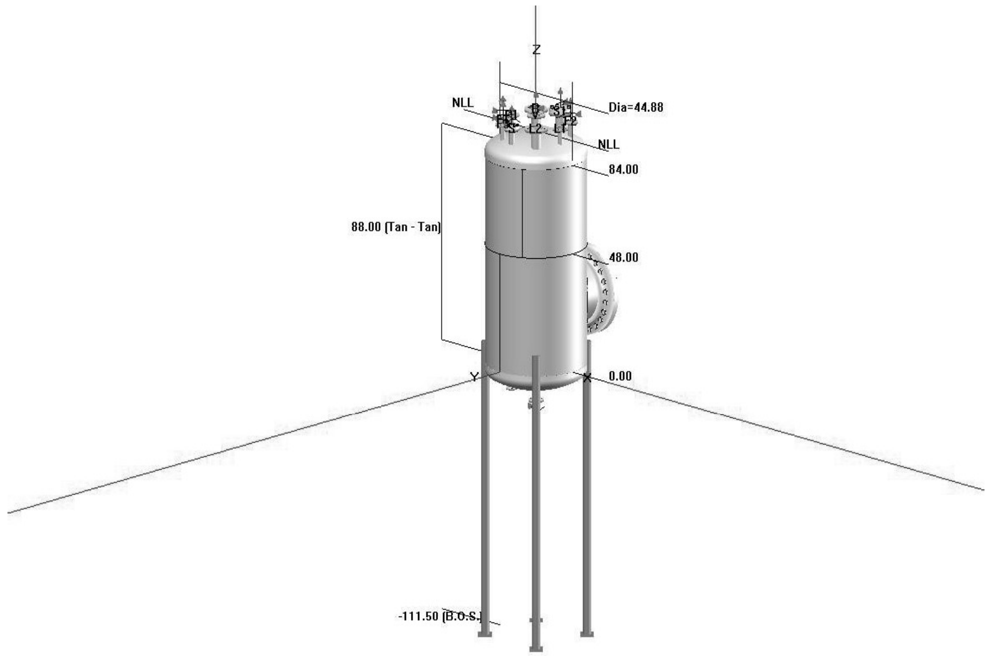
Savannah Tank and Equipment Corp.

1517 Telfair Rd

Savannah, GA-31415



COMPRESS Pressure Vessel Design Calculations

Item:	Q9044
Vessel No:	V-22008
Customer:	JACOBS
Designer:	RS
Date:	Thursday, October 03, 2024

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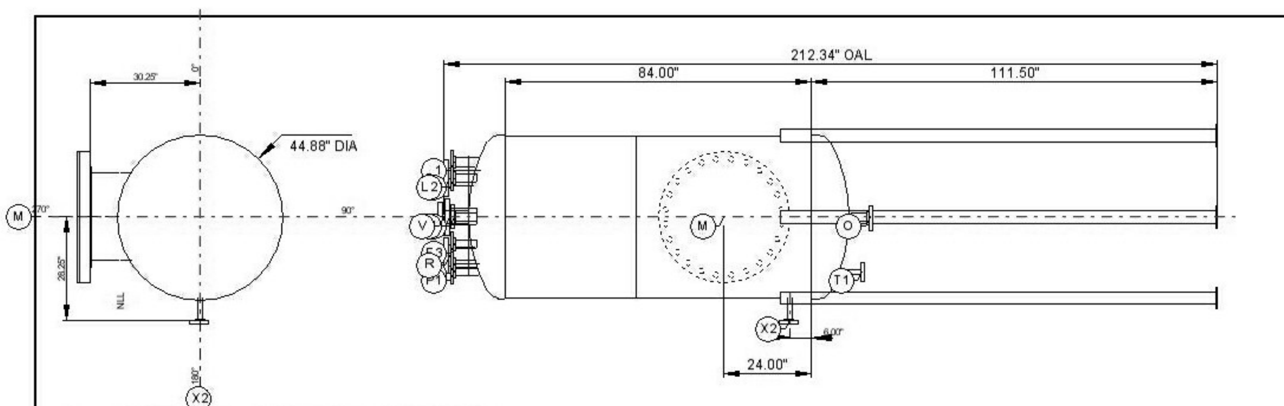


MARK	NOZZLE	SIZE & SCH	FLANGE
F1	PROCESS INLET	NPS 2 Sch 40S (St	NPS 2 SO Class 3
F3	PROCESS INLET	NPS 2 Sch 40S (St	NPS 2 SO Class 3
F2	PROCESS INLET	NPS 2 Sch 40S (St	NPS 2 SO Class 3
S1	SPARE	NPS 4 Sch 40S (St	NPS 4 SO Class 3
R	RELIEF VALVE	NPS 4 Sch 40S (St	NPS 4 SO Class 3
P1	PRESSURE TRAN	NPS 2 Sch 40S (St	NPS 2 SO Class 3
S	SPARE	NPS 2 Sch 40S (St	NPS 2 SO Class 3
L2	LEVEL TRANSMIT	NPS 4 Sch 40S (St	NPS 4 SO Class 3
L1	LEVEL SWITCH	NPS 2 Sch 40S (St	NPS 2 SO Class 3

MARK	NOZZLE	SIZE & SCH	FLANGE
T1	THERMOWELL	NPS 1 Sch 40S (St	NPS 1 SO Class 3
O	OUTLET	NPS 2 Sch 40S (St	NPS 2 SO Class 3
X2	pH SENSOR	NPS 1 Sch 40S (St	NPS 1 SO Class 3
M	MANWAY	24 OD x 0.5	NPS 24 SO Class
V	VENT	NPS 3 Sch 40S (St	NPS 3 SO Class 3

NOZZLE SCHEDULE

REV	DATE	DESCRIPTION
0	10/02/20	FOR APPROV

REVISIONS

DESIGN DATA

Design Pressure	150 psi
Vacuum Pressure	0 psi
Test Pressure (Shop)	197.96 psi
Design Temperature	350 °F
MDMT	-20 °F
Corrosion Allowance	0 "
Radiography	None
PWHT	None

Estimated Weights

Dry: 3,445 lb Wet: 8,930 lb

Materials

Cylinder(s):	SA-240 316
Head(s):	SA-240 316
Transition(s):	
Support:	SS304

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

DWN BY:
CHK BY:
DATE:

General Arrangement

DWG NO. 145685-1 Rev 0

V-22008

Deficiencies Summary

No deficiencies found.

Nozzle Schedule

Specifications										
Nozzle mark	Identifier	Size	Service	Materials		Impact Tested	Normalized	Fine Grain	Flange	Blind
F1	PROCESS INLET	NPS 2 Sch 40S (Std)	NOZ	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 300 SO A182 F316	No
F2	PROCESS INLET	NPS 2 Sch 40S (Std)	NOZ	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 300 SO A182 F316	No
F3	PROCESS INLET	NPS 2 Sch 40S (Std)	NOZ	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 300 SO A182 F316	No
L1	LEVEL SWITCH	NPS 2 Sch 40S (Std)	LEVEL	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 300 SO A182 F316	No
L2	LEVEL TRANSMITTER	NPS 4 Sch 40S (Std)	LEVEL	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 4 Class 300 SO A182 F316	No
M	MANWAY	24 OD x 0.5		Nozzle	SA-240 316	No	No	No	NPS 24 Class 300 SO A182 F316	NPS 24 Class 300 A182 F316
				Pad	SA-240 304	No	No	No		
O	OUTLET	NPS 2 Sch 40S (Std)	NOZ	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 300 SO A182 F316	No
P1	PRESSURE TRANSMITTER	NPS 2 Sch 40S (Std)	PG	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 300 SO A182 F316	No
R	RELIEF VALVE	NPS 4 Sch 40S (Std)	PRV	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 4 Class 300 SO A182 F316	No
S	SPARE	NPS 2 Sch 40S (Std)	NOZ	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 2 Class 300 SO A182 F316	NPS 2 Class 300 A182 F316
S1	SPARE	NPS 4 Sch 40S (Std)	NOZ	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 4 Class 300 SO A182 F316	NPS 4 Class 300 A182 F316
T1	THERMOWELL	NPS 1 Sch 40S (Std)		Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 1 Class 300 SO A182 F316	No
V	VENT	NPS 3 Sch 40S (Std)	LEVEL	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 3 Class 300 SO A182 F316	No
X2	pH SENSOR	NPS 1 Sch 40S (Std)	NOZ	Nozzle	SA-312 TP316 Wld pipe	No	No	No	NPS 1 Class 300 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)		
F1	2.375	0.154	0.154	Yes	Yes	0.4375*	0.2516		N/A	N/A	0	100.0
F2	2.375	0.154	0.154	Yes	Yes	0.4375*	N/A		N/A	N/A	0	Exempt
F3	2.375	0.154	0.154	Yes	Yes	0.4375*	0.2516		N/A	N/A	0	100.0
L1	2.375	0.154	0.154	Yes	Yes	0.4375*	N/A		N/A	N/A	0	Exempt
L2	4.5	0.237	0.237	Yes	Yes	0.4375*	0.2556		N/A	N/A	0	100.0
M	24	0.5	0.1766	Yes	Yes	0.25	0.1766		4.5	0.25	0	100.0
O	2.375	0.154	0.154	Yes	Yes	0.4375*	N/A		N/A	N/A	0	Exempt
P1	2.375	0.154	0.154	Yes	Yes	0.4375*	N/A		N/A	N/A	0	Exempt
R	4.5	0.237	0.237	Yes	Yes	0.4375*	0.2556		N/A	N/A	0	100.0
S	2.375	0.154	0.154	Yes	Yes	0.4375*	N/A		N/A	N/A	0	Exempt
S1	4.5	0.237	0.237	Yes	Yes	0.4375*	0.2556		N/A	N/A	0	100.0
T1	1.315	0.133	0.133	Yes	Yes	0.4375*	N/A		N/A	N/A	0	Exempt
V	3.5	0.216	0.216	Yes	Yes	0.4375*	0.2637		N/A	N/A	0	100.0
X2	1.315	0.133	0.133	Yes	Yes	0.25	N/A		N/A	N/A	0	Exempt

*Head minimum thickness after forming

Definitions	
t_n	Nozzle thickness
Req t_n	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**
F&D Head #1	150	350	197.18	200.47	-320	Note 1	No
Straight Flange on F&D Head #1	150	350	375.09	381.17	-320	Note 2	No
Cylinder #1	150	350	153.98	158.01	-320	Note 3	No
Cylinder #2	150	350	152.25	158.01	-320	Note 3	No
Straight Flange on F&D Head #2	150	350	371.98	381.17	-320	Note 5	No
F&D Head #2	150	350	193.72	200.47	-320	Note 4	No
Legs #1	150	350	150	N/A	N/A	N/A	N/A
PROCESS INLET (F1)	150	350	224.97	228.5	-55	Note 6	No
PROCESS INLET (F2)	150	350	295.87	396.94	-55	Note 6	No
PROCESS INLET (F3)	150	350	224.97	228.5	-55	Note 6	No
LEVEL SWITCH (L1)	150	350	390.88	396.94	-55	Note 6	No
LEVEL TRANSMITTER (L2)	150	350	228.5	232.08	-55	Note 6	No
MANWAY (M)	150	350	152.44	159.76	-55	Nozzle: Note 6	No
						Pad: Note 3	No
OUTLET (O)	150	350	302.38	396.94	-55	Note 6	No
PRESSURE TRANSMITTER (P1)	150	350	390.88	396.94	-55	Note 6	No
RELIEF VALVE (R)	150	350	228.5	232.08	-55	Note 6	No
SPARE (S)	150	350	295.87	396.94	-55	Note 6	No
SPARE (S1)	150	350	228.5	232.08	-55	Note 6	No
THERMOWELL (T1)	150	350	387.11	396.94	-55	Note 6	No
VENT (V)	150	350	235.82	239.42	-55	Note 6	No
pH SENSOR (X2)	150	350	219.16	225.73	-55	Note 6	No

Chamber Summary	
Design MDMT	-20 °F
Rated MDMT	-20 °F @ 150 psi
MAWP hot & corroded	150 psi @ 350 °F
MAP cold & new	158.01 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.	Straight Flange governs MDMT	
2.	Impact test exempt per UHA-51(g) (coincident ratio = 0.3326)	
3.	Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F	
4.	Straight Flange governs MDMT	
5.	Impact test exempt per UHA-51(g) (coincident ratio = 0.3395)	
6.	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	

Revision History

Revisions			
No.	Date	Operator	Notes
0	10/ 2/2024	rutang	New vessel created ASME Section VIII Division 1 [COMPRESS 2024 Build 8400]

Settings Summary

COMPRESS 2025 Build 8510	
ASME Section VIII Division 1, 2023 Edition	
Units	U.S. Customary
Datum Line Location	0.00" 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	3"
Juncture calculations for α > 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	No
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	
F&D Head #1	N/A	Seamless No RT	N/A	N/A	B	None UW-11(c) / Type 1	None
Cylinder #1	A	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	None
Cylinder #2	A	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	None
F&D Head #2	N/A	Seamless No RT	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**		
LEVEL SWITCH (L1)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
LEVEL TRANSMITTER (L2)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
SPARE (S)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
PRESSURE TRANSMITTER (P1)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
RELIEF VALVE (R)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
SPARE (S1)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
PROCESS INLET (F2)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
PROCESS INLET (F3)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
PROCESS INLET (F1)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
VENT (V)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
MANWAY (M)	A	None UW-11(c) / Type 1	D	N/A / Type 7	C	N/A / Type 4	None
pH SENSOR (X2)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
OUTLET (O)	N/A	Welded pipe	D	N/A / Type 7	C	N/A / Type 4	N/A
THERMOWELL (T1)	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 LEVEL SWITCH (L1)	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 LEVEL TRANSMITTER (L2)	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 SPARE (S)	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 PRESSURE TRANSMITTER (P1)	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 RELIEF VALVE (R)	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 SPARE (S1)	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 PROCESS INLET (F2)	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 PROCESS INLET (F3)	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 PROCESS INLET (F1)	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 VENT (V)	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 MANWAY (M)	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 pH SENSOR (X2)	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 OUTLET (O)	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 THERMOWELL (T1)	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**
F&D Head #1	SA-240 316	44 ID	8.1966	0.4375*	0.3329	0	0.85	Internal
Straight Flange on F&D Head #1	SA-240 316	44 ID	2	0.5	0.1987	0	0.85	Internal
Cylinder #1	SA-240 316	44 ID	36	0.25	0.2436	0	0.70	Internal
Cylinder #2	SA-240 316	44 ID	48	0.25	0.2464	0	0.70	Internal
Straight Flange on F&D Head #2	SA-240 316	44 ID	2	0.5	0.2028	0	0.85	Internal
F&D Head #2	SA-240 316	44 ID	8.1966	0.4375*	0.3406	0	0.85	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
F&D Head #1	SA-240 316	No	No	No	No
Cylinder #1	SA-240 316	No	No	No	No
Cylinder #2	SA-240 316	No	No	No	No
F&D Head #2	SA-240 316	No	No	No	No
PROCESS INLET (F1)	SA-312 TP316 Wld pipe	No	No	No	No
PROCESS INLET (F2)	SA-312 TP316 Wld pipe	No	No	No	No
PROCESS INLET (F3)	SA-312 TP316 Wld pipe	No	No	No	No
LEVEL SWITCH (L1)	SA-312 TP316 Wld pipe	No	No	No	No
LEVEL TRANSMITTER (L2)	SA-312 TP316 Wld pipe	No	No	No	No
MANWAY (M)	SA-240 316	No	No	No	No
MANWAY (M) Pad	SA-240 304	No	No	No	No
OUTLET (O)	SA-312 TP316 Wld pipe	No	No	No	No
PRESSURE TRANSMITTER (P1)	SA-312 TP316 Wld pipe	No	No	No	No
RELIEF VALVE (R)	SA-312 TP316 Wld pipe	No	No	No	No
SPARE (S)	SA-312 TP316 Wld pipe	No	No	No	No
SPARE (S1)	SA-312 TP316 Wld pipe	No	No	No	No
THERMOWELL (T1)	SA-312 TP316 Wld pipe	No	No	No	No
VENT (V)	SA-312 TP316 Wld pipe	No	No	No	No
pH SENSOR (X2)	SA-312 TP316 Wld pipe	No	No	No	No
ASME B16.5/16.47 flange attached to LEVEL SWITCH (L1)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to LEVEL TRANSMITTER (L2)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to SPARE (S)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to PRESSURE TRANSMITTER (P1)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to RELIEF VALVE (R)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to SPARE (S1)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to PROCESS INLET (F2)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to PROCESS INLET (F3)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to PROCESS INLET (F1)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to VENT (V)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to MANWAY (M)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to pH SENSOR (X2)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to OUTLET (O)	A182 F316	No	No	No	No
ASME B16.5/16.47 flange attached to THERMOWELL (T1)	A182 F316	No	No	No	No
ASME B16.5/16.47 Blind on ASME B16.5/16.47 flange attached to SPARE (S)	A182 F316	No	No	No	No (N/A)
ASME B16.5/16.47 Blind on ASME B16.5/16.47 flange attached to SPARE (S1)	A182 F316	No	No	No	No (N/A)
ASME B16.5/16.47 Blind on ASME B16.5/16.47 flange attached to MANWAY (M)	A182 F316	No	No	No	No (N/A)

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 ft^2
							New	Corroded	New	Corroded	
F&D Head #1	269	269	0	0	0	0	386.9	386.9	391.2	391.2	15
Cylinder #1	362.8	362.8	0	0	0	0	1,975.9	1,975.9	1,975.9	1,975.9	35
Cylinder #2	450.9	450.9	0	0	0	0	2,747.2	2,747.2	2,747.2	2,747.2	43
F&D Head #2	279	279	0	0	0	0	375.8	375.8	375.8	375.8	16
Legs #1	323.3	323.3	0	0	0	0	0	0	0	0	38
TOTAL:	**1,685**	**1,685**	**0**	**0**	**0**	**0**	**5,485.8**	**5,485.8**	**5,490.1**	**5,490.1**	**147**

*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 ft^2
	New	Corroded	New	Corroded							
F&D Head #1	0	0	203.5	203.5	0	0	0	0	0	0	9
Cylinder #1	0	0	0	0	0	0	0	0	0	0	0
Cylinder #2	0	0	1,543.2	1,543.2	0	0	0	0	0	0	17
F&D Head #2	0	0	12.9	12.9	0	0	0	0	0	0	1
Legs #1	0	0	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**1,759.5**	**1,759.5**	**0**	**0**	**0**	**0**	**0**	**0**	**26**

Vessel Totals		
	New	Corroded
Operating Weight (lb)	8,930	8,930
Empty Weight (lb)	3,445	3,445
Test Weight (lb)	8,935	8,935
Surface Area (ft^2)	174	-
Capacity** (US gal)	643	643

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

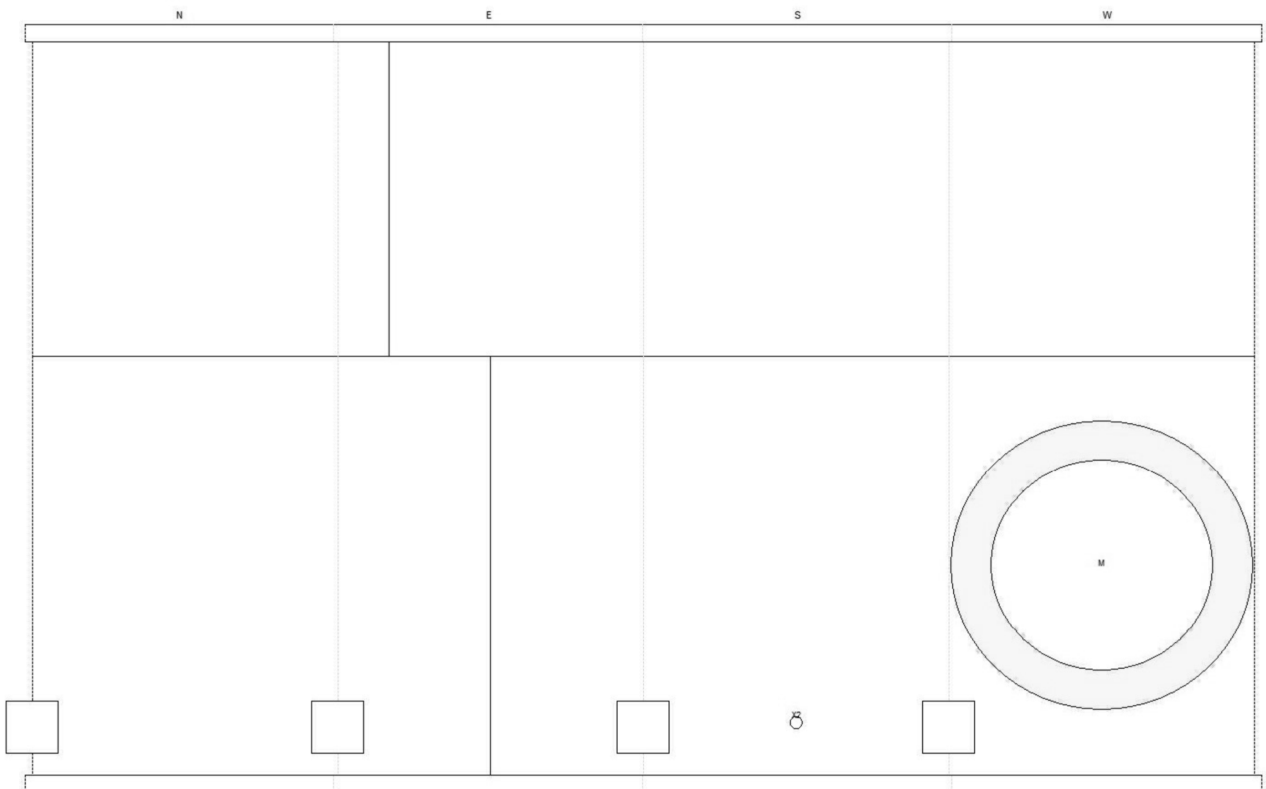
Vessel Lift Condition	
Vessel Lift Weight, New (lb)	3,445
Center of Gravity from Datum (in)	29.0093

Long Seam Summary

Shell Long Seam Angles	
Component	**Seam 1**
Cylinder #1	60°
Cylinder #2	90°

Shell Plate Lengths		
Component	**Starting Angle**	**Plate 1**
Cylinder #1	60°	139.0155"
Cylinder #2	90°	139.0155"

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

Hydrostatic Test

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

Gauge pressure at 70°F $= 1.3 \cdot MAWP \cdot LSR$

$= 1.3 \cdot 150 \cdot 1.0152$

$= 197.96 \;\; \text{psi}$

Horizontal shop hydrostatic test				
Identifier	**Local test pressure (psi)**	**Test liquid static head (psi)**	**UG-99(b) stress ratio**	**UG-99(b) pressure factor**
F&D Head #1 (1)	199.552	1.588	1.0152	1.30
Straight Flange on F&D Head #1	199.552	1.588	1.0152	1.30
Cylinder #1	199.552	1.588	1.0152	1.30
Cylinder #2	199.552	1.588	1.0152	1.30
Straight Flange on F&D Head #2	199.552	1.588	1.0152	1.30
F&D Head #2	199.552	1.588	1.0152	1.30
LEVEL SWITCH (L1)	198.254	0.29	1.018	1.30
LEVEL TRANSMITTER (L2)	198.448	0.484	1.018	1.30
MANWAY (M)	199.173	1.209	1.0152	1.30
OUTLET (O)	198.795	0.831	1.018	1.30
PRESSURE TRANSMITTER (P1)	199.337	1.373	1.018	1.30
PROCESS INLET (F1)	199.264	1.3	1.018	1.30
PROCESS INLET (F2)	198.413	0.449	1.018	1.30
PROCESS INLET (F3)	199.066	1.102	1.018	1.30
RELIEF VALVE (R)	199.214	1.25	1.018	1.30
SPARE (S)	198.795	0.831	1.018	1.30
SPARE (S1)	198.831	0.867	1.018	1.30
THERMOWELL (T1)	199.319	1.355	1.018	1.30
VENT (V)	198.814	0.85	1.018	1.30
pH SENSOR (X2)	199.778	1.814	1.018	1.30
(1) F&D Head #1 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)**
F&D Head #1	-320	-290
Straight Flange on F&D Head #1	-320	-290
Cylinder #1	-320	-290
Cylinder #2	-320	-290
Straight Flange on F&D Head #2	-320	-290
F&D Head #2	-320	-290
LEVEL SWITCH (L1)	-320	-290
LEVEL TRANSMITTER (L2)	-320	-290
MANWAY (M)	-320	-290
OUTLET (O)	-320	-290
PRESSURE TRANSMITTER (P1)	-320	-290
PROCESS INLET (F1)	-320	-290
PROCESS INLET (F2)	-320	-290
PROCESS INLET (F3)	-320	-290
RELIEF VALVE (R)	-320	-290
SPARE (S)	-320	-290
SPARE (S1)	-320	-290
THERMOWELL (T1)	-320	-290
VENT (V)	-320	-290
pH SENSOR (X2)	-320	-290
Chamber Rated MDMT	-20	**10**
Limit chamber rated MDMT to Design MDMT option is active.		

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	3,925	8,930
Weight Only (D)	Operating, New	0	3,925	8,930
Weight Only (D)	Empty, Corroded	0	3,925	3,445
Weight Only (D)	Empty, New	0	3,925	3,445
Weight Only (D)	Shop Hydrotest, New	0	3,925	8,935
Wind Only (0.6 * W)	Operating, Corroded	364	4,640	0
Wind Only (0.6 * W)	Operating, New	364	4,640	0
Wind Only (0.6 * W)	Empty, Corroded	298	3,790	0
Wind Only (0.6 * W)	Empty, New	298	3,790	0
Seismic Only (0.7 * E)	Operating, Corroded	63	813	0
Seismic Only (0.7 * E)	Operating, New	63	813	0
Seismic Only (0.7 * E)	Empty, Corroded	24	299	0
Seismic Only (0.7 * E)	Empty, New	24	299	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	6"
Base Plate Width	6"
Base Plate Thickness	0.5"
Number of Anchor Bolts Per Base Plate	1
Bolt Circle Diameter	46.5"
Bolt Size and Type	1/2" coarse bolt
Bolt Hole Clearance	0.25"
Center of Gravity (Distance from Support Base)	140.5093"

Bill of Materials

Heads / Covers						
Item #	Type	Material	Thk [in]	Dia. [in]	Wt. [lb] (ea.)	Qty
H1	F&D Head	SA-240 316	0.4375 (min.)	44 ID	279.7	2
H2	ASME B16.5/B16.47 Blind NPS 2 Class 300	A182 F316	0.88	6.5 OD	10	1
H3	ASME B16.5/B16.47 Blind NPS 4 Class 300	A182 F316	1.25	10 OD	31	1
H4	ASME B16.5/B16.47 Blind NPS 24 Class 300	A182 F316	2.75	36 OD	914	1

Shells							
Item #	Type	Material	Thk [in]	Dia. [in]	Length [in]	Wt. [lb] (ea.)	Qty
S1	Cylinder	SA-240 316	0.25	44 ID	36	362.8	1
S2	Cylinder	SA-240 316	0.25	44 ID	48	483.8	1

Legs						
Item #	Type	Material	Thk [in]	Length [in]	Wt. [lb]	Qty
L1	3 inch sch 40 pipe	SS304	0.216	120	80.8	4

Nozzles							
Item #	Type	Material	NPS	Thk [in]	Dia. [in]	Length [in]	Wt. [lb]
Noz1	Nozzle	SA-312 TP316 Wld pipe	NPS 2 Sch 40S (Std)	0.154	2.375 OD	48.2	15
Noz2	Nozzle	SA-312 TP316 Wld pipe	NPS 4 Sch 40S (Std)	0.237	4.5 OD	26	23.9
Noz3	Nozzle	SA-312 TP316 Wld pipe	NPS 3 Sch 40S (Std)	0.216	3.5 OD	6.9	4.5
Noz4	Nozzle	SA-240 316	-	0.5	24 OD	11.3	150.3
Noz5	Nozzle	SA-312 TP316 Wld pipe	NPS 1 Sch 40S (Std)	0.133	1.315 OD	13	1.9

Flanges						
Item #	Type	Material	NPS	Dia. [in]	Wt. [lb] (ea.)	Qty
AF1	ASME B16.5 Slip On - Class 300	A182 F316	2	6.5 x 2.44	7	7
AF2	ASME B16.5 Slip On - Class 300	A182 F316	4	10 x 4.57	22	3
AF3	ASME B16.5 Slip On - Class 300	A182 F316	3	8.25 x 3.57	13	1
AF4	ASME B16.5 Slip On - Class 300	A182 F316	24	36 x 24.25	475	1
AF5	ASME B16.5 Slip On - Class 300	A182 F316	1	4.88 x 1.36	3	2

Fasteners				
Item #	Description	Material	Length [in]	Qty
FB1	5/8" coarse bolt	SA-193 B7 Bolt <= 2 1/2	3	56
FB2	3/4" coarse bolt	SA-193 B7 Bolt <= 2 1/2	3.8	24
FB3	3/4" coarse bolt	SA-193 B7 Bolt <= 2 1/2	3.5	8
FB4	1-1/2" series 8 bolt	SA-193 B7 Bolt <= 2 1/2	7.8	24
FB5	5/8" coarse bolt	SA-193 B7 Bolt <= 2 1/2	2.5	8
SB1	1/2" coarse bolt	Support Leg bolt material	-	4
All listed flange bolts require associated nuts and washers in accordance with Division 1, UCS-11.				

Plates				
Item #	Material	Thk [in]	Wt. [lb]	Qty [ft^2]
Plate1	SA-240 304	0.25	248	5.94
Plate1 - Note: Applies to nozzle pad				
Plate2	SS304	0.5	20.4	1
Plate2 - Note: Applies to support leg base plates				

Wind Code

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		0.5000
Risk Category (Table 1.5-1)		II
Basic Wind Speed, V		120.00 mph
Exposure Category		C
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		17.1414 ft
Effective Width, b	Operating, Corroded	3.5843 ft
	Empty, Corroded	3.5843 ft
Fundamental Frequency, n_1	Operating, Corroded	0.8889 Hz
	Empty, Corroded	1.4708 Hz
Damping coefficient, β	Operating, Corroded	0.0250
	Empty, Corroded	0.0200

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)
F&D Head #1	195.5	3.74	26.7	*	0	31	57	0.5217
Cylinder #1	159.5	3.71	26.7	0.4102	0	163	351	0.5217
Cylinder #2 (top)	111.5	3.71	26.7	0.4102	0	331	5,197	0.5214
Legs #1	0	0	26.7	0.0005826	0	364	8,565	0.5212
Cylinder #2 (bottom)	111.5	3.71	26.7	0.4102	0	33	18	0.5212
F&D Head #2	111.5	3.74	26.7	*	0	30	16	0.5212
*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)
F&D Head #1	195.5	3.74	28.3	*	0	25	54	0.4278
Cylinder #1	159.5	3.71	28.3	0.4102	0	131	288	0.4277
Cylinder #2 (top)	111.5	3.71	28.3	0.4102	0	271	4,955	0.4275
Legs #1	0	0	26.7	0.0005826	0	298	7,715	0.4273
Cylinder #2 (bottom)	111.5	3.71	28.3	0.4102	0	27	16	0.4273
F&D Head #2	111.5	3.74	28.3	*	0	25	14	0.4273
*Moment of Inertia I varies over the length of the component								

Wind Pressure (WP) Calculations

Gust Factor (G) Calculations

$$Kz = 2.41 \cdot (Z/Zg)^{2/\alpha}$$
$$= 2.41 \cdot (Z/2{,}460.00)^{0.2041}$$

$$qz = 0.00256 \cdot Kz \cdot Kzt \cdot Ke \cdot V^2$$
$$= 0.00256 \cdot Kz \cdot 1.0000 \cdot 1.0000 \cdot 120.0000^{\ 2}$$
$$= 36.8640 \cdot Kz$$

$$WP = 0.6 \cdot \max\left[qz \cdot Kd \cdot G \cdot Cf, 16 \ \ \mathrm{lb}/ft^2)\right]$$
$$= 0.6 \cdot \max\left[qz \cdot 0.9500 \cdot G \cdot 0.5000, 16 \ \ \mathrm{lb}/ft^2)\right]$$

Design Wind Pressures							
Height Z (')	Kz	qz (psf)	WP (psf)				
			Operating	Empty	Hydrotest New	Hydrotest Corroded	Vacuum
15.0	0.8512	31.38	11.55	9.60	N.A.	N.A.	N.A.
20.0	0.9026	33.27	12.25	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 flexible structure as n_1 = 0.8889 Hz < 1 Hz.

$$z^- = \max[0.60 \cdot h, z_{\min}]$$
$$= \max[0.60 \cdot 17.1414, 15.0000]$$
$$=15.0000$$

$$I_{z^-} = c \cdot \left(\frac{33}{z^-}\right)^{\frac{1}{6}}$$
$$= 0.2000 \cdot \left(\frac{33}{15.0000}\right)^{\frac{1}{6}}$$
$$=0.2281$$

$$L_{z^-} = l \cdot \left(\frac{z^-}{33}\right)^{ep}$$

$$= 500.0000 \cdot \left(\frac{15.0000}{33}\right)^{0.2000}$$

$$=427.0566$$

$$Q^2 = \frac{1}{1 + 0.63 \cdot \left(\frac{b+h}{L_{z^-}}\right)^{0.63}}$$

$$= \frac{1}{1 + 0.63 \cdot \left(\frac{3.5843+17.1414}{427.0566}\right)^{0.63}}$$

$$=0.9144$$

$$V_{z^-} = b^- \cdot \left(\frac{z^-}{33}\right)^{a^-} \cdot Vref \cdot \left(\frac{88}{60}\right)$$

$$= 0.6600 \cdot \left(\frac{15.0000}{33}\right)^{0.1562} \cdot 120.00 \cdot \left(\frac{88}{60}\right)$$

$$=102.6959$$

$$N_1 = n_1 \cdot \frac{L_{z^-}}{V_{z^-}}$$

$$= 0.8889 \cdot \frac{427.0566}{102.6959}$$

$$=3.6964$$

$$R_n = 7.465 \cdot \frac{N_1}{(1 + 10.302 \cdot N_1)^{\frac{5}{3}}}$$

$$= 7.465 \cdot \frac{3.6964}{(1 + 10.302 \cdot 3.6964)^{\frac{5}{3}}}$$

$$=0.0614$$

$$n_h = 4.60 \cdot n_1 \cdot \frac{h}{Vz^-}$$

$$= 4.60 \cdot 0.8889 \cdot \frac{17.1414}{102.6959}$$

$$=0.6825$$

$$R_h = \frac{1}{n_h} - \frac{1 - e^{-2 \cdot n_h}}{2 \cdot n_h^2}$$

$$= \frac{1}{0.6825} - \frac{1 - e^{-2 \cdot 0.6825}}{2 \cdot 0.6825^{\ 2}}$$

$$=0.6659$$

$$n_b = 4.60 \cdot n_1 \cdot \frac{b}{Vz^-}$$

$$= 4.60 \cdot 0.8889 \cdot \frac{3.5843}{102.6959}$$

$$=0.1427$$

$$R_b = \frac{1}{n_b} - \frac{1 - e^{-2 \cdot n_b}}{2 \cdot n_b^2}$$

$$= \frac{1}{0.1427} - \frac{1 - e^{-2 \cdot 0.1427}}{2 \cdot 0.1427^{\ 2}}$$

$$= 0.9113$$

$$n_d = 15.40 \cdot n_1 \cdot \frac{b}{V z^-}$$

$$= 15.40 \cdot 0.8889 \cdot \frac{3.5843}{102.6959}$$

$$= 0.4778$$

$$R_d = \frac{1}{n_d} - \frac{1 - e^{-2 \cdot n_d}}{2 \cdot n_d^2}$$

$$= \frac{1}{0.4778} - \frac{1 - e^{-2 \cdot 0.4778}}{2 \cdot 0.4778^{\ 2}}$$

$$= 0.7451$$

$$R^2 = \left(\frac{1}{\beta}\right) \cdot R_n \cdot R_h \cdot R_b \cdot (0.53 + 0.47 \cdot R_L)$$

$$= \left(\frac{1}{0.0250}\right) \cdot 0.0614 \cdot 0.6659 \cdot 0.9113 \cdot (0.53 + 0.47 \cdot 0.7451)$$

$$= 1.3113$$

$$g_R = \sqrt{2 \cdot \ln(3600 \cdot n_1)} + \frac{0.577}{\sqrt{2 \cdot \ln(3600 \cdot n_1)}}$$

$$= \sqrt{2 \cdot \ln(3600 \cdot 0.8889)} + \frac{0.577}{\sqrt{2 \cdot \ln(3600 \cdot 0.8889)}}$$

$$= 4.1613$$

$$G = 0.925 \cdot \left(1 + 1.7 \cdot I_z^- \cdot \frac{\sqrt{g_Q^2 \cdot Q^2 + g_R^2 \cdot R^2}}{1 + 1.7 \cdot g_v \cdot I_z^-}\right)$$

$$= 0.925 \cdot \left(1 + 1.7 \cdot 0.2281 \cdot \frac{\sqrt{3.40^{\ 2} \cdot 0.9144 + 4.1613^{\ 2} \cdot 1.3113}}{1 + 1.7 \cdot 3.40 \cdot 0.2281}\right)$$

$$= 1.2914$$

Gust Factor Calculations: Empty, Corroded

Vessel is considered a rigid structure as n_1 = 1.4708 Hz ≥ 1 Hz.

$$z^{-} = \max[0.60 \cdot h, z_{\min}]$$

$$= \max[0.60 \cdot 17.1414, 15.0000]$$

$$=15.0000$$

$$I_{z^{-}} = c \cdot \left(\frac{33}{z^{-}}\right)^{\frac{1}{6}}$$

$$= 0.2000 \cdot \left(\frac{33}{15.0000}\right)^{\frac{1}{6}}$$

$$=0.2281$$

$$L_{z^{-}} = l \cdot \left(\frac{z^{-}}{33}\right)^{ep}$$

$$= 500.0000 \cdot \left(\frac{15.0000}{33}\right)^{0.2000}$$

$$=427.0566$$

$$Q = \sqrt{\frac{1}{1 + 0.63 \cdot \left(\frac{b+h}{L_{z^{-}}}\right)^{0.63}}}$$

$$= \sqrt{\frac{1}{1 + 0.63 \cdot \left(\frac{3.5843+17.1414}{427.0566}\right)^{0.63}}}$$

$$=0.9562$$

$$G = 0.925 \cdot \frac{1 + 1.7 \cdot g_Q \cdot I_{z^{-}} \cdot Q}{1 + 1.7 \cdot g_v \cdot I_{z^{-}}}$$

$$= 0.925 \cdot \frac{1 + 1.7 \cdot 3.40 \cdot 0.2281 \cdot 0.9562}{1 + 1.7 \cdot 3.40 \cdot 0.2281}$$

$$=0.9020$$

Table Lookup Values	
α = 9.8000, z_g = 2,460.00 ft	[Table 26.11-1, page 278]
c = 0.2000, l = 500.0000, ep = 0.2000	[Table 26.11-1, page 278]
$\bar{a}$ = 0.1562, $\bar{b}$ = 0.6600	[Table 26.11-1, page 278]
z_{min} = 15.0000 ft	[Table 26.11-1, page 278]
g_Q = 3.40	[26.11.5 page 278]
g_v = 3.40	[26.11.5 page 278]

Seismic Code

Building Code: ASCE 7-22 ground supported		
Risk Category (Table 1.5-1)		II
Site Class		D
Importance Factor, I_e		1.0000
Spectral Response Acceleration at short periods (% g), S_S		5.70%
Adjusted Spectral Response Acceleration at short periods (% g), S_{MS}		9.10%
Spectral Response Acceleration at 1 second period (% g), S_1		3.90%
Adjusted Spectral Response Acceleration at 1 second period (% g), S_{M1}		9.30%
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		17.1414 ft
Weight	Operating, Corroded	8,930 lb
	Empty, Corroded	3,445 lb
Period of Vibration Calculation		
Fundamental Period, T	Operating, Corroded	1.125 sec (f = 0.9 Hz)
	Empty, Corroded	0.680 sec (f = 1.5 Hz)

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

$$T = 2 \cdot \pi \cdot \sqrt{\frac{\sum (W_i \cdot y_i^2)}{g \cdot \sum (W_i \cdot y_i)}}$$, 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)
F&D Head #1	195.5	26.7	*	9	50
Cylinder #1	159.5	26.7	0.4102	29	108
Cylinder #2 (top)	111.5	26.7	0.4102	58	4,161
Legs #1	0	26.7	0.0006	63	4,738
Cylinder #2 (bottom)	111.5	26.7	0.4102	4	7
F&D Head #2	111.5	26.7	*	3	6
*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)
F&D Head #1	195.5	28.3	*	5	48
Cylinder #1	159.5	28.3	0.4102	8	68
Cylinder #2 (top)	111.5	28.3	0.4102	21	4,004
Legs #1	0	26.7	0.0006	24	4,224
Cylinder #2 (bottom)	111.5	28.3	0.4102	2	6
F&D Head #2	111.5	28.3	*	2	6
*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}

$$S_{DS} = \frac{2}{3} \cdot \frac{S_{MS}}{100} = \frac{2}{3} \cdot \frac{9.10}{100} = 0.0607$$

Design earthquake spectral response acceleration at 1 s period, S_{D1}

$$S_{D1} = \frac{2}{3} \cdot \frac{S_{M1}}{100} = \frac{2}{3} \cdot \frac{9.30}{100} = 0.0620$$

11.6 Seismic Design Category

The Risk Category is II.
From Table 11.6-1, the Seismic Design Category based on S_{DS} = 0.0607 is A.
From Table 11.6-2, the Seismic Design Category based on S_{D1} = 0.0620 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} = 0.0620) < 0.067, and (S_{DS} = 0.0607) < 0.167.
In accordance with ASCE Section 11.7, seismic load is determined with Equation 1.4-1.

$V = 0.01 \cdot W \cdot 0.7$ (Only 70% of seismic load considered as per Section 2.4.1)

$= 0.01 \cdot 8{,}930.2959 \cdot 0.7$

= 62.51 lb

Base Shear Calculations: Empty, Corroded

Per ASCE Section 11.6, this vessel is assigned to Seismic Design Category A, as ($\underline{S_{D1}}$ = 0.0620) < 0.067, and ($\underline{S_{DS}}$ = 0.0607) < 0.167.
In accordance with ASCE Section 11.7, seismic load is determined with Equation 1.4-1.

$V \quad = 0.01 \cdot W \cdot 0.7$ (Only 70% of seismic load considered as per Section 2.4.1)

$\quad = 0.01 \cdot 3{,}444.5278 \cdot 0.7$

= 24.11 lb

F&D Head #1

ASME Section VIII Division 1, 2023 Edition				
Component		F&D Head		
Material		SA-240 316 (II-D p. 76, ln. 21)		
Attached To		Cylinder #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		150	350	-20
Static Liquid Head				
Condition		P_s (psi)	H_s (in)	SG
Operating		0.29	8	1
Test horizontal		1.59	44	1
Dimensions				
Inner Diameter		44"		
Crown Radius L		44"		
Knuckle Radius r		3.15"		
Minimum Thickness		0.4375"		
Corrosion	Inner	0"		
	Outer	0"		
Length L_{sf}		2"		
Nominal Thickness t_{sf}		0.5"		
Weight and Capacity				
		Weight (lb)[1]		Capacity (US gal)[1]
New		269.04		44.96
Corroded		269.04		44.96
Radiography				
Category A joints		Seamless No RT		
Head to shell seam		None UW-11(c) Type 1		

[1] includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.3329"
Maximum allowable working pressure (MAWP)	197.18 psi
Maximum allowable pressure (MAP)	200.47 psi
Straight Flange governs MDMT	-320°F

Note: Endnote 66 used to determine allowable stress.

Factor M		
$M = \frac{1}{4} \cdot \left[3 + \left(\frac{L}{r}\right)^{\frac{1}{2}}\right]$		
Corroded	$M = \frac{1}{4} \cdot \left[3 + \left(\frac{44}{3.15}\right)^{\frac{1}{2}}\right]$	1.6844
New	$M = \frac{1}{4} \cdot \left[3 + \left(\frac{44}{3.15}\right)^{\frac{1}{2}}\right]$	1.6844

Design thickness for internal pressure, (Corroded at 350 °F) Appendix 1-4(d)

$$t = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{150.29 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.29} + 0 = \underline{0.3329}''$$

Maximum allowable working pressure, (Corroded at 350 °F) Appendix 1-4(d)

$$P = \frac{2 \cdot S \cdot E \cdot t}{L \cdot M + 0.2 \cdot t} - P_s = \frac{2 \cdot 19{,}700 \cdot 0.85 \cdot 0.4375}{44 \cdot 1.6844 + 0.2 \cdot 0.4375} - 0.29 = \underline{197.18} \text{ psi}$$

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

$$P = \frac{2 \cdot S \cdot E \cdot t}{L \cdot M + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 0.85 \cdot 0.4375}{44 \cdot 1.6844 + 0.2 \cdot 0.4375} - 0 = \underline{200.47} \text{ psi}$$

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

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 0.5}{3.4}\right) \cdot \left(1 - \frac{3.4}{\infty}\right) = 11.0294\,\%$$

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 F&D Head #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		150	350	-20
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		0.36	10	1
Test horizontal		1.59	44	1
Dimensions				
Inner Diameter		44"		
Length		2"		
Nominal Thickness		0.5"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		40.54		13.16
Corroded		40.54		13.16
Radiography				
Longitudinal seam		Seamless No RT		
Bottom Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.1987"
Design thickness due to combined loadings + corrosion	0.0994"
Maximum allowable working pressure (MAWP)	375.09 psi
Maximum allowable pressure (MAP)	381.17 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \dfrac{150.36 \cdot 22}{20{,}000 \cdot 0.85 - 0.6 \cdot 150.36} =$	0.1956"
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0.1956 \cdot 0.85}{0.5 - 0} =$	0.3326
$\text{Stress ratio longitudinal} = \dfrac{2{,}722 \cdot 0.8}{20{,}000 \cdot 0.7} =$	0.1556
Impact test exempt per UHA-51(g) (coincident ratio = 0.3326)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 350 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{150.36 \cdot 22}{19{,}700 \cdot 0.85 - 0.60 \cdot 150.36} + 0 = \underline{0.1987}"$$

Maximum allowable working pressure, (at 350 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}700 \cdot 0.85 \cdot 0.5}{22 + 0.60 \cdot 0.5} - 0.36 = \underline{375.09} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 0.85 \cdot 0.5}{22 + 0.60 \cdot 0.5} = \underline{381.17} \text{ psi}$$

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

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.5}{22.25}\right) \cdot \left(1 - \frac{22.25}{\infty}\right) = 1.1236\,\%$$

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	150	19,700	11,263	350	0	Wind	0.0994	0.0993
						Seismic	0.0994	0.0993
Operating, Hot & New	150	19,700	11,263	350	0	Wind	0.0994	0.0993
						Seismic	0.0994	0.0993
Hot Shut Down, Corroded	0	19,700	11,263	350	0	Wind	0.0001	0.0003
						Seismic	0.0001	0.0003
Hot Shut Down, New	0	19,700	11,263	350	0	Wind	0.0001	0.0003
						Seismic	0.0001	0.0003
Empty, Corroded	0	20,000	12,430	70	0	Wind	0.0001	0.0003
						Seismic	0.0001	0.0003
Empty, New	0	20,000	12,430	70	0	Wind	0.0001	0.0003
						Seismic	0.0001	0.0003
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	19,700	11,263	350	0	Weight	0.0003	0.0003

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.5/0.5} = 0.002778$$

$$B = 11{,}263 \quad \text{psi}$$

$$S = \frac{19{,}700}{1.00} = 19{,}700 \quad \text{psi}$$

$S_{cHC} = \min(B, S) =$ 11,263 psi

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

$S_c HN = S_c HC =$ 11,263 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.5/0.5} = 0.002778$$

$$B = 12{,}430 \quad \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \quad \text{psi}$$

$S_{cCN} = \min(B, S) =$ 12,430 psi

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

$S_c\mathbb{C} = S_c CN =$ 12,430 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.5/0.5} = 0.002778$$

$$B = 11{,}263 \quad \text{psi}$$

$$S = \frac{19{,}700}{1.00} = 19{,}700 \quad \text{psi}$$

$S_{cVC} = \min(B, S) =$ 11,263 psi

Operating, Hot & Corroded, Wind, Bottom Seam

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

= $\frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\frac{678}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

t_w = $\frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{0.60*472.5}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0001"

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

= $0.0995 + 0 - (0.0001)$

= <u>0.0994"</u>

$t_{w\ c}$ = $\frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{472.5}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0002"

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

= $|0 + (0.0002) - (0.0995)|$

= <u>0.0993"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.5 - 0 + (0.0001))}{22 - 0.40 \cdot (0.5 - 0 + (0.0001))}$

= <u>759.23</u> psi

<u>Operating, Hot & New, Wind, Bottom Seam</u>

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

= $\frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\frac{678}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

t_w = $\frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{0.60*472.5}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0001"

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

= $0.0995{+}0 - (0.0001)$

= <u>0.0994"</u>

$t_{w\,c}$ = $\frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{472.5}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0002"

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

= $|0 + (0.0002) - (0.0995)|$

= <u>0.0993"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.5 - 0 + (0.0001))}{22 - 0.40 \cdot (0.5 - 0 + (0.0001))}$

= 759.23 psi

<u>Hot Shut Down, Corroded, Wind, Bottom Seam</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{678}{\pi \cdot 22.25\ ^2 \cdot 11{,}263.33 \cdot 1.20}$

= 0"

$t_w = 0.6 \cdot \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{0.60*472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.20}$

= 0.0002"

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

$= |0 + 0 - (0.0002)|$

= <u>0.0001"</u>

$t_{w\,c} = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.20}$

= 0.0003"

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

$= 0 + (0.0003) - (0)$

= <u>0.0003"</u>

<u>Hot Shut Down, New, Wind, Bottom Seam</u>

t_p = 0" (Pressure)

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

$$= \frac{678}{\pi \cdot 22.25\ ^2 \cdot 11{,}263.33 \cdot 1.20}$$

= 0"

$$t_w = 0.6 \cdot \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{0.60{*}472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.20}$$

= 0.0002"

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

$$= |0 + 0 - (0.0002)|$$

= <u>0.0001"</u>

$$t_{w\,c} = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.20}$$

= 0.0003"

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

$$= 0 + (0.0003) - (0)$$

= <u>0.0003"</u>

<u>Empty, Corroded, Wind, Bottom Seam</u>

t_p = 0" (Pressure)

$t_m = \frac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \frac{649}{\pi \cdot 22.25^{\ 2} \cdot 12{,}429.58 \cdot 1.20}$

= 0"

$t_w = 0.6 \cdot \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \frac{0.60*472.5}{2 \cdot \pi \cdot 22.25 \cdot 12{,}429.58 \cdot 1.20}$

= 0.0001"

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

$= |0 + 0 - (0.0001)|$

= <u>0.0001"</u>

$t_{w\,c} = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \frac{472.5}{2 \cdot \pi \cdot 22.25 \cdot 12{,}429.58 \cdot 1.20}$

= 0.0002"

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

$= 0 + (0.0002) - (0)$

= <u>0.0003"</u>

Empty, New, Wind, Bottom Seam

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{649}{\pi \cdot 22.25\ ^2 \cdot 12{,}429.58 \cdot 1.20}$

= 0"

$t_w = 0.6 \cdot \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{0.60*472.5}{2 \cdot \pi \cdot 22.25 \cdot 12{,}429.58 \cdot 1.20}$

= 0.0001"

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

$= |0 + 0 - (0.0001)|$

= <u>0.0001"</u>

$t_{w\,c} = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{472.5}{2 \cdot \pi \cdot 22.25 \cdot 12{,}429.58 \cdot 1.20}$

= 0.0002"

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

$= 0 + (0.0002) - (0)$

= <u>0.0003"</u>

<u>Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Bottom Seam</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{544}{\pi \cdot 22.25\ ^2 \cdot 11{,}263.33 \cdot 1.00}$

= 0"

$t_w = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.00}$

= 0.0003"

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

$= |0 + 0 - (0.0003)|$

= <u>0.0003"</u>

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

$= 0 + (0.0003) - (0)$

= <u>0.0003"</u>

Operating, Hot & Corroded, Seismic, Bottom Seam

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

$= \frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

$t_m = \frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \frac{595}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

$t_w = \frac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{0.59 * 472.5}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0001"

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

$= 0.0995 + 0 - (0.0001)$

= 0.0994"

$t_{w\,c} = \frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{1.01 * 472.5}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0002"

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

$= |0 + (0.0002) - (0.0995)|$

= 0.0993"

Maximum allowable working pressure, Longitudinal Stress

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

$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.5 - 0 + (0.0001))}{22 - 0.40 \cdot (0.5 - 0 + (0.0001))}$

= 759.23 psi

Operating, Hot & New, Seismic, Bottom Seam

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

$$= \frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$$

= 0.0995"

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

$$= \frac{595}{\pi \cdot 22.25^{\,2} \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$$

= 0"

$$t_w = \frac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{0.59*472.5}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$$

= 0.0001"

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

$$= 0.0995 + 0 - (0.0001)$$

= <u>0.0994"</u>

$$t_{w\,c} = \frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{1.01*472.5}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$$

= 0.0002"

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

$$= |0 + (0.0002) - (0.0995)|$$

= <u>0.0993"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.5 - 0 + (0.0001))}{22 - 0.40 \cdot (0.5 - 0 + (0.0001))}$$

= 759.23 psi

<u>Hot Shut Down, Corroded, Seismic, Bottom Seam</u>

t_p = 0" (Pressure)

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

= $\frac{595}{\pi \cdot 22.25\ ^2 \cdot 11{,}263.33 \cdot 1.20}$

= 0"

t_w = $(0.6 - 0.14 \cdot S_{DS}) \cdot \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\frac{0.59*472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.20}$

= 0.0001"

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

= $|0 + 0 - (0.0001)|$

= <u>0.0001"</u>

$t_{w\,c}$ = $\frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\frac{1.01*472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.20}$

= 0.0003"

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

= $0 + (0.0003) - (0)$

= <u>0.0003"</u>

<u>Hot Shut Down, New, Seismic, Bottom Seam</u>

t_p = 0" (Pressure)

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

$$= \frac{595}{\pi \cdot 22.25\ ^2 \cdot 11{,}263.33 \cdot 1.20}$$

= 0"

$$t_w = (0.6 - 0.14 \cdot S_{DS}) \cdot \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{0.59 * 472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.20}$$

= 0.0001"

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

$$= |0 + 0 - (0.0001)|$$

= <u>0.0001"</u>

$$t_{w\,c} = \frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{1.01 * 472.5}{2 \cdot \pi \cdot 22.25 \cdot 11{,}263.33 \cdot 1.20}$$

= 0.0003"

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

$$= 0 + (0.0003) - (0)$$

= <u>0.0003"</u>

<u>Empty, Corroded, Seismic, Bottom Seam</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{579}{\pi \cdot 22.25\ ^2 \cdot 12{,}429.58 \cdot 1.20}$

= 0"

$t_w = (0.6 - 0.14 \cdot S_{DS}) \cdot \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{0.59*472.5}{2 \cdot \pi \cdot 22.25 \cdot 12{,}429.58 \cdot 1.20}$

= 0.0001"

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

$= |0 + 0 - (0.0001)|$

= <u>0.0001"</u>

$t_{w\,c} = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{1.01*472.5}{2 \cdot \pi \cdot 22.25 \cdot 12{,}429.58 \cdot 1.20}$

= 0.0002"

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

$= 0 + (0.0002) - (0)$

= <u>0.0003"</u>

<u>Empty, New, Seismic, Bottom Seam</u>

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

= $\dfrac{579}{\pi \cdot 22.25\ ^2 \cdot 12{,}429.58 \cdot 1.20}$

= 0"

t_w = $(0.6 - 0.14 \cdot S_{DS}) \cdot \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\dfrac{0.59*472.5}{2 \cdot \pi \cdot 22.25 \cdot 12{,}429.58 \cdot 1.20}$

= 0.0001"

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

= $|0 + 0 - (0.0001)|$

= <u>0.0001"</u>

$t_{w\,c}$ = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\dfrac{1.01*472.5}{2 \cdot \pi \cdot 22.25 \cdot 12{,}429.58 \cdot 1.20}$

= 0.0002"

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

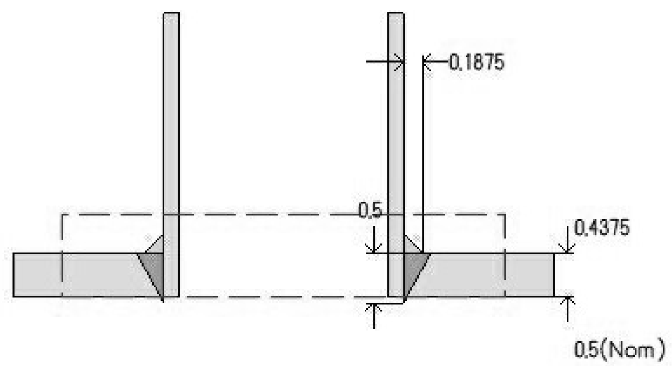
= $0 + (0.0002) - (0)$

= <u>0.0003"</u>

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

LEVEL SWITCH (L1)

ASME Section VIII Division 1, 2023 Edition	



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

Location and Orientation	
Located on	F&D Head #1
Orientation	0°
End of nozzle to datum line	97.8643"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No
Nozzle	
Service	Level Indicator (LEVEL)
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	2.1983"
Projection available outside vessel, Lpr	5.7148"
Projection available outside vessel to flange face, Lf	5.8688"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.5"
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 300 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	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.154, 0.435\right] =$	0.2156"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.2156 + \frac{0}{0.7} =$	0.2156"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text(")} + \frac{C_i}{0.7}\right] = \min\left[0.154, 0.25 + \frac{0}{0.7}\right] =$	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	
$t_r = \frac{150.1 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 150.1} =$	0.0092"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0092 \cdot 1}{0.1348 - 0} =$	0.0681
Impact test exempt per UHA-51(g) (coincident ratio = 0.0681)	
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 = 150.1 psi @ 350 °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 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ \ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \ \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ \ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ \ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \ \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.1028 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$

$$= 0.0079 \ \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$$

$$= 0.1678 \ \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \ \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.1078 in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1028 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$

$$= 0.0093 \text{ in}$$

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

$$= \max\left[0.0093,\ 0\right]$$

$$= 0.0093 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$

$$= 0.2826 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2826,\ 0.0625\right]$$

$$= 0.2826 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.2826\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0093,\ 0.1348\right]$$

$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.154 = 0.1348$ 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 = 390.99 psi @ 350 °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 390.99 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{390.9852 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 390.9852}$$

$$= 0.0208 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{390.9852 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 390.9852}$$

$$= 0.4375 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{390.99 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 390.99} = 0.8673 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1078}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{390.9852 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 390.9852} + 0$$

$$= 0.0245 \text{ in}$$

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

$$= \max\left[0.0245,\ 0\right]$$

$$= 0.0245 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{390.99 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 390.99} + 0$$

$$= 0.7369 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.7369\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0245,\ 0.1348\right]$$

$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 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 = 396.94 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 396.94 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ \ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \ \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ \ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ \ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \ \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{396.9414 \cdot 1.0335}{20{,}000 \cdot 1 - 0.6 \cdot 396.9414}$$

$$= 0.0208 \ \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{396.9414 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.9414}$$

$$= 0.4375 \ \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 396.94} = 0.8673 \ \ \text{in}$$

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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{396.9414 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 396.9414} + 0$$

$$= 0.0245 \text{ in}$$

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

$$= \max\left[0.0245,\ 0\right]$$

$$= 0.0245 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.94} + 0$$

$$= 0.7369 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.7369\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0245,\ 0.1348\right]$$

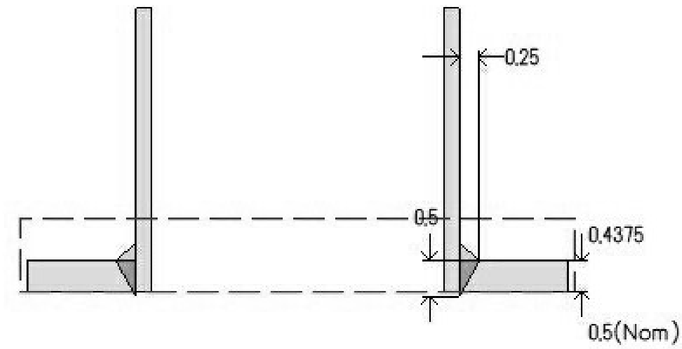
$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

LEVEL TRANSMITTER (L2)

ASME Section VIII Division 1, 2023 Edition	



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

Location and Orientation	
Located on	F&D Head #1
Orientation	45°
End of nozzle to datum line	99.1673"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No
Nozzle	
Service	Level Indicator (LEVEL)
Description	NPS 4 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	4.026"
Pipe nominal wall thickness	0.237"
Pipe minimum wall thickness[1]	0.2074"
Corrosion allowance	0"
Opening chord length	4.2821"
Projection available outside vessel, Lpr	6.602"
Projection available outside vessel to flange face, Lf	6.839"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi
Welds	
Inner fillet, Leg_{41}	0.25"
Nozzle to vessel groove weld	0.5"
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 4 Class 300 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	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 psi @ 70°F
External fillet weld leg (UW-21)	0.3318" (0.3318" min)
Internal fillet weld leg (UW-21)	0.237" (0.237" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.237, 0.59\right] =$	0.3318"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.3318 + \frac{0}{0.7} =$	0.3318"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text(")} + \frac{C_i}{0.7}\right] = \min\left[0.237, 0.25 + \frac{0}{0.7}\right] =$	0.237"
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	
$t_r = \frac{150.1 \cdot 2.013}{17{,}000 \cdot 1 - 0.6 \cdot 150.1} =$	0.0179"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0179 \cdot 1}{0.2074 - 0} =$	0.0862
Impact test exempt per UHA-51(g) (coincident ratio = 0.0862)	
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 = 150.1 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.7184	1.4802	1.1551	0.2626	–	–	0.0625	0.2074	0.2074

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1659	0.175	weld size is adequate

Calculations for internal pressure 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$

$$= 4.2821 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$

$$= 0.5925 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.1028 \cdot 2.013}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$

$$= 0.0154 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$$

$$= 0.1678 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 4.2821 \cdot 0.1678 \cdot 1 + 2 \cdot 0.237 \cdot 0.1678 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.7184}\ \text{in}^2 \end{aligned}$$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{1.1551}$ in^2

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1) \\ &= 1.1551\ \ \text{in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1) \\ &= 0.3639\ \ \text{in}^2 \end{aligned}$$

A_2 = smaller of the following= $\underline{0.2626}$ in^2

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.237 - 0.0154) \cdot 1 \cdot 0.4375 \\ &= 0.4848\ \ \text{in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.237 - 0.0154) \cdot 1 \cdot 0.237 \\ &= 0.2626\ \ \text{in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= Leg^2 \cdot f_{r2} \\ &= 0.25^{\ 2} \cdot 1 \\ &= \underline{0.0625}\ \text{in}^2 \end{aligned}$$

$$\begin{aligned} Area &= A_1 + A_2 + A_{41} \\ &= 1.1551 + 0.2626 + 0.0625 \\ &= \underline{1.4802}\ \text{in}^2 \end{aligned}$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[0.75,\ t_n,\ t] =$ 0.237 in

$t_{c(\min)} = \min\,[0.25,\ 0.7 \cdot t_{\min}] =$ $\underline{0.1659}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175\ \ \text{in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1028 \cdot 2.013}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$

$$= 0.0182 \text{ in}$$

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

$$= \max\left[0.0182,\ 0\right]$$

$$= 0.0182 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$

$$= 0.2826 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2826,\ 0.0625\right]$$

$$= 0.2826 \text{ in}$$

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

$$= \min\left[0.2074,\ 0.2826\right]$$

$$= 0.2074 \text{ in}$$

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

$$= \max\left[0.0182,\ 0.2074\right]$$

$$= \underline{0.2074} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.237 = 0.2074$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 228.61 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0945	1.0945	0.779	0.253	–	–	0.0625	0.2074	0.2074

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1659	0.175	weld size is adequate

Calculations for internal pressure 228.61 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$

$$= 4.2821 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$

$$= 0.5925 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{228.6059 \cdot 2.013}{19{,}700 \cdot 1 - 0.6 \cdot 228.6059}$$

$$= 0.0235 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{228.6059 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 228.6059}$$

$$= 0.2556 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{228.61 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 228.61} = 0.5066 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

$$
\begin{aligned}
A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
&= 4.2821 \cdot 0.2556 \cdot 1 + 2 \cdot 0.237 \cdot 0.2556 \cdot 1 \cdot (1 - 1) \\
&= \underline{1.0945} \text{ in}^2
\end{aligned}
$$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{0.779}$ in^2

$$
\begin{aligned}
&= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
&= 4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1) \\
&= 0.779 \ \ \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
&= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
&= 2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1) \\
&= 0.2454 \ \ \text{in}^2
\end{aligned}
$$

A_2 = smaller of the following= $\underline{0.253}$ in^2

$$
\begin{aligned}
&= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\
&= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.4375 \\
&= 0.467 \ \ \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
&= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n \\
&= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.237 \\
&= 0.253 \ \ \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
A_{41} &= Leg^2 \cdot f_{r2} \\
&= 0.25^{\ 2} \cdot 1 \\
&= \underline{0.0625} \text{ in}^2
\end{aligned}
$$

$$
\begin{aligned}
Area &= A_1 + A_2 + A_{41} \\
&= 0.779 + 0.253 + 0.0625 \\
&= \underline{1.0945} \text{ in}^2
\end{aligned}
$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[0.75,\ t_n,\ t] =$ 0.237 in

$t_{c(\min)} = \min\,[0.25,\ 0.7 \cdot t_{\min}] =$ $\underline{0.1659}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{228.6059 \cdot 2.013}{16{,}700 \cdot 1 - 0.6 \cdot 228.6059} + 0$$

$$= 0.0278 \text{ in}$$

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

$$= \max\left[0.0278,\ 0\right]$$

$$= 0.0278 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{228.61 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 228.61} + 0$$

$$= 0.4305 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.4305,\ 0.0625\right]$$

$$= 0.4305 \text{ in}$$

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

$$= \min\left[0.2074,\ 0.4305\right]$$

$$= 0.2074 \text{ in}$$

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

$$= \max\left[0.0278,\ 0.2074\right]$$

$$= \underline{0.2074} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.237$ = 0.2074 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 232.08 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0945	1.0945	0.779	0.253	–	–	0.0625	0.2074	0.2074

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

Calculations for internal pressure 232.08 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$
$$= 4.2821 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$
$$= 0.5925 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{232.0821 \cdot 2.013}{20{,}000 \cdot 1 - 0.6 \cdot 232.0821}$$
$$= 0.0235 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$
$$= \frac{232.0821 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 232.0821}$$
$$= 0.2556 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{232.08 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 232.08} = 0.5066 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000 psi

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

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

A	=	$d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$
	=	$4.2821 \cdot 0.2556 \cdot 1 + 2 \cdot 0.237 \cdot 0.2556 \cdot 1 \cdot (1 - 1)$
	=	1.0945 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.779 in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$$

$$= 0.779 \ \ \mathrm{in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$$

$$= 0.2454 \ \ \mathrm{in}^2$$

A_2 = smaller of the following= 0.253 in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.4375$$

$$= 0.467 \ \ \mathrm{in}^2$$

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$$

$$= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.237$$

$$= 0.253 \ \ \mathrm{in}^2$$

A_{41}	=	$Leg^2 \cdot f_{r2}$
	=	$0.25^{\ 2} \cdot 1$
	=	0.0625 in^2

$Area$	$=$	$A_1 + A_2 + A_{41}$
	$=$	$0.779 + 0.253 + 0.0625$
	$=$	1.0945 in^2

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{232.0821 \cdot 2.013}{17{,}000 \cdot 1 - 0.6 \cdot 232.0821} + 0$$

$$= 0.0277 \ \ \mathrm{in}$$

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

$$= \max\left[0.0277,\ 0\right]$$

$$= 0.0277 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{232.08 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 232.08} + 0$$

$$= 0.4305 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.4305,\ 0.0625\right]$$

$$= 0.4305 \text{ in}$$

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

$$= \min\left[0.2074,\ 0.4305\right]$$

$$= 0.2074 \text{ in}$$

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

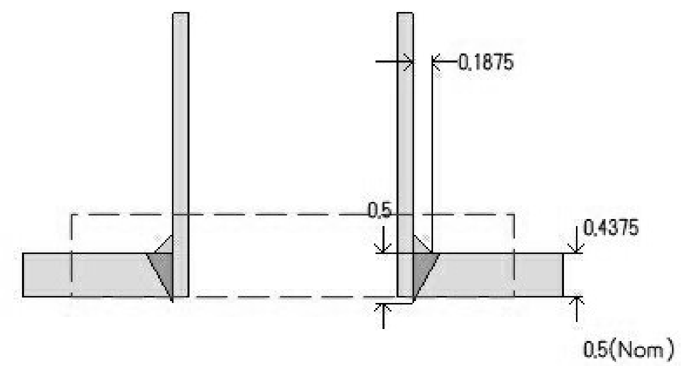
$$= \max\left[0.0277,\ 0.2074\right]$$

$$= \underline{0.2074} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.237 = 0.2074$ in

The nozzle neck thickness is adequate.

SPARE (S)

ASME Section VIII Division 1, 2023 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	F&D Head #1
Orientation	90°
End of nozzle to datum line	97.8643"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No
Nozzle	
Service	Process Nozzle (NOZ)
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	2.1983"
Projection available outside vessel, Lpr	5.7148"
Projection available outside vessel to flange face, Lf	5.8688"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.5"
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 300 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	Yes
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.154, 0.435\right] =$	0.2156"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.2156 + \frac{0}{0.7} =$	0.2156"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text(")} + \frac{C_i}{0.7}\right] = \min\left[0.154, 0.25 + \frac{0}{0.7}\right] =$	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	
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.085 \cdot 1}{0.1348 - 0} =$	0.6304
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -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 = 150.1 psi @ 350 °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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	150.1	-629	4,068	472	4,068	472	3,720	**34,623**	**59,100**	**15,713**	**29,550**	No
Load case 1 (Hot Shut Down)	0	-629	4,068	472	4,068	472	3,720	20,385	59,100	1,475	29,550	No
Load case 1 (Pr Reversed)	150.1	629	4,068	472	4,068	472	3,720	31,691	59,100	14,387	29,550	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	629	4,068	472	4,068	472	3,720	-20,385	59,100	-1,475	29,550	No

Calculations for internal pressure 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.1028 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$

$$= 0.0079 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$$

$$= 0.1678 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.1078 in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313 \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1028 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$

$$= 0.0093 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0721 \text{ in}$$

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

$$= \max\left[0.0093,\ 0.0721\right]$$

$$= 0.0721 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$

$$= 0.2826 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2826,\ 0.0625\right]$$

$$= 0.2826 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.2826\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0721,\ 0.1348\right]$$

$$= \underline{0.1348} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	150.1 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

Pressure stress intensity factor, $I = 1.8864$ (derived from Division 2 Part 4.5)

Local pressure stress = $\frac{I \cdot P \cdot R_i}{2 \cdot T} = 14{,}238 \ \text{psi}$

Maximum combined stress $(P_L + P_b + Q) = 34{,}623 \ \text{psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \ \text{psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 15{,}713 \ \text{psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \ \text{psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.2018	663	663	663	663	663	663	663	663
SR-2	$\frac{M_x}{P}$	0.1525	3,008	-3,008	3,008	-3,008	3,008	-3,008	3,008	-3,008
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1681	0	0	0	0	-812	-812	812	812
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5447	0	0	0	0	-15,793	15,793	15,793	-15,793
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1681	-812	-812	812	812	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5447	-15,793	15,793	15,793	-15,793	0	0	0	0
Pressure stress*			14,238	14,238	14,238	14,238	14,238	14,238	14,238	14,238
Total O_x stress			1,304	26,874	34,514	-3,088	1,304	26,874	34,514	-3,088
Membrane O_x stress*			14,089	14,089	15,713	15,713	14,089	14,089	15,713	15,713
SR-2*	$\frac{N_y \cdot T}{P}$	0.061	200	200	200	200	200	200	200	200
SR-2	$\frac{M_y}{P}$	0.0461	909	-909	909	-909	909	-909	909	-909
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0512	0	0	0	0	-247	-247	247	247
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1621	0	0	0	0	-4,699	4,699	4,699	-4,699
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0512	-247	-247	247	247	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1621	-4,699	4,699	4,699	-4,699	0	0	0	0
Pressure stress*			14,238	14,238	14,238	14,238	14,238	14,238	14,238	14,238
Total O_y stress			10,401	17,981	20,293	9,077	10,401	17,981	20,293	9,077
Membrane O_y stress*			14,191	14,191	14,685	14,685	14,191	14,191	14,685	14,685
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			10,569	27,046	34,546	12,239	10,450	26,924	34,623	12,419

(1) * denotes primary stress.
(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{150.1 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875^{\ 2} - 1.0335^{\ 2}\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}423 \ \ \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^{\,2} + 472^{\,2}}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^{\,2} \cdot 0.154} = 3{,}599 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \quad \text{psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAWP

Local stresses at the nozzle OD per WRC 537 govern the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 295.97 psi @ 350 °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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	295.97	-629	4,068	472	4,068	472	3,720	**48,460**	**59,100**	**29,550**	**29,550**	No
Load case 1 (Pr Reversed)	295.97	629	4,068	472	4,068	472	3,720	45,528	59,100	28,224	29,550	No

Calculations for internal pressure 295.97 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{295.9681 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 295.9681}$$

$$= 0.0157 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{295.9681 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 295.9681}$$

$$= 0.331 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{295.97 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 295.97} = 0.6561 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1078}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313 \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{295.9681 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 295.9681} + 0$$

$$= 0.0185 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0766 \text{ in}$$

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

$$= \max\left[0.0185,\ 0.0766\right]$$

$$= 0.0766 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{295.97 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 295.97} + 0$$

$$= 0.5576 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.5576,\ 0.0625\right]$$

$$= 0.5576 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.5576\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0766,\ 0.1348\right]$$

$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	295.97 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

Pressure stress intensity factor, $I = 1.8864$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 28{,}075 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 48{,}460 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \text{ psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 29{,}550 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \text{ psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.2018	663	663	663	663	663	663	663	663
SR-2	$\frac{M_x}{P}$	0.1525	3,008	-3,008	3,008	-3,008	3,008	-3,008	3,008	-3,008
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1681	0	0	0	0	-812	-812	812	812
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5447	0	0	0	0	-15,793	15,793	15,793	-15,793
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1681	-812	-812	812	812	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5447	-15,793	15,793	15,793	-15,793	0	0	0	0
Pressure stress*			28,075	28,075	28,075	28,075	28,075	28,075	28,075	28,075
Total O_x stress			15,141	40,711	48,351	10,749	15,141	40,711	48,351	10,749
Membrane O_x stress*			27,926	27,926	29,550	29,550	27,926	27,926	29,550	29,550
SR-2*	$\frac{N_y \cdot T}{P}$	0.061	200	200	200	200	200	200	200	200
SR-2	$\frac{M_y}{P}$	0.0461	909	-909	909	-909	909	-909	909	-909
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0512	0	0	0	0	-247	-247	247	247
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1621	0	0	0	0	-4,699	4,699	4,699	-4,699
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0512	-247	-247	247	247	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1621	-4,699	4,699	4,699	-4,699	0	0	0	0
Pressure stress*			28,075	28,075	28,075	28,075	28,075	28,075	28,075	28,075
Total O_y stress			24,238	31,818	34,130	22,914	24,238	31,818	34,130	22,914
Membrane O_y stress*			28,028	28,028	28,522	28,522	28,028	28,028	28,522	28,522
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			24,406	40,883	48,383	22,951	24,287	40,761	48,460	23,041
(1) * denotes primary stress. (2) The nozzle is assumed to be a rigid (solid) attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{295.97 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875^{\ 2} - 1.0335^{\ 2}\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}982 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^{\ 2} + 472^{\ 2}}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \ \text{ psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^{\ 2} \cdot 0.154} = 3{,}599 \ \text{ psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \ \text{ psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \ \text{ psi})$

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 = 396.94 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 396.94 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$
$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$
$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{396.9414 \cdot 1.0335}{20{,}000 \cdot 1 - 0.6 \cdot 396.9414}$$
$$= 0.0208 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$
$$= \frac{396.9414 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.9414}$$
$$= 0.4375 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 396.94} = 0.8673 \text{ in}$$

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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{396.9414 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 396.9414} + 0$$

$$= 0.0245 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0784 \text{ in}$$

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

$$= \max\left[0.0245,\ 0.0784\right]$$

$$= 0.0784 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.94} + 0$$

$$= 0.7369 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.7369\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0784,\ 0.1348\right]$$

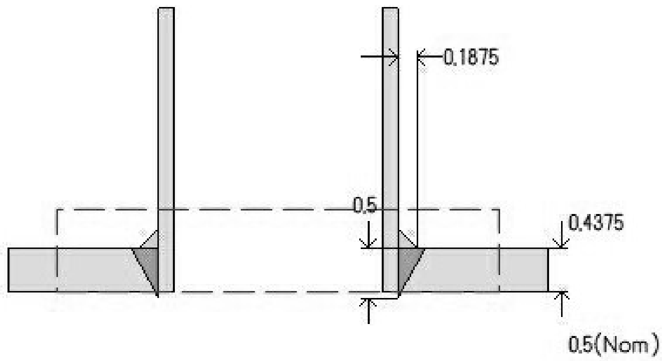
$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

PRESSURE TRANSMITTER (P1)

ASME Section VIII Division 1, 2023 Edition	



Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	F&D Head #1
Orientation	180°
End of nozzle to datum line	97.8643"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No
Nozzle	
Service	Pressure Gauge (PG)
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	2.1983"
Projection available outside vessel, Lpr	5.7148"
Projection available outside vessel to flange face, Lf	5.8688"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.5"
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 300 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	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.154, 0.435\right] =$	0.2156"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.2156 + \frac{0}{0.7} =$	0.2156"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text}('') + \frac{C_i}{0.7}\right] = \min\left[0.154, 0.25 + \frac{0}{0.7}\right] =$	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	
$t_r = \frac{150.1 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 150.1} =$	0.0092"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0092 \cdot 1}{0.1348 - 0} =$	0.0681
Impact test exempt per UHA-51(g) (coincident ratio = 0.0681)	
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 = 150.1 psi @ 350 °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 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ \ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \ \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ \ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ \ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \ \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.1028 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$

$$= 0.0079 \ \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$$

$$= 0.1678 \ \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \ \ \text{in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.1078 in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1028 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$

$$= 0.0093 \text{ in}$$

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

$$= \max\left[0.0093,\ 0\right]$$

$$= 0.0093 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$

$$= 0.2826 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2826,\ 0.0625\right]$$

$$= 0.2826 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.2826\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0093,\ 0.1348\right]$$

$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.154 = 0.1348$ 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 = 390.99 psi @ 350 °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 390.99 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{390.9852 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 390.9852}$$

$$= 0.0208 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{390.9852 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 390.9852}$$

$$= 0.4375 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{390.99 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 390.99} = 0.8673 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ <u>0.1078</u> in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313 \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{390.9852 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 390.9852} + 0$$

$$= 0.0245 \text{ in}$$

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

$$= \max\left[0.0245,\ 0\right]$$

$$= 0.0245 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{390.99 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 390.99} + 0$$

$$= 0.7369 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.7369\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0245,\ 0.1348\right]$$

$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 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 = 396.94 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 396.94 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{396.9414 \cdot 1.0335}{20{,}000 \cdot 1 - 0.6 \cdot 396.9414}$$

$$= 0.0208 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{396.9414 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.9414}$$

$$= 0.4375 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 396.94} = 0.8673 \text{ in}$$

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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{396.9414 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 396.9414} + 0$$

$$= 0.0245 \quad \text{in}$$

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

$$= \max\left[0.0245,\ 0\right]$$

$$= 0.0245 \quad \text{in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.94} + 0$$

$$= 0.7369 \quad \text{in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \quad \text{in}$$

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

$$= \min\left[0.1348,\ 0.7369\right]$$

$$= 0.1348 \quad \text{in}$$

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

$$= \max\left[0.0245,\ 0.1348\right]$$

$$= \underline{0.1348} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

RELIEF VALVE (R)

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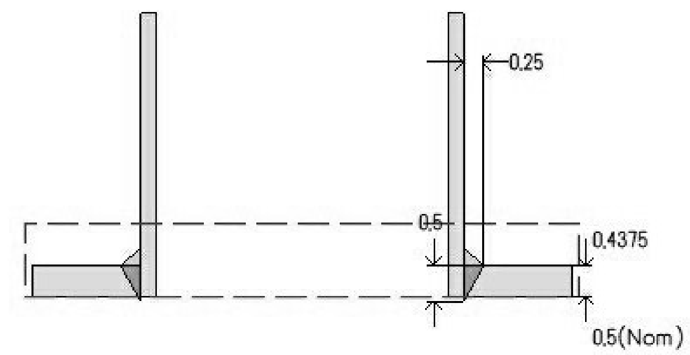


Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	F&D Head #1
Orientation	225°
End of nozzle to datum line	99.1673"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No

Nozzle	
Service	Pressure Relief Valve (PRV)
Description	NPS 4 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	4.026"
Pipe nominal wall thickness	0.237"
Pipe minimum wall thickness[1]	0.2074"
Corrosion allowance	0"
Opening chord length	4.2821"
Projection available outside vessel, Lpr	6.602"
Projection available outside vessel to flange face, Lf	6.839"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi

Welds	
Inner fillet, Leg_{41}	0.25"
Nozzle to vessel groove weld	0.5"

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 4 Class 300 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	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 psi @ 70°F
External fillet weld leg (UW-21)	0.3318" (0.3318" min)
Internal fillet weld leg (UW-21)	0.237" (0.237" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.237, 0.59\right] =$	0.3318"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.3318 + \frac{0}{0.7} =$	0.3318"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text(")} + \frac{C_i}{0.7}\right] = \min\left[0.237, 0.25 + \frac{0}{0.7}\right] =$	0.237"
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	
$t_r = \frac{150.1 \cdot 2.013}{17{,}000 \cdot 1 - 0.6 \cdot 150.1} =$	0.0179"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0179 \cdot 1}{0.2074 - 0} =$	0.0862
Impact test exempt per UHA-51(g) (coincident ratio = 0.0862)	
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 = 150.1 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.7184	1.4802	1.1551	0.2626	–	–	0.0625	0.2074	0.2074

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1659	0.175	weld size is adequate

Calculations for internal pressure 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$

$$= 4.2821 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$

$$= 0.5925 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.1028 \cdot 2.013}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$

$$= 0.0154 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$$

$$= 0.1678 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

A = $d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$

= $4.2821 \cdot 0.1678 \cdot 1 + 2 \cdot 0.237 \cdot 0.1678 \cdot 1 \cdot (1 - 1)$

= 0.7184 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.1551 in^2

= $d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1)$

= $1.1551 \ \ \mathrm{in}^2$

= $2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1)$

= $0.3639 \ \ \mathrm{in}^2$

A_2 = smaller of the following= 0.2626 in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$

= $5 \cdot (0.237 - 0.0154) \cdot 1 \cdot 0.4375$

= $0.4848 \ \ \mathrm{in}^2$

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$

= $5 \cdot (0.237 - 0.0154) \cdot 1 \cdot 0.237$

= $0.2626 \ \ \mathrm{in}^2$

A_{41} = $Leg^2 \cdot f_{r2}$

= $0.25^{\ 2} \cdot 1$

= 0.0625 in^2

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

= $1.1551 + 0.2626 + 0.0625$

= 1.4802 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[0.75,\ t_n,\ t] =$ 0.237 in

$t_{c(\min)} = \min\,[0.25,\ 0.7 \cdot t_{\min}] =$ 0.1659 in

$t_{c(actual)} = 0.7 \cdot \mathrm{Leg} = 0.7 \cdot 0.25 = 0.175 \ \ \mathrm{in}$

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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1028 \cdot 2.013}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$

$$= 0.0182 \text{ in}$$

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

$$= \max\left[0.0182,\ 0\right]$$

$$= 0.0182 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$

$$= 0.2826 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2826,\ 0.0625\right]$$

$$= 0.2826 \text{ in}$$

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

$$= \min\left[0.2074,\ 0.2826\right]$$

$$= 0.2074 \text{ in}$$

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

$$= \max\left[0.0182,\ 0.2074\right]$$

$$= \underline{0.2074} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.237 = 0.2074$ in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 228.61 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0945	1.0945	0.779	0.253	–	–	0.0625	0.2074	0.2074

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1659	0.175	weld size is adequate

Calculations for internal pressure 228.61 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$

$$= 4.2821 \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$

$$= 0.5925 \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{228.6059 \cdot 2.013}{19{,}700 \cdot 1 - 0.6 \cdot 228.6059}$$

$$= 0.0235 \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{228.6059 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 228.6059}$$

$$= 0.2556 \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{228.61 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 228.61} = 0.5066 \ \text{in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$

$$= 4.2821 \cdot 0.2556 \cdot 1 + 2 \cdot 0.237 \cdot 0.2556 \cdot 1 \cdot (1 - 1)$$

= <u>1.0945</u> in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0.779</u> in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$$

$$= 0.779 \ \ \mathrm{in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$$

$$= 0.2454 \ \ \mathrm{in}^2$$

A_2 = smaller of the following= <u>0.253</u> in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.4375$$

$$= 0.467 \ \ \mathrm{in}^2$$

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$$

$$= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.237$$

$$= 0.253 \ \ \mathrm{in}^2$$

$$A_{41} = Leg^2 \cdot f_{r2}$$

$$= 0.25^{\ 2} \cdot 1$$

= <u>0.0625</u> in^2

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

$$= 0.779 + 0.253 + 0.0625$$

= <u>1.0945</u> in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[0.75,\ t_n,\ t] =$ 0.237 in

$t_{c(\min)} = \min\,[0.25,\ 0.7 \cdot t_{\min}] =$ <u>0.1659</u> in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175 \;\; \text{in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{228.6059 \cdot 2.013}{16{,}700 \cdot 1 - 0.6 \cdot 228.6059} + 0$$

$$= 0.0278 \;\; \text{in}$$

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

$$= \max\left[0.0278,\;\; 0\right]$$

$$= 0.0278 \;\; \text{in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{228.61 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 228.61} + 0$$

$$= 0.4305 \;\; \text{in}$$

$$t_{b1} = \max\left[t_{b1},\; t_{b\text{UG16}}\right]$$

$$= \max\left[0.4305,\;\; 0.0625\right]$$

$$= 0.4305 \;\; \text{in}$$

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

$$= \min\left[0.2074,\;\; 0.4305\right]$$

$$= 0.2074 \;\; \text{in}$$

$$t_{\text{UG-45}} = \max\left[t_a,\; t_b\right]$$

$$= \max\left[0.0278,\;\; 0.2074\right]$$

$$= \underline{0.2074} \;\; \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.237$ = 0.2074 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 232.08 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0945	1.0945	0.779	0.253	–	–	0.0625	0.2074	0.2074

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

Calculations for internal pressure 232.08 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$

$$= 4.2821 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$

$$= 0.5925 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{232.0821 \cdot 2.013}{20{,}000 \cdot 1 - 0.6 \cdot 232.0821}$$

$$= 0.0235 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{232.0821 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 232.0821}$$

$$= 0.2556 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{232.08 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 232.08} = 0.5066 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000 psi

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

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

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$
$$= 4.2821 \cdot 0.2556 \cdot 1 + 2 \cdot 0.237 \cdot 0.2556 \cdot 1 \cdot (1 - 1)$$
$$= \underline{1.0945} \text{ in}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{0.779}$ in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$
$$= 4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$$
$$= 0.779 \text{ in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$
$$= 2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$$
$$= 0.2454 \text{ in}^2$$

A_2 = smaller of the following= $\underline{0.253}$ in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$
$$= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.4375$$
$$= 0.467 \text{ in}^2$$

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$$
$$= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.237$$
$$= 0.253 \text{ in}^2$$

$$A_{41} = Leg^2 \cdot f_{r2}$$
$$= 0.25^2 \cdot 1$$
$$= \underline{0.0625} \text{ in}^2$$

$$Area = A_1 + A_2 + A_{41}$$
$$= 0.779 + 0.253 + 0.0625$$
$$= \underline{1.0945} \text{ in}^2$$

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$
$$= \frac{232.0821 \cdot 2.013}{17{,}000 \cdot 1 - 0.6 \cdot 232.0821} + 0$$
$$= 0.0277 \text{ in}$$

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

$= \max\left[0.0277,\ 0\right]$

$= 0.0277$ in

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{232.08 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 232.08} + 0$$

$= 0.4305$ in

$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$

$= \max\left[0.4305,\ 0.0625\right]$

$= 0.4305$ in

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

$= \min\left[0.2074,\ 0.4305\right]$

$= 0.2074$ in

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

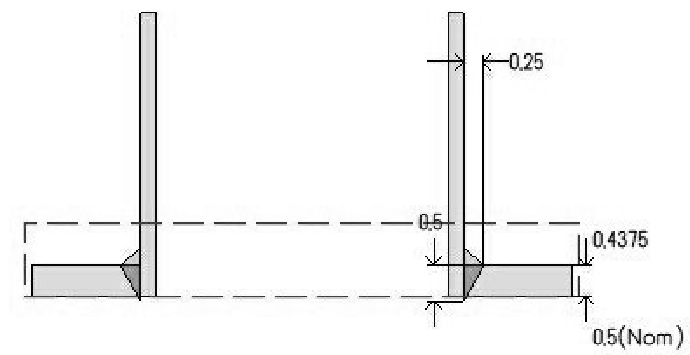
$= \max\left[0.0277,\ 0.2074\right]$

$= \underline{0.2074}$ in

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.237$ = 0.2074 in

The nozzle neck thickness is adequate.

SPARE (S1)

ASME Section VIII Division 1, 2023 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	F&D Head #1
Orientation	270°
End of nozzle to datum line	99.1673"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No
Nozzle	
Service	Process Nozzle (NOZ)
Description	NPS 4 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	4.026"
Pipe nominal wall thickness	0.237"
Pipe minimum wall thickness[1]	0.2074"
Corrosion allowance	0"
Opening chord length	4.2821"
Projection available outside vessel, Lpr	6.602"
Projection available outside vessel to flange face, Lf	6.839"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi
Welds	
Inner fillet, Leg_{41}	0.25"
Nozzle to vessel groove weld	0.5"
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 4 Class 300 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	Yes
Rated MDMT	-55°F
Liquid static head	0 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 psi @ 70°F
External fillet weld leg (UW-21)	0.3318" (0.3318" min)
Internal fillet weld leg (UW-21)	0.237" (0.237" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.237, 0.59\right] =$	0.3318"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.3318 + \frac{0}{0.7} =$	0.3318"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text(")} + \frac{C_i}{0.7}\right] = \min\left[0.237, 0.25 + \frac{0}{0.7}\right] =$	0.237"
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	
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0941 \cdot 1}{0.2074 - 0} =$	0.4539
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -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 = 150.1 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.7184	1.4802	1.1551	0.2626	–	–	0.0625	0.2074	0.2074

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1659	0.175	weld size is adequate

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	150.1	-1,259	16,260	944	16,260	944	14,868	**48,653**	**59,100**	**18,002**	**29,550**	No
Load case 1 (Hot Shut Down)	0	-1,259	16,260	944	16,260	944	14,868	34,332	59,100	3,681	29,550	No
Load case 1 (Pr Reversed)	150.1	1,259	16,260	944	16,260	944	14,868	41,312	59,100	16,242	29,550	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	1,259	16,260	944	16,260	944	14,868	-34,332	59,100	-3,681	29,550	No

Calculations for internal pressure 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$
$$= 4.2821 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$
$$= 0.5925 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{150.1028 \cdot 2.013}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$
$$= 0.0154 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$$

$$= 0.1678 \quad \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \quad \text{in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$

$$= 4.2821 \cdot 0.1678 \cdot 1 + 2 \cdot 0.237 \cdot 0.1678 \cdot 1 \cdot (1 - 1)$$

= <u>0.7184</u> in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>1.1551</u> in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1)$$

$$= 1.1551 \quad \text{in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1)$$

$$= 0.3639 \quad \text{in}^2$$

A_2 = smaller of the following= <u>0.2626</u> in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (0.237 - 0.0154) \cdot 1 \cdot 0.4375$$

$$= 0.4848 \quad \text{in}^2$$

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$$

$$= 5 \cdot (0.237 - 0.0154) \cdot 1 \cdot 0.237$$

$$= 0.2626 \quad \text{in}^2$$

A_{41} = $Leg^2 \cdot f_{r2}$

= $0.25^{\,2} \cdot 1$

= $\underline{0.0625}$ in^2

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

$= 1.1551 + 0.2626 + 0.0625$

$= \underline{1.4802}$ in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.237 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1659}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1028 \cdot 2.013}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$

$$= 0.0182 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0806 \text{ in}$$

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

$$= \max\left[0.0182,\ 0.0806\right]$$

$$= 0.0806 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$

$$= 0.2826 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2826,\ 0.0625\right]$$

$$= 0.2826 \text{ in}$$

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

$$= \min\left[0.2074,\ 0.2826\right]$$

$$= 0.2074 \text{ in}$$

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

$$= \max\left[0.0806,\ 0.2074\right]$$

$$= \underline{0.2074} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.237$ = 0.2074 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-1,259 lb_f
Circumferential moment, M_1	16,260 lb_f-in
Circumferential shear, V_2	944 lb_f
Longitudinal moment, M_2	16,260 lb_f-in
Longitudinal shear, V_1	944 lb_f
Torsion moment, M_t	14,868 lb_f-in
Internal pressure, P	150.1 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{2.25}{\sqrt{44.2188 \cdot 0.4375}} = 0.512$$

Pressure stress intensity factor, $I = 1.8973$ (derived from Division 2 Part 4.5)

Local pressure stress = $\frac{I \cdot P \cdot R_i}{2 \cdot T} = 14{,}321 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 48{,}653 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \text{ psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 18{,}002 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \text{ psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.1338	880	880	880	880	880	880	880	880
SR-2	$\frac{M_x}{P}$	0.0811	3,199	-3,199	3,199	-3,199	3,199	-3,199	3,199	-3,199
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.145	0	0	0	0	-2,801	-2,801	2,801	2,801
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.2362	0	0	0	0	-27,373	27,373	27,373	-27,373
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.145	-2,801	-2,801	2,801	2,801	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.2362	-27,373	27,373	27,373	-27,373	0	0	0	0
Pressure stress*			14,321	14,321	14,321	14,321	14,321	14,321	14,321	14,321
Total O_x stress			-11,774	36,574	48,574	-12,570	-11,774	36,574	48,574	-12,570
Membrane O_x stress*			12,400	12,400	18,002	18,002	12,400	12,400	18,002	18,002
SR-2*	$\frac{N_y \cdot T}{P}$	0.0401	264	264	264	264	264	264	264	264
SR-2	$\frac{M_y}{P}$	0.0251	990	-990	990	-990	990	-990	990	-990
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0443	0	0	0	0	-856	-856	856	856
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0711	0	0	0	0	-8,234	8,234	8,234	-8,234
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0443	-856	-856	856	856	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0711	-8,234	8,234	8,234	-8,234	0	0	0	0
Pressure stress*			14,321	14,321	14,321	14,321	14,321	14,321	14,321	14,321
Total O_y stress			6,485	20,973	24,665	6,217	6,485	20,973	24,665	6,217
Membrane O_y stress*			13,729	13,729	15,441	15,441	13,729	13,729	15,441	15,441
Shear from M_t			1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068
Shear from V_1			0	0	0	0	-305	-305	305	305
Shear from V_2			305	305	-305	-305	0	0	0	0
Total Shear stress			1,373	1,373	763	763	763	763	1,373	1,373
Combined stress (P_L+P_b+Q)			18,464	36,694	48,598	18,849	18,323	36,611	48,653	18,987

(1) * denotes primary stress.
(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{150.1 \cdot 2.013}{2 \cdot 0.2074} - \frac{-1{,}259}{\pi \cdot \left(2.25^{\,2} - 2.013^{\,2}\right)} + \frac{22{,}995.1 \cdot 2.25}{7.2326}$$

$$= 8{,}279 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{944^2 + 944^2}}{\pi \cdot 2.013 \cdot 0.237} = 891 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{14{,}868}{2 \cdot \pi \cdot 2.013^2 \cdot 0.237} = 2{,}464 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 891 + 2{,}464 = 3{,}355 \quad \text{psi}$$

UG-45: The total combined shear stress (3,355 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAWP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 228.61 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0945	1.0945	0.779	0.253	–	–	0.0625	0.2074	0.2074

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1659	0.175	weld size is adequate

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	228.61	-1,259	16,260	944	16,260	944	14,868	**56,142**	**59,100**	**25,491**	**29,550**	No
Load case 1 (Pr Reversed)	228.61	1,259	16,260	944	16,260	944	14,868	48,801	59,100	23,731	29,550	No

Calculations for internal pressure 228.61 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$

$$= 4.2821 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$

$$= 0.5925 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{228.6059 \cdot 2.013}{19{,}700 \cdot 1 - 0.6 \cdot 228.6059}$$

$$= 0.0235 \text{ in}$$

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

t_r = $\dfrac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$

= $\dfrac{228.6059 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 228.6059}$

= $0.2556 \ \text{in}$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{228.61 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 228.61} = 0.5066 \ \text{in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

A = $d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$

= $4.2821 \cdot 0.2556 \cdot 1 + 2 \cdot 0.237 \cdot 0.2556 \cdot 1 \cdot (1 - 1)$

= <u>1.0945</u> in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= <u>0.779</u> in^2

= $d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$

= $0.779 \ \text{in}^2$

= $2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$

= $0.2454 \ \text{in}^2$

A_2 = smaller of the following= <u>0.253</u> in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$

= $5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.4375$

= $0.467 \ \text{in}^2$

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$

= $5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.237$

= $0.253 \ \text{in}^2$

$$A_{41} = Leg^2 \cdot f_{r2}$$
$$= 0.25^{\,2} \cdot 1$$
$$= \underline{0.0625}\ \text{in}^2$$

$$Area = A_1 + A_2 + A_{41}$$
$$= 0.779 + 0.253 + 0.0625$$
$$= \underline{1.0945}\ \text{in}^2$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.237 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1659}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175\ \text{in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$
$$= \frac{228.6059 \cdot 2.013}{16{,}700 \cdot 1 - 0.6 \cdot 228.6059} + 0$$
$$= 0.0278\ \text{in}$$

$$t_{a\text{UG-22}} = 0.0851\ \text{in}$$

$$t_a = \max\left[t_{a\text{UG-27}},\ t_{a\text{UG-22}}\right]$$
$$= \max\left[0.0278,\ 0.0851\right]$$
$$= 0.0851\ \text{in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$
$$= \frac{228.61 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 228.61} + 0$$
$$= 0.4305\ \text{in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$
$$= \max\left[0.4305,\ 0.0625\right]$$
$$= 0.4305\ \text{in}$$

$$t_b = \min\left[t_{b3},\ t_{b1}\right]$$
$$= \min\left[0.2074,\ 0.4305\right]$$
$$= 0.2074\ \text{in}$$

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

$$= \max\left[0.0851,\ 0.2074\right]$$

$$= \underline{0.2074} \ \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.237$ = 0.2074 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-1,259 lb_f
Circumferential moment, M_1	16,260 lb_f-in
Circumferential shear, V_2	944 lb_f
Longitudinal moment, M_2	16,260 lb_f-in
Longitudinal shear, V_1	944 lb_f
Torsion moment, M_t	14,868 lb_f-in
Internal pressure, P	228.61 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{2.25}{\sqrt{44.2188 \cdot 0.4375}} = 0.512$$

Pressure stress intensity factor, $I = 1.8973$ (derived from Division 2 Part 4.5)

Local pressure stress = $\frac{I \cdot P \cdot R_i}{2 \cdot T} = 21{,}810 \ \text{psi}$

Maximum combined stress $(P_L + P_b + Q) = 56{,}142 \ \text{psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \ \text{psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 25{,}491 \ \text{psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \ \text{psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.1338	880	880	880	880	880	880	880	880
SR-2	$\frac{M_x}{P}$	0.0811	3,199	-3,199	3,199	-3,199	3,199	-3,199	3,199	-3,199
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.145	0	0	0	0	-2,801	-2,801	2,801	2,801
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.2362	0	0	0	0	-27,373	27,373	27,373	-27,373
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.145	-2,801	-2,801	2,801	2,801	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.2362	-27,373	27,373	27,373	-27,373	0	0	0	0
Pressure stress*			21,810	21,810	21,810	21,810	21,810	21,810	21,810	21,810
Total O_x stress			-4,285	44,063	56,063	-5,081	-4,285	44,063	56,063	-5,081
Membrane O_x stress*			19,889	19,889	25,491	25,491	19,889	19,889	25,491	25,491
SR-2*	$\frac{N_y \cdot T}{P}$	0.0401	264	264	264	264	264	264	264	264
SR-2	$\frac{M_y}{P}$	0.0251	990	-990	990	-990	990	-990	990	-990
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0443	0	0	0	0	-856	-856	856	856
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0711	0	0	0	0	-8,234	8,234	8,234	-8,234
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0443	-856	-856	856	856	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0711	-8,234	8,234	8,234	-8,234	0	0	0	0
Pressure stress*			21,810	21,810	21,810	21,810	21,810	21,810	21,810	21,810
Total O_y stress			13,974	28,462	32,154	13,706	13,974	28,462	32,154	13,706
Membrane O_y stress*			21,218	21,218	22,930	22,930	21,218	21,218	22,930	22,930
Shear from M_t			1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068
Shear from V_1			0	0	0	0	-305	-305	305	305
Shear from V_2			305	305	-305	-305	0	0	0	0
Total Shear stress			1,373	1,373	763	763	763	763	1,373	1,373
Combined stress (P_L+P_b+Q)			18,464	44,183	56,087	18,849	18,323	44,100	56,142	18,987
(1) * denotes primary stress. (2) The nozzle is assumed to be a rigid (solid) attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{228.61 \cdot 2.013}{2 \cdot 0.2074} - \frac{-1{,}259}{\pi \cdot \left(2.25^{\ 2} - 2.013^{\ 2}\right)} + \frac{22{,}995.1 \cdot 2.25}{7.2326}$$

$$= 8{,}660 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{944^{\,2} + 944^{\,2}}}{\pi \cdot 2.013 \cdot 0.237} = 891 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{14{,}868}{2 \cdot \pi \cdot 2.013^{\,2} \cdot 0.237} = 2{,}464 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 891 + 2{,}464 = 3{,}355 \quad \text{psi}$$

UG-45: The total combined shear stress (3,355 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 232.08 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.0945	1.0945	0.779	0.253	–	–	0.0625	0.2074	0.2074

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

Calculations for internal pressure 232.08 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[4.2821,\ 2.1411 + (0.237 - 0) + (0.4375 - 0)\right]$$
$$= 4.2821 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.237 - 0) + 0\right]$$
$$= 0.5925 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{232.0821 \cdot 2.013}{20{,}000 \cdot 1 - 0.6 \cdot 232.0821}$$
$$= 0.0235 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$
$$= \frac{232.0821 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 232.0821}$$
$$= 0.2556 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{232.08 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 232.08} = 0.5066 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000 psi

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

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

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$
$$= 4.2821 \cdot 0.2556 \cdot 1 + 2 \cdot 0.237 \cdot 0.2556 \cdot 1 \cdot (1 - 1)$$
$$= \underline{1.0945} \text{ in}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.779 in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$
$$= 4.2821 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$$
$$= 0.779 \text{ in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$
$$= 2 \cdot (0.4375 + 0.237) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) - 2 \cdot 0.237 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2556) \cdot (1 - 1)$$
$$= 0.2454 \text{ in}^2$$

A_2 = smaller of the following= 0.253 in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$
$$= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.4375$$
$$= 0.467 \text{ in}^2$$

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$$
$$= 5 \cdot (0.237 - 0.0235) \cdot 1 \cdot 0.237$$
$$= 0.253 \text{ in}^2$$

$$A_{41} = Leg^2 \cdot f_{r2}$$
$$= 0.25^2 \cdot 1$$
$$= \underline{0.0625} \text{ in}^2$$

$$Area = A_1 + A_2 + A_{41}$$
$$= 0.779 + 0.253 + 0.0625$$
$$= \underline{1.0945} \text{ in}^2$$

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$
$$= \frac{232.0821 \cdot 2.013}{17{,}000 \cdot 1 - 0.6 \cdot 232.0821} + 0$$
$$= 0.0277 \text{ in}$$

$t_{a\text{UG-22}} = 0.0839 \text{ in}$

$$\begin{aligned} t_a &= \max\left[t_{a\text{UG-27}},\ t_{a\text{UG-22}}\right] \\ &= \max\left[0.0277,\ 0.0839\right] \\ &= 0.0839 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} \\ &= \frac{232.08 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 232.08} + 0 \\ &= 0.4305 \text{ in} \end{aligned}$$

$$\begin{aligned} t_{b1} &= \max\left[t_{b1},\ t_{b\text{UG16}}\right] \\ &= \max\left[0.4305,\ 0.0625\right] \\ &= 0.4305 \text{ in} \end{aligned}$$

$$\begin{aligned} t_b &= \min\left[t_{b3},\ t_{b1}\right] \\ &= \min\left[0.2074,\ 0.4305\right] \\ &= 0.2074 \text{ in} \end{aligned}$$

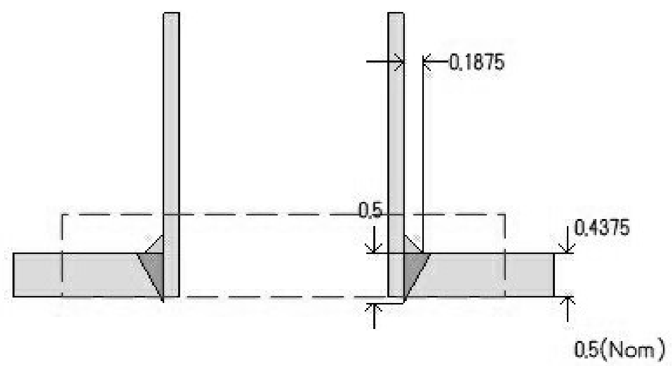
$$\begin{aligned} t_{\text{UG-45}} &= \max\left[t_a,\ t_b\right] \\ &= \max\left[0.0839,\ 0.2074\right] \\ &= \underline{0.2074} \text{ in} \end{aligned}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.237 = 0.2074$ in

The nozzle neck thickness is adequate.

PROCESS INLET (F2)

ASME Section VIII Division 1, 2023 Edition	



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

Location and Orientation	
Located on	F&D Head #1
Orientation	315°
End of nozzle to datum line	97.8643"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No

Nozzle	
Service	Process Nozzle (NOZ)
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	2.1983"
Projection available outside vessel, Lpr	5.7148"
Projection available outside vessel to flange face, Lf	5.8688"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi

Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.5"

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 300 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
Consider External Loads on Flange MAWP Rating	No
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.154, 0.435\right] =$	0.2156"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.2156 + \frac{0}{0.7} =$	0.2156"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text}('') + \frac{C_i}{0.7}\right] = \min\left[0.154, 0.25 + \frac{0}{0.7}\right] =$	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	
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.085 \cdot 1}{0.1348 - 0} =$	0.6304
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -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 = 150.1 psi @ 350 °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

WRC 537													
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	150.1	-629	4,068	472	4,068	472	3,720	**34,623**	**59,100**	**15,713**	**29,550**	No
Load case 1 (Hot Shut Down)	0	-629	4,068	472	4,068	472	3,720	20,385	59,100	1,475	29,550	No
Load case 1 (Pr Reversed)	150.1	629	4,068	472	4,068	472	3,720	31,691	59,100	14,387	29,550	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	629	4,068	472	4,068	472	3,720	-20,385	59,100	-1,475	29,550	No

Calculations for internal pressure 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983\ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385\ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.1028 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$

$$= 0.0079\ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$$

$$= 0.1678 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.1078 in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313 \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1028 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$

$$= 0.0093 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0721 \text{ in}$$

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

$$= \max\left[0.0093,\ 0.0721\right]$$

$$= 0.0721 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$

$$= 0.2826 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2826,\ 0.0625\right]$$

$$= 0.2826 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.2826\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0721,\ 0.1348\right]$$

$$= \underline{0.1348}\ \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	150.1 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

Pressure stress intensity factor, $I = 1.8864$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 14{,}238 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 34{,}623 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \text{ psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 15{,}713 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \text{ psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537

Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.2018	663	663	663	663	663	663	663	663
SR-2	$\frac{M_x}{P}$	0.1525	3,008	-3,008	3,008	-3,008	3,008	-3,008	3,008	-3,008
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1681	0	0	0	0	-812	-812	812	812
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5447	0	0	0	0	-15,793	15,793	15,793	-15,793
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1681	-812	-812	812	812	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5447	-15,793	15,793	15,793	-15,793	0	0	0	0
Pressure stress*			14,238	14,238	14,238	14,238	14,238	14,238	14,238	14,238
Total O_x stress			1,304	26,874	34,514	-3,088	1,304	26,874	34,514	-3,088
Membrane O_x stress*			14,089	14,089	15,713	15,713	14,089	14,089	15,713	15,713
SR-2*	$\frac{N_y \cdot T}{P}$	0.061	200	200	200	200	200	200	200	200
SR-2	$\frac{M_y}{P}$	0.0461	909	-909	909	-909	909	-909	909	-909
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0512	0	0	0	0	-247	-247	247	247
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1621	0	0	0	0	-4,699	4,699	4,699	-4,699
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0512	-247	-247	247	247	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1621	-4,699	4,699	4,699	-4,699	0	0	0	0
Pressure stress*			14,238	14,238	14,238	14,238	14,238	14,238	14,238	14,238
Total O_y stress			10,401	17,981	20,293	9,077	10,401	17,981	20,293	9,077
Membrane O_y stress*			14,191	14,191	14,685	14,685	14,191	14,191	14,685	14,685
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			10,569	27,046	34,546	12,239	10,450	26,924	34,623	12,419

(1) * denotes primary stress.
(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{150.1 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875^{\ 2} - 1.0335^{\ 2}\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}423 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^{\,2} + 472^{\,2}}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^{\,2} \cdot 0.154} = 3{,}599 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \quad \text{psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAWP

Local stresses at the nozzle OD per WRC 537 govern the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 295.97 psi @ 350 °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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	295.97	-629	4,068	472	4,068	472	3,720	**48,460**	**59,100**	**29,550**	**29,550**	No
Load case 1 (Pr Reversed)	295.97	629	4,068	472	4,068	472	3,720	45,528	59,100	28,224	29,550	No

Calculations for internal pressure 295.97 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{295.9681 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 295.9681}$$

$$= 0.0157 \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{295.9681 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 295.9681}$$

$$= 0.331 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{295.97 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 295.97} = 0.6561 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.1078 in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{295.9681 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 295.9681} + 0$$

$$= 0.0185 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0766 \text{ in}$$

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

$$= \max\left[0.0185,\ 0.0766\right]$$

$$= 0.0766 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{295.97 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 295.97} + 0$$

$$= 0.5576 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.5576,\ 0.0625\right]$$

$$= 0.5576 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.5576\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0766,\ 0.1348\right]$$

$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	295.97 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

Pressure stress intensity factor, $I = 1.8864$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 28{,}075 \ \text{psi}$

Maximum combined stress $(P_L + P_b + Q) = 48{,}460 \ \text{psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \ \text{psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 29{,}550 \ \text{psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \ \text{psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.2018	663	663	663	663	663	663	663	663
SR-2	$\frac{M_x}{P}$	0.1525	3,008	-3,008	3,008	-3,008	3,008	-3,008	3,008	-3,008
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1681	0	0	0	0	-812	-812	812	812
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5447	0	0	0	0	-15,793	15,793	15,793	-15,793
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1681	-812	-812	812	812	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5447	-15,793	15,793	15,793	-15,793	0	0	0	0
Pressure stress*			28,075	28,075	28,075	28,075	28,075	28,075	28,075	28,075
Total O_x stress			15,141	40,711	48,351	10,749	15,141	40,711	48,351	10,749
Membrane O_x stress*			27,926	27,926	29,550	29,550	27,926	27,926	29,550	29,550
SR-2*	$\frac{N_y \cdot T}{P}$	0.061	200	200	200	200	200	200	200	200
SR-2	$\frac{M_y}{P}$	0.0461	909	-909	909	-909	909	-909	909	-909
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0512	0	0	0	0	-247	-247	247	247
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1621	0	0	0	0	-4,699	4,699	4,699	-4,699
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0512	-247	-247	247	247	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1621	-4,699	4,699	4,699	-4,699	0	0	0	0
Pressure stress*			28,075	28,075	28,075	28,075	28,075	28,075	28,075	28,075
Total O_y stress			24,238	31,818	34,130	22,914	24,238	31,818	34,130	22,914
Membrane O_y stress*			28,028	28,028	28,522	28,522	28,028	28,028	28,522	28,522
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			24,406	40,883	48,383	22,951	24,287	40,761	48,460	23,041

(1) * denotes primary stress.
(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{295.97 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875\ ^2 - 1.0335\ ^2\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}982 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^{\,2} + 472^{\,2}}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^{\,2} \cdot 0.154} = 3{,}599 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \quad \text{psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

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 = 396.94 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 396.94 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983\ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385\ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{396.9414 \cdot 1.0335}{20{,}000 \cdot 1 - 0.6 \cdot 396.9414}$$

$$= 0.0208\ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{396.9414 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.9414}$$

$$= 0.4375\ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 396.94} = 0.8673\ \text{in}$$

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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{396.9414 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 396.9414} + 0$$

$$= 0.0245 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0784 \text{ in}$$

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

$$= \max\left[0.0245,\ 0.0784\right]$$

$$= 0.0784 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.94} + 0$$

$$= 0.7369 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.7369\right]$$

$$= 0.1348 \text{ in}$$

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

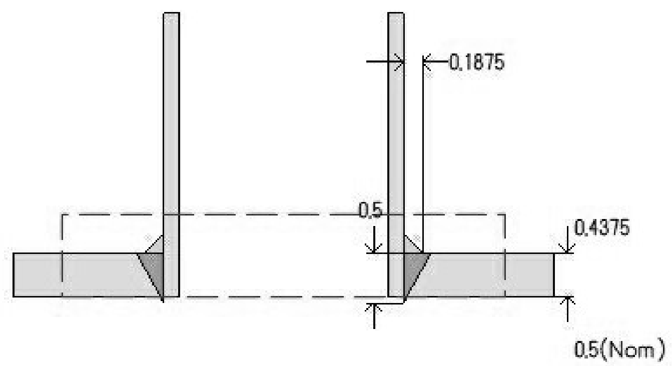
$$= \max\left[0.0784,\ 0.1348\right]$$

$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

PROCESS INLET (F3)

ASME Section VIII Division 1, 2023 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	F&D Head #1
Orientation	120°
End of nozzle to datum line	97.8643"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No
Nozzle	
Service	Process Nozzle (NOZ)
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	2.1983"
Projection available outside vessel, Lpr	5.7148"
Projection available outside vessel to flange face, Lf	5.8688"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.5"
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 300 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
Consider External Loads on Flange MAWP Rating	No
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.154, 0.435\right] =$	0.2156"
$\text{External Leg}_{\ \min} = X_{\min} + \frac{C_o}{0.7} = 0.2156 + \frac{0}{0.7} =$	0.2156"
$\text{Internal Leg}_{\ \min} = \min\left[t_n, 0.25\text{text(")} + \frac{C_i}{0.7}\right] = \min\left[0.154, 0.25 + \frac{0}{0.7}\right] =$	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	
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.085 \cdot 1}{0.1348 - 0} =$	0.6304
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -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 = 150.1 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.3688	0.7407	0.593	0.1125	–	–	0.0352	0.1348	0.1348

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

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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	150.1	-629	4,068	472	4,068	472	3,720	**34,623**	**59,100**	**15,713**	**29,550**	No
Load case 1 (Hot Shut Down)	0	-629	4,068	472	4,068	472	3,720	20,385	59,100	1,475	29,550	No
Load case 1 (Pr Reversed)	150.1	629	4,068	472	4,068	472	3,720	31,691	59,100	14,387	29,550	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	629	4,068	472	4,068	472	3,720	-20,385	59,100	-1,475	29,550	No

Calculations for internal pressure 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.1028 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$

$$= 0.0079 \text{ in}$$

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

t_r = $\dfrac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$

= $\dfrac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$

= $0.1678 \ \text{in}$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \ \text{in}$$

Opening S is too close per UG-36(c)(3)(d) to allow an exemption per UG-36(c)(3)(a). Reinforcement calculations performed.

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

A = $d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$

= $2.1983 \cdot 0.1678 \cdot 1 + 2 \cdot 0.154 \cdot 0.1678 \cdot 1 \cdot (1 - 1)$

= $\underline{0.3688}$ in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{0.593}$ in^2

= $d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2.1983 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1)$

= $0.593 \ \text{in}^2$

= $2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2 \cdot (0.4375 + 0.154) \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1)$

= $0.3191 \ \text{in}^2$

A_2 = smaller of the following= $\underline{0.1125}$ in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$

= $5 \cdot (0.154 - 0.0079) \cdot 1 \cdot 0.4375$

= $0.3196 \ \text{in}^2$

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$

= $5 \cdot (0.154 - 0.0079) \cdot 1 \cdot 0.154$

= $0.1125 \ \text{in}^2$

$$A_{41} = Leg^2 \cdot f_{r2}$$
$$= 0.1875^{\,2} \cdot 1$$
$$= \underline{0.0352}\ \text{in}^2$$

$$Area = A_1 + A_2 + A_{41}$$
$$= 0.593 + 0.1125 + 0.0352$$
$$= \underline{0.7407}\ \text{in}^2$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1078}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$
$$= \frac{150.1028 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$
$$= 0.0093\ \text{in}$$

$$t_{a\text{UG-22}} = 0.0721\ \text{in}$$

$$t_a = \max\left[t_{a\text{UG-27}},\ t_{a\text{UG-22}}\right]$$
$$= \max\left[0.0093,\ 0.0721\right]$$
$$= 0.0721\ \text{in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$
$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$
$$= 0.2826\ \text{in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$
$$= \max\left[0.2826,\ 0.0625\right]$$
$$= 0.2826\ \text{in}$$

$$t_b = \min\left[t_{b3},\ t_{b1}\right]$$
$$= \min\left[0.1348,\ 0.2826\right]$$
$$= 0.1348\ \text{in}$$

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

$$= \max\left[0.0721,\ 0.1348\right]$$

$$= \underline{0.1348} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	150.1 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

Pressure stress intensity factor, $I = 1.8864$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 14{,}238 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 34{,}623 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \text{ psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 15{,}713 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \text{ psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.2018	663	663	663	663	663	663	663	663
SR-2	$\frac{M_x}{P}$	0.1525	3,008	-3,008	3,008	-3,008	3,008	-3,008	3,008	-3,008
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1681	0	0	0	0	-812	-812	812	812
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5447	0	0	0	0	-15,793	15,793	15,793	-15,793
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1681	-812	-812	812	812	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5447	-15,793	15,793	15,793	-15,793	0	0	0	0
Pressure stress*			14,238	14,238	14,238	14,238	14,238	14,238	14,238	14,238
Total O_x stress			1,304	26,874	34,514	-3,088	1,304	26,874	34,514	-3,088
Membrane O_x stress*			14,089	14,089	15,713	15,713	14,089	14,089	15,713	15,713
SR-2*	$\frac{N_y \cdot T}{P}$	0.061	200	200	200	200	200	200	200	200
SR-2	$\frac{M_y}{P}$	0.0461	909	-909	909	-909	909	-909	909	-909
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0512	0	0	0	0	-247	-247	247	247
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1621	0	0	0	0	-4,699	4,699	4,699	-4,699
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0512	-247	-247	247	247	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1621	-4,699	4,699	4,699	-4,699	0	0	0	0
Pressure stress*			14,238	14,238	14,238	14,238	14,238	14,238	14,238	14,238
Total O_y stress			10,401	17,981	20,293	9,077	10,401	17,981	20,293	9,077
Membrane O_y stress*			14,191	14,191	14,685	14,685	14,191	14,191	14,685	14,685
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			10,569	27,046	34,546	12,239	10,450	26,924	34,623	12,419

(1) * denotes primary stress.
(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{150.1 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875^{\ 2} - 1.0335^{\ 2}\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}423 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^2 + 472^2}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \ \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^2 \cdot 0.154} = 3{,}599 \ \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \ \text{psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \ \text{psi})$

Reinforcement Calculations for MAWP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 225.07 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.5532	0.5532	0.4086	0.1094	–	–	0.0352	0.1348	0.1348

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

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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	225.07	-629	4,068	472	4,068	472	3,720	**41,735**	**59,100**	**22,825**	**29,550**	No
Load case 1 (Pr Reversed)	225.07	629	4,068	472	4,068	472	3,720	38,803	59,100	21,499	29,550	No

Calculations for internal pressure 225.07 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{225.0739 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 225.0739}$$

$$= 0.0119 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{225.0739 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 225.0739}$$

$$= 0.2516 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{225.07 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 225.07} = 0.4987 \text{ in}$$

Opening S is too close per UG-36(c)(3)(d) to allow an exemption per UG-36(c)(3)(a). Reinforcement calculations performed.

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$

$$= 2.1983 \cdot 0.2516 \cdot 1 + 2 \cdot 0.154 \cdot 0.2516 \cdot 1 \cdot (1 - 1)$$

= 0.5532 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.4086 in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2.1983 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) \cdot (1 - 1)$$

$$= 0.4086 \text{ in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (0.4375 + 0.154) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) \cdot (1 - 1)$$

$$= 0.2199 \text{ in}^2$$

A_2 = smaller of the following= 0.1094 in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (0.154 - 0.0119) \cdot 1 \cdot 0.4375$$

$$= 0.3108 \text{ in}^2$$

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$$

$$= 5 \cdot (0.154 - 0.0119) \cdot 1 \cdot 0.154$$

$$= 0.1094 \text{ in}^2$$

$$A_{41} = Leg^2 \cdot f_{r2}$$
$$= 0.1875^{\ 2} \cdot 1$$
$$= \underline{0.0352}\ \text{in}^2$$

$$Area = A_1 + A_2 + A_{41}$$
$$= 0.4086 + 0.1094 + 0.0352$$
$$= \underline{0.5532}\ \text{in}^2$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1078}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$
$$= \frac{225.0739 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 225.0739} + 0$$
$$= 0.014\ \text{in}$$

$$t_{a\text{UG-22}} = 0.0744\ \text{in}$$

$$t_a = \max\left[t_{a\text{UG-27}},\ t_{a\text{UG-22}}\right]$$
$$= \max\left[0.014,\ 0.0744\right]$$
$$= 0.0744\ \text{in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$
$$= \frac{225.07 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 225.07} + 0$$
$$= 0.4238\ \text{in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$
$$= \max\left[0.4238,\ 0.0625\right]$$
$$= 0.4238\ \text{in}$$

$$t_b = \min\left[t_{b3},\ t_{b1}\right]$$
$$= \min\left[0.1348,\ 0.4238\right]$$
$$= 0.1348\ \text{in}$$

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

$$= \max\left[0.0744,\ 0.1348\right]$$

$$= \underline{0.1348} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	225.07 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

Pressure stress intensity factor, $I = 1.8864$ (derived from Division 2 Part 4.5)

Local pressure stress = $\frac{I \cdot P \cdot R_i}{2 \cdot T} = 21{,}350 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 41{,}735 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \text{ psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 22{,}825 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \text{ psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.2018	663	663	663	663	663	663	663	663
SR-2	$\frac{M_x}{P}$	0.1525	3,008	-3,008	3,008	-3,008	3,008	-3,008	3,008	-3,008
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1681	0	0	0	0	-812	-812	812	812
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5447	0	0	0	0	-15,793	15,793	15,793	-15,793
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1681	-812	-812	812	812	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5447	-15,793	15,793	15,793	-15,793	0	0	0	0
Pressure stress*			21,350	21,350	21,350	21,350	21,350	21,350	21,350	21,350
Total O_x stress			8,416	33,986	41,626	4,024	8,416	33,986	41,626	4,024
Membrane O_x stress*			21,201	21,201	22,825	22,825	21,201	21,201	22,825	22,825
SR-2*	$\frac{N_y \cdot T}{P}$	0.061	200	200	200	200	200	200	200	200
SR-2	$\frac{M_y}{P}$	0.0461	909	-909	909	-909	909	-909	909	-909
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0512	0	0	0	0	-247	-247	247	247
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1621	0	0	0	0	-4,699	4,699	4,699	-4,699
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0512	-247	-247	247	247	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1621	-4,699	4,699	4,699	-4,699	0	0	0	0
Pressure stress*			21,350	21,350	21,350	21,350	21,350	21,350	21,350	21,350
Total O_y stress			17,513	25,093	27,405	16,189	17,513	25,093	27,405	16,189
Membrane O_y stress*			21,303	21,303	21,797	21,797	21,303	21,303	21,797	21,797
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			17,681	34,158	41,658	16,226	17,562	34,036	41,735	16,316

(1) * denotes primary stress.
(2) The nozzle is assumed to be a rigid (solid) attachment.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{225.07 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875^{\ 2} - 1.0335^{\ 2}\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}710 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^{\,2} + 472^{\,2}}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^{\,2} \cdot 0.154} = 3{,}599 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \quad \text{psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 228.5 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.5532	0.5532	0.4086	0.1094	–	–	0.0352	0.1348	0.1348

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

Calculations for internal pressure 228.5 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{228.5031 \cdot 1.0335}{20{,}000 \cdot 1 - 0.6 \cdot 228.5031}$$

$$= 0.0119 \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{228.5031 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 228.5031}$$

$$= 0.2516 \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{228.5 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 228.5} = 0.4988 \ \text{in}$$

Opening S is too close per UG-36(c)(3)(d) to allow an exemption per UG-36(c)(3)(a). Reinforcement calculations performed.

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000 psi

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

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

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$

$$= 2.1983 \cdot 0.2516 \cdot 1 + 2 \cdot 0.154 \cdot 0.2516 \cdot 1 \cdot (1 - 1)$$

$$= \underline{0.5532} \text{ in}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{0.4086}$ in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2.1983 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) \cdot (1 - 1)$$

$$= 0.4086 \text{ in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (0.4375 + 0.154) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) \cdot (1 - 1)$$

$$= 0.2199 \text{ in}^2$$

A_2 = smaller of the following= $\underline{0.1094}$ in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (0.154 - 0.0119) \cdot 1 \cdot 0.4375$$

$$= 0.3108 \text{ in}^2$$

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$$

$$= 5 \cdot (0.154 - 0.0119) \cdot 1 \cdot 0.154$$

$$= 0.1094 \text{ in}^2$$

$$A_{41} = Leg^2 \cdot f_{r2}$$

$$= 0.1875^{\ 2} \cdot 1$$

$$= \underline{0.0352} \text{ in}^2$$

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

$$= 0.4086 + 0.1094 + 0.0352$$

$$= \underline{0.5532} \text{ in}^2$$

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{228.5031 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 228.5031} + 0$$

$$= 0.014 \ \text{in}$$

$$t_{a\text{UG-22}} = 0.0733 \ \text{in}$$

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

$$= \max\left[0.014,\ 0.0733\right]$$

$$= 0.0733 \ \text{in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{228.5 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 228.5} + 0$$

$$= 0.4239 \ \text{in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.4239,\ 0.0625\right]$$

$$= 0.4239 \ \text{in}$$

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

$$= \min\left[0.1348,\ 0.4239\right]$$

$$= 0.1348 \ \text{in}$$

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

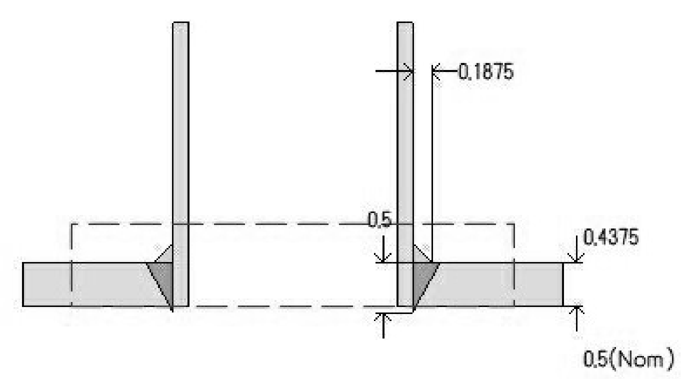
$$= \max\left[0.0733,\ 0.1348\right]$$

$$= \underline{0.1348} \ \text{in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.154 = 0.1348$ in

The nozzle neck thickness is adequate.

PROCESS INLET (F1)

ASME Section VIII Division 1, 2023 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	F&D Head #1
Orientation	150°
End of nozzle to datum line	97.8643"
Calculated as hillside	Yes
Distance to head center, R	15"
Passes through a Category A joint	No
Nozzle	
Service	Process Nozzle (NOZ)
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	2.1983"
Projection available outside vessel, Lpr	5.7148"
Projection available outside vessel to flange face, Lf	5.8688"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.1 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.5"
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 300 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
Consider External Loads on Flange MAWP Rating	No
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.154, 0.435\right] =$	0.2156"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.2156 + \frac{0}{0.7} =$	0.2156"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text(")} + \frac{C_i}{0.7}\right] = \min\left[0.154, 0.25 + \frac{0}{0.7}\right] =$	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	
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.085 \cdot 1}{0.1348 - 0} =$	0.6304
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -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 = 150.1 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.3688	0.7407	0.593	0.1125	–	–	0.0352	0.1348	0.1348

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

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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	150.1	-629	4,068	472	4,068	472	3,720	**34,623**	**59,100**	**15,713**	**29,550**	No
Load case 1 (Hot Shut Down)	0	-629	4,068	472	4,068	472	3,720	20,385	59,100	1,475	29,550	No
Load case 1 (Pr Reversed)	150.1	629	4,068	472	4,068	472	3,720	31,691	59,100	14,387	29,550	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	629	4,068	472	4,068	472	3,720	-20,385	59,100	-1,475	29,550	No

Calculations for internal pressure 150.1 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.1028 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 150.1028}$$

$$= 0.0079 \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.1028 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1028}$$

$$= 0.1678 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.1} = 0.3325 \text{ in}$$

Opening P1 is too close per UG-36(c)(3)(d) to allow an exemption per UG-36(c)(3)(a). Reinforcement calculations performed.

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$

$$= 2.1983 \cdot 0.1678 \cdot 1 + 2 \cdot 0.154 \cdot 0.1678 \cdot 1 \cdot (1 - 1)$$

$= \underline{0.3688}$ in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{0.593}$ in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2.1983 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1)$$

$$= 0.593 \text{ in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (0.4375 + 0.154) \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.1678) \cdot (1 - 1)$$

$$= 0.3191 \text{ in}^2$$

A_2 = smaller of the following= $\underline{0.1125}$ in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (0.154 - 0.0079) \cdot 1 \cdot 0.4375$$

$$= 0.3196 \text{ in}^2$$

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$$

$$= 5 \cdot (0.154 - 0.0079) \cdot 1 \cdot 0.154$$

$$= 0.1125 \text{ in}^2$$

A_{41} = $Leg^2 \cdot f_{r2}$

= $0.1875^{\ 2} \cdot 1$

= $\underline{0.0352}$ in^2

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

$= 0.593 + 0.1125 + 0.0352$

$= \underline{0.7407}$ in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1078}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1028 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 150.1028} + 0$$

$$= 0.0093 \ \text{in}$$

$$t_{a\text{UG-22}} = 0.0721 \ \text{in}$$

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

$$= \max\left[0.0093,\ 0.0721\right]$$

$$= 0.0721 \ \text{in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.1 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.1} + 0$$

$$= 0.2826 \ \text{in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2826,\ 0.0625\right]$$

$$= 0.2826 \ \text{in}$$

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

$$= \min\left[0.1348,\ 0.2826\right]$$

$$= 0.1348 \ \text{in}$$

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

$$= \max\left[0.0721,\ 0.1348\right]$$

$$= \underline{0.1348} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	150.1 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

Pressure stress intensity factor, $I = 1.8864$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 14{,}238 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 34{,}623 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \text{ psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 15{,}713 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \text{ psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.2018	663	663	663	663	663	663	663	663
SR-2	$\frac{M_x}{P}$	0.1525	3,008	-3,008	3,008	-3,008	3,008	-3,008	3,008	-3,008
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1681	0	0	0	0	-812	-812	812	812
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5447	0	0	0	0	-15,793	15,793	15,793	-15,793
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1681	-812	-812	812	812	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5447	-15,793	15,793	15,793	-15,793	0	0	0	0
Pressure stress*			14,238	14,238	14,238	14,238	14,238	14,238	14,238	14,238
Total O_x stress			1,304	26,874	34,514	-3,088	1,304	26,874	34,514	-3,088
Membrane O_x stress*			14,089	14,089	15,713	15,713	14,089	14,089	15,713	15,713
SR-2*	$\frac{N_y \cdot T}{P}$	0.061	200	200	200	200	200	200	200	200
SR-2	$\frac{M_y}{P}$	0.0461	909	-909	909	-909	909	-909	909	-909
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0512	0	0	0	0	-247	-247	247	247
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1621	0	0	0	0	-4,699	4,699	4,699	-4,699
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0512	-247	-247	247	247	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1621	-4,699	4,699	4,699	-4,699	0	0	0	0
Pressure stress*			14,238	14,238	14,238	14,238	14,238	14,238	14,238	14,238
Total O_y stress			10,401	17,981	20,293	9,077	10,401	17,981	20,293	9,077
Membrane O_y stress*			14,191	14,191	14,685	14,685	14,191	14,191	14,685	14,685
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			10,569	27,046	34,546	12,239	10,450	26,924	34,623	12,419
(1) * denotes primary stress. (2) The nozzle is assumed to be a rigid (solid) attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{150.1 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875\ ^2 - 1.0335\ ^2\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}423 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^2 + 472^2}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^2 \cdot 0.154} = 3{,}599 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \quad \text{psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAWP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 225.07 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.5532	0.5532	0.4086	0.1094	–	–	0.0352	0.1348	0.1348

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

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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	225.07	-629	4,068	472	4,068	472	3,720	**41,735**	**59,100**	**22,825**	**29,550**	No
Load case 1 (Pr Reversed)	225.07	629	4,068	472	4,068	472	3,720	38,803	59,100	21,499	29,550	No

Calculations for internal pressure 225.07 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{225.0739 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 225.0739}$$

$$= 0.0119 \text{ in}$$

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

t_r = $\dfrac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$

= $\dfrac{225.0739 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 225.0739}$

= 0.2516 in

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{225.07 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 225.07} = 0.4987 \text{ in}$$

Opening P1 is too close per UG-36(c)(3)(d) to allow an exemption per UG-36(c)(3)(a). Reinforcement calculations performed.

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

A = $d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$

= $2.1983 \cdot 0.2516 \cdot 1 + 2 \cdot 0.154 \cdot 0.2516 \cdot 1 \cdot (1 - 1)$

= 0.5532 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.4086 in^2

= $d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2.1983 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) \cdot (1 - 1)$

= 0.4086 in^2

= $2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2 \cdot (0.4375 + 0.154) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) \cdot (1 - 1)$

= 0.2199 in^2

A_2 = smaller of the following= 0.1094 in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$

= $5 \cdot (0.154 - 0.0119) \cdot 1 \cdot 0.4375$

= 0.3108 in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$

= $5 \cdot (0.154 - 0.0119) \cdot 1 \cdot 0.154$

= 0.1094 in^2

$$A_{41} = Leg^2 \cdot f_{r2}$$
$$= 0.1875^{\ 2} \cdot 1$$
$$= \underline{0.0352} \text{ in}^2$$

$$Area = A_1 + A_2 + A_{41}$$
$$= 0.4086 + 0.1094 + 0.0352$$
$$= \underline{0.5532} \text{ in}^2$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1078}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$
$$= \frac{225.0739 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 225.0739} + 0$$
$$= 0.014 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0744 \text{ in}$$

$$t_a = \max\left[t_{a\text{UG-27}},\ t_{a\text{UG-22}}\right]$$
$$= \max\left[0.014,\ 0.0744\right]$$
$$= 0.0744 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$
$$= \frac{225.07 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 225.07} + 0$$
$$= 0.4238 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$
$$= \max\left[0.4238,\ 0.0625\right]$$
$$= 0.4238 \text{ in}$$

$$t_b = \min\left[t_{b3},\ t_{b1}\right]$$
$$= \min\left[0.1348,\ 0.4238\right]$$
$$= 0.1348 \text{ in}$$

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

$$= \max[0.0744,\ 0.1348]$$

$$= \underline{0.1348} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	225.07 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

Pressure stress intensity factor, $I = 1.8864$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 21{,}350 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 41{,}735 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \text{ psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 22{,}825 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \text{ psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.2018	663	663	663	663	663	663	663	663
SR-2	$\frac{M_x}{P}$	0.1525	3,008	-3,008	3,008	-3,008	3,008	-3,008	3,008	-3,008
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1681	0	0	0	0	-812	-812	812	812
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5447	0	0	0	0	-15,793	15,793	15,793	-15,793
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1681	-812	-812	812	812	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5447	-15,793	15,793	15,793	-15,793	0	0	0	0
Pressure stress*			21,350	21,350	21,350	21,350	21,350	21,350	21,350	21,350
Total O_x stress			8,416	33,986	41,626	4,024	8,416	33,986	41,626	4,024
Membrane O_x stress*			21,201	21,201	22,825	22,825	21,201	21,201	22,825	22,825
SR-2*	$\frac{N_y \cdot T}{P}$	0.061	200	200	200	200	200	200	200	200
SR-2	$\frac{M_y}{P}$	0.0461	909	-909	909	-909	909	-909	909	-909
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0512	0	0	0	0	-247	-247	247	247
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1621	0	0	0	0	-4,699	4,699	4,699	-4,699
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0512	-247	-247	247	247	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1621	-4,699	4,699	4,699	-4,699	0	0	0	0
Pressure stress*			21,350	21,350	21,350	21,350	21,350	21,350	21,350	21,350
Total O_y stress			17,513	25,093	27,405	16,189	17,513	25,093	27,405	16,189
Membrane O_y stress*			21,303	21,303	21,797	21,797	21,303	21,303	21,797	21,797
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			17,681	34,158	41,658	16,226	17,562	34,036	41,735	16,316
(1) * denotes primary stress. (2) The nozzle is assumed to be a rigid (solid) attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{225.07 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875\ ^2 - 1.0335\ ^2\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}710 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^{\,2} + 472^{\,2}}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^{\,2} \cdot 0.154} = 3{,}599 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \quad \text{psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 228.5 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.5532	0.5532	0.4086	0.1094	–	–	0.0352	0.1348	0.1348

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

Calculations for internal pressure 228.5 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.1983,\ 1.0992 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.1983 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{228.5031 \cdot 1.0335}{20{,}000 \cdot 1 - 0.6 \cdot 228.5031}$$

$$= 0.0119 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{228.5031 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 228.5031}$$

$$= 0.2516 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{228.5 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 228.5} = 0.4988 \text{ in}$$

Opening P1 is too close per UG-36(c)(3)(d) to allow an exemption per UG-36(c)(3)(a). Reinforcement calculations performed.

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000 psi

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

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

A = $d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$

= $2.1983 \cdot 0.2516 \cdot 1 + 2 \cdot 0.154 \cdot 0.2516 \cdot 1 \cdot (1 - 1)$

= 0.5532 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.4086 in^2

= $d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2.1983 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) \cdot (1 - 1)$

= $0.4086 \ \ \mathrm{in}^2$

= $2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2 \cdot (0.4375 + 0.154) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) - 2 \cdot 0.154 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2516) \cdot (1 - 1)$

= $0.2199 \ \ \mathrm{in}^2$

A_2 = smaller of the following= 0.1094 in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$

= $5 \cdot (0.154 - 0.0119) \cdot 1 \cdot 0.4375$

= $0.3108 \ \ \mathrm{in}^2$

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$

= $5 \cdot (0.154 - 0.0119) \cdot 1 \cdot 0.154$

= $0.1094 \ \ \mathrm{in}^2$

A_{41} = $Leg^2 \cdot f_{r2}$

= $0.1875^{\ 2} \cdot 1$

= 0.0352 in^2

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

$= 0.4086 + 0.1094 + 0.0352$

= 0.5532 in^2

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{228.5031 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 228.5031} + 0$$

$$= 0.014 \quad \text{in}$$

$$t_{a\text{UG-22}} = 0.0733 \quad \text{in}$$

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

$$= \max\left[0.014,\ 0.0733\right]$$

$$= 0.0733 \quad \text{in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{228.5 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 228.5} + 0$$

$$= 0.4239 \quad \text{in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.4239,\ 0.0625\right]$$

$$= 0.4239 \quad \text{in}$$

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

$$= \min\left[0.1348,\ 0.4239\right]$$

$$= 0.1348 \quad \text{in}$$

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

$$= \max\left[0.0733,\ 0.1348\right]$$

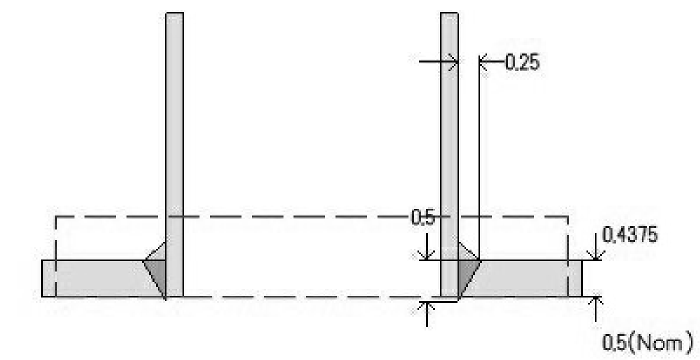
$$= \underline{0.1348} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

VENT (V)

ASME Section VIII Division 1, 2023 Edition	



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

Location and Orientation	
Located on	F&D Head #1
Orientation	0°
End of nozzle to datum line	100.8438"
Calculated as hillside	No
Distance to head center, R	0"
Passes through a Category A joint	No
Nozzle	
Service	Level Indicator (LEVEL)
Description	NPS 3 Sch 40S (Std)
Access opening	No
Material specification	SA-312 TP316 Wld pipe (II-D p. 76, ln. 29)
Inside diameter, new	3.068"
Pipe nominal wall thickness	0.216"
Pipe minimum wall thickness[1]	0.189"
Corrosion allowance	0"
Projection available outside vessel, Lpr	6.4657"
Projection available outside vessel to flange face, Lf	6.6817"
Local vessel minimum thickness	0.4375"
Liquid static head included	0.01 psi
Welds	
Inner fillet, Leg_{41}	0.25"
Nozzle to vessel groove weld	0.5"
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 3 Class 300 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
Consider External Loads on Flange MAWP Rating	No
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 psi @ 70°F
External fillet weld leg (UW-21)	0.3318" (0.3024" min)
Internal fillet weld leg (UW-21)	0.216" (0.216" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.216, 0.525\right] =$	0.3024"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.3024 + \frac{0}{0.7} =$	0.3024"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text(")}) + \frac{C_i}{0.7}\right] = \min\left[0.216, 0.25 + \frac{0}{0.7}\right] =$	0.216"
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	
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0872 \cdot 1}{0.189 - 0} =$	0.4614
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -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 = 150.01 psi @ 350 °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)							0.189	0.189

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})	0.1512	0.175	weld size is adequate

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	150.01	-944	9,144	708	9,144	708	8,364	**40,875**	**59,100**	**15,782**	**29,550**	No
Load case 1 (Hot Shut Down)	0	-944	9,144	708	9,144	708	8,364	27,637	59,100	2,544	29,550	No
Load case 1 (Pr Reversed)	150.01	944	9,144	708	9,144	708	8,364	35,806	59,100	14,188	29,550	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	944	9,144	708	9,144	708	8,364	-27,637	59,100	-2,544	29,550	No

Calculations for internal pressure 150.01 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[3.068,\ 1.534 + (0.216 - 0) + (0.4375 - 0)\right]$$

$$= 3.068 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.216 - 0) + 0\right]$$

$$= 0.54 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{150.0087 \cdot 1.534}{19{,}700 \cdot 1 - 0.6 \cdot 150.0087}$$

$$= 0.0117 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{150.0087 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.0087}$$

$$= 0.1677 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{150.01 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 150.01} = 0.3323 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.216 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ <u>0.1512</u> in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175 \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{150.0087 \cdot 1.534}{16{,}700 \cdot 1 - 0.6 \cdot 150.0087} + 0$$

$$= 0.0139 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0745 \text{ in}$$

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

$$= \max\left[0.0139,\ 0.0745\right]$$

$$= 0.0745 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{150.01 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 150.01} + 0$$

$$= 0.2824 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2824,\ 0.0625\right]$$

$$= 0.2824 \text{ in}$$

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

$$= \min\left[0.189,\ 0.2824\right]$$

$$= 0.189 \ \text{in}$$

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

$$= \max\left[0.0745,\ 0.189\right]$$

$$= \underline{0.189} \ \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.216$ = 0.189 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-944 lb_f
Circumferential moment, M_1	9,144 lb_f-in
Circumferential shear, V_2	708 lb_f
Longitudinal moment, M_2	9,144 lb_f-in
Longitudinal shear, V_1	708 lb_f
Torsion moment, M_t	8,364 lb_f-in
Internal pressure, P	150.01 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.75}{\sqrt{44.2188 \cdot 0.4375}} = 0.398$$

Pressure stress intensity factor, $I = 1.755$ (derived from Division 2 Part 4.5)

Local pressure stress = $\frac{I \cdot P \cdot R_i}{2 \cdot T} = 13{,}238 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 40{,}875 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \text{ psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 15{,}782 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \text{ psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SR-2*	$\frac{N_x \cdot T}{P}$	0.1616	797	797	797	797	797	797	797	797
SR-2	$\frac{M_x}{P}$	0.106	3,136	-3,136	3,136	-3,136	3,136	-3,136	3,136	-3,136
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1609	0	0	0	0	-1,747	-1,747	1,747	1,747
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.3356	0	0	0	0	-21,871	21,871	21,871	-21,871
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1609	-1,747	-1,747	1,747	1,747	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.3356	-21,871	21,871	21,871	-21,871	0	0	0	0
Pressure stress*			13,238	13,238	13,238	13,238	13,238	13,238	13,238	13,238
Total O_x stress			-6,447	31,023	40,789	-9,225	-6,447	31,023	40,789	-9,225
Membrane O_x stress*			12,288	12,288	15,782	15,782	12,288	12,288	15,782	15,782
SR-2*	$\frac{N_y \cdot T}{P}$	0.0485	239	239	239	239	239	239	239	239
SR-2	$\frac{M_y}{P}$	0.0325	961	-961	961	-961	961	-961	961	-961
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0491	0	0	0	0	-534	-534	534	534
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1005	0	0	0	0	-6,552	6,552	6,552	-6,552
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0491	-534	-534	534	534	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1005	-6,552	6,552	6,552	-6,552	0	0	0	0
Pressure stress*			13,238	13,238	13,238	13,238	13,238	13,238	13,238	13,238
Total O_y stress			7,352	18,534	21,524	6,498	7,352	18,534	21,524	6,498
Membrane O_y stress*			12,943	12,943	14,011	14,011	12,943	12,943	14,011	14,011
Shear from M_t			994	994	994	994	994	994	994	994
Shear from V_1			0	0	0	0	-294	-294	294	294
Shear from V_2			294	294	-294	-294	0	0	0	0
Total Shear stress			1,288	1,288	700	700	700	700	1,288	1,288
Combined stress (P_L+P_b+Q)			14,037	31,154	40,814	15,785	13,870	31,062	40,875	15,933
(1) * denotes primary stress. (2) The nozzle is assumed to be a rigid (solid) attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{150.01 \cdot 1.534}{2 \cdot 0.189} - \frac{-944}{\pi \cdot \left(1.75^{\ 2} - 1.534^{\ 2}\right)} + \frac{12{,}931.6 \cdot 1.75}{3.0172}$$

$$= 8{,}533 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{708^{\,2} + 708^{\,2}}}{\pi \cdot 1.534 \cdot 0.216} = 962 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{8{,}364}{2 \cdot \pi \cdot 1.534^{\,2} \cdot 0.216} = 2{,}619 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 962 + 2{,}619 = 3{,}581 \quad \text{psi}$$

UG-45: The total combined shear stress (3,581 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAWP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 235.83 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.809	0.8091	0.5333	0.2133	–	–	0.0625	0.189	0.189

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1512	0.175	weld size is adequate

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	235.83	-944	9,144	708	9,144	708	8,364	**48,449**	**59,100**	**23,356**	**29,550**	No
Load case 1 (Pr Reversed)	235.83	944	9,144	708	9,144	708	8,364	43,380	59,100	21,762	29,550	No

Calculations for internal pressure 235.83 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[3.068,\ 1.534 + (0.216 - 0) + (0.4375 - 0)\right]$$

$$= 3.068 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.216 - 0) + 0\right]$$

$$= 0.54 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{235.8295 \cdot 1.534}{19{,}700 \cdot 1 - 0.6 \cdot 235.8295}$$

$$= 0.0185 \text{ in}$$

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

t_r = $\dfrac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$

= $\dfrac{235.8295 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 235.8295}$

= $0.2637 \;\; \text{in}$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} \;\; = \frac{235.83 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 235.83} \;\; = 0.5226 \;\; \text{in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700 psi

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

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

A = $d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$

= $3.068 \cdot 0.2637 \cdot 1 + 2 \cdot 0.216 \cdot 0.2637 \cdot 1 \cdot (1 - 1)$

= 0.809 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.5333 in^2

= $d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $3.068 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2637) - 2 \cdot 0.216 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2637) \cdot (1 - 1)$

= $0.5333 \;\; \text{in}^2$

= $2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2 \cdot (0.4375 + 0.216) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2637) - 2 \cdot 0.216 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2637) \cdot (1 - 1)$

= $0.2272 \;\; \text{in}^2$

A_2 = smaller of the following= 0.2133 in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$

= $5 \cdot (0.216 - 0.0185) \cdot 1 \cdot 0.4375$

= $0.432 \;\; \text{in}^2$

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n$

= $5 \cdot (0.216 - 0.0185) \cdot 1 \cdot 0.216$

= $0.2133 \;\; \text{in}^2$

A_{41} = $Leg^2 \cdot f_{r2}$

= $0.25^{\,2} \cdot 1$

= $\underline{0.0625}$ in^2

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

$= 0.5333 + 0.2133 + 0.0625$

$= \underline{0.8091}$ in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.216 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.1512}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175\ \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$

$= \frac{235.8295 \cdot 1.534}{16{,}700 \cdot 1 - 0.6 \cdot 235.8295} + 0$

$= 0.0218\ \text{ in}$

$t_{a\text{UG-22}} = 0.0783\ \text{ in}$

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

$= \max\left[0.0218,\ 0.0783\right]$

$= 0.0783\ \text{ in}$

$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$

$= \frac{235.83 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 235.83} + 0$

$= 0.4441\ \text{ in}$

$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$

$= \max\left[0.4441,\ 0.0625\right]$

$= 0.4441\ \text{ in}$

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

$= \min\left[0.189,\ 0.4441\right]$

$= 0.189\ \text{ in}$

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

$$= \max\left[0.0783,\ 0.189\right]$$

$$= \underline{0.189} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.216$ = 0.189 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-944 lb_f
Circumferential moment, M_1	9,144 lb_f-in
Circumferential shear, V_2	708 lb_f
Longitudinal moment, M_2	9,144 lb_f-in
Longitudinal shear, V_1	708 lb_f
Torsion moment, M_t	8,364 lb_f-in
Internal pressure, P	235.83 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.75}{\sqrt{44.2188 \cdot 0.4375}} = 0.398$$

Pressure stress intensity factor, $I = 1.755$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 20{,}812 \ \text{psi}$

Maximum combined stress $(P_L + P_b + Q) = 48{,}449 \ \text{psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \ \text{psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 23{,}356 \ \text{psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \ \text{psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
SR-2*	$\frac{N_x \cdot T}{P}$	0.1616	797	797	797	797	797	797	797	797
SR-2	$\frac{M_x}{P}$	0.106	3,136	-3,136	3,136	-3,136	3,136	-3,136	3,136	-3,136
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1609	0	0	0	0	-1,747	-1,747	1,747	1,747
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.3356	0	0	0	0	-21,871	21,871	21,871	-21,871
SR-3*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1609	-1,747	-1,747	1,747	1,747	0	0	0	0
SR-3	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.3356	-21,871	21,871	21,871	-21,871	0	0	0	0
Pressure stress*			20,812	20,812	20,812	20,812	20,812	20,812	20,812	20,812
Total O_x stress			1,127	38,597	48,363	-1,651	1,127	38,597	48,363	-1,651
Membrane O_x stress*			19,862	19,862	23,356	23,356	19,862	19,862	23,356	23,356
SR-2*	$\frac{N_y \cdot T}{P}$	0.0485	239	239	239	239	239	239	239	239
SR-2	$\frac{M_y}{P}$	0.0325	961	-961	961	-961	961	-961	961	-961
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.0491	0	0	0	0	-534	-534	534	534
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1005	0	0	0	0	-6,552	6,552	6,552	-6,552
SR-3*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.0491	-534	-534	534	534	0	0	0	0
SR-3	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1005	-6,552	6,552	6,552	-6,552	0	0	0	0
Pressure stress*			20,812	20,812	20,812	20,812	20,812	20,812	20,812	20,812
Total O_y stress			14,926	26,108	29,098	14,072	14,926	26,108	29,098	14,072
Membrane O_y stress*			20,517	20,517	21,585	21,585	20,517	20,517	21,585	21,585
Shear from M_t			994	994	994	994	994	994	994	994
Shear from V_1			0	0	0	0	-294	-294	294	294
Shear from V_2			294	294	-294	-294	0	0	0	0
Total Shear stress			1,288	1,288	700	700	700	700	1,288	1,288
Combined stress (P_L+P_b+Q)			15,045	38,728	48,388	15,785	14,961	38,636	48,449	15,933
(1) * denotes primary stress. (2) The nozzle is assumed to be a rigid (solid) attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{235.83 \cdot 1.534}{2 \cdot 0.189} - \frac{-944}{\pi \cdot \left(1.75^{\,2} - 1.534^{\,2}\right)} + \frac{12{,}931.6 \cdot 1.75}{3.0172}$$

$$= 8{,}881 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{708^2 + 708^2}}{\pi \cdot 1.534 \cdot 0.216} = 962 \quad \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{8{,}364}{2 \cdot \pi \cdot 1.534^2 \cdot 0.216} = 2{,}619 \quad \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 962 + 2{,}619 = 3{,}581 \quad \text{psi}$$

UG-45: The total combined shear stress (3,581 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \quad \text{psi})$

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 239.42 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.809	0.8091	0.5333	0.2133	–	–	0.0625	0.189	0.189

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

Calculations for internal pressure 239.42 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[3.068,\ 1.534 + (0.216 - 0) + (0.4375 - 0)\right]$$

$$= 3.068 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.216 - 0) + 0\right]$$

$$= 0.54 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{239.4186 \cdot 1.534}{20{,}000 \cdot 1 - 0.6 \cdot 239.4186}$$

$$= 0.0185 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{239.4186 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 239.4186}$$

$$= 0.2637 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{239.42 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 239.42} = 0.5226 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000 psi

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

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

$$
\begin{aligned}
A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\
&= 3.068 \cdot 0.2637 \cdot 1 + 2 \cdot 0.216 \cdot 0.2637 \cdot 1 \cdot (1 - 1) \\
&= \underline{0.809} \text{ in}^2
\end{aligned}
$$

Area available from FIG. UG-37.1

A_1 = larger of the following= $\underline{0.5333}$ in^2

$$
\begin{aligned}
&= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
&= 3.068 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2637) - 2 \cdot 0.216 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2637) \cdot (1 - 1) \\
&= 0.5333 \quad \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
&= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\
&= 2 \cdot (0.4375 + 0.216) \cdot (1 \cdot 0.4375 - 1 \cdot 0.2637) - 2 \cdot 0.216 \cdot (1 \cdot 0.4375 - 1 \cdot 0.2637) \cdot (1 - 1) \\
&= 0.2272 \quad \text{in}^2
\end{aligned}
$$

A_2 = smaller of the following= $\underline{0.2133}$ in^2

$$
\begin{aligned}
&= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\
&= 5 \cdot (0.216 - 0.0185) \cdot 1 \cdot 0.4375 \\
&= 0.432 \quad \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
&= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n \\
&= 5 \cdot (0.216 - 0.0185) \cdot 1 \cdot 0.216 \\
&= 0.2133 \quad \text{in}^2
\end{aligned}
$$

$$
\begin{aligned}
A_{41} &= Leg^2 \cdot f_{r2} \\
&= 0.25\ ^2 \cdot 1 \\
&= \underline{0.0625} \text{ in}^2
\end{aligned}
$$

$$
\begin{aligned}
Area &= A_1 + A_2 + A_{41} \\
&= 0.5333 + 0.2133 + 0.0625 \\
&= \underline{0.8091} \text{ in}^2
\end{aligned}
$$

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$
\begin{aligned}
t_{a\text{UG-27}} &= \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion} \\
&= \frac{239.4186 \cdot 1.534}{17{,}000 \cdot 1 - 0.6 \cdot 239.4186} + 0 \\
&= 0.0218 \quad \text{in}
\end{aligned}
$$

$$t_{a\text{UG-22}} = 0.0772 \text{ in}$$

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

$$= \max\left[0.0218,\ 0.0772\right]$$

$$= 0.0772 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{239.42 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 239.42} + 0$$

$$= 0.4441 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.4441,\ 0.0625\right]$$

$$= 0.4441 \text{ in}$$

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

$$= \min\left[0.189,\ 0.4441\right]$$

$$= 0.189 \text{ in}$$

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

$$= \max\left[0.0772,\ 0.189\right]$$

$$= \underline{0.189} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.216$ = 0.189 in

The nozzle neck thickness is adequate.

Cylinder #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		150	350	-20
Static Liquid Head				
Condition		**P_S (psi)**	**H_S (in)**	**SG**
Operating		1.66	46	1
Test horizontal		1.59	44	1
Dimensions				
Inner Diameter		44"		
Length		36"		
Nominal Thickness		0.25"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		362.83		236.97
Corroded		362.83		236.97
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	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.2436"
Design thickness due to combined loadings + corrosion	0.0995"
Maximum allowable working pressure (MAWP)	153.98 psi
Maximum allowable pressure (MAP)	158.01 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \dfrac{151.66 \cdot 22}{20{,}000 \cdot 0.7 - 0.6 \cdot 151.66} =$	0.2399"
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0.2399 \cdot 0.8}{0.25 - 0} =$	0.7676
$\text{Stress ratio longitudinal} = \dfrac{5{,}472 \cdot 0.8}{20{,}000 \cdot 0.7} =$	0.3127
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F	
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 350 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{151.66 \cdot 22}{19{,}700 \cdot 0.70 - 0.60 \cdot 151.66} + 0 = \underline{0.2436}"$$

Maximum allowable working pressure, (at 350 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}700 \cdot 0.70 \cdot 0.25}{22 + 0.60 \cdot 0.25} - 1.66 = \underline{153.98} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 0.70 \cdot 0.25}{22 + 0.60 \cdot 0.25} = \underline{158.01} \text{ psi}$$

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

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.25}{22.125}\right) \cdot \left(1 - \frac{22.125}{\infty}\right) = 0.565\,\%$$

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	150	19,700	9,743	350	0	Wind	0.0995	0.099
						Seismic	0.0994	0.0991
Operating, Hot & New	150	19,700	9,743	350	0	Wind	0.0995	0.099
						Seismic	0.0994	0.0991
Hot Shut Down, Corroded	0	19,700	9,743	350	0	Wind	0.0001	0.0007
						Seismic	0.0002	0.0006
Hot Shut Down, New	0	19,700	9,743	350	0	Wind	0.0001	0.0007
						Seismic	0.0002	0.0006
Empty, Corroded	0	20,000	10,878	70	0	Wind	0.0001	0.0006
						Seismic	0.0002	0.0005
Empty, New	0	20,000	10,878	70	0	Wind	0.0001	0.0006
						Seismic	0.0002	0.0005
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	19,700	9,743	350	0	Weight	0.0006	0.0007

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.25/0.25} = 0.001404$$

$$B = 9{,}743 \quad \text{psi}$$

$$S = \frac{19{,}700}{1.00} = 19{,}700 \quad \text{psi}$$

$S_{cHC} \ = \ \min\,(B, S) =$ <u>9,743 psi</u>

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

$S_c H N = S_c H C =$ <u>9,743 psi</u>

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.25/0.25} = 0.001404$$

$$B = 10{,}878 \quad \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \quad \text{psi}$$

$S_{cCN} \ = \ \min\,(B, S) =$ <u>10,878 psi</u>

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

$S_c \mathbb{C} = S_c C N =$ <u>10,878 psi</u>

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.25/0.25} = 0.001404$$

$$B = 9{,}743 \quad \text{psi}$$

$$S = \frac{19{,}700}{1.00} = 19{,}700 \quad \text{psi}$$

$S_{cVC} \ = \ \min\,(B, S) =$ <u>9,743 psi</u>

<u>Operating, Hot & Corroded, Wind, Bottom Seam</u>

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

$$= \frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$$

= 0.0995"

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

$$= \frac{4{,}210}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$$

= 0.0002"

$$t_w = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{0.60{*}835.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$$

= 0.0002"

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

$$= 0.0995{+}0.0002 - (0.0002)$$

= <u>0.0995"</u>

$$t_{w\,c} = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{835.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$$

= 0.0004"

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

$$= |0.0002 + (0.0004) - (0.0995)|$$

= <u>0.099"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.25 - 0.0002 + (0.0002))}{22 - 0.40 \cdot (0.25 - 0.0002 + (0.0002))}$$

= <u>377.89</u> psi

<u>Operating, Hot & New, Wind, Bottom Seam</u>

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

$= \frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

$t_m = \frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \frac{4{,}210}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0002"

$t_w = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{0.60*835.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0002"

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

$= 0.0995{+}0.0002 - (0.0002)$

= <u>0.0995"</u>

$t_{w\,c} = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{835.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0004"

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

$= |0.0002 + (0.0004) - (0.0995)|$

= <u>0.099"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.25 - 0.0002 + (0.0002))}{22 - 0.40 \cdot (0.25 - 0.0002 + (0.0002))}$

= 377.89 psi

<u>Hot Shut Down, Corroded, Wind, Bottom Seam</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{4{,}210}{\pi \cdot 22.125\ ^2 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0002"

$t_w = 0.6 \cdot \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{0.60*835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0003"

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

$= |0 + 0.0002 - (0.0003)|$

= <u>0.0001"</u>

$t_{w\,c} = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0005"

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

$= 0.0002 + (0.0005) - (0)$

= <u>0.0007"</u>

<u>Hot Shut Down, New, Wind, Bottom Seam</u>

t_p = 0" (Pressure)

$t_m = \frac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \frac{4{,}210}{\pi \cdot 22.125^{\ 2} \cdot 9{,}742.71 \cdot 1.20}$

= 0.0002"

$t_w = 0.6 \cdot \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \frac{0.60*835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0003"

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

$= |0 + 0.0002 - (0.0003)|$

= <u>0.0001"</u>

$t_{w\,c} = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \frac{835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0005"

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

$= 0.0002 + (0.0005) - (0)$

= <u>0.0007"</u>

<u>Empty, Corroded, Wind, Bottom Seam</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{3{,}455}{\pi \cdot 22.125^{\ 2} \cdot 10{,}878.1 \cdot 1.20}$

= 0.0002"

$t_w = 0.6 \cdot \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{0.60{*}835.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0003"

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

$= |0 + 0.0002 - (0.0003)|$

= <u>0.0001"</u>

$t_{w\,c} = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{835.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0005"

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

$= 0.0002 + (0.0005) - (0)$

= <u>0.0006"</u>

<u>Empty, New, Wind, Bottom Seam</u>

t_p = 0" (Pressure)

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

= $\frac{3{,}455}{\pi \cdot 22.125\ ^2 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0002"

t_w = $0.6 \cdot \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\frac{0.60*835.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0003"

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

= $|0 + 0.0002 - (0.0003)|$

= <u>0.0001"</u>

$t_{w\,c}$ = $\frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\frac{835.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0005"

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

= $0.0002{+}(0.0005) - (0)$

= <u>0.0006"</u>

<u>Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Bottom Seam</u>

t_p = 0" (Pressure)

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

= $\frac{544}{\pi \cdot 22.125\ ^2 \cdot 9{,}742.71 \cdot 1.00}$

= 0"

t_w = $\frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\frac{835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.00}$

= 0.0006"

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

= $|0 + 0 - (0.0006)|$

= <u>0.0006"</u>

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

= $0 + (0.0006) - (0)$

= <u>0.0007"</u>

<u>Operating, Hot & Corroded, Seismic, Bottom Seam</u>

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

$= \dfrac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{1{,}299}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0001"

$t_w = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.59{*}835.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0002"

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

$= 0.0995{+}0.0001 - (0.0002)$

= <u>0.0994"</u>

$t_{w\,c} = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.01{*}835.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0004"

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

$= |0.0001 + (0.0004) - (0.0995)|$

= <u>0.0991"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.25 - 0.0001 + (0.0002))}{22 - 0.40 \cdot (0.25 - 0.0001 + (0.0002))}$$

= <u>378.06</u> psi

<u>Operating, Hot & New, Seismic, Bottom Seam</u>

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

= $\dfrac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{1{,}299}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0001"

t_w = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59*835.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0002"

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

= $0.0995{+}0.0001 - (0.0002)$

= <u>0.0994"</u>

$t_{w\,c}$ = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.01*835.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0.0004"

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

= $|0.0001 + (0.0004) - (0.0095)|$

= <u>0.0991"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\dfrac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.25 - 0.0001 + (0.0002))}{22 - 0.40 \cdot (0.25 - 0.0001 + (0.0002))}$

= 378.06 psi

<u>**Hot Shut Down, Corroded, Seismic, Bottom Seam**</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{1{,}299}{\pi \cdot 22.125\ ^2 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0001"

$t_w = (0.6 - 0.14 \cdot S_{DS}) \cdot \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{0.59*835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0003"

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

$= |0 + 0.0001 - (0.0003)|$

= <u>0.0002"</u>

$t_{w\,c} = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{1.01*835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0005"

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

$= 0.0001{+}(0.0005) - (0)$

= <u>0.0006"</u>

<u>Hot Shut Down, New, Seismic, Bottom Seam</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{1{,}299}{\pi \cdot 22.125\ ^2 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0001"

$t_w = (0.6 - 0.14 \cdot S_{DS}) \cdot \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{0.59*835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0003"

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

$= |0 + 0.0001 - (0.0003)|$

= <u>0.0002"</u>

$t_{w\,c} = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{1.01*835.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0005"

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

$= 0.0001 + (0.0005) - (0)$

= <u>0.0006"</u>

<u>Empty, Corroded, Seismic, Bottom Seam</u>

t_p = 0" (Pressure)

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

$$= \frac{814}{\pi \cdot 22.125^{\ 2} \cdot 10{,}878.1 \cdot 1.20}$$

= 0"

$$t_w = (0.6 - 0.14 \cdot S_{DS}) \cdot \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{0.59*835.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$$

= 0.0003"

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

$$= |0 + 0 - (0.0003)|$$

= <u>0.0002"</u>

$$t_{w\,c} = \frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{1.01*835.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$$

= 0.0005"

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

$$= 0 + (0.0005) - (0)$$

= <u>0.0005"</u>

<u>Empty, New, Seismic, Bottom Seam</u>

t_p = 0" (Pressure)

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

$$= \frac{814}{\pi \cdot 22.125^{\ 2} \cdot 10{,}878.1 \cdot 1.20}$$

= 0"

$$t_w = (0.6 - 0.14 \cdot S_{DS}) \cdot \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{0.59*835.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$$

= 0.0003"

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

$$= |0 + 0 - (0.0003)|$$

= <u>0.0002"</u>

$$t_{w\,c} = \frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{1.01*835.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$$

= 0.0005"

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

$$= 0 + (0.0005) - (0)$$

= <u>0.0005"</u>

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

Cylinder #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		150	350	-20
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		3.39	94	1
Test horizontal		1.59	44	1
Dimensions				
Inner Diameter		44"		
Length		48"		
Nominal Thickness		0.25"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		450.88		315.95
Corroded		450.88		315.95
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	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.2464"
Design thickness due to combined loadings + corrosion	0.0715"
Maximum allowable working pressure (MAWP)	152.25 psi
Maximum allowable pressure (MAP)	158.01 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \dfrac{153.39 \cdot 22}{20{,}000 \cdot 0.7 - 0.6 \cdot 153.39} =$	0.2426"
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0.2426 \cdot 0.8}{0.25 - 0} =$	0.7765
$\text{Stress ratio longitudinal} = \dfrac{5{,}615 \cdot 1}{20{,}000 \cdot 1} =$	0.2807
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F	
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 350 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{153.39 \cdot 22}{19{,}700 \cdot 0.70 - 0.60 \cdot 153.39} + 0 = \underline{0.2464}"$$

Maximum allowable working pressure, (at 350 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}700 \cdot 0.70 \cdot 0.25}{22 + 0.60 \cdot 0.25} - 3.39 = \underline{152.25} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 0.70 \cdot 0.25}{22 + 0.60 \cdot 0.25} = \underline{158.01} \text{ psi}$$

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

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.25}{22.125}\right) \cdot \left(1 - \frac{22.125}{\infty}\right) = 0.565\,\%$$

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	150	19,700	9,743	350	0	Top	Wind	0.0709	0.0671
							Seismic	0.0706	0.0675
						Bottom	Wind	0.0715	0.0708
							Seismic	0.0715	0.0707
Operating, Hot & New	150	19,700	9,743	350	0	Top	Wind	0.0709	0.0671
							Seismic	0.0706	0.0675
						Bottom	Wind	0.0715	0.0708
							Seismic	0.0715	0.0707
Hot Shut Down, Corroded	0	19,700	9,743	350	0	Top	Wind	0.0012	0.0052
							Seismic	0.0009	0.0045
						Bottom	Wind	0.0018	0.001
							Seismic	0.0018	0.001
Hot Shut Down, New	0	19,700	9,743	350	0	Top	Wind	0.0012	0.0052
							Seismic	0.0009	0.0045
						Bottom	Wind	0.0018	0.001
							Seismic	0.0018	0.001
Empty, Corroded	0	20,000	10,878	70	0	Top	Wind	0.0011	0.0045
							Seismic	0.0008	0.004
						Bottom	Wind	0.0001	0
							Seismic	0.0001	0.0001
Empty, New	0	20,000	10,878	70	0	Top	Wind	0.0011	0.0045
							Seismic	0.0008	0.004
						Bottom	Wind	0.0001	0
							Seismic	0.0001	0.0001
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	19,700	9,743	350	0	Top	Weight	0.0005	0.0052
						Bottom	Weight	0.0021	0.0021

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.25/0.25} = 0.001404$$

$$B = 9{,}743 \quad \text{psi}$$

$$S = \frac{19{,}700}{1.00} = 19{,}700 \quad \text{psi}$$

$S_{cHC} = \min(B, S) =$ 9,743 psi

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

$S_cHN = S_cHC =$ 9,743 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.25/0.25} = 0.001404$$

$$B = 10{,}878 \quad \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \quad \text{psi}$$

$S_{cCN} = \min(B, S) =$ 10,878 psi

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

$S_c\mathbb{C} = S_cCN =$ 10,878 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.25/0.25} = 0.001404$$

$$B = 9{,}743 \quad \text{psi}$$

$$S = \frac{19{,}700}{1.00} = 19{,}700 \quad \text{psi}$$

$S_{cVC} = \min(B, S) =$ 9,743 psi

Operating, Hot & Corroded, Wind, Above Support Point

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

$$= \frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 + 0.40 \cdot |150|}$$

= 0.0697"

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

$$= \frac{62{,}369}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$$

= 0.0017"

$$t_w = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{0.60 * 2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$$

= 0.0005"

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

$$= 0.0697 + 0.0017 - (0.0005)$$

= <u>0.0709"</u>

$$t_{w\,c} = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$$

= 0.0009"

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

$$= |0.0017 + (0.0009) - (0.0697)|$$

= <u>0.0671"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 \cdot (0.25 - 0.0017 + (0.0005))}{22 - 0.40 \cdot (0.25 - 0.0017 + (0.0005))}$$

= <u>537.12</u> psi

<u>Operating, Hot & New, Wind, Above Support Point</u>

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

$= \dfrac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 + 0.40 \cdot |150|}$

= 0.0697"

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{62{,}369}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0017"

$t_w = \dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.60{*}2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

$= 0.0697{+}0.0017 - (0.0005)$

= <u>0.0709"</u>

$t_{w\,c} = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0009"

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

$= |0.0017 + (0.0009) - (0.0697)|$

= <u>0.0671"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$= \dfrac{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 \cdot (0.25 - 0.0017 + (0.0005))}{22 - 0.40 \cdot (0.25 - 0.0017 + (0.0005))}$

= 537.12 psi

<u>Hot Shut Down, Corroded, Wind, Above Support Point</u>

t_p = 0" (Pressure)

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

$$= \frac{62{,}369}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$$

= 0.0017"

$$t_w = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{0.60{*}2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$$

= 0.0005"

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

= $0 + 0.0017 - (0.0005)$

= <u>0.0012"</u>

$$t_{mc} = \frac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s} \quad \text{(bending)}$$

$$= \frac{62{,}369}{\pi \cdot 22.125^{\ 2} \cdot 9{,}742.71 \cdot 1.20}$$

= 0.0035"

$$t_{wc} = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$$

= 0.0017"

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

= $0.0035 + (0.0017) - (0)$

= <u>0.0052"</u>

<u>Hot Shut Down, New, Wind, Above Support Point</u>

t_p = 0" (Pressure)

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

$$= \frac{62{,}369}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$$

= 0.0017"

$$t_w = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{0.60*2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$$

= 0.0005"

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

= $0 + 0.0017 - (0.0005)$

= <u>0.0012"</u>

$$t_{mc} = \frac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s} \quad \text{(bending)}$$

$$= \frac{62{,}369}{\pi \cdot 22.125^{\ 2} \cdot 9{,}742.71 \cdot 1.20}$$

= 0.0035"

$$t_{wc} = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \quad \text{(Weight)}$$

$$= \frac{2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$$

= 0.0017"

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

= $0.0035 + (0.0017) - (0)$

= <u>0.0052"</u>

<u>Empty, Corroded, Wind, Above Support Point</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{59{,}460}{\pi \cdot 22.125^{\ 2} \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0.0016"

$t_w = \dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.60*2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

$= 0 + 0.0016 - (0.0005)$

= <u>0.0011"</u>

$t_{mc} = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{59{,}460}{\pi \cdot 22.125^{\ 2} \cdot 10{,}878.1 \cdot 1.20}$

= 0.003"

$t_{wc} = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0016"

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

$= 0.003 + (0.0016) - (0)$

= <u>0.0045"</u>

<u>Empty, New, Wind, Above Support Point</u>

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{59{,}460}{\pi \cdot 22.125\ ^2 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0.0016"

t_w = $\dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.60*2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

= $0 + 0.0016 - (0.0005)$

= <u>0.0011"</u>

t_{mc} = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

= $\dfrac{59{,}460}{\pi \cdot 22.125\ ^2 \cdot 10{,}878.1 \cdot 1.20}$

= 0.003"

t_{wc} = $\dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\dfrac{2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0016"

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

= $0.003 + (0.0016) - (0)$

= <u>0.0045"</u>

<u>Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Above Support Point</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{47{,}100}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.00 \cdot 1.00}$

= 0.0016"

$t_w = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.00 \cdot 1.00}$

= 0.001"

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

$= 0 + 0.0016 - (0.001)$

= <u>0.0005"</u>

$t_{mc} = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{47{,}100}{\pi \cdot 22.125^{\ 2} \cdot 9{,}742.71 \cdot 1.00}$

= 0.0031"

$t_{wc} = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.00}$

= 0.0021"

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

$= 0.0031 + (0.0021) - (0)$

= <u>0.0052"</u>

<u>Operating, Hot & Corroded, Wind, Below Support Point</u>

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

$= \frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 + 0.40 \cdot |150|}$

= 0.0697"

$t_m = \frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \frac{218}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0"

$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{-5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0018"

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

$= 0.0697 + 0 - (-0.0018)$

= <u>0.0715"</u>

$t_{w\,c} = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{0.60 * -5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0011"

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

$= |0 + (-0.0011) - (0.0697)|$

= <u>0.0708"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 \cdot (0.25 - 0 + (-0.0018))}{22 - 0.40 \cdot (0.25 - 0 + (-0.0018))}$

= <u>535.9</u> psi

<u>**Operating, Hot & New, Wind, Below Support Point**</u>

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

$= \dfrac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 + 0.40 \cdot |150|}$

= 0.0697"

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{218}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0"

$t_w = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{-5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0018"

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

$= 0.0697 + 0 - (-0.0018)$

= 0.0715"

$t_{w\,c} = \dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.60 * -5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0011"

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

$= |0 + (-0.0011) - (0.0697)|$

= 0.0708"

Maximum allowable working pressure, Longitudinal Stress

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

$= \dfrac{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 \cdot (0.25 - 0 + (-0.0018))}{22 - 0.40 \cdot (0.25 - 0 + (-0.0018))}$

= 535.9 psi

Hot Shut Down, Corroded, Wind, Below Support Point

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{218}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0"

t_w = $\dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{-5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0018"

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

= $0 + 0 - (-0.0018)$

= <u>0.0018"</u>

$t_{w\,c}$ = $\dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.60*-5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0011"

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

= $|0 + (-0.0011) - (0)|$

= <u>0.001"</u>

<u>Hot Shut Down, New, Wind, Below Support Point</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{218}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0"

$t_w = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{-5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0018"

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

$= 0 + 0 - (-0.0018)$

= 0.0018"

$t_{w\,c} = \dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.60^{*}\text{-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0011"

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

$= |0 + (-0.0011) - (0)|$

= 0.001"

Empty, Corroded, Wind, Below Support Point

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{191}{\pi \cdot 22.125^{\ 2} \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0"

t_w = $\dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{\text{-301.9}}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= -0.0001"

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

= $0 + 0 - (-0.0001)$

= <u>0.0001"</u>

$t_{w\,c}$ = $\dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.60\text{*-}301.9}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= -0.0001"

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

= $|0 + (-0.0001) - (0)|$

= <u>0"</u>

<u>Empty, New, Wind, Below Support Point</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{191}{\pi \cdot 22.125\ ^2 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0"

$t_w = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{-301.9}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= -0.0001"

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

$= 0 + 0 - (-0.0001)$

= 0.0001"

$t_{w\,c} = \dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.60{*}{-301.9}}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= -0.0001"

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

$= |0 + (-0.0001) - (0)|$

= 0"

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

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{60}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.00 \cdot 1.00}$

= 0"

$t_w = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{-5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.00 \cdot 1.00}$

= -0.0021"

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

$= 0 + 0 - (-0.0021)$

= 0.0021"

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

$= |0 + (-0.0021) - (0)|$

= 0.0021"

Operating, Hot & Corroded, Seismic, Above Support Point

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

= $\dfrac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 + 0.40 \cdot |150|}$

= 0.0697"

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{49{,}935}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0014"

t_w = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59{*}2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

= $0.0697{+}0.0014 - (0.0005)$

= <u>0.0706"</u>

$t_{w\,c}$ = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.01{*}2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0009"

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

= $|0.0014 + (0.0009) - (0.0697)|$

= <u>0.0675"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\dfrac{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 \cdot (0.25 - 0.0014 + (0.0005))}{22 - 0.40 \cdot (0.25 - 0.0014 + (0.0005))}$

= <u>537.85</u> psi

<u>**Operating, Hot & New, Seismic, Above Support Point**</u>

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

= $\frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 + 0.40 \cdot |150|}$

= 0.0697"

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\frac{49{,}935}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0014"

t_w = $\frac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{0.59 * 2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

= $0.0697 + 0.0014 - (0.0005)$

= <u>0.0706"</u>

$t_{w\,c}$ = $\frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{1.01 * 2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0009"

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

= $|0.0014 + (0.0009) - (0.0697)|$

= <u>0.0675"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 \cdot (0.25 - 0.0014 + (0.0005))}{22 - 0.40 \cdot (0.25 - 0.0014 + (0.0005))}$

= 537.85 psi

<u>Hot Shut Down, Corroded, Seismic, Above Support Point</u>

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{49{,}935}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0014"

t_w = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59*2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

= $0 + 0.0014 - (0.0005)$

= <u>0.0009"</u>

t_{mc} = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

= $\dfrac{49{,}935}{\pi \cdot 22.125^{\ 2} \cdot 9{,}742.71 \cdot 1.20}$

= 0.0028"

t_{wc} = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\dfrac{1.01*2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0017"

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

= $0.0028 + (0.0017) - (0)$

= <u>0.0045"</u>

Hot Shut Down, New, Seismic, Above Support Point

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{49{,}935}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0014"

$t_w = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.59*2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

$= 0 + 0.0014 - (0.0005)$

= <u>0.0009"</u>

$t_{mc} = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{49{,}935}{\pi \cdot 22.125\ ^2 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0028"

$t_{w\,c} = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{1.01*2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 9{,}742.71 \cdot 1.20}$

= 0.0017"

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

$= 0.0028 + (0.0017) - (0)$

= <u>0.0045"</u>

<u>Empty, Corroded, Seismic, Above Support Point</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{48{,}054}{\pi \cdot 22.125\ ^2 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0.0013"

$t_w = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.59{*}2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

$= 0 + 0.0013 - (0.0005)$

= <u>0.0008"</u>

$t_{mc} = \dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

$= \dfrac{48{,}054}{\pi \cdot 22.125\ ^2 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0024"

$t_{w\,c} = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

$= \dfrac{1.01{*}2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0016"

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

$= 0.0024 + (0.0016) - (0)$

= <u>0.004"</u>

<u>Empty, New, Seismic, Above Support Point</u>

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{48{,}054}{\pi \cdot 22.125\ ^2 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0.0013"

t_w = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59{*}2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0.0005"

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

= $0 + 0.0013 - (0.0005)$

= <u>0.0008"</u>

t_{mc} = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_c \cdot K_s}$ (bending)

= $\dfrac{48{,}054}{\pi \cdot 22.125\ ^2 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0024"

$t_{w\,c}$ = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s}$ (Weight)

= $\dfrac{1.01{*}2{,}819.3}{2 \cdot \pi \cdot 22.125 \cdot 10{,}878.1 \cdot 1.20}$

= 0.0016"

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

= $0.0024{+}(0.0016) - (0)$

= <u>0.004"</u>

<u>Operating, Hot & Corroded, Seismic, Below Support Point</u>

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

= $\dfrac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 + 0.40 \cdot |150|}$

= 0.0697"

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{78}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0"

t_w = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.01*\text{-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0018"

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

= $0.0697{+}0 - (-0.0018)$

= <u>0.0715"</u>

$t_{w\,c}$ = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59*\text{-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.001"

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

= $|0 + (-0.001) - (0.0697)|$

= <u>0.0707"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\dfrac{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 \cdot (0.25 - 0 + (-0.0018))}{22 - 0.40 \cdot (0.25 - 0 + (-0.0018))}$

= <u>535.88</u> psi

<u>Operating, Hot & New, Seismic, Below Support Point</u>

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

= $\dfrac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 + 0.40 \cdot |150|}$

= 0.0697"

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{78}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0"

t_w = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.01\text{*-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0018"

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

= $0.0697 + 0 - (-0.0018)$

= <u>0.0715"</u>

t_{wc} = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59\text{*-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.001"

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

= $|0 + (-0.001) - (0.0697)|$

= <u>0.0707"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\dfrac{2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00 \cdot (0.25 - 0 + (-0.0018))}{22 - 0.40 \cdot (0.25 - 0 + (-0.0018))}$

= 535.88 psi

<u>Hot Shut Down, Corroded, Seismic, Below Support Point</u>

t_p = 0" (Pressure)

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\frac{78}{\pi \cdot 22.125\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0"

t_w = $\frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{1.01*\text{-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0018"

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

= $0 + 0 - (-0.0018)$

= <u>0.0018"</u>

$t_{w\,c}$ = $\frac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{0.59*\text{-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.001"

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

= $|0 + (-0.001) - (0)|$

= <u>0.001"</u>

<u>Hot Shut Down, New, Seismic, Below Support Point</u>

t_p = 0" (Pressure)

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\frac{78}{\pi \cdot 22.125^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= 0"

t_w = $\frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{1.01\text{*-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.0018"

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

= $0 + 0 - (-0.0018)$

= <u>0.0018"</u>

$t_{w\,c}$ = $\frac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{0.59\text{*-}5{,}774.8}{2 \cdot \pi \cdot 22.125 \cdot 19{,}700 \cdot 1.20 \cdot 1.00}$

= -0.001"

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

= $|0 + (-0.001) - (0)|$

= <u>0.001"</u>

<u>Empty, Corroded, Seismic, Below Support Point</u>

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{70}{\pi \cdot 22.125\ ^2 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0"

t_w = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.01\text{*-}301.9}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= -0.0001"

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

= $0 + 0 - (-0.0001)$

= <u>0.0001"</u>

$t_{w\,c}$ = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59\text{*-}301.9}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= -0.0001"

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

= $|0 + (-0.0001) - (0)|$

= <u>0.0001"</u>

<u>Empty, New, Seismic, Below Support Point</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{70}{\pi \cdot 22.125^{\ 2} \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= 0"

$t_w = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.01\text{*-}301.9}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= -0.0001"

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

$= 0 + 0 - (-0.0001)$

= <u>0.0001"</u>

$t_{w\,c} = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.59\text{*-}301.9}{2 \cdot \pi \cdot 22.125 \cdot 20{,}000 \cdot 1.20 \cdot 1.00}$

= -0.0001"

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

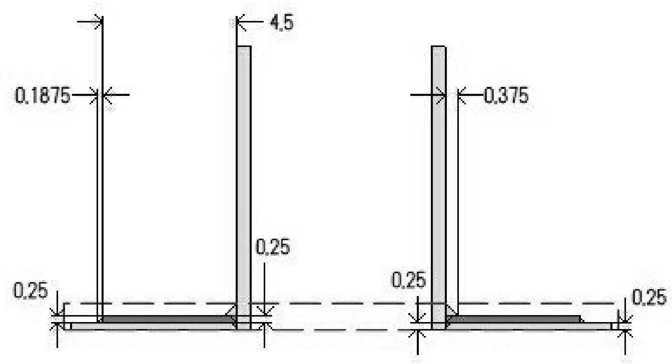
$= |0 + (-0.0001) - (0)|$

= <u>0.0001"</u>

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

MANWAY (M)

ASME Section VIII Division 1, 2023 Edition	



Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Cylinder #2
Orientation	270°
Nozzle center line offset to datum line	24"
End of nozzle to shell center	30.25"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-240 316 (II-D p. 76, ln. 21)
Inside diameter, new	23"
Nominal wall thickness	0.5"
Corrosion allowance	0"
Projection available outside vessel, Lpr	7.5"
Projection available outside vessel to flange face, Lf	8"
Local vessel minimum thickness	0.25"
Liquid static head included	2.94 psi
Reinforcing Pad	
Material specification	SA-240 304 (II-D p. 92, ln. 14)
Diameter, D_p	33"
Thickness, t_e	0.25"
Is split	Yes
Butt welds tested to confirm full penetration	No
Butt welds located at least 45° from long seam	No
Joint efficiency	0.75
Welds	
Inner fillet, Leg_{41}	0.375"
Outer fillet, Leg_{42}	0.1875"
Nozzle to vessel groove weld	0.25"
Pad groove weld	0.25"
Radiography	
Longitudinal seam	None UW-11(c) Type 1

ASME B16.5-2020 Flange	
Description	NPS 24 Class 300 SO A182 F316
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	Yes
Rated MDMT	-55°F
Liquid static head	2.53 psi
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 psi @ 70°F
External fillet weld leg (UW-21)	0.7" (0.7" min)
Internal fillet weld leg (UW-21)	0.25" (0.25" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.5, 1.685\right] =$	0.7"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.7 + \frac{0}{0.7} =$	0.7"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text}(") + \frac{C_i}{0.7}\right] = \min\left[0.5, 0.25 + \frac{0}{0.7}\right] =$	0.25"
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	
$t_r = \frac{152.94 \cdot 22}{20{,}000 \cdot 1 - 0.6 \cdot 152.94} =$	0.169"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.169 \cdot 1}{0.25 - 0} =$	0.676
$\text{Stress ratio longitudinal} = \frac{5{,}479 \cdot 1}{20{,}000 \cdot 1} =$	0.2739
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -320°F	
Material is exempt from impact testing at the Design MDMT of -20°F.	

UHA-51 Material Toughness Requirements Pad	
$t_r = \frac{152.94 \cdot 22}{20{,}000 \cdot 1 - 0.6 \cdot 152.94} =$	0.169"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.169 \cdot 1}{0.25 - 0} =$	0.676
$\text{Stress ratio longitudinal} = \frac{5{,}479 \cdot 1}{20{,}000 \cdot 1} =$	0.2739
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -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 = 152.94 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.9468	4.0754	1.8032	0.5129	–	1.5933	0.166	0.1716	0.5

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
43,773.4	44,763.08	343,101.78	17,645.29	395,963.19	49,688.08	225,976.13

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.175	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.125	0.1313	weld size is adequate

Calculations for internal pressure 152.94 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[23,\ 11.5 + (0.5 - 0) + (0.25 - 0)\right]$$
$$= 23 \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.5 - 0) + 0.25\right]$$
$$= 0.625 \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{152.9419 \cdot 11.5}{19{,}700 \cdot 1 - 0.6 \cdot 152.9419}$$
$$= 0.0897 \ \text{in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$
$$= \frac{152.9419 \cdot 22}{19{,}700 \cdot 1 - 0.6 \cdot 152.9419}$$
$$= 0.1716 \ \text{in}$$

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

t_r = $\dfrac{P \cdot R}{S \cdot E - 0.6 \cdot P}$

= $\dfrac{152.9419 \cdot 22}{19{,}700 \cdot 0.7 - 0.6 \cdot 152.9419}$

= $0.2456 \ \text{in}$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700, S_p = 18,600 psi

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

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

f_{r3} = lesser of f_{r2} or $\dfrac{S_p}{S_v}$ = 0.9442

f_{r4} = lesser of 1 or $\dfrac{S_p}{S_v}$ = 0.9442

A = $d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$

= $23 \cdot 0.1716 \cdot 1 + 2 \cdot 0.5 \cdot 0.1716 \cdot 1 \cdot (1 - 1)$

= 3.9468 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.8032 in^2

= $d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $23 \cdot (1 \cdot 0.25 - 1 \cdot 0.1716) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1716) \cdot (1 - 1)$

= $1.8032 \ \text{in}^2$

= $2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2 \cdot (0.25 + 0.5) \cdot (1 \cdot 0.25 - 1 \cdot 0.1716) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1716) \cdot (1 - 1)$

= $0.1176 \ \text{in}^2$

A_2 = smaller of the following= 0.5129 in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$

= $5 \cdot (0.5 - 0.0897) \cdot 1 \cdot 0.25$

= $0.5129 \ \text{in}^2$

= $2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2}$

= $2 \cdot (0.5 - 0.0897) \cdot (2.5 \cdot 0.5 + 0.25) \cdot 1$

= $1.2309 \ \text{in}^2$

A_{41} = $Leg^2 \cdot f_{r3}$

= $0.375^{\ 2} \cdot 0.9442$

= $\underline{0.1328}$ in^2

A_{42} = $Leg^2 \cdot f_{r4}$

= $0.1875^{\ 2} \cdot 0.9442$

= $\underline{0.0332}$ in^2

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} \cdot E_p$

= $(33 - 23 - 2 \cdot 0.5) \cdot 0.25 \cdot 0.9442 \cdot 0.75$

= $\underline{1.5933}$ in^2

$Area$ = $A_1 + A_2 + A_{41} + A_{42} + A_5$

= $1.8032 + 0.5129 + 0.1328 + 0.0332 + 1.5933$

= $\underline{4.0754}$ in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\,[0.75,\ \ t_n,\ \ t_e] =$ 0.25 in

$t_{c(\min)} = \min\,[0.25,\ \ 0.7 \cdot t_{\min}] =$ $\underline{0.175}$ in

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

Outer fillet: $t_{\min} = \min\,[0.75,\ \ t_e,\ \ t] =$ 0.25 in

$t_{w(\min)} = 0.5 \cdot t_{\min} = \underline{0.125}$ in

$t_{w(actual)} = 0.7 \cdot \mathrm{Leg} = 0.7 \cdot 0.1875 = 0.1313$ in

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{152.9419 \cdot 11.5}{19{,}700 \cdot 0.7 - 0.6 \cdot 152.9419} + 0$$

$$= 0.1284 \ \text{in}$$

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

$$= \max\,[0.1284,\ \ 0]$$

$$= 0.1284 \ \text{in}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{152.9419 \cdot 22}{19{,}700 \cdot 1 - 0.6 \cdot 152.9419} + 0$$

$$= 0.1716 \ \text{in}$$

$t_{b1} = \max[t_{b1},\ t_{b\text{UG16}}]$

$= \max[0.1716,\ 0.0625]$

$= 0.1716$ in

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

$= \min[0.3281,\ 0.1716]$

$= 0.1716$ in

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

$= \max[0.1284,\ 0.1716]$

$= \underline{0.1716}$ in

Available nozzle wall thickness new, t_n = 0.5 in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

Groove weld in tension:	$0.74 \cdot 19{,}700$ =	14,578 psi
Nozzle wall in shear:	$0.7 \cdot 19{,}700$ =	13,790 psi
Inner fillet weld in shear:	$0.49 \cdot 18{,}600$ =	9,114 psi
Outer fillet weld in shear:	$0.49 \cdot 18{,}600$ =	9,114 psi
Upper groove weld in tension:	$0.74 \cdot 18{,}600$ =	13,764 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 24 \cdot 0.375 \cdot 9{,}114$ = 128,846.14 lb_f

(2) Outer fillet weld in shear
$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 33 \cdot 0.1875 \cdot 9{,}114$ = 88,581.72 lb_f

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 23.5 \cdot 0.5 \cdot 13{,}790$ = 254,520.05 lb_f

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 24 \cdot 0.25 \cdot 14{,}578$ = 137,394.41 lb_f

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 24 \cdot 0.25 \cdot 13{,}764$ = 129,722.64 lb_f

Loading on welds per UG-41(b)(1)

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(3.9468 - 1.8032 + 2 \cdot 0.5 \cdot 1 \cdot (1 \cdot 0.25 - 1 \cdot 0.1716)) \cdot 19{,}700$

= $\underline{43{,}773.4}$ lb_f

$W_{1\text{-}1}$ = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.5129 + 1.5933 + 0.1328 + 0.0332) \cdot 19{,}700$

= 44,763.08 lb_f

$W_{2\text{-}2}$ = $(A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$

= $(0.5129 + 0 + 0.1328 + 0 + 2 \cdot 0.5 \cdot 0.25 \cdot 1) \cdot 19{,}700$

= 17,645.29 lb_f

$W_{3\text{-}3}$ = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$

= $(0.5129 + 0 + 1.5933 + 0.1328 + 0.0332 + 0 + 2 \cdot 0.5 \cdot 0.25 \cdot 1) \cdot 19{,}700$

= 49,688.08 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 43,773.4 lb_f
Path 1-1 through (2) & (3) = 88,581.72 + 254,520.05 = 343,101.78 lb_f
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 17,645.29 lb_f
Path 2-2 through (1), (4), (6) = 128,846.14 + 137,394.41 + 129,722.64 = 395,963.19 lb_f
Path 2-2 is stronger than $W_{2\text{-}2}$ so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 43,773.4 lb_f
Path 3-3 through (2), (4) = 88,581.72 + 137,394.41 = 225,976.13 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*3.9468 = 2.6312 in^2

L_R = $\max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right]$

= $\max\left[23,\ \ 11.5 + (0.5 - 0) + (0.25 - 0)\right]$

= $17.25 \ \ \text{in}$

A_1 = $(2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $(2 \cdot 17.25 - 23) \cdot (1 \cdot 0.25 - 1 \cdot 0.1716) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1716) \cdot (1 - 1)$

= $0.9016 \ \ \text{in}^2$

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} \cdot E_p$

= $(33 - 23 - 2 \cdot 0.5) \cdot 0.25 \cdot 0.9442 \cdot 0.75$

= $1.5933 \ \ \text{in}^2$

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

= $0.9016 + 0.5129 + 0 + 0.1328 + 0.0332 + 0 + 1.5933$

= 3.1738 in^2

The area replacement requirements of Appendix 1-7(a) are satisfied.

Check Large Opening per Appendix 1-7(b)

1-7(b)(1)(a) $\frac{R_n}{R} = \frac{11.5}{22} = 0.5227 \le 0.7$ True

1-7(b)(1)(b) $D_i = 44 \ \text{ in} > 60 \ \text{ in}$ False

1-7(b)(1)(c) $d = 23 \ \text{ in} > 40 \ \text{ in}$ False

1-7(b)(1)(c) $d = 23 \ \text{ in} > 3.4 \cdot \sqrt{22 \cdot 0.25} = 7.9737 \ \text{ in}$ True

The opening is not within the size range defined by 1-7(b)(1)(b) and (c) so it is exempt from the requirements of 1-7(b)(2),(3) and (4).

R_n / R = 0.5227 does not exceed 0.7 so a U-2(g) analysis is not required per 1-7(b)(1).

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

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.5}{11.75}\right) \cdot \left(1 - \frac{11.75}{\infty}\right) = 2.1277\,\%$$

Reinforcement Calculations for MAWP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 155.38 psi @ 350 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.0101	4.0104	1.74	0.5111	–	1.5933	0.166	0.1744	0.5

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
46,210.29	44,727.62	343,101.78	17,609.83	395,963.19	49,652.62	225,976.13

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.175	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.125	0.1313	weld size is adequate

Calculations for internal pressure 155.38 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[23,\ 11.5 + (0.5 - 0) + (0.25 - 0)\right]$$

$$= 23 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.5 - 0) + 0.25\right]$$

$$= 0.625 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{155.3843 \cdot 11.5}{19{,}700 \cdot 1 - 0.6 \cdot 155.3843}$$

$$= 0.0911 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{155.3843 \cdot 22}{19{,}700 \cdot 1 - 0.6 \cdot 155.3843}$$

$$= 0.1744 \text{ in}$$

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

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{155.3843 \cdot 22}{19{,}700 \cdot 0.7 - 0.6 \cdot 155.3843}$$

$$= 0.2496 \ \text{in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 19,700, S_v = 19,700, S_p = 18,600 psi

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

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

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9442

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9442

$$A = d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$$

$$= 23 \cdot 0.1744 \cdot 1 + 2 \cdot 0.5 \cdot 0.1744 \cdot 1 \cdot (1 - 1)$$

= 4.0101 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.74 in^2

$$= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 23 \cdot (1 \cdot 0.25 - 1 \cdot 0.1744) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1744) \cdot (1 - 1)$$

$$= 1.74 \ \text{in}^2$$

$$= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$$

$$= 2 \cdot (0.25 + 0.5) \cdot (1 \cdot 0.25 - 1 \cdot 0.1744) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1744) \cdot (1 - 1)$$

$$= 0.1135 \ \text{in}^2$$

A_2 = smaller of the following= 0.5111 in^2

$$= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$$

$$= 5 \cdot (0.5 - 0.0911) \cdot 1 \cdot 0.25$$

$$= 0.5111 \ \text{in}^2$$

$$= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2}$$

$$= 2 \cdot (0.5 - 0.0911) \cdot (2.5 \cdot 0.5 + 0.25) \cdot 1$$

$$= 1.2267 \ \text{in}^2$$

A_{41} = $Leg^2 \cdot f_{r3}$

= $0.375^{\ 2} \cdot 0.9442$

= $\underline{0.1328}$ in^2

A_{42} = $Leg^2 \cdot f_{r4}$

= $0.1875^{\ 2} \cdot 0.9442$

= $\underline{0.0332}$ in^2

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} \cdot E_p$

= $(33 - 23 - 2 \cdot 0.5) \cdot 0.25 \cdot 0.9442 \cdot 0.75$

= $\underline{1.5933}$ in^2

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$

$= 1.74 + 0.5111 + 0.1328 + 0.0332 + 1.5933$

$= \underline{4.0104}$ in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\left[0.75,\ \ t_n,\ \ t_e\right] =$ 0.25 in

$t_{c(\min)} = \min\left[0.25,\ \ 0.7 \cdot t_{\min}\right] =$ $\underline{0.175}$ in

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

Outer fillet: $t_{\min} = \min\left[0.75,\ \ t_e,\ \ t\right] =$ 0.25 in

$t_{w(\min)} = 0.5 \cdot t_{\min} = \underline{0.125}$ in

$t_{w(actual)} = 0.7 \cdot \mathrm{Leg} = 0.7 \cdot 0.1875 = 0.1313$ in

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{155.3843 \cdot 11.5}{19{,}700 \cdot 0.7 - 0.6 \cdot 155.3843} + 0$$

$$= 0.1305 \text{ in}$$

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

$$= \max\left[0.1305,\ \ 0\right]$$

$$= 0.1305 \text{ in}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{155.3843 \cdot 22}{19{,}700 \cdot 1 - 0.6 \cdot 155.3843} + 0$$

$$= 0.1744 \text{ in}$$

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

$= \max[0.1744,\ 0.0625]$

$= 0.1744$ in

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

$= \min[0.3281,\ 0.1744]$

$= 0.1744$ in

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

$= \max[0.1305,\ 0.1744]$

$= \underline{0.1744}$ in

Available nozzle wall thickness new, t_n = 0.5 in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

Groove weld in tension:	$0.74 \cdot 19{,}700$ =	14,578 psi
Nozzle wall in shear:	$0.7 \cdot 19{,}700$ =	13,790 psi
Inner fillet weld in shear:	$0.49 \cdot 18{,}600$ =	9,114 psi
Outer fillet weld in shear:	$0.49 \cdot 18{,}600$ =	9,114 psi
Upper groove weld in tension:	$0.74 \cdot 18{,}600$ =	13,764 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 24 \cdot 0.375 \cdot 9{,}114$ = 128,846.14 lb_f

(2) Outer fillet weld in shear
$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 33 \cdot 0.1875 \cdot 9{,}114$ = 88,581.72 lb_f

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 23.5 \cdot 0.5 \cdot 13{,}790$ = 254,520.05 lb_f

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 24 \cdot 0.25 \cdot 14{,}578$ = 137,394.41 lb_f

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 24 \cdot 0.25 \cdot 13{,}764$ = 129,722.64 lb_f

Loading on welds per UG-41(b)(1)

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(4.0101 - 1.74 + 2 \cdot 0.5 \cdot 1 \cdot (1 \cdot 0.25 - 1 \cdot 0.1744)) \cdot 19{,}700$

= $\underline{46{,}210.29}$ lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.5111 + 1.5933 + 0.1328 + 0.0332) \cdot 19{,}700$

= 44,727.62 lb_f

W_{2-2} = $(A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$

= $(0.5111 + 0 + 0.1328 + 0 + 2 \cdot 0.5 \cdot 0.25 \cdot 1) \cdot 19{,}700$

= 17,609.83 lb_f

W_{3-3} = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$

= $(0.5111 + 0 + 1.5933 + 0.1328 + 0.0332 + 0 + 2 \cdot 0.5 \cdot 0.25 \cdot 1) \cdot 19{,}700$

= 49,652.62 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 44,727.62 lb_f
Path 1-1 through (2) & (3) = 88,581.72 + 254,520.05 = 343,101.78 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 17,609.83 lb_f
Path 2-2 through (1), (4), (6) = 128,846.14 + 137,394.41 + 129,722.64 = 395,963.19 lb_f
Path 2-2 is stronger than W_{2-2} so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or W_{3-3} = 46,210.29 lb_f
Path 3-3 through (2), (4) = 88,581.72 + 137,394.41 = 225,976.13 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*4.0101 = 2.6734 in^2

L_R = $\max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$

= $\max\left[23,\ 11.5 + (0.5 - 0) + (0.25 - 0)\right]$

= $17.25 \ \text{in}$

A_1 = $(2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $(2 \cdot 17.25 - 23) \cdot (1 \cdot 0.25 - 1 \cdot 0.1744) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1744) \cdot (1 - 1)$

= $0.87 \ \text{in}^2$

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} \cdot E_p$

= $(33 - 23 - 2 \cdot 0.5) \cdot 0.25 \cdot 0.9442 \cdot 0.75$

= $1.5933 \ \text{in}^2$

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

= $0.87 + 0.5111 + 0 + 0.1328 + 0.0332 + 0 + 1.5933$

= 3.1404 in^2

The area replacement requirements of Appendix 1-7(a) are satisfied.

Check Large Opening per Appendix 1-7(b)

1-7(b)(1)(a) $\dfrac{R_n}{R} = \dfrac{11.5}{22} = 0.5227 \leq 0.7$ True

1-7(b)(1)(b) $D_i = 44\ \text{ in} > 60\ \text{ in}$ False

1-7(b)(1)(c) $d = 23\ \text{ in} > 40\ \text{ in}$ False

1-7(b)(1)(c) $d = 23\ \text{ in} > 3.4 \cdot \sqrt{22 \cdot 0.25} = 7.9737\ \text{ in}$ True

The opening is not within the size range defined by 1-7(b)(1)(b) and (c) so it is exempt from the requirements of 1-7(b)(2),(3) and (4).

R_n / R = 0.5227 does not exceed 0.7 so a U-2(g) analysis is not required per 1-7(b)(1).

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 159.76 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.0613	4.0616	1.6887	0.5096	–	1.6875	0.1758	0.1766	0.5

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
48,921.2	47,458	353,645.16	18,004	417,517.66	52,458	234,735.88

Calculations for internal pressure 159.76 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[23,\ 11.5 + (0.5 - 0) + (0.25 - 0)\right]$$

$$= 23 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.5 - 0) + 0.25\right]$$

$$= 0.625 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{159.76 \cdot 11.5}{20{,}000 \cdot 1 - 0.6 \cdot 159.76}$$

$$= 0.0923 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{159.76 \cdot 22}{20{,}000 \cdot 1 - 0.6 \cdot 159.76}$$

$$= 0.1766 \text{ in}$$

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

t_r = $\frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$

= $\frac{159.76 \cdot 22}{20{,}000 \cdot 0.7 - 0.6 \cdot 159.76}$

= $0.2528 \quad \text{in}$

Area required per UG-37(c)

Allowable stresses: S_n = 20,000, S_v = 20,000, S_p = 20,000 psi

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

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

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 1

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 1

A = $d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$

= $23 \cdot 0.1766 \cdot 1 + 2 \cdot 0.5 \cdot 0.1766 \cdot 1 \cdot (1 - 1)$

= 4.0613 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.6887 in^2

= $d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $23 \cdot (1 \cdot 0.25 - 1 \cdot 0.1766) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1766) \cdot (1 - 1)$

= $1.6887 \quad \text{in}^2$

= $2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $2 \cdot (0.25 + 0.5) \cdot (1 \cdot 0.25 - 1 \cdot 0.1766) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1766) \cdot (1 - 1)$

= $0.1101 \quad \text{in}^2$

A_2 = smaller of the following= 0.5096 in^2

= $5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$

= $5 \cdot (0.5 - 0.0923) \cdot 1 \cdot 0.25$

= $0.5096 \quad \text{in}^2$

= $2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2}$

= $2 \cdot (0.5 - 0.0923) \cdot (2.5 \cdot 0.5 + 0.25) \cdot 1$

= $1.2231 \quad \text{in}^2$

A_{41} = $Leg^2 \cdot f_{r3}$

= $0.375^{2} \cdot 1$

= $\underline{0.1406}$ in^2

A_{42} = $Leg^2 \cdot f_{r4}$

= $0.1875^{2} \cdot 1$

= $\underline{0.0352}$ in^2

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} \cdot E_p$

= $(33 - 23 - 2 \cdot 0.5) \cdot 0.25 \cdot 1 \cdot 0.75$

= $\underline{1.6875}$ in^2

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$

$= 1.6887 + 0.5096 + 0.1406 + 0.0352 + 1.6875$

$=$ $\underline{4.0616}$ in^2

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{159.76 \cdot 11.5}{20{,}000 \cdot 0.7 - 0.6 \cdot 159.76} + 0$$

$$= 0.1321 \text{ in}$$

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

$$= \max\left[0.1321,\ 0\right]$$

$$= 0.1321 \text{ in}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{159.76 \cdot 22}{20{,}000 \cdot 1 - 0.6 \cdot 159.76} + 0$$

$$= 0.1766 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.1766,\ 0.0625\right]$$

$$= 0.1766 \text{ in}$$

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

$$= \min\left[0.3281,\ 0.1766\right]$$

$$= 0.1766 \text{ in}$$

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

$= \max[0.1321,\ 0.1766]$

$= \underline{0.1766}$ in

Available nozzle wall thickness new, t_n = 0.5 in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

Groove weld in tension:	$0.74 \cdot 20{,}000$ =	14,800 psi
Nozzle wall in shear:	$0.7 \cdot 20{,}000$ =	14,000 psi
Inner fillet weld in shear:	$0.49 \cdot 20{,}000$ =	9,800 psi
Outer fillet weld in shear:	$0.49 \cdot 20{,}000$ =	9,800 psi
Upper groove weld in tension:	$0.74 \cdot 20{,}000$ =	14,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 24 \cdot 0.375 \cdot 9{,}800$ = 138,544.24 lb_f

(2) Outer fillet weld in shear
$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 33 \cdot 0.1875 \cdot 9{,}800$ = 95,249.16 lb_f

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 23.5 \cdot 0.5 \cdot 14{,}000$ = 258,395.99 lb_f

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 24 \cdot 0.25 \cdot 14{,}800$ = 139,486.71 lb_f

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 24 \cdot 0.25 \cdot 14{,}800$ = 139,486.71 lb_f

Loading on welds per UG-41(b)(1)

W $= (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

$= (4.0613 - 1.6887 + 2 \cdot 0.5 \cdot 1 \cdot (1 \cdot 0.25 - 1 \cdot 0.1766)) \cdot 20{,}000$

= $\underline{48{,}921.2}$ lb_f

$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

$= (0.5096 + 1.6875 + 0.1406 + 0.0352) \cdot 20{,}000$

= $\underline{47{,}458}$ lb_f

$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$

$= (0.5096 + 0 + 0.1406 + 0 + 2 \cdot 0.5 \cdot 0.25 \cdot 1) \cdot 20{,}000$

= $\underline{18{,}004}$ lb_f

$W_{3\text{-}3}$ = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$

= $(0.5096 + 0 + 1.6875 + 0.1406 + 0.0352 + 0 + 2 \cdot 0.5 \cdot 0.25 \cdot 1) \cdot 20{,}000$

= 52,458 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 47,458 lb_f
Path 1-1 through (2) & (3) = 95,249.16 + 258,395.99 = 353,645.16 lb_f
Path 1-1 is stronger than $W_{1\text{-}1}$ so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 18,004 lb_f
Path 2-2 through (1), (4), (6) = 138,544.24 + 139,486.71 + 139,486.71 = 417,517.66 lb_f
Path 2-2 is stronger than $W_{2\text{-}2}$ so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 48,921.2 lb_f
Path 3-3 through (2), (4) = 95,249.16 + 139,486.71 = 234,735.88 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Check Large Opening per Appendix 1-7(a)

Area required within 75 percent of the limits of reinforcement
= 2 / 3*A = (2 / 3)*4.0613 = 2.7076 in^2

L_R = $\max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$

= $\max\left[23,\ 11.5 + (0.5 - 0) + (0.25 - 0)\right]$

= $17.25\ \text{in}$

A_1 = $(2 \cdot L_R - d) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$

= $(2 \cdot 17.25 - 23) \cdot (1 \cdot 0.25 - 1 \cdot 0.1766) - 2 \cdot 0.5 \cdot (1 \cdot 0.25 - 1 \cdot 0.1766) \cdot (1 - 1)$

= $0.8443\ \text{in}^2$

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4} \cdot E_p$

= $(33 - 23 - 2 \cdot 0.5) \cdot 0.25 \cdot 1 \cdot 0.75$

= $1.6875\ \text{in}^2$

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

= $0.8443 + 0.5096 + 0 + 0.1406 + 0.0352 + 0 + 1.6875$

= 3.2172 in^2

The area replacement requirements of Appendix 1-7(a) are satisfied.

Check Large Opening per Appendix 1-7(b)

1-7(b)(1)(a)	$\frac{R_n}{R} = \frac{11.5}{22} = 0.5227 \leq 0.7$	True
1-7(b)(1)(b)	$D_i = 44\ \text{in} > 60\ \text{in}$	False
1-7(b)(1)(c)	$d = 23\ \text{in} > 40\ \text{in}$	False
1-7(b)(1)(c)	$d = 23\ \text{in} > 3.4 \cdot \sqrt{22 \cdot 0.25} = 7.9737\ \text{in}$	True

The opening is not within the size range defined by 1-7(b)(1)(b) and (c) so it is exempt from the requirements of 1-7(b)(2),(3) and (4).

R_n / R = 0.5227 does not exceed 0.7 so a U-2(g) analysis is not required per 1-7(b)(1).

Legs #1

Inputs	
Leg material	SS304
Leg description	3 inch sch 40 pipe
Number of legs, N	4
Overall length	120"
Base to girth seam length	111.5"
User defined leg eccentricity	0"
Effective length coefficient, K	1.5
Coefficient, C_m	0.85
Leg yield stress, F_y	26,700 psi
Leg elastic modulus, E	26,700,000 psi
Angular Position	45°
Anchor Bolts	
Anchor bolt size	0.5" coarse threaded
Anchor bolt material	
Bolt circle, BC	46.5"
Anchor bolts/leg, n	1
Anchor bolt allowable stress, S_b	20,000 psi
Anchor bolt corrosion allowance	0"
Anchor bolt hole clearance	0.25"
Base Plate	
Base plate length	6"
Base plate width	6"
Base plate thickness	0.5" (0.1848" required)
Base plate allowable stress	20,000 psi
Foundation allowable bearing stress	1,658 psi
Welds	
Leg to shell fillet weld	0.25" (0.0308" 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 = 5,184.3 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}
45	45	-107.0	91.0	-48	5,771	0	0.2695	0.3245
	135	2,151.7	91.0	965	0	5,771	0.4634	0.3877
	225	3,549.8	91.0	1,592	5,771	0	0.5925	0.4269
	315	2,151.7	91.0	965	0	5,771	0.4634	0.3877
90	45	-107.0	91.0	-48	4,081	4,081	0.3840	0.4602
	135	-107.0	91.0	-48	4,081	4,081	0.3840	0.4602
	225	3,549.8	91.0	1,592	4,081	4,081	0.7423	0.5625
	315	3,549.8	91.0	1,592	4,081	4,081	0.7423	0.5625

Wind empty corroded, Moment = 4,944.1 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}
45	45	-865.1	74.6	-388	4,731	0	0.1599	0.2443
	135	780.3	74.6	350	0	4,731	0.2911	0.2903
	225	2,113.6	74.6	948	4,731	0	0.4019	0.3276
	315	780.3	74.6	350	0	4,731	0.2911	0.2903
90	45	-865.1	74.6	-388	3,345	3,345	0.2494	0.3555
	135	-865.1	74.6	-388	3,345	3,345	0.2494	0.3555
	225	2,113.6	74.6	948	3,345	3,345	0.5114	0.4389
	315	2,113.6	74.6	948	3,345	3,345	0.5114	0.4389

Seismic operating corroded, Moment = 4,159.8 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}
45	45	151.0	15.6	68	992	0	0.0581	0.0605
	135	2,170.0	15.6	973	0	992	0.1967	0.1170
	225	3,291.8	15.6	1,476	992	0	0.2747	0.1484
	315	2,170.0	15.6	973	0	992	0.1967	0.1170
90	45	151.0	15.6	68	701	701	0.0781	0.0838
	135	151.0	15.6	68	701	701	0.0781	0.0838
	225	3,291.8	15.6	1,476	701	701	0.2999	0.1717
	315	3,291.8	15.6	1,476	701	701	0.2999	0.1717

Seismic empty corroded, Moment = 4,003.6 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}
45	45	-618.1	6.0	-277	382	0	-0.0224	0.0044
	135	786.9	6.0	353	0	382	0.0706	0.0437
	225	1,866.6	6.0	837	382	0	0.1423	0.0740
	315	786.9	6.0	353	0	382	0.0706	0.0437
90	45	-618.1	6.0	-277	270	270	-0.0151	0.0134
	135	-618.1	6.0	-277	270	270	-0.0151	0.0134
	225	1,866.6	6.0	837	270	270	0.1510	0.0829
	315	1,866.6	6.0	837	270	270	0.1510	0.0829

Leg Calculations (AISC manual ninth edition)

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

$$P_1 = \frac{W_t}{N} + \frac{48 \cdot M_t}{N \cdot D} = \frac{8{,}607}{4} + \frac{48 \cdot 5{,}184.3}{4 \cdot 44.5} = \underline{3{,}549.77} \quad \text{lb}_f$$

Allowable axial compressive stress, F_a (AISC chapter E)

$$C_c = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{F_y}} = \sqrt{\frac{2 \cdot \pi^2 \cdot 26{,}700{,}000}{26{,}700}} = 140.4963$$

$$\frac{K \cdot l}{r} = \frac{1.5 \cdot 109.5}{1.1637} = 141.1414$$

$$F_a = \frac{1 \cdot 12 \cdot \pi^2 \cdot E}{23 \cdot (K \cdot l \ / \ r)^2} = \frac{1 \cdot 12 \cdot \pi^2 \cdot 26{,}700{,}000}{23 \cdot (141.1414)^2} = 6{,}902 \quad \text{psi}$$

Allowable axial compression and bending (AISC chapter H)

$$F'_{ex} = \frac{1 \cdot 12 \cdot \pi^2 \cdot E}{23 \cdot (K \cdot l/r)^2} = \frac{1 \cdot 12 \cdot \pi^2 \cdot 26{,}700{,}000}{23 \cdot (141.1414)^2} = 6{,}902 \quad \text{psi}$$

$$F'_{ey} = \frac{1 \cdot 12 \cdot \pi^2 \cdot E}{23 \cdot (K \cdot l/r)^2} = \frac{1 \cdot 12 \cdot \pi^2 \cdot 26{,}700{,}000}{23 \cdot (141.1414)^2} = 6{,}902 \quad \text{psi}$$

$$F_b = 1 \cdot 0.66 \cdot F_y = 1 \cdot 0.66 \cdot 26{,}700 = 17{,}622 \quad \text{psi}$$

Compressive axial stress

$$f_a = \frac{P_1}{A} = \frac{3{,}549.77}{2.23} = \underline{1{,}592} \quad \text{psi}$$

Bending stresses

$$f_{bx} = \frac{F \cdot \cos(\alpha) \cdot L}{I_x / C_x} + \frac{P_1 \cdot E_{cc}}{I_x / C_x} = \frac{90.95 \cdot \cos(45) \cdot 109.5}{3.02/1.75} + \frac{3{,}549.77 \cdot 0}{3.02/1.75} = \underline{4{,}081} \quad \text{psi}$$

$$f_{by} = \frac{F \cdot \sin(\alpha) \cdot L}{I_y / C_y} = \frac{90.95 \cdot \sin(45) \cdot 109.5}{3.02/1.75} = \underline{4{,}081} \quad \text{psi}$$

AISC equation $H_{1\text{-}1}$

$$H_{1-1} = \frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{(1 - f_a / F'_{ex}) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{(1 - f_a / F'_{ey}) \cdot F_{by}}$$
$$= \frac{1{,}592}{6{,}902} + \frac{0.85 \cdot 4{,}081}{(1 - 1{,}592/6{,}902) \cdot 17{,}622} + \frac{0.85 \cdot 4{,}081}{(1 - 1{,}592/6{,}902) \cdot 17{,}622}$$
$$= \underline{0.7423}$$

AISC equation $H_{1\text{-}2}$

$$H_{1-2} = \frac{f_a}{0.6 \cdot 1 \cdot F_y} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = \frac{1{,}592}{0.6 \cdot 1 \cdot 26{,}700} + \frac{4{,}081}{17{,}622} + \frac{4{,}081}{17{,}622} = \underline{0.5625}$$

4, 3 inch sch 40 pipe legs are adequate.

Anchor bolts - Wind empty corroded condition governs

Tensile loading per leg (1 bolt per leg)

$$R = \frac{48 \cdot M}{N \cdot BC} - \frac{0.6 \cdot W}{N} = \frac{48 \cdot 7{,}715.4}{4 \cdot 46.5} - \frac{0.6 \cdot 3{,}444.53}{4} = 1{,}474.39 \quad \text{lb}_f$$

Required area per bolt

$$A_b = \frac{R}{S_b \cdot n} = \frac{1{,}474.39}{20{,}000 \cdot 1} = 0.0737 \quad \text{in}^2$$

Area of a 0.5" coarse threaded bolt (corroded) = 0.126 in^2

0.5" coarse threaded bolts are satisfactory.

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

Note: continuous welding is assumed for all support leg fillet welds.

$$Z_w = \frac{2 \cdot b \cdot d + d^2}{3} = \frac{2 \cdot 3.5 \cdot 10.5 + 10.5^2}{3} = 61.25 \quad \text{in}^2$$

$$J_w = \frac{(b + 2 \cdot d)^3}{12} - \frac{d^2 \cdot (b + d)^2}{b + 2 \cdot d}$$
$$= \frac{(3.5 + 2 \cdot 10.5)^3}{12} - \frac{10.5^2 \cdot (3.5 + 10.5)^2}{3.5 + 2 \cdot 10.5}$$
$$= 343.5104 \quad \text{in}^3$$

$$E = \frac{d^2}{b + 2 \cdot d} = \frac{10.5^2}{3.5 + 2 \cdot 10.5} = 4.5 \quad \text{in}$$

Governing weld load $f_x = \text{Cos}(45) \cdot 90.95 = 64.31 \quad \text{lb}_f$

Governing weld load $f_y = \text{Sin}(45) \cdot 90.95 = 64.31 \quad \text{lb}_f$

$$f_1 = \frac{P_1}{L_{\text{weld}}} = \frac{3{,}549.77}{24.5} = 144.89 \quad \text{lb}_f/\text{in}$$ (V_L direct shear)

$$f_2 = \frac{f_y \cdot L_{\text{leg}} \cdot 0.5 \cdot b}{J_w} = \frac{64.31 \cdot 109.5 \cdot 0.5 \cdot 3.5}{343.5104} = 35.88 \ \ \text{lb}_f/\text{in}$$ (V_L torsion shear)

$$f_3 = \frac{f_y}{L_{\text{weld}}} = \frac{64.31}{24.5} = 2.63 \ \ \text{lb}_f/\text{in}$$ (V_c direct shear)

$$f_4 = \frac{f_y \cdot L_{\text{leg}} \cdot E}{J_w} = \frac{64.31 \cdot 109.5 \cdot 4.5}{343.5104} = 92.26 \ \ \text{lb}_f/\text{in}$$ (V_c torsion shear)

$$f_5 = \frac{f_x \cdot L_{\text{leg}} + P_1 \cdot E_{\text{cc}}}{Z_w} = \frac{64.31 \cdot 109.5 + 3{,}549.77 \cdot 0}{61.25} = 114.98 \ \ \text{lb}_f/\text{in}$$ (M_L bending)

$$f_6 = \frac{f_x}{L_{\text{weld}}} = \frac{64.31}{24.5} = 2.63 \ \ \text{lb}_f/\text{in}$$ (Direct outward radial shear)

$$f = \sqrt{(f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2}$$

$$= \sqrt{(144.89 + 35.88)^2 + (2.63 + 92.26)^2 + (114.98 + 2.63)^2}$$

$$= 235.6 \ \ \text{lb}_f/\text{in}$$ (Resultant shear load)

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

$$t_w = \frac{f}{0.707 \cdot 0.55 \cdot S_a} = \frac{235.6}{0.707 \cdot 0.55 \cdot 19{,}700} = \underline{0.0308} \ \ \text{in}$$

The 0.25 in leg to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$$f_p = \frac{P}{B \cdot N} = \frac{4{,}442.84}{6 \cdot 6} = 123 \ \ \text{psi}$$

$$t_b = \frac{N - (d - t_L)}{2} \cdot \sqrt{\frac{3 \cdot f_p}{S_b}} = \frac{6 - (3.5 - 0.216)}{2} \cdot \sqrt{\frac{3 \cdot 123}{20{,}000}} = \underline{0.1848} \ \ \text{in}$$

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	-90.95 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	9,959.5 lb_f-in
Longitudinal shear, V_L	-106.97 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	153.39 psi
Mean shell radius, R_m	22.125"
Local shell thickness, T	0.25"
Design factor	3

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

$$\gamma = \frac{R_m}{T} = \frac{22.125}{0.25} = 88.5$$

$$C_1 = 1.75, C_2 = 7 \ \text{ in}$$

Note: Actual lug $\frac{C_1}{C_2} < \frac{1}{4}, \frac{C_1}{C_2} = \frac{1}{4}$ used as this is the minimum ratio covered by WRC 537.

Local circumferential pressure stress $= \frac{P \cdot R_i}{T} = 13{,}499 \ \text{ psi}$

Local longitudinal pressure stress $= \frac{P \cdot R_i}{2 \cdot T} = 6{,}750 \ \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 20{,}733 \ \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \ \text{ psi}$

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

Maximum local primary membrane stress $(P_L) = 15{,}133 \ \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \ \text{ psi}$

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*	4.1224	0.2341	0	0	0	0	68	68	68	68
4C*	11.6018	0.1898	191	191	191	191	0	0	0	0
1C	0.0677	0.1392	0	0	0	0	591	-591	591	-591
2C-1	0.0371	0.1392	324	-324	324	-324	0	0	0	0
3A*	4.0754	0.1256	0	0	0	0	0	0	0	0
1A	0.0697	0.148	0	0	0	0	0	0	0	0
3B*	6.63	0.1993	-1,443	-1,443	1,443	1,443	0	0	0	0
1B-1	0.02	0.1637	-5,276	5,276	5,276	-5,276	0	0	0	0
Pressure stress*			13,499	13,499	13,499	13,499	13,499	13,499	13,499	13,499
Total circumferential stress			7,295	17,199	20,733	9,533	14,158	12,976	14,158	12,976
Primary membrane circumferential stress*			12,247	12,247	15,133	15,133	13,567	13,567	13,567	13,567
3C*	5.6675	0.1898	93	93	93	93	0	0	0	0
4C*	9.9965	0.2341	0	0	0	0	164	164	164	164
1C-1	0.0469	0.1977	409	-409	409	-409	0	0	0	0
2C	0.03	0.1977	0	0	0	0	262	-262	262	-262
4A*	7.7404	0.1256	0	0	0	0	0	0	0	0
2A	0.0261	0.187	0	0	0	0	0	0	0	0
4B*	3.178	0.1993	-1,366	-1,366	1,366	1,366	0	0	0	0
2B-1	0.0198	0.2264	-3,779	3,779	3,779	-3,779	0	0	0	0
Pressure stress*			6,750	6,750	6,750	6,750	6,750	6,750	6,750	6,750
Total longitudinal stress			2,107	8,847	12,397	4,021	7,176	6,652	7,176	6,652
Primary membrane longitudinal stress*			5,477	5,477	8,209	8,209	6,914	6,914	6,914	6,914
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	15	15	-15	-15
Total Shear stress			0	0	0	0	15	15	-15	-15
Combined stress (P_L+P_b+Q)			7,295	17,199	20,733	9,533	14,158	12,976	14,158	12,976

* denotes primary stress.

pH SENSOR (X2)

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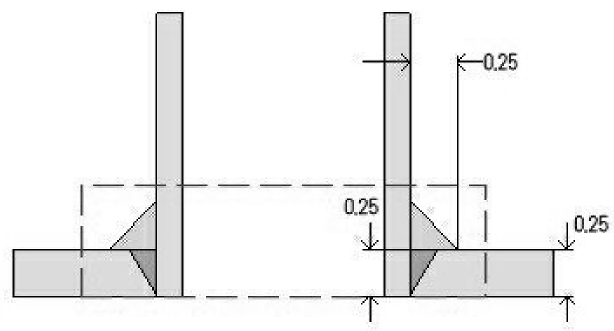


Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	Cylinder #2
Orientation	180°
Nozzle center line offset to datum line	6"
End of nozzle to shell center	28.25"
Passes through a Category A joint	No
Nozzle	
Service	Process Nozzle (NOZ)
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"
Projection available outside vessel, Lpr	5.867"
Projection available outside vessel to flange face, Lf	6"
Local vessel minimum thickness	0.25"
Liquid static head included	3.2 psi
Welds	
Inner fillet, Leg_{41}	0.25"
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 300 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	3.18 psi
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 psi @ 70°F
External fillet weld leg (UW-21)	0.2156" (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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.133, 0.38\right] =$	0.1862"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.1862 + \frac{0}{0.7} =$	0.1862"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text}('') + \frac{C_i}{0.7}\right] = \min\left[0.133, 0.25 + \frac{0}{0.7}\right] =$	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	
$t_r = \frac{153.2 \cdot 0.5245}{17{,}000 \cdot 1 - 0.6 \cdot 153.2} =$	0.0048"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0048 \cdot 1}{0.1164 - 0} =$	0.0408
Impact test exempt per UHA-51(g) (coincident ratio = 0.0408)	
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 = 153.2 psi @ 350 °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	0.175	weld size is adequate

Calculations for internal pressure 153.2 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[1.049,\ 0.5245 + (0.133 - 0) + (0.25 - 0)\right]$$

$$= 1.049 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.133 - 0) + 0\right]$$

$$= 0.3325 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{153.1955 \cdot 0.5245}{19{,}700 \cdot 1 - 0.6 \cdot 153.1955}$$

$$= 0.0041 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{153.1955 \cdot 22}{19{,}700 \cdot 1 - 0.6 \cdot 153.1955}$$

$$= 0.1719 \text{ in}$$

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

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{153.1955 \cdot 22}{19{,}700 \cdot 0.7 - 0.6 \cdot 153.1955}$$

$$= 0.246 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min[0.75,\ t_n,\ t] =$ 0.133 in

$t_{c(\min)} = \min[0.25,\ 0.7 \cdot t_{\min}] =$ 0.0931 in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175$ 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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{153.1955 \cdot 0.5245}{16{,}700 \cdot 1 - 0.6 \cdot 153.1955} + 0$$

$$= 0.0048 \text{ in}$$

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

$$= \max[0.0048,\ 0]$$

$$= 0.0048 \text{ in}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{153.1955 \cdot 22}{19{,}700 \cdot 1 - 0.6 \cdot 153.1955} + 0$$

$$= 0.1719 \text{ in}$$

$$t_{b1} = \max[t_{b1},\ t_{b\text{UG16}}]$$

$$= \max[0.1719,\ 0.0625]$$

$$= 0.1719 \text{ in}$$

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

$$= \min[0.1164,\ 0.1719]$$

$$= 0.1164 \text{ in}$$

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

$$= \max[0.0048,\ 0.1164]$$

$$= \underline{0.1164} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.133 = 0.1164$ 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 = 222.35 psi @ 350 °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	0.175	weld size is adequate

Calculations for internal pressure 222.35 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[1.049,\ 0.5245 + (0.133 - 0) + (0.25 - 0)\right]$$

$$= 1.049 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.133 - 0) + 0\right]$$

$$= 0.3325 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{222.352 \cdot 0.5245}{19{,}700 \cdot 1 - 0.6 \cdot 222.352}$$

$$= 0.006 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{222.352 \cdot 22}{19{,}700 \cdot 1 - 0.6 \cdot 222.352}$$

$$= 0.25 \text{ in}$$

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

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{222.352 \cdot 22}{19{,}700 \cdot 0.7 - 0.6 \cdot 222.352}$$

$$= 0.3582 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.133 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.0931}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.25 = 0.175$ 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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{222.352 \cdot 0.5245}{16{,}700 \cdot 1 - 0.6 \cdot 222.352} + 0$$

$$= 0.007 \text{ in}$$

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

$$= \max\left[0.007,\ 0\right]$$

$$= 0.007 \text{ in}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{222.352 \cdot 22}{19{,}700 \cdot 1 - 0.6 \cdot 222.352} + 0$$

$$= 0.25 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.25,\ 0.0625\right]$$

$$= 0.25 \text{ in}$$

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

$$= \min\left[0.1164,\ 0.25\right]$$

$$= 0.1164 \text{ in}$$

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

$$= \max\left[0.007,\ 0.1164\right]$$

$$= \underline{0.1164} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.133 = 0.1164$ 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 = 225.73 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 225.73 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[1.049,\ 0.5245 + (0.133 - 0) + (0.25 - 0)\right]$$

$$= 1.049 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.133 - 0) + 0\right]$$

$$= 0.3325 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{225.7319 \cdot 0.5245}{20{,}000 \cdot 1 - 0.6 \cdot 225.7319}$$

$$= 0.006 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{225.7319 \cdot 22}{20{,}000 \cdot 1 - 0.6 \cdot 225.7319}$$

$$= 0.25 \text{ in}$$

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

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{225.7319 \cdot 22}{20{,}000 \cdot 0.7 - 0.6 \cdot 225.7319}$$

$$= 0.3582 \text{ in}$$

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{225.7319 \cdot 0.5245}{17{,}000 \cdot 1 - 0.6 \cdot 225.7319} + 0$$

$$= 0.007 \quad \text{in}$$

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

$$= \max\left[0.007,\ 0\right]$$

$$= 0.007 \quad \text{in}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{225.7319 \cdot 22}{20{,}000 \cdot 1 - 0.6 \cdot 225.7319} + 0$$

$$= 0.25 \quad \text{in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.25,\ 0.0625\right]$$

$$= 0.25 \quad \text{in}$$

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

$$= \min\left[0.1164,\ 0.25\right]$$

$$= 0.1164 \quad \text{in}$$

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

$$= \max\left[0.007,\ 0.1164\right]$$

$$= \underline{0.1164} \quad \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.133$ = 0.1164 in

The nozzle neck thickness is adequate.

Straight Flange on F&D Head #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		150	350	-20
Static Liquid Head				
Condition		P_S (psi)	H_S (in)	SG
Operating		3.47	96	1
Test horizontal		1.59	44	1
Dimensions				
Inner Diameter		44"		
Length		2"		
Nominal Thickness		0.5"		
Corrosion	Inner	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		Capacity (US gal)
New		40.54		13.16
Corroded		40.54		13.16
Radiography				
Longitudinal seam		Seamless No RT		
Top Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.2028"
Design thickness due to combined loadings + corrosion	0.102"
Maximum allowable working pressure (MAWP)	371.98 psi
Maximum allowable pressure (MAP)	381.17 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \dfrac{153.47 \cdot 22}{20{,}000 \cdot 0.85 - 0.6 \cdot 153.47} =$	0.1997"
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0.1997 \cdot 0.85}{0.5 - 0} =$	0.3395
$\text{Stress ratio longitudinal} = \dfrac{2{,}793 \cdot 0.8}{20{,}000 \cdot 0.7} =$	0.1596
Impact test exempt per UHA-51(g) (coincident ratio = 0.3395)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 350 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{153.47 \cdot 22}{19{,}700 \cdot 0.85 - 0.60 \cdot 153.47} + 0 = \underline{0.2028}"$$

Maximum allowable working pressure, (at 350 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{19{,}700 \cdot 0.85 \cdot 0.5}{22 + 0.60 \cdot 0.5} - 3.47 = \underline{371.98} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 0.85 \cdot 0.5}{22 + 0.60 \cdot 0.5} = \underline{381.17} \text{ psi}$$

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

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.5}{22.25}\right) \cdot \left(1 - \frac{22.25}{\infty}\right) = 1.1236\,\%$$

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	150	19,700	11,263	350	0	Wind	0.102	0.101
						Seismic	0.102	0.101
Operating, Hot & New	150	19,700	11,263	350	0	Wind	0.102	0.101
						Seismic	0.102	0.101
Hot Shut Down, Corroded	0	19,700	11,263	350	0	Wind	0.0025	0.0015
						Seismic	0.0025	0.0014
Hot Shut Down, New	0	19,700	11,263	350	0	Wind	0.0025	0.0015
						Seismic	0.0025	0.0014
Empty, Corroded	0	20,000	12,430	70	0	Wind	0.0001	0.0001
						Seismic	0.0001	0.0001
Empty, New	0	20,000	12,430	70	0	Wind	0.0001	0.0001
						Seismic	0.0001	0.0001
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0	19,700	11,263	350	0	Weight	0.0029	0.0029

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.5/0.5} = 0.002778$$

$$B = 11{,}263 \quad \text{psi}$$

$$S = \frac{19{,}700}{1.00} = 19{,}700 \quad \text{psi}$$

$$S_{cHC} \ = \ \min\left(B, S\right) = \underline{11{,}263 \text{ psi}}$$

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

$$S_c HN = S_c HC = \underline{11{,}263 \text{ psi}}$$

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.5/0.5} = 0.002778$$

$$B = 12{,}430 \quad \text{psi}$$

$$S = \frac{20{,}000}{1.00} = 20{,}000 \quad \text{psi}$$

$$S_{cCN} \ = \ \min\left(B, S\right) = \underline{12{,}430 \text{ psi}}$$

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

$$S_c \mathbb{C} = S_c CN = \underline{12{,}430 \text{ psi}}$$

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{22.5/0.5} = 0.002778$$

$$B = 11{,}263 \quad \text{psi}$$

$$S = \frac{19{,}700}{1.00} = 19{,}700 \quad \text{psi}$$

$$S_{cVC} \ = \ \min\left(B, S\right) = \underline{11{,}263 \text{ psi}}$$

Operating, Hot & Corroded, Wind, Top Seam

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

$= \frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

$t_m = \frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \frac{187}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{-5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0024"

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

$= 0.0995 + 0 - (-0.0024)$

= <u>0.102"</u>

$t_{w\ c} = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{0.60 * -5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0015"

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

$= |0 + (-0.0015) - (0.0995)|$

= <u>0.101"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.5 - 0 + (-0.0024))}{22 - 0.40 \cdot (0.5 - 0 + (-0.0024))}$

= <u>755.33</u> psi

<u>Operating, Hot & New, Wind, Top Seam</u>

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

$= \frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

$t_m = \frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \frac{187}{\pi \cdot 22.25^{\ 2} \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{-5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0024"

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

$= 0.0995 + 0 - (-0.0024)$

= <u>0.102"</u>

$t_{w\,c} = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \frac{0.60 * -5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0015"

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

$= |0 + (-0.0015) - (0.0995)|$

= <u>0.101"</u>

Maximum allowable working pressure, Longitudinal Stress

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

$= \frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.5 - 0 + (-0.0024))}{22 - 0.40 \cdot (0.5 - 0 + (-0.0024))}$

= 755.33 psi

<u>Hot Shut Down, Corroded, Wind, Top Seam</u>

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{187}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

t_w = $\dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{-5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0024"

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

= $0 + 0 - (-0.0024)$

= 0.0025"

$t_{w\,c}$ = $\dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.60 * -5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -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 = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{187}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

t_w = $\dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{-5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0024"

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

= $0 + 0 - (-0.0024)$

= 0.0025"

$t_{w\,c}$ = $\dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.60{*}{-5{,}652.1}}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -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)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{165}{\pi \cdot 22.25\ ^2 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= 0"

$t_w = \dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{-291.8}{2 \cdot \pi \cdot 22.25 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= -0.0001"

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

$= 0 + 0 - (\,-0.0001)$

= <u>0.0001"</u>

$t_{w\,c} = \dfrac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.60*\text{-}291.8}{2 \cdot \pi \cdot 22.25 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= -0.0001"

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

$= |0 + (\,-0.0001) - (0)|$

= <u>0.0001"</u>

<u>Empty, New, Wind, Top Seam</u>

t_p = 0" (Pressure)

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

$$= \frac{165}{\pi \cdot 22.25^{\ 2} \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$$

= 0"

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

$$= \frac{-291.8}{2 \cdot \pi \cdot 22.25 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$$

= -0.0001"

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

$$= 0 + 0 - (-0.0001)$$

= <u>0.0001"</u>

$$t_{w\,c} = \frac{0.6 \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \quad \text{(Weight)}$$

$$= \frac{0.60 * -291.8}{2 \cdot \pi \cdot 22.25 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$$

= -0.0001"

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

$$= |0 + (-0.0001) - (0)|$$

= <u>0.0001"</u>

<u>Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Top Seam</u>

t_p = 0" (Pressure)

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

$$= \frac{60}{\pi \cdot 22.25^{\ 2} \cdot 19{,}700 \cdot 1.00 \cdot 0.70}$$

= 0"

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

$$= \frac{-5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.00 \cdot 0.70}$$

= -0.0029"

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

$$= 0 + 0 - (-0.0029)$$

= <u>0.0029"</u>

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

$$= |0 + (-0.0029) - (0)|$$

= <u>0.0029"</u>

<u>Operating, Hot & Corroded, Seismic, Top Seam</u>

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

= $\frac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

t_m = $\frac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\frac{75}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

t_w = $\frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{1.01\text{*-}5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0025"

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

= $0.0995 + 0 - (-0.0025)$

= <u>0.102"</u>

$t_{w\,c}$ = $\frac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\frac{0.59\text{*-}5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0014"

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

= $|0 + (-0.0014) - (0.0995)|$

= <u>0.101"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\frac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.5 - 0 + (-0.0025))}{22 - 0.40 \cdot (0.5 - 0 + (-0.0025))}$

= <u>755.3</u> psi

<u>Operating, Hot & New, Seismic, Top Seam</u>

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

= $\dfrac{150 \cdot 22}{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 + 0.40 \cdot |150|}$

= 0.0995"

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{75}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

t_w = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.01\text{*-}5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0025"

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

= $0.0995 + 0 - (-0.0025)$

= <u>0.102"</u>

t_{wc} = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59\text{*-}5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0014"

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

= $|0 + (-0.0014) - (0.0995)|$

= <u>0.101"</u>

Maximum allowable working pressure, Longitudinal Stress

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

= $\dfrac{2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70 \cdot (0.5 - 0 + (-0.0025))}{22 - 0.40 \cdot (0.5 - 0 + (-0.0025))}$

= 755.3 psi

<u>Hot Shut Down, Corroded, Seismic, Top Seam</u>

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{75}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

t_w = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.01\text{*-}5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0025"

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

= $0 + 0 - (-0.0025)$

= <u>0.0025"</u>

$t_{w\,c}$ = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59\text{*-}5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0014"

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

= $|0 + (-0.0014) - (0)|$

= <u>0.0014"</u>

<u>Hot Shut Down, New, Seismic, Top Seam</u>

t_p = 0" (Pressure)

t_m = $\dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

= $\dfrac{75}{\pi \cdot 22.25\ ^2 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= 0"

t_w = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.01\text{*-}5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0025"

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

= $0 + 0 - (- 0.0025)$

= <u>0.0025"</u>

$t_{w\,c}$ = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.59\text{*-}5{,}652.1}{2 \cdot \pi \cdot 22.25 \cdot 19{,}700 \cdot 1.20 \cdot 0.70}$

= -0.0014"

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

= $|0 + (- 0.0014) - (0)|$

= <u>0.0014"</u>

<u>Empty, Corroded, Seismic, Top Seam</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{69}{\pi \cdot 22.25\ ^2 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= 0"

$t_w = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.01\text{*-}291.8}{2 \cdot \pi \cdot 22.25 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= -0.0001"

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

$= 0 + 0 - (-0.0001)$

= <u>0.0001"</u>

$t_{w\,c} = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.59\text{*-}291.8}{2 \cdot \pi \cdot 22.25 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= -0.0001"

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

$= |0 + (-0.0001) - (0)|$

= <u>0.0001"</u>

<u>Empty, New, Seismic, Top Seam</u>

t_p = 0" (Pressure)

$t_m = \dfrac{M}{\pi \cdot R_m^2 \cdot S_t \cdot K_s \cdot E_c}$ (bending)

$= \dfrac{69}{\pi \cdot 22.25\ ^2 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= 0"

$t_w = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.01\text{*-}291.8}{2 \cdot \pi \cdot 22.25 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= -0.0001"

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

$= 0 + 0 - (-0.0001)$

= <u>0.0001"</u>

$t_{wc} = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.59\text{*-}291.8}{2 \cdot \pi \cdot 22.25 \cdot 20{,}000 \cdot 1.20 \cdot 0.70}$

= -0.0001"

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

$= |0 + (-0.0001) - (0)|$

= <u>0.0001"</u>

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

F&D Head #2

<table>
<tr><th colspan="5">ASME Section VIII Division 1, 2023 Edition</th></tr>
<tr><td colspan="2">Component</td><td colspan="3">F&D Head</td></tr>
<tr><td colspan="2">Material</td><td colspan="3">SA-240 316 (II-D p. 76, ln. 21)</td></tr>
<tr><td colspan="2">Attached To</td><td colspan="3">Cylinder #2</td></tr>
<tr><td>Impact Tested</td><td>Normalized</td><td>Fine Grain Practice</td><td>PWHT</td><td>Maximize MDMT/ No MAWP</td></tr>
<tr><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td colspan="2"></td><td>Design Pressure (psi)</td><td>Design Temperature (°F)</td><td>Design MDMT (°F)</td></tr>
<tr><td colspan="2">Internal</td><td>150</td><td>350</td><td>-20</td></tr>
<tr><th colspan="5">Static Liquid Head</th></tr>
<tr><td colspan="2">Condition</td><td>P_s (psi)</td><td>H_s (in)</td><td>SG</td></tr>
<tr><td colspan="2">Operating</td><td>3.75</td><td>103.7591</td><td>1</td></tr>
<tr><td colspan="2">Test horizontal</td><td>1.59</td><td>44</td><td>1</td></tr>
<tr><th colspan="5">Dimensions</th></tr>
<tr><td colspan="2">Inner Diameter</td><td colspan="3">44"</td></tr>
<tr><td colspan="2">Crown Radius L</td><td colspan="3">44"</td></tr>
<tr><td colspan="2">Knuckle Radius r</td><td colspan="3">3.15"</td></tr>
<tr><td colspan="2">Minimum Thickness</td><td colspan="3">0.4375"</td></tr>
<tr><td rowspan="2">Corrosion</td><td>Inner</td><td colspan="3">0"</td></tr>
<tr><td>Outer</td><td colspan="3">0"</td></tr>
<tr><td colspan="2">Length L_{sf}</td><td colspan="3">2"</td></tr>
<tr><td colspan="2">Nominal Thickness t_{sf}</td><td colspan="3">0.5"</td></tr>
<tr><th colspan="5">Weight and Capacity</th></tr>
<tr><td colspan="2"></td><td colspan="2">Weight (lb)[1]</td><td>Capacity (US gal)[1]</td></tr>
<tr><td colspan="2">New</td><td colspan="2">278.96</td><td>44.96</td></tr>
<tr><td colspan="2">Corroded</td><td colspan="2">278.96</td><td>44.96</td></tr>
<tr><th colspan="5">Radiography</th></tr>
<tr><td colspan="2">Category A joints</td><td colspan="3">Seamless No RT</td></tr>
<tr><td colspan="2">Head to shell seam</td><td colspan="3">None UW-11(c) Type 1</td></tr>
</table>

[1] includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.3406"
Maximum allowable working pressure (MAWP)	193.72 psi
Maximum allowable pressure (MAP)	200.47 psi
Straight Flange governs MDMT	-320°F

Note: Endnote 66 used to determine allowable stress.

Factor M		
$M = \frac{1}{4} \cdot \left[3 + \left(\frac{L}{r} \right)^{\frac{1}{2}} \right]$		
Corroded	$M = \frac{1}{4} \cdot \left[3 + \left(\frac{44}{3.15} \right)^{\frac{1}{2}} \right]$	1.6844
New	$M = \frac{1}{4} \cdot \left[3 + \left(\frac{44}{3.15} \right)^{\frac{1}{2}} \right]$	1.6844

Design thickness for internal pressure, (Corroded at 350 °F) Appendix 1-4(d)

$$t = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} \;= \frac{153.75 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 153.75} + 0 \;= \underline{0.3405}''$$

Maximum allowable working pressure, (Corroded at 350 °F) Appendix 1-4(d)

$$P = \frac{2 \cdot S \cdot E \cdot t}{L \cdot M + 0.2 \cdot t} - P_s \;= \frac{2 \cdot 19{,}700 \cdot 0.85 \cdot 0.4375}{44 \cdot 1.6844 + 0.2 \cdot 0.4375} - 3.75 \;= \underline{193.72} \text{ psi}$$

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

$$P = \frac{2 \cdot S \cdot E \cdot t}{L \cdot M + 0.2 \cdot t} - P_s \;= \frac{2 \cdot 20{,}000 \cdot 0.85 \cdot 0.4375}{44 \cdot 1.6844 + 0.2 \cdot 0.4375} - 0 \;= \underline{200.47} \text{ psi}$$

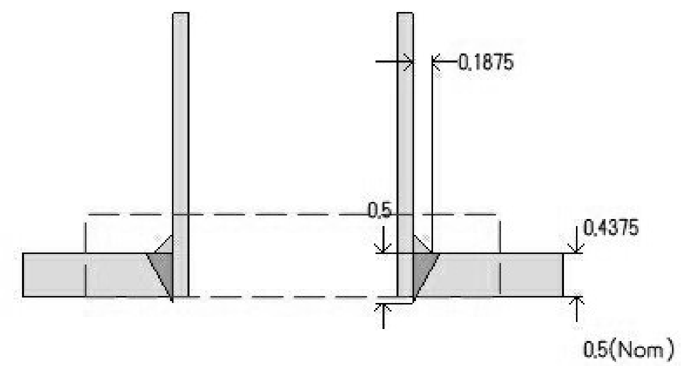
% Forming strain - UHA-44(a)(2)

$$EFE = \left(\frac{75 \cdot t}{R_f} \right) \cdot \left(1 - \frac{R_f}{R_o} \right) = \left(\frac{75 \cdot 0.5}{3.4} \right) \cdot \left(1 - \frac{3.4}{\infty} \right) = 11.0294\,\%$$

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

OUTLETT (O)

ASME Section VIII Division 1, 2023 Edition	



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

Location and Orientation	
Located on	F&D Head #2
Orientation	0°
End of nozzle to datum line	-16.0343"
Calculated as hillside	No
Distance to head center, R	0"
Passes through a Category A joint	No
Nozzle	
Service	Process Nozzle (NOZ)
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	5.6996"
Projection available outside vessel to flange face, Lf	5.8536"
Local vessel minimum thickness	0.4375"
Liquid static head included	3.96 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.5"
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 300 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	3.97 psi
Consider External Loads on Flange MAWP Rating	No
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.154, 0.435\right] =$	0.2156"
$\text{External Leg}_{\min} = X_{\min} + \dfrac{C_o}{0.7} = 0.2156 + \dfrac{0}{0.7} =$	0.2156"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text}(") + \dfrac{C_i}{0.7}\right] = \min\left[0.154, 0.25 + \dfrac{0}{0.7}\right] =$	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	
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0.0851 \cdot 1}{0.1348 - 0} =$	0.6315
Rated MDMT per UHA-51(d)(1)(a), (carbon content does not exceed 0.10%) = -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 = 153.96 psi @ 350 °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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	153.96	-629	4,068	472	4,068	472	3,720	**33,643**	**59,100**	**15,709**	**29,550**	No
Load case 1 (Hot Shut Down)	0	-629	4,068	472	4,068	472	3,720	19,659	59,100	1,725	29,550	No
Load case 1 (Pr Reversed)	153.96	629	4,068	472	4,068	472	3,720	30,198	59,100	14,942	29,550	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	629	4,068	472	4,068	472	3,720	-19,659	59,100	-1,725	29,550	No

Calculations for internal pressure 153.96 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.067,\ \ 1.0335 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.067 \ \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ \ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ \ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \ \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{153.9561 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 153.9561}$$

$$= 0.0081 \ \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{153.9561 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 153.9561}$$

$$= 0.1721 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{153.96 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 153.96} = 0.341 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.1078 in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313 \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{153.9719 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 153.9719} + 0$$

$$= 0.0096 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0723 \text{ in}$$

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

$$= \max\left[0.0096,\ 0.0723\right]$$

$$= 0.0723 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{153.96 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 153.96} + 0$$

$$= 0.2898 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2898,\ 0.0625\right]$$

$$= 0.2898 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.2898\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0723,\ 0.1348\right]$$

$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	153.96 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{r_m}{t} = \frac{1.1009}{0.1348} = 8.1698$$

$$\rho = \frac{T}{t} = \frac{0.4375}{0.1348} = 3.2468$$

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

WRC 537 Nondimensional Coefficients

$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$

γ = 5, ρ = 2	SP-3				SM-3			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0.3656	0.6924	194.6898	0.1169	3,575.8953	-1,612.8152	1.1658	-0.2512
b	20.761	41.4599	35,425.74	0.0485	18,337.83	-16,367.04	6.6119	-4.0064
c	2.1174	6.5648	6,712.6521	1.0834	-148,402.8	19,145.7	-1.8023	1.206
d	39.8904	56.9657	67,541.61	6.5638	-1,113,150	231,710.9	-7.5795	11.6011
e	-1.5403	-10.362	-7,076.6023	-1.4491	1,808,340	174,103.8	0.7851	-0.9153
f	6.0842	50.3033	-38,750.21	-8.5622	1.9219E+07	969,880.3	-0.5602	-10.415
g	0.3004	5.2068	7,127.4907	0.6633	-121,264.6	74,723.92	0.0402	0.1529
h	0	-124.8434	52,813.19	4.7651	4,868,062	1,365,329	2.7493	3.6043
i	0	-0.8506	-976.6428	-0.1059	-427,941.1	-91,957.24	0	0
j	0	45.9146	0	-0.7887	8,286,525	1,729,110	0	0
Y	0.0863	0.108	0.1161	0.2347	0.2668	0.4172	0.3296	0.0185

WRC 537 Nondimensional Coefficients								
$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$								
γ = 5 ρ = 4	SP-4				SM-4			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0.1955	0.7443	2.537	0.1606	-3.9242	12.6132	-0.9607	-6.9959
b	355.6102	7.533	1,071.7354	22.9473	-68.5346	29.9988	-43.2509	114.214
c	21.1677	-2.6223	127.4587	10.3372	228.2976	-129.5801	-7.5852	81.2222
d	1,539.5199	-7.6574	2,112.6475	-190.1285	9,214.6671	-214.241	8.1123	-726.9062
e	-9.9855	9.5634	-131.0041	-76.2413	341.9835	558.1185	5.3251	-296.5262
f	356.7674	64.1716	-8,161.6149	517.979	12,323.9	595.3023	11.1703	1,724.0898
g	0	-5.6615	-54.494	186.8225	-372.3161	-319.0507	0	427.4096
h	0	62.296	7,160.3101	-483.8102	0	2,813.0991	0	-1,948.4552
i	0	0	102.0928	-102.4669	0	0	0	-195.9934
j	0	0	-1,577.3732	408.8865	0	0	0	1,040.0273
Y	0.024	0.1528	0.0841	0.3404	0.084	0.5972	0.2656	0.1757

WRC 537 Nondimensional Coefficients								
$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$								
γ = 15 ρ = 2	SP-6				SM-6			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0.4364	0.4568	0.5408	0.199	1.2527	1.9756	3.4348	-0.6545
b	23.8528	18.4406	86.1146	1.3701	-9.7364	-10.5872	32.542	2.3553
c	3.1218	0.5744	10.6552	0.9562	42.3407	-7.1545	-9.1948	3.7495
d	57.2195	2.9177	210.1066	4.8904	581.7506	267.0319	0.2003	6.5143
e	-1.23	0.2335	-2.8821	-0.1717	-11.5154	184.7135	14.4342	-2.6465
f	-0.5058	37.5435	66.5636	-0.1752	-363.3128	406.7564	-130.0729	-5.4867
g	0.4263	0	1.9553	0	4.4567	337.601	1.057	0.5907
h	16.5587	0	0	0	555.7041	5,118.1159	350.2929	1.9002
i	0	0	0	0	0	-155.8292	0	0
j	0	0	0	0	0	2,619.7988	0	0
Y	0.1025	0.0907	0.0794	0.2581	0.3262	0.3416	0.2225	0.0877

WRC 537 Nondimensional Coefficients								
$Y = \dfrac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$								
γ = 15 ρ = 4	SP-7				SM-7			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0.1225	1.1858	0.152	0.2586	81,160.67	54.8627	-7.2531E+09	-2,889.5632
b	10.2618	30.9469	6.4077	2.6992	2,773,928	313.4235	2.0933E+11	44,457.77
c	0.0628	0.7386	-0.2621	2.1956	11,224.63	-805.6348	2.2821E+11	31,259.89
d	2.5604	-22.7834	-20.1141	10.0386	-888,508.9	-5,199.714	6.2796E+12	-175,466.5
e	-9.8501E-04	0.8686	0.1324	0.3281	-4,806.5269	2,622.0799	1.5072E+12	-81,861.2
f	7.9918	86.4361	30.2989	-5.923	3,917,797	23,612.83	3.0942E+13	299,387.2
g	0	-0.3301	0.2529	-0.3719	0	4,442.2399	1.7691E+11	85,306.95
h	0	0	-12.616	4.2863	0	-21,199.17	3.2234E+12	-247,881.6
i	0	0	-0.0853	0	0	-1,946.6481	0	-22,718.26
j	0	0	1.8294	0	0	79,566.95	0	113,956.5
Y	0.0339	0.1535	0.0531	0.3668	0.1101	0.6108	0.1619	0.2888

Pressure stress intensity factor, $I = 1.8064$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 13{,}984 \ \text{psi}$

Maximum combined stress $(P_L + P_b + Q) = 33{,}643 \ \text{psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100 \ \text{psi}$

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 15{,}709 \ \text{psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550 \ \text{psi}$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SP-1 to 10*	$\frac{N_x \cdot T}{P}$	0.0857	281	281	281	281	281	281	281	281
SP-1 to 10	$\frac{M_x}{P}$	0.0513	1,012	-1,012	1,012	-1,012	1,012	-1,012	1,012	-1,012
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.2564	0	0	0	0	-1,239	-1,239	1,239	1,239
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1651	0	0	0	0	-4,786	4,786	4,786	-4,786
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.2564	-1,239	-1,239	1,239	1,239	0	0	0	0
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1651	-4,786	4,786	4,786	-4,786	0	0	0	0
Pressure stress*			13,984	13,984	13,984	13,984	13,984	13,984	13,984	13,984
Total O_x stress			9,252	16,800	21,302	9,706	9,252	16,800	21,302	9,706
Membrane O_x stress*			13,026	13,026	15,504	15,504	13,026	13,026	15,504	15,504
SP-1 to 10*	$\frac{N_y \cdot T}{P}$	0.3086	1,014	1,014	1,014	1,014	1,014	1,014	1,014	1,014
SP-1 to 10	$\frac{M_y}{P}$	0.134	2,642	-2,642	2,642	-2,642	2,642	-2,642	2,642	-2,642
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1471	0	0	0	0	-711	-711	711	711
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5231	0	0	0	0	-15,166	15,166	15,166	-15,166
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1471	-711	-711	711	711	0	0	0	0
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5231	-15,166	15,166	15,166	-15,166	0	0	0	0
Pressure stress*			13,984	13,984	13,984	13,984	13,984	13,984	13,984	13,984
Total O_y stress			1,763	26,811	33,517	-2,099	1,763	26,811	33,517	-2,099
Membrane O_y stress*			14,287	14,287	15,709	15,709	14,287	14,287	15,709	15,709
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			9,455	26,964	33,554	11,881	9,312	26,856	33,643	12,066
(1) * denotes primary stress. (2) The nozzle is analyzed as a hollow attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{153.96 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875^{\ 2} - 1.0335^{\ 2}\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 11{,}438 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^2 + 472^2}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \ \ \text{psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^{\ 2} \cdot 0.154} = 3{,}599 \ \ \text{psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \ \ \text{psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \ \ \text{psi})$

Reinforcement Calculations for MAWP

Local stresses at the nozzle OD per WRC 537 govern the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 306.33 psi @ 350 °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

WRC 537												
Load Case	P (psi)	P_r (lb_f)	M_1 (lb_f-in)	V_2 (lb_f)	M_2 (lb_f-in)	V_1 (lb_f)	M_t (lb_f-in)	Max Comb Stress (psi)	Allow Comb Stress (psi)	Max Local Primary Stress (psi)	Allow Local Primary Stress (psi)	Over stressed
Load case 1	306.33	-629	4,068	472	4,068	472	3,720	**47,484**	**59,100**	**29,550**	**29,550**	No
Load case 1 (Pr Reversed)	306.33	629	4,068	472	4,068	472	3,720	44,039	59,100	28,783	29,550	No

Calculations for internal pressure 306.33 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[2.067,\ 1.0335 + (0.154 - 0) + (0.4375 - 0)\right]$$

$$= 2.067 \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$

$$= 0.385 \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{306.3312 \cdot 1.0335}{19{,}700 \cdot 1 - 0.6 \cdot 306.3312}$$

$$= 0.0162 \ \text{in}$$

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

$t_r \quad = \quad \dfrac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$

$= \quad \dfrac{306.3312 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 306.3312}$

$= \quad 0.3426 \ \text{ in}$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{306.33 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 306.33} = 0.6791 \ \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.154 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.1078 in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313 \ \text{ in}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$t_{a\text{UG-27}} \quad = \quad \dfrac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$

$= \quad \dfrac{306.347 \cdot 1.0335}{16{,}700 \cdot 1 - 0.6 \cdot 306.347} + 0$

$= \quad 0.0192 \ \text{ in}$

$t_{a\text{UG-22}} \quad = \quad 0.0769 \ \text{ in}$

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

$= \quad \max\left[0.0192,\ 0.0769\right]$

$= \quad 0.0769 \ \text{ in}$

$t_{b1} \quad = \quad \dfrac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$

$= \quad \dfrac{306.33 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 306.33} + 0$

$= \quad 0.5771 \ \text{ in}$

$t_{b1} \quad = \quad \max\left[t_{b1},\ t_{b\text{UG16}}\right]$

$= \quad \max\left[0.5771,\ 0.0625\right]$

$= \quad 0.5771 \ \text{ in}$

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

$$= \min\left[0.1348,\ 0.5771\right]$$

$$= 0.1348 \ \text{in}$$

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

$$= \max\left[0.0769,\ 0.1348\right]$$

$$= \underline{0.1348} \ \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-629 lb_f
Circumferential moment, M_1	4,068 lb_f-in
Circumferential shear, V_2	472 lb_f
Longitudinal moment, M_2	4,068 lb_f-in
Longitudinal shear, V_1	472 lb_f
Torsion moment, M_t	3,720 lb_f-in
Internal pressure, P	306.33 psi
Mean dish radius, R_m	44.2188"
Local head thickness, T	0.4375"
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{r_m}{t} = \frac{1.1009}{0.1348} = 8.1698$$

$$\rho = \frac{T}{t} = \frac{0.4375}{0.1348} = 3.2468$$

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{1.1875}{\sqrt{44.2188 \cdot 0.4375}} = 0.27$$

WRC 537 Nondimensional Coefficients

$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$

γ = 5 ρ = 2	SP-3				SM-3			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0.3656	0.6924	194.6898	0.1169	3,575.8953	-1,612.8152	1.1658	-0.2512
b	20.761	41.4599	35,425.74	0.0485	18,337.83	-16,367.04	6.6119	-4.0064
c	2.1174	6.5648	6,712.6521	1.0834	-148,402.8	19,145.7	-1.8023	1.206
d	39.8904	56.9657	67,541.61	6.5638	-1,113,150	231,710.9	-7.5795	11.6011
e	-1.5403	-10.362	-7,076.6023	-1.4491	1,808,340	174,103.8	0.7851	-0.9153
f	6.0842	50.3033	-38,750.21	-8.5622	1.9219E+07	969,880.3	-0.5602	-10.415
g	0.3004	5.2068	7,127.4907	0.6633	-121,264.6	74,723.92	0.0402	0.1529
h	0	-124.8434	52,813.19	4.7651	4,868,062	1,365,329	2.7493	3.6043
i	0	-0.8506	-976.6428	-0.1059	-427,941.1	-91,957.24	0	0
j	0	45.9146	0	-0.7887	8,286,525	1,729,110	0	0
Y	0.0863	0.108	0.1161	0.2347	0.2668	0.4172	0.3296	0.0185

WRC 537 Nondimensional Coefficients								
$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$								
γ = 5 ρ = 4	SP-4				SM-4			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0.1955	0.7443	2.537	0.1606	-3.9242	12.6132	-0.9607	-6.9959
b	355.6102	7.533	1,071.7354	22.9473	-68.5346	29.9988	-43.2509	114.214
c	21.1677	-2.6223	127.4587	10.3372	228.2976	-129.5801	-7.5852	81.2222
d	1,539.5199	-7.6574	2,112.6475	-190.1285	9,214.6671	-214.241	8.1123	-726.9062
e	-9.9855	9.5634	-131.0041	-76.2413	341.9835	558.1185	5.3251	-296.5262
f	356.7674	64.1716	-8,161.6149	517.979	12,323.9	595.3023	11.1703	1,724.0898
g	0	-5.6615	-54.494	186.8225	-372.3161	-319.0507	0	427.4096
h	0	62.296	7,160.3101	-483.8102	0	2,813.0991	0	-1,948.4552
i	0	0	102.0928	-102.4669	0	0	0	-195.9934
j	0	0	-1,577.3732	408.8865	0	0	0	1,040.0273
Y	0.024	0.1528	0.0841	0.3404	0.084	0.5972	0.2656	0.1757

WRC 537 Nondimensional Coefficients								
$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$								
γ = 15 ρ = 2	SP-6				SM-6			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0.4364	0.4568	0.5408	0.199	1.2527	1.9756	3.4348	-0.6545
b	23.8528	18.4406	86.1146	1.3701	-9.7364	-10.5872	32.542	2.3553
c	3.1218	0.5744	10.6552	0.9562	42.3407	-7.1545	-9.1948	3.7495
d	57.2195	2.9177	210.1066	4.8904	581.7506	267.0319	0.2003	6.5143
e	-1.23	0.2335	-2.8821	-0.1717	-11.5154	184.7135	14.4342	-2.6465
f	-0.5058	37.5435	66.5636	-0.1752	-363.3128	406.7564	-130.0729	-5.4867
g	0.4263	0	1.9553	0	4.4567	337.601	1.057	0.5907
h	16.5587	0	0	0	555.7041	5,118.1159	350.2929	1.9002
i	0	0	0	0	0	-155.8292	0	0
j	0	0	0	0	0	2,619.7988	0	0
Y	0.1025	0.0907	0.0794	0.2581	0.3262	0.3416	0.2225	0.0877

WRC 537 Nondimensional Coefficients								
$Y = \dfrac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$								
γ = 15 ρ = 4	**SP-7**				**SM-7**			
	M_x	**M_y**	**N_x**	**N_y**	**M_x**	**M_y**	**N_x**	**N_y**
a	0.1225	1.1858	0.152	0.2586	81,160.67	54.8627	-7.2531E+09	-2,889.5632
b	10.2618	30.9469	6.4077	2.6992	2,773,928	313.4235	2.0933E+11	44,457.77
c	0.0628	0.7386	-0.2621	2.1956	11,224.63	-805.6348	2.2821E+11	31,259.89
d	2.5604	-22.7834	-20.1141	10.0386	-888,508.9	-5,199.714	6.2796E+12	-175,466.5
e	-9.8501E-04	0.8686	0.1324	0.3281	-4,806.5269	2,622.0799	1.5072E+12	-81,861.2
f	7.9918	86.4361	30.2989	-5.923	3,917,797	23,612.83	3.0942E+13	299,387.2
g	0	-0.3301	0.2529	-0.3719	0	4,442.2399	1.7691E+11	85,306.95
h	0	0	-12.616	4.2863	0	-21,199.17	3.2234E+12	-247,881.6
i	0	0	-0.0853	0	0	-1,946.6481	0	-22,718.26
j	0	0	1.8294	0	0	79,566.95	0	113,956.5
Y	0.0339	0.1535	0.0531	0.3668	0.1101	0.6108	0.1619	0.2888

Pressure stress intensity factor, $I = 1.8064$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 27{,}825$ psi

Maximum combined stress $(P_L + P_b + Q) = 47{,}484$ psi

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 59{,}100$ psi

Note: The allowable combined stress $(P_L + P_b + Q)$ is based on the strain hardening characteristics of this material.

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

Maximum local primary membrane stress $(P_L) = 29{,}550$ psi

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 29{,}550$ psi

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SP-1 to 10*	$\frac{N_x \cdot T}{P}$	0.0857	281	281	281	281	281	281	281	281
SP-1 to 10	$\frac{M_x}{P}$	0.0513	1,012	-1,012	1,012	-1,012	1,012	-1,012	1,012	-1,012
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.2564	0	0	0	0	-1,239	-1,239	1,239	1,239
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1651	0	0	0	0	-4,786	4,786	4,786	-4,786
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.2564	-1,239	-1,239	1,239	1,239	0	0	0	0
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1651	-4,786	4,786	4,786	-4,786	0	0	0	0
Pressure stress*			27,825	27,825	27,825	27,825	27,825	27,825	27,825	27,825
Total O_x stress			23,093	30,641	35,143	23,547	23,093	30,641	35,143	23,547
Membrane O_x stress*			26,867	26,867	29,345	29,345	26,867	26,867	29,345	29,345
SP-1 to 10*	$\frac{N_y \cdot T}{P}$	0.3086	1,014	1,014	1,014	1,014	1,014	1,014	1,014	1,014
SP-1 to 10	$\frac{M_y}{P}$	0.134	2,642	-2,642	2,642	-2,642	2,642	-2,642	2,642	-2,642
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0.1471	0	0	0	0	-711	-711	711	711
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0.5231	0	0	0	0	-15,166	15,166	15,166	-15,166
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0.1471	-711	-711	711	711	0	0	0	0
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0.5231	-15,166	15,166	15,166	-15,166	0	0	0	0
Pressure stress*			27,825	27,825	27,825	27,825	27,825	27,825	27,825	27,825
Total O_y stress			15,604	40,652	47,358	11,742	15,604	40,652	47,358	11,742
Membrane O_y stress*			28,128	28,128	29,550	29,550	28,128	28,128	29,550	29,550
Shear from M_t			960	960	960	960	960	960	960	960
Shear from V_1			0	0	0	0	-289	-289	289	289
Shear from V_2			289	289	-289	-289	0	0	0	0
Total Shear stress			1,249	1,249	671	671	671	671	1,249	1,249
Combined stress (P_L+P_b+Q)			23,296	40,805	47,395	23,585	23,153	40,697	47,484	23,678
(1) * denotes primary stress. (2) The nozzle is analyzed as a hollow attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{306.33 \cdot 1.0335}{2 \cdot 0.1348} - \frac{-629}{\pi \cdot \left(1.1875\ ^2 - 1.0335\ ^2\right)} + \frac{5{,}753 \cdot 1.1875}{0.6657}$$

$$= 12{,}022 \quad \text{psi}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 16,700 psi)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} = \frac{\sqrt{472^{\,2} + 472^{\,2}}}{\pi \cdot 1.0335 \cdot 0.154} = 1{,}335 \text{ psi}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} = \frac{3{,}720}{2 \cdot \pi \cdot 1.0335^{\,2} \cdot 0.154} = 3{,}599 \text{ psi}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 1{,}335 + 3{,}599 = 4{,}934 \text{ psi}$$

UG-45: The total combined shear stress (4,934 psi) ≤ allowable $(0.7 \cdot S_n = 0.7 \cdot 16{,}700 = 11{,}690 \text{ psi})$

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 = 396.94 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 396.94 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[2.067,\ 1.0335 + (0.154 - 0) + (0.4375 - 0)\right]$$
$$= 2.067\ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.154 - 0) + 0\right]$$
$$= 0.385\ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{396.9414 \cdot 1.0335}{20{,}000 \cdot 1 - 0.6 \cdot 396.9414}$$
$$= 0.0208\ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$
$$= \frac{396.9414 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.9414}$$
$$= 0.4375\ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 396.94} = 0.8673\ \text{in}$$

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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{396.9414 \cdot 1.0335}{17{,}000 \cdot 1 - 0.6 \cdot 396.9414} + 0$$

$$= 0.0245 \text{ in}$$

$$t_{a\text{UG-22}} = 0.0784 \text{ in}$$

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

$$= \max\left[0.0245,\ 0.0784\right]$$

$$= 0.0784 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.94} + 0$$

$$= 0.7369 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \text{ in}$$

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

$$= \min\left[0.1348,\ 0.7369\right]$$

$$= 0.1348 \text{ in}$$

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

$$= \max\left[0.0784,\ 0.1348\right]$$

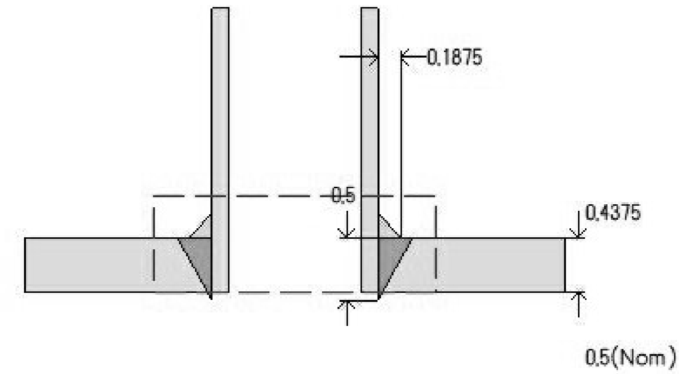
$$= \underline{0.1348} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.154$ = 0.1348 in

The nozzle neck thickness is adequate.

THERMOWELL (T1)

ASME Section VIII Division 1, 2023 Edition



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

Location and Orientation	
Located on	F&D Head #2
Orientation	180°
End of nozzle to datum line	-13.8768"
Calculated as hillside	Yes
Distance to head center, R	15"
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	1.1156"
Projection available outside vessel, Lpr	5.9253"
Projection available outside vessel to flange face, Lf	6.0583"
Local vessel minimum thickness	0.4375"
Liquid static head included	3.88 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.5"
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 300 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	3.89 psi
MAWP rating	537.5 psi @ 350°F
MAP rating	720 psi @ 70°F
Hydrotest rating	1,100 psi @ 70°F
External fillet weld leg (UW-21)	0.2156" (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	
$X_{\min} = \min\left[1.4 \cdot t_n, g_0\right] = \left[1.4 \cdot 0.133, 0.38\right] =$	0.1862"
$\text{External Leg}_{\min} = X_{\min} + \frac{C_o}{0.7} = 0.1862 + \frac{0}{0.7} =$	0.1862"
$\text{Internal Leg}_{\min} = \min\left[t_n, 0.25\text{text}('') + \frac{C_i}{0.7}\right] = \min\left[0.133, 0.25 + \frac{0}{0.7}\right] =$	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	
$t_r = \frac{153.88 \cdot 0.5245}{17{,}000 \cdot 1 - 0.6 \cdot 153.88} =$	0.0048"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0048 \cdot 1}{0.1164 - 0} =$	0.041
Impact test exempt per UHA-51(g) (coincident ratio = 0.041)	
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 = 153.88 psi @ 350 °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 153.88 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[1.1156,\ 0.5578 + (0.133 - 0) + (0.4375 - 0)\right]$$
$$= 1.1283 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.4375 - 0),\ 2.5 \cdot (0.133 - 0) + 0\right]$$
$$= 0.3325 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{153.8782 \cdot 0.5245}{19{,}700 \cdot 1 - 0.6 \cdot 153.8782}$$
$$= 0.0041 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$
$$= \frac{153.8782 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 153.8782}$$
$$= 0.172 \text{ in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{153.88 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 153.88} = 0.3408 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.133 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ $\underline{0.0931}$ in

$t_{c(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{153.894 \cdot 0.5245}{16{,}700 \cdot 1 - 0.6 \cdot 153.894} + 0$$

$$= 0.0049 \text{ in}$$

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

$$= \max\left[0.0049,\ 0\right]$$

$$= 0.0049 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{153.88 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 153.88} + 0$$

$$= 0.2897 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.2897,\ 0.0625\right]$$

$$= 0.2897 \text{ in}$$

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

$$= \min\left[0.1164,\ 0.2897\right]$$

$$= 0.1164 \text{ in}$$

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

$$= \max\left[0.0049,\ 0.1164\right]$$

$$= \underline{0.1164} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.133$ = 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 = 390.98 psi @ 350 °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 390.98 psi @ 350 °F

Parallel Limit of reinforcement per UG-40

$$
\begin{aligned}
L_R &= \max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right] \\
&= \max\left[1.1156,\ \ 0.5578 + (0.133 - 0) + (0.4375 - 0)\right] \\
&= 1.1283 \ \ \text{in}
\end{aligned}
$$

Outer Normal Limit of reinforcement per UG-40

$$
\begin{aligned}
L_H &= \min\left[2.5 \cdot (t - C),\ \ 2.5 \cdot (t_n - C_n) + t_e\right] \\
&= \min\left[2.5 \cdot (0.4375 - 0),\ \ 2.5 \cdot (0.133 - 0) + 0\right] \\
&= 0.3325 \ \ \text{in}
\end{aligned}
$$

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

$$
\begin{aligned}
t_{rn} &= \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} \\
&= \frac{390.9844 \cdot 0.5245}{19{,}700 \cdot 1 - 0.6 \cdot 390.9844} \\
&= 0.0105 \ \ \text{in}
\end{aligned}
$$

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

$$
\begin{aligned}
t_r &= \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} \\
&= \frac{390.9844 \cdot 44 \cdot 1}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 390.9844} \\
&= 0.4375 \ \ \text{in}
\end{aligned}
$$

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

$$
t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{390.98 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 0.85 - 0.2 \cdot 390.98} = 0.8673 \ \ \text{in}
$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75,\ t_n,\ t\right] =$ 0.133 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.0931 in

$t_{c(actual)} = 0.7 \cdot \mathrm{Leg} = 0.7 \cdot 0.1875 = 0.1313$ 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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{391.0002 \cdot 0.5245}{16{,}700 \cdot 1 - 0.6 \cdot 391.0002} + 0$$

$$= 0.0125 \text{ in}$$

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

$$= \max\left[0.0125,\ 0\right]$$

$$= 0.0125 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{390.98 \cdot 44 \cdot 1.6844}{2 \cdot 19{,}700 \cdot 1 - 0.2 \cdot 390.98} + 0$$

$$= 0.7369 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \text{ in}$$

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

$$= \min\left[0.1164,\ 0.7369\right]$$

$$= 0.1164 \text{ in}$$

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

$$= \max\left[0.0125,\ 0.1164\right]$$

$$= \underline{0.1164} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.133$ = 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 = 396.94 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 396.94 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ \ R_n + (t_n - C_n) + (t - C)\right]$$

$$= \max\left[1.1156,\ \ 0.5578 + (0.133 - 0) + (0.4375 - 0)\right]$$

$$= 1.1283 \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ \ 2.5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2.5 \cdot (0.4375 - 0),\ \ 2.5 \cdot (0.133 - 0) + 0\right]$$

$$= 0.3325 \ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$

$$= \frac{396.9414 \cdot 0.5245}{20{,}000 \cdot 1 - 0.6 \cdot 396.9414}$$

$$= 0.0105 \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{396.9414 \cdot 44 \cdot 1}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.9414}$$

$$= 0.4375 \ \text{in}$$

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

$$t_r = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 0.85 - 0.2 \cdot 396.94} = 0.8673 \ \text{in}$$

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.

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{396.9414 \cdot 0.5245}{17{,}000 \cdot 1 - 0.6 \cdot 396.9414} + 0$$

$$= 0.0124 \text{ in}$$

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

$$= \max\left[0.0124,\ 0\right]$$

$$= 0.0124 \text{ in}$$

$$t_{b1} = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$

$$= \frac{396.94 \cdot 44 \cdot 1.6844}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 396.94} + 0$$

$$= 0.7369 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.7369,\ 0.0625\right]$$

$$= 0.7369 \text{ in}$$

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

$$= \min\left[0.1164,\ 0.7369\right]$$

$$= 0.1164 \text{ in}$$

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

$$= \max\left[0.0124,\ 0.1164\right]$$

$$= \underline{0.1164} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.133 = 0.1164$ in

The nozzle neck thickness is adequate.

Liquid Level bounded by F&D Head #2

ASME Section VIII Division 1, 2023 Edition	
Location from Datum (in)	94
Operating Liquid Specific Gravity	1