min)
Internal fillet weld leg (UW-21)	0.154" (0.154" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
X_{min} = min[1.4*t_n , g_0] = [1.4*0.154 , 0.31] =	0.2156"
External Leg_{min} = X_{min} + C_o / 0.7 = 0.2156 + 0 / 0.7 =	0.2156"
Internal Leg_{min} = min[t_n , 0.25" + C_i / 0.7] = min[0.154 , 0.25 + 0 / 0.7] =	0.154"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UHA-51 Material Toughness Requirements Nozzle	
t_r = 10.25*54*1 / (2*20,000*1 - 0.2*10.25) =	0.0138"
Stress ratio = t_r*E^* / (t_n - c) = 0.0138*1 / (0.125 - 0) =	0.1107
Impact test exempt per UHA-51(g) (coincident ratio = 0.1107)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 10.25 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.1348

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1078	0.1313	weld size is adequate

Calculations for internal pressure 10.25 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.067, 1.0335 + (0.154 - 0) + (0.125 - 0))
= 2.067 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 10.2486*1.0335 / (20,000*1 - 0.6*10.2486)
= 0.0005 in

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

t_r = P*L*M / (2*S*E - 0.2*P)

= 10.2486*54*1 / (2*20,000*1 - 0.2*10.2486)
= 0.0138 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 10.25*54*1.7659 / (2*20,000*0.7 - 0.2*10.25)
= 0.0349 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.154 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1078 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 10.2486*1.0335 / (17,000*1 - 0.6*10.2486) + 0
= 0.0006 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0006 , 0]
= 0.0006 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 10.25*54*1.7659 / (2*20,000*1 - 0.2*10.25) + 0
= 0.0244 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.0244 , 0.0625]
= 0.0625 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.0625]
= 0.0625 in

t_{UG-45} = max[t_a , t_b]
= max[0.0006 , 0.0625]
= 0.0625 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 92.54 psi @ 175 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1348

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1078	0.1313	weld size is adequate

Calculations for internal pressure 92.54 psi @ 175 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= MAX(d, R_n + (t_n - C_n) + (t - C)) \\ &= MAX(2.067, 1.0335 + (0.154 - 0) + (0.125 - 0)) \\ &= 2.067 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\ &= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0) \\ &= 0.3125 \text{ in} \end{aligned}$$

Inner Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_I &= MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C)) \\ &= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0)) \\ &= 0.3125 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\ &= 92.5446*1.0335 / (20{,}000*1 - 0.6*92.5446) \\ &= 0.0048 \text{ in} \end{aligned}$$

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5446*54*1 / (2*20,000*1 - 0.2*92.5446)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.54*54*1.7659 / (2*20,000*0.7 - 0.2*92.54)
= 0.3154 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.154 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1078 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = P*R_n / (S_n*E - 0.6*P) + Corrosion
= 92.5446*1.0335 / (17,000*1 - 0.6*92.5446) + 0
= 0.0056 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0056 , 0]
= 0.0056 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.54*54*1.7659 / (2*20,000*1 - 0.2*92.54) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.2207]
= 0.1348 in

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

= max[0.0056 , 0.1348]
= 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

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 (in^2)							UG-45 Summary (in)	
For P = 92.55 psi @ 70 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1348	0.1348

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

Calculations for internal pressure 92.55 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(2.067, 1.0335 + (0.154 - 0) + (0.125 - 0))
= 2.067 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.125 - 0), 2.5*(0.154 - 0) + 0)
= 0.3125 in

Inner Normal Limit of reinforcement per UG-40

L_I = MIN(h, 2.5*(t - C), 2.5*(t_i - C_n - C))
= MIN(1, 2.5*(0.125 - 0), 2.5*(0.154 - 0 - 0))
= 0.3125 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 92.5532*1.0335 / (20,000*1 - 0.6*92.5532)
= 0.0048 in

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

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.5532*54*1 / (2*20,000*1 - 0.2*92.5532)
= 0.125 in

Required thickness t_r per Interpretation VIII-1-07-50

t_r = P*L*M / (2*S*E - 0.2*P)
= 92.55*54*1.7659 / (2*20,000*0.7 - 0.2*92.55)
= 0.3154 in

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\ UG-27}$ = $P*R_n / (S_n*E - 0.6*P)$ + Corrosion
= 92.5532*1.0335 / (17,000*1 - 0.6*92.5532) + 0
= 0.0056 in

t_a = max[$t_{a\ UG-27}$, $t_{a\ UG-22}$]
= max[0.0056 , 0]
= 0.0056 in

t_{b1} = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 92.55*54*1.7659 / (2*20,000*1 - 0.2*92.55) + 0
= 0.2207 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.2207 , 0.0625]
= 0.2207 in

t_b = min[t_{b3} , t_{b1}]
= min[0.1348 , 0.2207]
= 0.1348 in

t_{UG-45} = max[t_a , t_b]
= max[0.0056 , 0.1348]
= 0.1348 in

Available nozzle wall thickness new, t_n = 0.875*0.154 = 0.1348 in

The nozzle neck thickness is adequate.

SHELL 2

ASME Section VIII Division 1, 2023 Edition				
Component		Cylinder		
Material		SA-240 316 (II-D p. 76, ln. 21)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		10	175	-20
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		1.27	31.2562	1.13
Test horizontal		1.95	54	1
Dimensions				
Inner Diameter		54"		
Length		14"		
Nominal Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		129.59		138.8
Corroded		129.59		138.8
Insulation				
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**
Insulation		2	9.36	26.86
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**
Insulation Supports		0	0	0
Radiography				
Longitudinal seam		None UW-11(c) Type 1		
Top Circumferential seam		None UW-11(c) Type 1		
Bottom Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0218"
Design thickness due to combined loadings + corrosion	0.008"
Maximum allowable working pressure (MAWP)	95.54 psi
Maximum allowable pressure (MAP)	96.82 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
t_r = 11.27*27 / (20,000*0.7 - 0.6*11.27) =	0.0218"
Stress ratio = t_r*E^* / (t_n - c) = 0.0218*0.8 / (0.1875 - 0) =	0.0928
Stress ratio longitudinal = 595*0.8 / (20,000*0.7) =	0.034
Impact test exempt per UHA-51(g) (coincident ratio = 0.0928)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 175 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 11.27*27 / (20,000*0.70 - 0.60*11.27) + 0
= 0.0218"

Maximum allowable working pressure, (at 175 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 20,000*0.70*0.1875 / (27 + 0.60*0.1875) - 1.27
= 95.54 psi

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 20,000*0.70*0.1875 / (27 + 0.60*0.1875)
= 96.82 psi

% Forming strain - UHA-44(a)(2)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*0.1875 / 27.0938)*(1 - 27.0938 / ∞)
= 0.346%

Thickness Required Due to Pressure + External Loads								
Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	10	20,000	9,100	175	0	Wind	0.008	0.0079
						Seismic	0.008	0.0079
Operating, Hot & New	10	20,000	9,100	175	0	Wind	0.008	0.0079
						Seismic	0.008	0.0079
Hot Shut Down, Corroded	0	20,000	9,100	175	0	Wind	0.0001	0.0002
						Seismic	0.0001	0.0002
Hot Shut Down, New	0	20,000	9,100	175	0	Wind	0.0001	0.0002
						Seismic	0.0001	0.0002
Empty, Corroded	0	20,000	9,365	70	0	Wind	0.0001	0.0002
						Seismic	0.0001	0.0002
Empty, New	0	20,000	9,365	70	0	Wind	0.0001	0.0002
						Seismic	0.0001	0.0002
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	9,100	175	0	Weight	0.0002	0.0002

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

A = 0.125 / (R_o / t)
= 0.125 / (27.1875 / 0.1875)
= 0.000862

B = 9,100 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cHC} = min(B, S) = 9,100 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

S_{cHN} = S_{cHC}
= 9,100 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (27.1875 / 0.1875)
= 0.000862

B = 9,365 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cCN} = min(B, S) = 9,365 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

S_{cCC} = S_{cCN}
= 9,365 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (27.1875 / 0.1875)
= 0.000862

B = 9,365 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cVC} = min(B, S) = 9.365 psi

Operating, Hot & Corroded, Wind, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 1,183 / (π*27.0938^2*20,000*1.20*0.70)
= 0"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*374.5 / (2*π*27.0938*20,000*1.20*0.70)
= 0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.008 + 0 - (0.0001)
= 0.008"

t_{wc} = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 374.5 / (2*π*27.0938*20,000*1.20*0.70)
= 0.0001"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0001) - (0.008)|
= 0.0079"

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*20,000*1.20*0.70*(0.1875 - 0 + (0.0001)) / (27 - 0.40*(0.1875 - 0 + (0.0001)))
= 234.04 psi

Operating, Hot & New, Wind, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 1,183 / (π*27.0938^2*20,000*1.20*0.70)
= 0"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*374.5 / (2*π*27.0938*20,000*1.20*0.70)
= 0.0001"

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.008 + 0 - (0.0001)$
$= 0.008"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 374.5 / (2*\pi*27.0938*20,000*1.20*0.70)$
$= 0.0001"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (0.0001) - (0.008)|$
$= 0.0079"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20,000*1.20*0.70*(0.1875 - 0 + (0.0001)) / (27 - 0.40*(0.1875 - 0 + (0.0001)))$
$= 234.04$ psi

Hot Shut Down, Corroded, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 1,183 / (\pi*27.0938^2*9,099.82*1.20)$
$= 0"$

$t_w = 0.6*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.60*374.5 / (2*\pi*27.0938*9,099.82*1.20)$
$= 0.0001"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0001)|$
$= 0.0001"$

$t_{wc} = W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 374.5 / (2*\pi*27.0938*9,099.82*1.20)$
$= 0.0002"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0002) - (0)$
$= 0.0002"$

Hot Shut Down, New, Wind, Bottom Seam

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 1,183 / (\pi*27.0938^2*9,099.82*1.20)$
$= 0"$

$t_w = 0.6*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.60*374.5 / (2*\pi*27.0938*9,099.82*1.20)$
$= 0.0001"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0001)|$
$= 0.0001"$

t_{wc} = W / (2*π*R_m*S_c*K_s) (Weight)
= 374.5 / (2*π*27.0938*9,099.82*1.20)
= 0.0002"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0002) - (0)
= 0.0002"

Empty, Corroded, Wind, Bottom Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 1,183 / (π*27.0938^2*9,364.51*1.20)
= 0"

t_w = 0.6*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.60*374.5 / (2*π*27.0938*9,364.51*1.20)
= 0.0001"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_{wc} = W / (2*π*R_m*S_c*K_s) (Weight)
= 374.5 / (2*π*27.0938*9,364.51*1.20)
= 0.0002"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0002) - (0)
= 0.0002"

Empty, New, Wind, Bottom Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 1,183 / (π*27.0938^2*9,364.51*1.20)
= 0"

t_w = 0.6*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.60*374.5 / (2*π*27.0938*9,364.51*1.20)
= 0.0001"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_{wc} = W / (2*π*R_m*S_c*K_s) (Weight)
= 374.5 / (2*π*27.0938*9,364.51*1.20)
= 0.0002"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0002) - (0)
= 0.0002"

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

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 139 / (π*27.0938^2*9,099.82*1.00)
= 0"

t_w = W / (2*π*R_m*S_c*K_s) (Weight)
= 374.5 / (2*π*27.0938*9,099.82*1.00)
= 0.0002"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0002)|
= 0.0002"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0002) - (0)
= 0.0002"

Operating, Hot & Corroded, Seismic, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 416 / (π*27.0938^2*20,000*1.20*0.70)
= 0"

t_w = (0.6 - 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.59*374.5 / (2*π*27.0938*20,000*1.20*0.70)
= 0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.008 + 0 - (0.0001)
= 0.008"

t_{wc} = (1 + 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1.01*374.5 / (2*π*27.0938*20,000*1.20*0.70)
= 0.0001"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0001) - (0.008)|
= 0.0079"

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*20,000*1.20*0.70*(0.1875 - 0 + (0.0001)) / (27 - 0.40*(0.1875 - 0 + (0.0001)))
= 234.07 psi

Operating, Hot & New, Seismic, Bottom Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 416 / (π*27.0938^2*20,000*1.20*0.70)
= 0"

t_w = (0.6 - 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.59*374.5 / (2*π*27.0938*20,000*1.20*0.70)
= 0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.008 + 0 - (0.0001)
= 0.008"

t_{wc} = (1 + 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1.01*374.5 / (2*π*27.0938*20,000*1.20*0.70)
= 0.0001"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0001) - (0.008)|
= 0.0079"

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*20,000*1.20*0.70*(0.1875 - 0 + (0.0001)) / (27 - 0.40*(0.1875 - 0 + (0.0001)))
= 234.07 psi

Hot Shut Down, Corroded, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 416 / (π*27.0938^2*9,099.82*1.20)
= 0"

t_w = (0.6 - 0.14*S_{DS})*W / (2*π*R_m*S_c*K_s) (Weight)
= 0.59*374.5 / (2*π*27.0938*9,099.82*1.20)
= 0.0001"

t_t = |t_p + t_m - t_w| (total, net compressive)
= |0 + 0 - (0.0001)|
= 0.0001"

t_{wc} = (1 + 0.14*S_{DS})*W / (2*π*R_m*S_c*K_s) (Weight)
= 1.01*374.5 / (2*π*27.0938*9,099.82*1.20)
= 0.0002"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0 + (0.0002) - (0)
= 0.0002"

Hot Shut Down, New, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_c*K_s) (bending)
= 416 / (π*27.0938^2*9,099.82*1.20)
= 0"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $0.59*374.5 / (2*\pi*27.0938*9{,}099.82*1.20)$
= 0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0001)|$
= 0.0001"

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.01*374.5 / (2*\pi*27.0938*9{,}099.82*1.20)$
= 0.0002"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0002) - (0)$
= 0.0002"

Empty, Corroded, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $199 / (\pi*27.0938^2*9{,}364.51*1.20)$
= 0"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $0.59*374.5 / (2*\pi*27.0938*9{,}364.51*1.20)$
= 0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0001)|$
= 0.0001"

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.01*374.5 / (2*\pi*27.0938*9{,}364.51*1.20)$
= 0.0002"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= $0 + (0.0002) - (0)$
= 0.0002"

Empty, New, Seismic, Bottom Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_c*K_s)$ (bending)
= $199 / (\pi*27.0938^2*9{,}364.51*1.20)$
= 0"

t_w = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $0.59*374.5 / (2*\pi*27.0938*9{,}364.51*1.20)$
= 0.0001"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= $|0 + 0 - (0.0001)|$
= 0.0001"

t_{wc} = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
= $1.01*374.5 / (2*\pi*27.0938*9{,}364.51*1.20)$

= 0.0002"

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

= 0 + (0.0002) - (0)

= 0.0002"

ASME Section VIII Division 1 UG-80(a) Out-of-Roundness
($D_{max} - D_{min}$) shall not exceed 1% of D
When the cross section passes through an opening or within 1 I.D. of the opening, ($D_{max} - D_{min}$) shall not exceed 1% of D + 2% of the inside diameter of the opening

SHELL 1

ASME Section VIII Division 1, 2023 Edition				
Component		Cylinder		
Material		SA-240 316 (II-D p. 76, ln. 21)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		10	175	-20
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		3.23	79.2562	1.13
Test horizontal		1.95	54	1
Dimensions				
Inner Diameter		54"		
Length		48"		
Nominal Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		444.31		475.89
Corroded		444.31		475.89
Insulation				
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**
Insulation		2	9.36	92.1
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**
Insulation Supports		0	0	0
Radiography				
Longitudinal seam		None UW-11(c) Type 1		
Top Circumferential seam		None UW-11(c) Type 1		
Bottom Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0256"
Design thickness due to combined loadings + corrosion	0.0075"
Maximum allowable working pressure (MAWP)	93.59 psi
Maximum allowable pressure (MAP)	96.82 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
t_r = 13.23*27 / (20,000*0.7 - 0.6*13.23) =	0.0255"
Stress ratio = t_r*E^* / (t_n - c) = 0.0255*0.8 / (0.1875 - 0) =	0.1089
Stress ratio longitudinal = 794*1 / (20,000*1) =	0.0397
Impact test exempt per UHA-51(g) (coincident ratio = 0.1089)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 175 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 13.23*27 / (20,000*0.70 - 0.60*13.23) + 0
= 0.0256"

Maximum allowable working pressure, (at 175 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 20,000*0.70*0.1875 / (27 + 0.60*0.1875) - 3.23
= 93.59 psi

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 20,000*0.70*0.1875 / (27 + 0.60*0.1875)
= 96.82 psi

% Forming strain - UHA-44(a)(2)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*0.1875 / 27.0938)*(1 - 27.0938 / ∞)
= 0.346%

Thickness Required Due to Pressure + External Loads									
Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Location	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c						
Operating, Hot & Corroded	10	20,000	9.100	175	0	Top	Wind	0.0057	0.0053
							Seismic	0.0055	0.0054
						Bottom	Wind	0.0074	0.0067
							Seismic	0.0075	0.0067
Operating, Hot & New	10	20,000	9.100	175	0	Top	Wind	0.0057	0.0053
							Seismic	0.0055	0.0054
						Bottom	Wind	0.0074	0.0067
							Seismic	0.0075	0.0067
Hot Shut Down, Corroded	0	20,000	9.100	175	0	Top	Wind	0.0001	0.0008
							Seismic	0.0002	0.0005
						Bottom	Wind	0.0018	0.0011
							Seismic	0.0018	0.0011
Hot Shut Down, New	0	20,000	9.100	175	0	Top	Wind	0.0001	0.0008
							Seismic	0.0002	0.0005
						Bottom	Wind	0.0018	0.0011
							Seismic	0.0018	0.0011
Empty, Corroded	0	20,000	9.365	70	0	Top	Wind	0.0001	0.0008
							Seismic	0.0002	0.0004
						Bottom	Wind	0	0
							Seismic	0	0
Empty, New	0	20,000	9.365	70	0	Top	Wind	0.0001	0.0008
							Seismic	0.0002	0.0004
						Bottom	Wind	0	0
							Seismic	0	0
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	9.100	175	0	Top	Weight	0.0005	0.0005
						Bottom	Weight	0.0022	0.0022

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

A = $0.125 / (R_o / t)$
= 0.125 / (27.1875 / 0.1875)
= 0.000862

B = 9,100 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cHC} = min(B, S) = 9,100 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

S_{cHN} = S_{cHC}
= 9,100 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (27.1875 / 0.1875)
= 0.000862

B = 9,365 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cCN} = min(B, S) = 9,365 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

S_{cCC} = S_{cCN}
= 9,365 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (27.1875 / 0.1875)
= 0.000862

B = 9,365 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cVC} = min(B, S) = 9,365 psi

Operating, Hot & Corroded, Wind, Above Support Point

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 10*27 / (2*20{,}000*1.20*1.00 + 0.40*|10|)$
$= 0.0056"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 9{,}698 / (\pi*27.0938^2*20{,}000*1.20*1.00)$
$= 0.0002"$

$t_w = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*809.6 / (2*\pi*27.0938*20{,}000*1.20*1.00)$
$= 0.0001"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.0056 + 0.0002 - (0.0001)$
$= 0.0057"$

$t_{wc} = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 809.6 / (2*\pi*27.0938*20{,}000*1.20*1.00)$
$= 0.0002"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.0002 + (0.0002) - (0.0056)|$
$= 0.0053"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*1.00*(0.1875 - 0.0002 + (0.0001)) / (27 - 0.40*(0.1875 - 0.0002 + (0.0001)))$
= 334.16 psi

Operating, Hot & New, Wind, Above Support Point

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*1.00 + 0.40*|10|)
= 0.0056"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 9,698 / (π*27.0938^2*20,000*1.20*1.00)
= 0.0002"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*809.6 / (2*π*27.0938*20,000*1.20*1.00)
= 0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.0056 + 0.0002 - (0.0001)
= 0.0057"

t_{wc} = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 809.6 / (2*π*27.0938*20,000*1.20*1.00)
= 0.0002"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0.0002 + (0.0002) - (0.0056)|
= 0.0053"

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*20,000*1.20*1.00*(0.1875 - 0.0002 + (0.0001)) / (27 - 0.40*(0.1875 - 0.0002 + (0.0001)))
= 334.16 psi

Hot Shut Down, Corroded, Wind, Above Support Point

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 9,698 / (π*27.0938^2*20,000*1.20*1.00)
= 0.0002"

t_w = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*809.6 / (2*π*27.0938*20,000*1.20*1.00)
= 0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0 + 0.0002 - (0.0001)
= 0.0001"

t_{mc} = M / (π*R_m^2*S_c*K_s) (bending)
= 9,698 / (π*27.0938^2*9,099.82*1.20)
= 0.0004"

t_{wc} = W / (2*π*R_m*S_c*K_s) (Weight)
= 809.6 / (2*π*27.0938*9,099.82*1.20)
= 0.0004"

t_c = t_{mc} + t_{wc} - t_{pc} (total required, compressive)
= 0.0004 + (0.0004) - (0)

= 0.0008"

Hot Shut Down, New, Wind, Above Support Point

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $9,698 / (\pi * 27.0938^2 * 20,000 * 1.20 * 1.00)$
= 0.0002"

t_w = $0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $0.60 * 809.6 / (2 * \pi * 27.0938 * 20,000 * 1.20 * 1.00)$
= 0.0001"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0002 - (0.0001)
= 0.0001"

t_{mc} = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $9,698 / (\pi * 27.0938^2 * 9,099.82 * 1.20)$
= 0.0004"

t_{wc} = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $809.6 / (2 * \pi * 27.0938 * 9,099.82 * 1.20)$
= 0.0004"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0004 + (0.0004) - (0)
= 0.0008"

Empty, Corroded, Wind, Above Support Point

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $9,698 / (\pi * 27.0938^2 * 20,000 * 1.20 * 1.00)$
= 0.0002"

t_w = $0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $0.60 * 809.6 / (2 * \pi * 27.0938 * 20,000 * 1.20 * 1.00)$
= 0.0001"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0002 - (0.0001)
= 0.0001"

t_{mc} = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $9,698 / (\pi * 27.0938^2 * 9,364.51 * 1.20)$
= 0.0004"

t_{wc} = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $809.6 / (2 * \pi * 27.0938 * 9,364.51 * 1.20)$
= 0.0004"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0004 + (0.0004) - (0)
= 0.0008"

Empty, New, Wind, Above Support Point

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $9,698 / (\pi * 27.0938^2 * 20,000 * 1.20 * 1.00)$
= 0.0002"

t_w = $0.6 * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $0.60 * 809.6 / (2 * \pi * 27.0938 * 20,000 * 1.20 * 1.00)$
= 0.0001"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0.0002 - (0.0001)
= 0.0001"

t_{mc} = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $9,698 / (\pi * 27.0938^2 * 9,364.51 * 1.20)$
= 0.0004"

t_{wc} = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $809.6 / (2 * \pi * 27.0938 * 9,364.51 * 1.20)$
= 0.0004"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.0004 + (0.0004) - (0)
= 0.0008"

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

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_c * K_s)$ (bending)
= $139 / (\pi * 27.0938^2 * 9,099.82 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_c * K_s)$ (Weight)
= $809.6 / (2 * \pi * 27.0938 * 9,099.82 * 1.00)$
= 0.0005"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0 + 0 - (0.0005)|
= 0.0005"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0 + (0.0005) - (0)
= 0.0005"

Operating, Hot & Corroded, Wind, Below Support Point

t_p = $P * R / (2 * S_t * K_s * E_c + 0.40 * |P|)$ (Pressure)
= $10 * 27 / (2 * 20,000 * 1.20 * 1.00 + 0.40 * |10|)$
= 0.0056"

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $206 / (\pi * 27.0938^2 * 20,000 * 1.20 * 1.00)$
= 0"

t_w = $W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)

= -7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0018"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0056 + 0 - (-0.0018)
= 0.0074"

t_{wc} = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.60*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0011"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0011) - (0.0056)|
= 0.0067"

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*20,000*1.20*1.00*(0.1875 - 0 + (-0.0018)) / (27 - 0.40*(0.1875 - 0 + (-0.0018)))
= 331.03 psi

Operating, Hot & New, Wind, Below Support Point

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 10*27 / (2*20,000*1.20*1.00 + 0.40*|10|)
= 0.0056"

t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 206 / (π*27.0938²*20,000*1.20*1.00)
= 0"

t_w = $W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= -7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0018"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0056 + 0 - (-0.0018)
= 0.0074"

t_{wc} = $0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.60*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0011"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0011) - (0.0056)|
= 0.0067"

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*20,000*1.20*1.00*(0.1875 - 0 + (-0.0018)) / (27 - 0.40*(0.1875 - 0 + (-0.0018)))
= 331.03 psi

Hot Shut Down, Corroded, Wind, Below Support Point

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 206 / (π*27.0938^2*20,000*1.20*1.00)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0018"

t_t = t_p + t_m - t_w (total required, tensile)
= 0 + 0 - (-0.0018)
= 0.0018"

t_{wc} = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0011"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (-0.0011) - (0)|
= 0.0011"

Hot Shut Down, New, Wind, Below Support Point

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 206 / (π*27.0938^2*20,000*1.20*1.00)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0018"

t_t = t_p + t_m - t_w (total required, tensile)
= 0 + 0 - (-0.0018)
= 0.0018"

t_{wc} = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0011"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (-0.0011) - (0)|
= 0.0011"

Empty, Corroded, Wind, Below Support Point

t_p = 0" (Pressure)

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 206 / (π*27.0938^2*20,000*1.20*1.00)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -169.8 / (2*π*27.0938*20,000*1.20*1.00)
= 0"

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0 - (0)$
$= 0"$

$t_{wc} = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*-169.8 / (2*\pi*27.0938*20,000*1.20*1.00)$
$= 0"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (0) - (0)|$
$= 0"$

Empty, New, Wind, Below Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 206 / (\pi*27.0938^2*20,000*1.20*1.00)$
$= 0"$

$t_w = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= -169.8 / (2*\pi*27.0938*20,000*1.20*1.00)$
$= 0"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0 - (0)$
$= 0"$

$t_{wc} = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*-169.8 / (2*\pi*27.0938*20,000*1.20*1.00)$
$= 0"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (0) - (0)|$
$= 0"$

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

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 0 / (\pi*27.0938^2*20,000*1.00*1.00)$
$= 0"$

$t_w = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= -7,379.1 / (2*\pi*27.0938*20,000*1.00*1.00)$
$= -0.0022"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0 - (-0.0022)$
$= 0.0022"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (-0.0022) - (0)|$
$= 0.0022"$

Operating, Hot & Corroded, Seismic, Above Support Point

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*1.00 + 0.40*|10|)
= 0.0056"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 2,311 / (π*27.0938^2*20,000*1.20*1.00)
= 0"

t_w = (0.6 - 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.59*809.6 / (2*π*27.0938*20,000*1.20*1.00)
= 0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.0056 + 0 - (0.0001)
= 0.0055"

t_{wc} = (1 + 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1.01*809.6 / (2*π*27.0938*20,000*1.20*1.00)
= 0.0002"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0002) - (0.0056)|
= 0.0054"

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*20,000*1.20*1.00*(0.1875 - 0 + (0.0001)) / (27 - 0.40*(0.1875 - 0 + (0.0001)))
= 334.4 psi

Operating, Hot & New, Seismic, Above Support Point

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*1.00 + 0.40*|10|)
= 0.0056"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 2,311 / (π*27.0938^2*20,000*1.20*1.00)
= 0"

t_w = (0.6 - 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.59*809.6 / (2*π*27.0938*20,000*1.20*1.00)
= 0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.0056 + 0 - (0.0001)
= 0.0055"

t_{wc} = (1 + 0.14*S_{DS})*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 1.01*809.6 / (2*π*27.0938*20,000*1.20*1.00)
= 0.0002"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0.0002) - (0.0056)|
= 0.0054"

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*1.00*(0.1875 - 0 + (0.0001)) / (27 - 0.40*(0.1875 - 0 + (0.0001)))$
$= 334.4$ psi

Hot Shut Down, Corroded, Seismic, Above Support Point

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 2{,}311 / (\pi*27.0938^2*9{,}099.82*1.20)$
$= 0.0001"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.59*809.6 / (2*\pi*27.0938*9{,}099.82*1.20)$
$= 0.0003"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0001 - (0.0003)|$
$= 0.0002"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.01*809.6 / (2*\pi*27.0938*9{,}099.82*1.20)$
$= 0.0004"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0001 + (0.0004) - (0)$
$= 0.0005"$

Hot Shut Down, New, Seismic, Above Support Point

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 2{,}311 / (\pi*27.0938^2*9{,}099.82*1.20)$
$= 0.0001"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.59*809.6 / (2*\pi*27.0938*9{,}099.82*1.20)$
$= 0.0003"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0.0001 - (0.0003)|$
$= 0.0002"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.01*809.6 / (2*\pi*27.0938*9{,}099.82*1.20)$
$= 0.0004"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.0001 + (0.0004) - (0)$
$= 0.0005"$

Empty, Corroded, Seismic, Above Support Point

$t_p = 0"$ (Pressure)

$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)

$= 468 / (\pi*27.0938^2*9{,}364.51*1.20)$
$= 0"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.59*809.6 / (2*\pi*27.0938*9{,}364.51*1.20)$
$= 0.0002"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0002)|$
$= 0.0002"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.01*809.6 / (2*\pi*27.0938*9{,}364.51*1.20)$
$= 0.0004"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0004) - (0)$
$= 0.0004"$

Empty, New, Seismic, Above Support Point

$t_p = 0"$ (Pressure)
$t_m = M / (\pi*R_m^2*S_c*K_s)$ (bending)
$= 468 / (\pi*27.0938^2*9{,}364.51*1.20)$
$= 0"$

$t_w = (0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 0.59*809.6 / (2*\pi*27.0938*9{,}364.51*1.20)$
$= 0.0002"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0 + 0 - (0.0002)|$
$= 0.0002"$

$t_{wc} = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_c*K_s)$ (Weight)
$= 1.01*809.6 / (2*\pi*27.0938*9{,}364.51*1.20)$
$= 0.0004"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0 + (0.0004) - (0)$
$= 0.0004"$

Operating, Hot & Corroded, Seismic, Below Support Point

$t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
$= 10*27 / (2*20{,}000*1.20*1.00 + 0.40*|10|)$
$= 0.0056"$

$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 23 / (\pi*27.0938^2*20{,}000*1.20*1.00)$
$= 0"$

$t_w = (1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 1.01*-7{,}379.1 / (2*\pi*27.0938*20{,}000*1.20*1.00)$
$= -0.0018"$

$t_t = t_p + t_m - t_w$ (total required, tensile)

= 0.0056 + 0 - (-0.0018)
= 0.0075"

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.59*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0011"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0011) - (0.0056)|
= 0.0067"

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*20,000*1.20*1.00*(0.1875 - 0 + (-0.0018)) / (27 - 0.40*(0.1875 - 0 + (-0.0018)))
= 330.99 psi

Operating, Hot & New, Seismic, Below Support Point

t_p = $P*R / (2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 10*27 / (2*20,000*1.20*1.00 + 0.40*|10|)
= 0.0056"

t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 23 / (π*27.0938²*20,000*1.20*1.00)
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 1.01*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0018"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.0056 + 0 - (-0.0018)
= 0.0075"

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.59*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0011"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0011) - (0.0056)|
= 0.0067"

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*20,000*1.20*1.00*(0.1875 - 0 + (-0.0018)) / (27 - 0.40*(0.1875 - 0 + (-0.0018)))
= 330.99 psi

Hot Shut Down, Corroded, Seismic, Below Support Point

t_p = 0" (Pressure)

t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 23 / (π*27.0938²*20,000*1.20*1.00)
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 1.01*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0018"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0018)
= 0.0018"

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.59*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0011"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0011) - (0)|
= 0.0011"

Hot Shut Down, New, Seismic, Below Support Point

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 23 / (π*27.0938²*20,000*1.20*1.00)
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 1.01*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0018"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0018)
= 0.0018"

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.59*-7,379.1 / (2*π*27.0938*20,000*1.20*1.00)
= -0.0011"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0011) - (0)|
= 0.0011"

Empty, Corroded, Seismic, Below Support Point

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 5 / (π*27.0938²*20,000*1.20*1.00)
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 1.01*-169.8 / (2*π*27.0938*20,000*1.20*1.00)
= 0"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (0)
= 0"

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.59*-169.8 / (2*π*27.0938*20,000*1.20*1.00)

= 0"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= $|0 + (0) - (0)|$
= 0"

Empty, New, Seismic, Below Support Point

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $5 / (\pi * 27.0938^2 * 20{,}000 * 1.20 * 1.00)$
= 0"

t_w = $(1 + 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $1.01 * -169.8 / (2 * \pi * 27.0938 * 20{,}000 * 1.20 * 1.00)$
= 0"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (0)
= 0"

t_{wc} = $(0.6 - 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $0.59 * -169.8 / (2 * \pi * 27.0938 * 20{,}000 * 1.20 * 1.00)$
= 0"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= $|0 + (0) - (0)|$
= 0"

ASME Section VIII Division 1 UG-80(a) Out-of-Roundness
$(D_{max} - D_{min})$ shall not exceed 1% of D
When the cross section passes through an opening or within 1 I.D. of the opening, $(D_{max} - D_{min})$ shall not exceed 1% of D + 2% of the inside diameter of the opening

Straight Flange on BOTTOM DISH

ASME Section VIII Division 1, 2023 Edition				
Component		Cylinder		
Material		SA-240 316 (II-D p. 76, ln. 21)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		10	175	-20
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		3.31	81.2562	1.13
Test horizontal		1.95	54	1
Dimensions				
Inner Diameter		54"		
Length		2"		
Nominal Thickness		0.25"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		24.71		19.83
Corroded		24.71		19.83
Insulation				
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**
Insulation		2	9.36	0
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**
Insulation Supports		0	0	0
Radiography				
Longitudinal seam		None UW-11(c) Type 1		
Top Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0257"
Design thickness due to combined loadings + corrosion	0.0106"
Maximum allowable working pressure (MAWP)	125.6 psi
Maximum allowable pressure (MAP)	128.91 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
t_r = 13.31*27 / (20,000*0.7 - 0.6*13.31) =	0.0257"
Stress ratio = t_r*E* / (t_n - c) = 0.0257*0.8 / (0.25 - 0) =	0.0822
Stress ratio longitudinal = 594*0.8 / (20,000*0.7) =	0.034
Impact test exempt per UHA-51(g) (coincident ratio = 0.0822)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 175 °F) UG-27(c)(1)

t = P*R / (S*E - 0.60*P) + Corrosion
= 13.31*27 / (20,000*0.70 - 0.60*13.31) + 0
= 0.0257"

Maximum allowable working pressure, (at 175 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t) - P_s
= 20,000*0.70*0.25 / (27 + 0.60*0.25) - 3.31
= 125.6 psi

Maximum allowable pressure, (at 70 °F) UG-27(c)(1)

P = S*E*t / (R + 0.60*t)
= 20,000*0.70*0.25 / (27 + 0.60*0.25)
= 128.91 psi

% Forming strain - UHA-44(a)(2)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*0.25 / 27.125)*(1 - 27.125 / ∞)
= 0.4608%

Thickness Required Due to Pressure + External Loads								
Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	10	20,000	9,909	175	0	Wind	0.0106	0.0096
						Seismic	0.0106	0.0095
Operating, Hot & New	10	20,000	9,909	175	0	Wind	0.0106	0.0096
						Seismic	0.0106	0.0095
Hot Shut Down, Corroded	0	20,000	9,909	175	0	Wind	0.0026	0.0015
						Seismic	0.0026	0.0015
Hot Shut Down, New	0	20,000	9,909	175	0	Wind	0.0026	0.0015
						Seismic	0.0026	0.0015
Empty, Corroded	0	20,000	10,222	70	0	Wind	0.0001	0
						Seismic	0.0001	0
Empty, New	0	20,000	10,222	70	0	Wind	0.0001	0
						Seismic	0.0001	0
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	20,000	9,909	175	0	Weight	0.0031	0.0031

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

A = $0.125 / (R_o / t)$
= $0.125 / (27.25 / 0.25)$
= 0.001147

B = 9,909 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cHC} = min(B, S) = 9,909 psi

Allowable Compressive Stress, Hot and New- S_{cHN}

S_{cHN} = S_{cHC}
= 9,909 psi

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

A = $0.125 / (R_o / t)$
= $0.125 / (27.25 / 0.25)$
= 0.001147

B = 10,222 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cCN} = min(B, S) = 10,222 psi

Allowable Compressive Stress, Cold and Corroded- S_{cCC}

S_{cCC} = S_{cCN}
= 10,222 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (27.25 / 0.25)
= 0.001147

B = 10,222 psi

S = 20,000 / 1.00 = 20,000 psi

S_{cVC} = min(B, S) = 10,222 psi

Operating, Hot & Corroded, Wind, Top Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 169 / (π*27.125^2*20,000*1.20*0.70)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0026"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.008 + 0 - (-0.0026)
= 0.0106"

t_{wc} = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*-7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0015"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (-0.0015) - (0.008)|
= 0.0096"

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*20,000*1.20*0.70*(0.25 - 0 + (-0.0026)) / (27 - 0.40*(0.25 - 0 + (-0.0026)))
= 309.04 psi

Operating, Hot & New, Wind, Top Seam

t_p = P*R / (2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 10*27 / (2*20,000*1.20*0.70 + 0.40*|10|)
= 0.008"

t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 169 / (π*27.125^2*20,000*1.20*0.70)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0026"

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.008 + 0 - (-0.0026)$
$=$ 0.0106"

$t_{wc} = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*-7{,}369.8 / (2*\pi*27.125*20{,}000*1.20*0.70)$
$=$ -0.0015"

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (-0.0015) - (0.008)|$
$=$ 0.0096"

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t - t_m + t_w) / (R - 0.40*(t - t_m + t_w))$
$= 2*20{,}000*1.20*0.70*(0.25 - 0 + (-0.0026)) / (27 - 0.40*(0.25 - 0 + (-0.0026)))$
$=$ 309.04 psi

Hot Shut Down, Corroded, Wind, Top Seam

$t_p =$ 0" (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 169 / (\pi*27.125^2*20{,}000*1.20*0.70)$
$=$ 0"

$t_w = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= -7{,}369.8 / (2*\pi*27.125*20{,}000*1.20*0.70)$
$=$ -0.0026"

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0 - (-0.0026)$
$=$ 0.0026"

$t_{wc} = 0.6*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= 0.60*-7{,}369.8 / (2*\pi*27.125*20{,}000*1.20*0.70)$
$=$ -0.0015"

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0 + (-0.0015) - (0)|$
$=$ 0.0015"

Hot Shut Down, New, Wind, Top Seam

$t_p =$ 0" (Pressure)
$t_m = M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
$= 169 / (\pi*27.125^2*20{,}000*1.20*0.70)$
$=$ 0"

$t_w = W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
$= -7{,}369.8 / (2*\pi*27.125*20{,}000*1.20*0.70)$
$=$ -0.0026"

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0 + 0 - (-0.0026)$
$=$ 0.0026"

t_{wc} = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*-7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0015"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (-0.0015) - (0)|
= 0.0015"

Empty, Corroded, Wind, Top Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 169 / (π*27.125^2*20,000*1.20*0.70)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -160.5 / (2*π*27.125*20,000*1.20*0.70)
= -0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0 + 0 - (-0.0001)
= 0.0001"

t_{wc} = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*-160.5 / (2*π*27.125*20,000*1.20*0.70)
= 0"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0) - (0)|
= 0"

Empty, New, Wind, Top Seam

t_p = 0" (Pressure)
t_m = M / (π*R_m^2*S_t*K_s*E_c) (bending)
= 169 / (π*27.125^2*20,000*1.20*0.70)
= 0"

t_w = W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= -160.5 / (2*π*27.125*20,000*1.20*0.70)
= -0.0001"

t_t = t_p + t_m - t_w (total required, tensile)
= 0 + 0 - (-0.0001)
= 0.0001"

t_{wc} = 0.6*W / (2*π*R_m*S_t*K_s*E_c) (Weight)
= 0.60*-160.5 / (2*π*27.125*20,000*1.20*0.70)
= 0"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0 + (0) - (0)|
= 0"

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

t_p = 0" (Pressure)

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $0 / (\pi * 27.125^2 * 20{,}000 * 1.00 * 0.70)$
= 0"

t_w = $W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $-7{,}369.8 / (2 * \pi * 27.125 * 20{,}000 * 1.00 * 0.70)$
= -0.0031"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0031)
= 0.0031"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0031) - (0)|
= 0.0031"

Operating, Hot & Corroded, Seismic, Top Seam

t_p = $P * R / (2 * S_t * K_s * E_c + 0.40 * |P|)$ (Pressure)
= $10 * 27 / (2 * 20{,}000 * 1.20 * 0.70 + 0.40 * |10|)$
= 0.008"

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $18 / (\pi * 27.125^2 * 20{,}000 * 1.20 * 0.70)$
= 0"

t_w = $(1 + 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $1.01 * -7{,}369.8 / (2 * \pi * 27.125 * 20{,}000 * 1.20 * 0.70)$
= -0.0026"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.008 + 0 - (-0.0026)
= 0.0106"

t_{wc} = $(0.6 - 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= $0.59 * -7{,}369.8 / (2 * \pi * 27.125 * 20{,}000 * 1.20 * 0.70)$
= -0.0015"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0015) - (0.008)|
= 0.0095"

Maximum allowable working pressure, Longitudinal Stress

$P = 2 * S_t * K_s * E_c * (t - t_m + t_w) / (R - 0.40 * (t - t_m + t_w))$
= $2 * 20{,}000 * 1.20 * 0.70 * (0.25 - 0 + (-0.0026)) / (27 - 0.40 * (0.25 - 0 + (-0.0026)))$
= 309 psi

Operating, Hot & New, Seismic, Top Seam

t_p = $P * R / (2 * S_t * K_s * E_c + 0.40 * |P|)$ (Pressure)
= $10 * 27 / (2 * 20{,}000 * 1.20 * 0.70 + 0.40 * |10|)$
= 0.008"

t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $18 / (\pi * 27.125^2 * 20{,}000 * 1.20 * 0.70)$
= 0"

t_w = $(1 + 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= 1.01*-7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0026"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.008 + 0 - (-0.0026)
= 0.0106"

t_{wc} = $(0.6 - 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= 0.59*-7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0015"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0015) - (0.008)|
= 0.0095"

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*20,000*1.20*0.70*(0.25 - 0 + (-0.0026)) / (27 - 0.40*(0.25 - 0 + (-0.0026)))
= 309 psi

Hot Shut Down, Corroded, Seismic, Top Seam

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $18 / (\pi * 27.125^2 * 20{,}000 * 1.20 * 0.70)$
= 0"

t_w = $(1 + 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= 1.01*-7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0026"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0026)
= 0.0026"

t_{wc} = $(0.6 - 0.14 * S_{DS}) * W / (2 * \pi * R_m * S_t * K_s * E_c)$ (Weight)
= 0.59*-7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0015"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0015) - (0)|
= 0.0015"

Hot Shut Down, New, Seismic, Top Seam

t_p = 0" (Pressure)
t_m = $M / (\pi * R_m^2 * S_t * K_s * E_c)$ (bending)
= $18 / (\pi * 27.125^2 * 20{,}000 * 1.20 * 0.70)$
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 1.01*-7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0026"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0026)
= 0.0026"

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.59*-7,369.8 / (2*π*27.125*20,000*1.20*0.70)
= -0.0015"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (-0.0015) - (0)|
= 0.0015"

Empty, Corroded, Seismic, Top Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 5 / (π*27.125²*20,000*1.20*0.70)
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 1.01*-160.5 / (2*π*27.125*20,000*1.20*0.70)
= -0.0001"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0001)
= 0.0001"

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.59*-160.5 / (2*π*27.125*20,000*1.20*0.70)
= 0"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0 + (0) - (0)|
= 0"

Empty, New, Seismic, Top Seam

t_p = 0" (Pressure)
t_m = $M / (\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 5 / (π*27.125²*20,000*1.20*0.70)
= 0"

t_w = $(1 + 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 1.01*-160.5 / (2*π*27.125*20,000*1.20*0.70)
= -0.0001"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0 + 0 - (-0.0001)
= 0.0001"

t_{wc} = $(0.6 - 0.14*S_{DS})*W / (2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 0.59*-160.5 / (2*π*27.125*20,000*1.20*0.70)

= 0"

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

= $|0 + (0) - (0)|$

= 0"

ASME Section VIII Division 1 UG-80(a) Out-of-Roundness
(D_{max} - D_{min}) shall not exceed 1% of D
When the cross section passes through an opening or within 1 I.D. of the opening, (D_{max} - D_{min}) shall not exceed 1% of D + 2% of the inside diameter of the opening

BOTTOM DISH

ASME Section VIII Division 1, 2023 Edition				
Component		F&D Head		
Material		SA-240 316 (II-D p. 76, ln. 21)		
Attached To		SHELL 1		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		10	175	-20
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		3.69	90.4185	1.13
Test horizontal		1.95	54	1
Dimensions				
Inner Diameter		54"		
Crown Radius L		54"		
Knuckle Radius r		3.27"		
Minimum Thickness		0.125"		
Corrosion	**Inner**	0"		
	Outer	0"		
Length L_{sf}		2"		
Nominal Thickness t_{sf}		0.25"		
Weight and Capacity				
		Weight (lb)[1]		**Capacity (US gal)[1]**
New		123.8		75.21
Corroded		123.8		75.21
Insulation				
		Thickness (in)	**Density (lb/ft^3)**	**Weight (lb)**
Insulation		2	9.36	36.73
		Spacing(in)	**Individual Weight (lb)**	**Total Weight (lb)**
Insulation Supports		0	0	0
Radiography				
Category A joints		None UW-11(c) Type 1		

Head to shell seam	None UW-11(c) Type 1

[1] includes straight flange

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0467"
Maximum allowable working pressure (MAWP)	33.01 psi
Maximum allowable pressure (MAP)	36.69 psi
Rated MDMT	-320°F

Note: Endnote 66 used to determine allowable stress.

UHA-51 Material Toughness Requirements	
t_r = 13.69*54*1 / (2*20,000*0.7 - 0.2*13.69) =	0.0264"
Stress ratio = t_r*E^* / (t_n - c) = 0.0264*0.8 / (0.125 - 0) =	0.169
Impact test exempt per UHA-51(g) (coincident ratio = 0.169)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Factor M		
M = 1/4*[3 + (L / r)$^{1/2}$]		
Corroded	M = 1/4*[3 + (54 / 3.27)$^{1/2}$]	1.7659
New	M = 1/4*[3 + (54 / 3.27)$^{1/2}$]	1.7659

Design thickness for internal pressure, (Corroded at 175 °F) Appendix 1-4(d)

t = P*L*M / (2*S*E - 0.2*P) + Corrosion
= 13.69*54*1.7659 / (2*20,000*0.7 - 0.2*13.69) + 0
= 0.0466"

Maximum allowable working pressure, (Corroded at 175 °F) Appendix 1-4(d)

P = 2*S*E*t / (L*M + 0.2*t) - P_s
= 2*20,000*0.7*0.125 / (54*1.7659 + 0.2*0.125) - 3.69
= 33.01 psi

Maximum allowable pressure, (New at 70 °F) Appendix 1-4(d)

P = 2*S*E*t / (L*M + 0.2*t) - P_s
= 2*20,000*0.7*0.125 / (54*1.7659 + 0.2*0.125) - 0
= 36.69 psi

% Forming strain - UHA-44(a)(2)

$$EFE = (75*t / R_f)*(1 - R_f / R_o)$$
$$= (75*0.25 / 3.395)*(1 - 3.395 / \infty)$$
$$= 5.5228\%$$

ASME Section VIII Division 1 UG-81(a) Out-of-Roundness
Inside surface shall not deviate outside the shape by more than 1.25% of D
Inside surface shall not deviate inside the shape by more than 0.625% of D