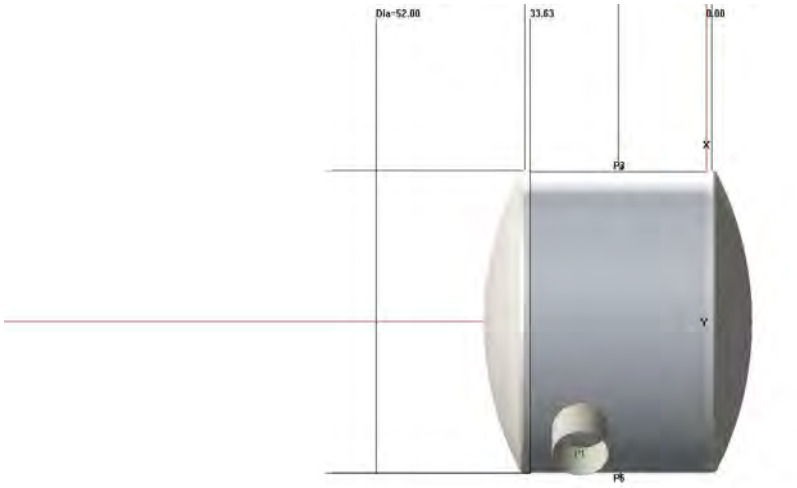
Seitz Stainless

Avon, Minnesota



NB 335 VAPOR BAND CALCULATIONS ONLY

BPV VIII-Div 1, 2019 Pressure Vessel Design Calculations

Item: Bustle (Vapor Band) for Project 20-3776
Vessel No: 20-3776
Customer: Caloris
Contract: Merit Functional Foods
Designer:

This set of calculations is for the bustle (AKA Vapor Band) for the project S/N 20-3776 shell-and-tube heat exchanger. ASME BPV Code treats the vapor band as a conventional jacket, and follows Appendix 9 rules. Per Appendix 9, this band is Type 1, and uses a flat, knuckled head as the closeure, per figure 9-5 (b-3). The required closure thickness is given by:

$$trc = 0.707jwP/S = 0.103"$$

where
$j = 4.8"$
$P = 25$ psi
$S = 27{,}000$ psi

Therefore, the minimum head (closure) thickness is 0.103". We have chosen 1/4".
Attachment to the main shell per Figure 9-5 (b-3) gives a minimum fillet weld of 1.25tc, equating to a face of 3/16".
Minimum knuckle radius is 3tc, or .75". We have chosen 1".

The shell thickness, welds, and nozzle calculations are contained herein. These calculations demonstrate that the shell thickness, welds, nozzles, and nozzle reinforcement is adequate.

Table of Contents

DESIGN DATA

Design Pressure	25 psi
Vacuum Pressure	15 psi
Test Pressure (Shop)	52.35 psi
Design Temperature	300 °F
MDMT	-20 °F
Corrosion Allowance	0 "
Radiography	None
PWHT	None

Estimated Weights

Dry: 597 lb Wet: 597 lb

Materials

Cylinder(s):	SA-240 304
Head(s):	SA-240 304
Transition(s):	
Support:	

NOZZLE SCHEDULE

MARK	NOZZLE	SIZE & SCH	FLANGE	MARK	NOZZLE	SIZE & SCH	FLANGE
P6	Nozzle P6	NPS 0.5 Class 300					
P3	Nozzle P3	NPS 0.75 Class 30					
P1	Nozzle P1	NPS 10 Sch 10S					

REVISIONS

REV	DATE	DESCRIPTION
0	01/24/20	FOR APPROV

Seitz Stainless
17578 400th Street
Avon, MN 56310

DWN BY:
CHK BY:
145685-1

General Arrangement

DWG NO. Rev 0

DATE:

Bustle as App 9 Jacket.CW7

Deficiencies Summary

Deficiencies for F&D Head #1
UG-32(i): The inside knuckle radius (1") is less than 6 percent of the head skirt outside diameter (0.06*52" = 3.12"). (Corroded)

Deficiencies for F&D Head #2
UG-32(i): The inside knuckle radius (1") is less than 6 percent of the head skirt outside diameter (0.06*52" = 3.12"). (Corroded)

Although flagged by Compress as a deficiency when used as a conventional full head, when used as a jacket close-out, these knucke radius rules do not apply. See the cover page for the applicable knuckle equation.

Nozzle Schedule

Specifications										
Nozzle mark	Identifier	Size	Service	Materials		Impact Tested	Normalized	Fine Grain	Flange	Blind
P1	Nozzle P1	NPS 10 Sch 10S	IN	Nozzle	SA-312 TP304L Wld & smls pipe	No	No	No	N/A	No
				Pad	SA-240 304L	No	No	No		
P3	Nozzle P3	NPS 0.75 Class 3000 - Threaded Half Coupling	PRV	Nozzle	SA-182 F304L <= 5	No	No	No	N/A	No
P6	Nozzle P6	NPS 0.5 Class 3000 - Threaded Half Coupling	DRN	Nozzle	SA-182 F304L <= 5	No	No	No	N/A	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)		
P1	10.75	0.165	0.1352	Yes	Yes	0.1875	0.1183		1.5	0.135	0	100.0
P3	1.38	0.16	0.0625	Yes	Yes	0.1875	N/A		N/A	N/A	0	Exempt
P6	1.12	0.14	0.0625	Yes	Yes	0.1875	N/A		N/A	N/A	0	Exempt

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)	MAEP (psi)	T_e external (°F)	MDMT (°F)	MDMT Exemption	Impact Tested
F&D Head #1	25	300	40.91	43.3	22.46	300	-320	Note 1	No
Straight Flange on F&D Head #1	25	300	102.08	108.02	27.19	300	-320	Note 2	No
Cylinder #1	25	300	95.73	101.3	23.85	300	-320	Note 3	No
Straight Flange on F&D Head #2	25	300	102.08	108.02	27.19	300	-320	Note 2	No
F&D Head #2	25	300	40.27	42.62	22.11	300	-320	Note 4	No
Nozzle P1 (P1)	25	300	86.43	90.26	15.71	300	-320	Nozzle / Note 5	No
								Pad / Note 6	No
Nozzle P3 (P3)	25	300	136.76	144.72	23.85	300	-320	Note 7	No
Nozzle P6 (P6)	25	300	136.76	144.72	23.85	300	-320	Note 8	No

Chamber Summary	
Design MDMT	-20 °F
Rated MDMT	-320 °F @ 40.27 psi
MAWP hot & corroded	40.27 psi @ 300 °F
MAP cold & new	42.62 psi @ 70 °F
MAEP	15.71 psi @ 300 °F

Notes for MDMT Rating		
Note #	Exemption	Details
1.	Impact test exempt per UHA-51(g) (coincident ratio = 0.2935)	
2.	Impact test exempt per UHA-51(g) (coincident ratio = 0.2974)	
3.	Impact test exempt per UHA-51(g) (coincident ratio = 0.3172)	
4.	Impact test exempt per UHA-51(g) (coincident ratio = 0.297)	
5.	Impact test exempt per UHA-51(g) (coincident ratio = 0.0872)	
6.	Impact test exempt per UHA-51(g) (coincident ratio = 0.2774)	
7.	Impact test exempt per UHA-51(g) (coincident ratio = 0.008)	
8.	Impact test exempt per UHA-51(g) (coincident ratio = 0.0073)	

Revision History

Revisions			
No.	**Date**	**Operator**	**Notes**
0	7/22/2020	jeffh	New vessel created ASME Section VIII Division 1 [COMPRESS 2020 Build 8000]

Settings Summary

COMPRESS 2020 Build 8000	
ASME Section VIII Division 1, 2019 Edition	
Units	U.S. Customary
Datum Line Location	0.00" from right seam
Vessel Design Mode	Design Mode
Minimum thickness	0.0625" per UG-16(b)
Design for cold shut down only	No
Design for lethal service (full radiography required)	No
Design nozzles for	Design P only
Corrosion weight loss	100% of theoretical loss
UG-23 Stress Increase	1.20
Skirt/legs stress increase	1.0
Minimum nozzle projection	6"
Juncture calculations for 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 Code Case 2547	No
Use Appendix 46	No
Use UG-44(b)	No
Use Code Case 2955	No
Apply interpretation VIII-1-83-66	Yes
Apply interpretation VIII-1-86-175	Yes
Apply interpretation VIII-1-01-37	Yes
Apply interpretation VIII-1-01-150	Yes
Apply interpretation VIII-1-07-50	Yes
Apply interpretation VIII-1-16-85	Yes
No UCS-66.1 MDMT reduction	No
No UCS-68(c) MDMT reduction	No

Disallow UG-20(f) exemptions	No
UG-22 Loadings	
UG-22(a) Internal or External Design Pressure	Yes
UG-22(b) Weight of the vessel and normal contents under operating or test conditions	No
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	No
UG-22(f) Wind reactions	No
UG-22(f) Seismic reactions	No
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	Seitz Stainless
License	Commercial
License Key ID	23841
Support Expires	May 24, 2021

Radiography Summary

UG-116 Radiography							
Component	Longitudinal Seam		Left Circumferential Seam		Right 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	A	None UW-11(c) / Type 1	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
F&D Head #2	A	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	N/A	N/A	None
Nozzle	**Longitudinal Seam**		**Nozzle to Vessel Circumferential Seam**		**Nozzle free end Circumferential Seam**		
Nozzle P1 (P1)	N/A	Welded pipe	D	N/A / Type 7	N/A	N/A	N/A
Nozzle P3 (P3)	N/A	Seamless No RT	D	N/A / Type 7	N/A	N/A	N/A
Nozzle P6 (P6)	N/A	Seamless No RT	D	N/A / Type 7	N/A	N/A	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-240 304	51.6 ID	7.7839	0.2*	0.1545	0	0.70	External
Straight Flange on F&D Head #1	SA-240 304	51.6 ID	1	0.2	0.1548	0	0.70	External
Cylinder #1	SA-240 304	51.6 ID	33.625	0.1875	0.1547	0	0.70	External
Straight Flange on F&D Head #2	SA-240 304	51.6 ID	1	0.2	0.1548	0	0.70	External
F&D Head #2	SA-240 304	51.6 ID	7.6942	0.2*	0.1563	0	0.70	External
*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

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	145.6	145.6	0	0	0	0	0	0	389.7	389.7	18
Cylinder #1	292.4	292.4	0	0	0	0	0	0	2,556.7	2,556.7	37
F&D Head #2	145.4	145.4	0	0	0	0	0	0	386.2	386.2	18
TOTAL:	**583.3**	**583.3**	**0**	**0**	**0**	**0**	**0**	**0**	**3,332.6**	**3,332.6**	**74**
*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	Trays	Tray Supports	Rings & Clips	Vertical Loads	Surface Area ft^2
	New	Corroded	New	Corroded						
F&D Head #1	0	0	0	0	0	0	0	0	0	0
Cylinder #1	0	0	13.3	13.3	0	0	0	0	0	1
F&D Head #2	0	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**13.3**	**13.3**	**0**	**0**	**0**	**0**	**0**	**1**

Vessel Totals		
	New	Corroded
Operating Weight (lb)	597	597
Empty Weight (lb)	597	597
Test Weight (lb)	3,929	3,929
Surface Area (ft^2)	75	-
Capacity** (US gal)	397	397
**The vessel capacity does not include volume of nozzle, piping or other attachments.		

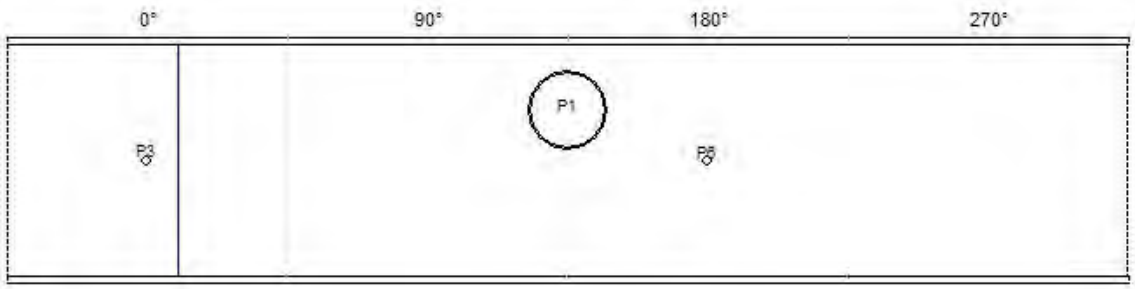
Vessel Lift Condition	
Vessel Lift Weight, New (lb)	597
Center of Gravity from Datum (in)	16.9309

Long Seam Summary

Shell Long Seam Angles	
Component	**Seam 1**
Cylinder #1	10°

Shell Plate Lengths		
Component	**Starting Angle**	**Plate 1**
Cylinder #1	10°	162.6952"

Note
1) Plate Lengths use the circumference of the vessel based on the mid diameter of the components.



Shell Rollout

Hydrostatic Test

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

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

$= 1.3 \cdot 40.27 \cdot 1$

$= 52.35 \text{ psi}$

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	54.253	1.898	1.0582	1.30
Straight Flange on F&D Head #1	54.253	1.898	1.0582	1.30
Cylinder #1	54.253	1.898	1.0582	1.30
Straight Flange on F&D Head #2	54.253	1.898	1.0582	1.30
F&D Head #2	54.253	1.898	1.0582	1.30
Nozzle P1 (P1) (1)	54.271	1.917	1	1.30
Nozzle P3 (P3)	52.383	0.029	1	1.30
Nozzle P6 (P6)	54.286	1.932	1	1.30
(1) Nozzle P1 (P1) 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.

Vacuum Summary

Largest Unsupported Length Le			
Component	**Line of Support**	**Elevation above Datum (in)**	**Length Le (in)**
F&D Head #1	-	42.4089	N/A
-	1/3 depth of F&D Head #1	37.153	N/A
Straight Flange on F&D Head #1 Left	-	34.625	40.651
Straight Flange on F&D Head #1 Right	-	33.625	40.651
Cylinder #1 Left	-	33.625	40.651
Cylinder #1 Right	-	0	40.651
Straight Flange on F&D Head #2 Left	-	0	40.651
Straight Flange on F&D Head #2 Right	-	-1	40.651
-	1/3 depth of F&D Head #2	-3.4981	N/A
F&D Head #2	-	-8.6942	N/A

Bill of Materials

Heads						
Item #	Type	Material	Thk [in]	Dia. [in]	Wt. [lb] (ea.)	Qty
H1	F&D Head	SA-240 304	0.2 (min.)	51.6 ID	145.6	1
H2	F&D Head	SA-240 304	0.2 (min.)	51.6 ID	145.4	1

Shells							
Item #	Type	Material	Thk [in]	Dia. [in]	Length [in]	Wt. [lb] (ea.)	Qty
S1	Cylinder	SA-240 304	0.1875	51.6 ID	33.6	297.5	1

Nozzles							
Item #	Type	Material	NPS	Thk [in]	Dia. [in]	Length [in]	Wt. [lb]
Noz1	Nozzle	SA-312 TP304L Wld & smls pipe	NPS 10 Sch 10S	0.165	10.75 OD	6.8	13

Nozzles - Couplings					
Item #	Type	Material	Dia. [in]	Length [in]	Qty
C1	NPS 0.75 Class 3000 - Threaded Half Coupling	SA-182 F304L <= 5	1.38 OD	1	1
C2	NPS 0.5 Class 3000 - Threaded Half Coupling	SA-182 F304L <= 5	1.12 OD	0.94	1

Plates				
Item #	Material	Thk [in]	Wt. [lb]	Qty [ft²]
Plate1	SA-240 304L	0.135	43.1	1.03
Plate1 - Note: Applies to nozzle pad				

F&D Head #1

ASME Section VIII Division 1, 2019 Edition				
Component		F&D Head		
Material		SA-240 304 (II-D p. 88, ln. 37)		
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		25	300	-20
External		15	300	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		1.9	52.5908	1
Dimensions				
Inner Diameter		51.6"		
Crown Radius L		51"		
Knuckle Radius r		1"		
Minimum Thickness		0.2"		
Corrosion	**Inner**	0"		
	Outer	0"		
Length L_{sf}		1"		
Nominal Thickness t_{sf}		0.2"		
Weight and Capacity				
		Weight (lb)[1]		**Capacity (US gal)[1]**
New		145.58		46.73
Corroded		145.58		46.73
Radiography				
Category A joints		None UW-11(c) Type 1		
Head to shell seam		None UW-11(c) Type 1		

[1] includes straight flange

Results Summary	
Governing condition	external pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.1222"
Design thickness due to external pressure (t_e)	0.1545"
Maximum allowable working pressure (MAWP)	40.91 psi
Maximum allowable pressure (MAP)	43.3 psi
Maximum allowable external pressure (MAEP)	22.46 psi
Rated MDMT	-320°F

Note: Endnote 90 used to determine allowable stress.

UHA-51 Material Toughness Requirements	
$t_r = \frac{40.27 \cdot 51 \cdot 1}{2 \cdot 20{,}000 \cdot 0.7 - 0.2 \cdot 40.27} =$	0.0734"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0734 \cdot 0.8}{0.2 - 0} =$	0.2935
Impact test exempt per UHA-51(g) (coincident ratio = 0.2935)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Factor M		
$M = \frac{1}{4} \cdot \left[3 + \left(\frac{L}{r}\right)^{\frac{1}{2}}\right]$		
Corroded	$M = \frac{1}{4} \cdot \left[3 + \left(\frac{51}{1}\right)^{\frac{1}{2}}\right]$	2.5354
New	$M = \frac{1}{4} \cdot \left[3 + \left(\frac{51}{1}\right)^{\frac{1}{2}}\right]$	2.5354

Design thickness for internal pressure, (Corroded at 300 °F) Appendix 1-4(d)

$$t = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{25 \cdot 51 \cdot 2.5354}{2 \cdot 18{,}900 \cdot 0.7 - 0.2 \cdot 25} + 0 = 0.1222"$$

Maximum allowable working pressure, (Corroded at 300 °F) Appendix 1-4(d)

$$P = \frac{2 \cdot S \cdot E \cdot t}{L \cdot M + 0.2 \cdot t} - P_s = \frac{2 \cdot 18{,}900 \cdot 0.7 \cdot 0.2}{51 \cdot 2.5354 + 0.2 \cdot 0.2} - 0 = 40.91 \text{ psi}$$

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

$$P = \frac{2 \cdot S \cdot E \cdot t}{L \cdot M + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 0.7 \cdot 0.2}{51 \cdot 2.5354 + 0.2 \cdot 0.2} - 0 = 43.3 \text{ psi}$$

Design thickness for external pressure, (Corroded at 300 °F) UG-33(e)

Equivalent outside spherical radius (R_o) = Outside crown radius $= 51.2 \text{ in}$

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{51.2 \ / \ 0.154426} = 0.000377$$

From Table HA-1:B = 4,973.251 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{4{,}973.251}{51.2 \ / \ 0.1544} = 15 \text{ psi}$$

t = 0.1544" + Corrosion = 0.1544" + 0" = 0.1544"

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

$$t = \frac{1.67 \cdot P_e \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot 1.67 \cdot P_e} + \text{Corrosion} = \frac{1.67 \cdot 15 \cdot 51 \cdot 2.5354}{2 \cdot 18{,}900 \cdot 1 - 0.2 \cdot 1.67 \cdot 15} + 0 = 0.0857"$$

The head external pressure design thickness (t_e) is 0.1544".

Maximum Allowable External Pressure, (Corroded at 300 °F) UG-33(e)

Equivalent outside spherical radius (R_o) = Outside crown radius $= 51.2 \text{ in}$

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{51.2 \ / \ 0.2} = 0.000488$$

From Table HA-1:B = 5,749.7679 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{5{,}749.7679}{51.2 \ / \ 0.2} = 22.46 \text{ psi}$$

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

$$P = \frac{2 \cdot S \cdot E \cdot t}{(L \cdot M + 0.2 \cdot t) \cdot 1.67} = \frac{2 \cdot 18{,}900 \cdot 1 \cdot 0.2}{(51 \cdot 2.5354 + 0.2 \cdot 0.2) \cdot 1.67} = 35 \text{ psi}$$

The maximum allowable external pressure (MAEP) is 22.46 psi.

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

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 0.2}{1.1}\right) \cdot \left(1 - \frac{1.1}{\infty}\right) = 13.6364 \%$$

Straight Flange on F&D Head #1

ASME Section VIII Division 1, 2019 Edition				
Component		Cylinder		
Material		SA-240 304 (II-D p. 88, ln. 37)		
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		25	300	-20
External		15	300	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		1.9	52.5908	1
Dimensions				
Inner Diameter		51.6"		
Length		1"		
Nominal Thickness		0.2"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)	**Capacity (US gal)**	
New		9.44	9.05	
Corroded		9.44	9.05	
Radiography				
Longitudinal seam		None UW-11(c) Type 1		
Right Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	External pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0489"
Design thickness due to external pressure (t_e)	0.1548"
Maximum allowable working pressure (MAWP)	102.08 psi
Maximum allowable pressure (MAP)	108.02 psi
Maximum allowable external pressure (MAEP)	27.19 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \frac{40.27 \cdot 25.8}{20{,}000 \cdot 0.7 - 0.6 \cdot 40.27} =$	0.0743"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0743 \cdot 0.8}{0.2 - 0} =$	0.2974
Impact test exempt per UHA-51(g) (coincident ratio = 0.2974)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 300 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{25 \cdot 25.8}{18{,}900 \cdot 0.70 - 0.60 \cdot 25} + 0 = \underline{0.0489}"$$

Maximum allowable working pressure, (at 300 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{18{,}900 \cdot 0.70 \cdot 0.2}{25.8 + 0.60 \cdot 0.2} - 0 = \underline{102.08} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 0.70 \cdot 0.2}{25.8 + 0.60 \cdot 0.2} = \underline{108.02} \text{ psi}$$

External Pressure, (Corroded & at 300 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{40.651}{52} = 0.7818$$

$$\frac{D_o}{t} = \frac{52}{0.1548} = 335.9886$$

From table G: $A = 0.000287$

From table HA-1: $B = 3{,}779.872$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 3{,}779.87}{3 \cdot (52 / 0.1548)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.1548 + 0 = \underline{0.1548}"$$

Maximum Allowable External Pressure, (Corroded & at 300 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{40.651}{52} = 0.7818$$

$$\frac{D_o}{t} = \frac{52}{0.2} = 260.0000$$

From table G: $A = 0.000412$

From table HA-1: $B = 5{,}302.6411$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 5{,}302.64}{3 \cdot (52 / 0.2)} = \underline{27.19} \text{ psi}$$

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

$$EFE = \left(\frac{50 \cdot t}{R_f} \right) \cdot \left(1 - \frac{R_f}{R_o} \right) = \left(\frac{50 \cdot 0.2}{25.9} \right) \cdot \left(1 - \frac{25.9}{\infty} \right) = 0.3861\,\%$$

Cylinder #1

ASME Section VIII Division 1, 2019 Edition				
Component		Cylinder		
Material		SA-240 304 (II-D p. 88, ln. 37)		
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		25	300	-20
External		15	300	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		1.9	52.5908	1
Dimensions				
Inner Diameter		51.6"		
Length		33.625"		
Nominal Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)	**Capacity (US gal)**	
New		292.4	304.4	
Corroded		292.4	304.4	
Radiography				
Longitudinal seam		None UW-11(c) Type 1		
Left Circumferential seam		None UW-11(c) Type 1		
Right Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	External pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0489"
Design thickness due to external pressure (t_e)	0.1547"
Maximum allowable working pressure (MAWP)	95.73 psi
Maximum allowable pressure (MAP)	101.3 psi
Maximum allowable external pressure (MAEP)	23.85 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \frac{40.27 \cdot 25.8}{20{,}000 \cdot 0.7 - 0.6 \cdot 40.27} =$	0.0743"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0743 \cdot 0.8}{0.1875 - 0} =$	0.3172
Impact test exempt per UHA-51(g) (coincident ratio = 0.3172)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 300 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{25 \cdot 25.8}{18{,}900 \cdot 0.70 - 0.60 \cdot 25} + 0 = \underline{0.0489}"$$

Maximum allowable working pressure, (at 300 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{18{,}900 \cdot 0.70 \cdot 0.1875}{25.8 + 0.60 \cdot 0.1875} - 0 = \underline{95.73} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 0.70 \cdot 0.1875}{25.8 + 0.60 \cdot 0.1875} = \underline{101.3} \text{ psi}$$

External Pressure, (Corroded & at 300 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{40.651}{51.975} = 0.7821$$

$$\frac{D_o}{t} = \frac{51.975}{0.1547} = 335.9171$$

From table G: $A = 0.000287$

From table HA-1: $B = 3{,}779.0742$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 3{,}779.07}{3 \cdot (51.975 / 0.1547)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.1547 + 0 = \underline{0.1547}"$$

Maximum Allowable External Pressure, (Corroded & at 300 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{40.651}{51.975} = 0.7821$$

$$\frac{D_o}{t} = \frac{51.975}{0.1875} = 277.2000$$

From table G: $A = 0.000376$

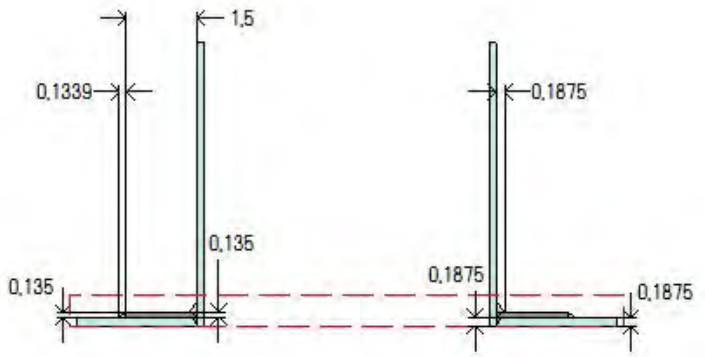
From table HA-1: $B = 4{,}957.965$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 4{,}957.97}{3 \cdot (51.975 / 0.1875)} = \underline{23.85} \text{ psi}$$

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

$$EFE = \left(\frac{50 \cdot t}{R_f} \right) \cdot \left(1 - \frac{R_f}{R_o} \right) = \left(\frac{50 \cdot 0.1875}{25.8938} \right) \cdot \left(1 - \frac{25.8938}{\infty} \right) = 0.3621\,\%$$

Nozzle P1 (P1)

ASME Section VIII Division 1, 2019 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Cylinder #1
Orientation	135°
Nozzle center line offset to datum line	24"
End of nozzle to shell center	31.9875"
Passes through a Category A joint	No
Nozzle	
Service	Inlet (IN)
Description	NPS 10 Sch 10S
Access opening	No
Material specification	SA-312 TP304L Wld & smls pipe (II-D p. 84, ln. 38)
Inside diameter, new	10.42"
Pipe nominal wall thickness	0.165"
Pipe minimum wall thickness[1]	0.1444"
Corrosion allowance	0"
Projection available outside vessel, Lpr	6"
Local vessel minimum thickness	0.1875"
Liquid static head included	0 psi
Longitudinal joint efficiency	1
Reinforcing Pad	
Material specification	SA-240 304L (II-D p. 84, ln. 33)
Diameter, D_p	13.75"
Thickness, t_e	0.135"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.1875"
Outer fillet, Leg_{42}	0.1339"

Nozzle to vessel groove weld	0.1875"
Pad groove weld	0.135"

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

UHA-51 Material Toughness Requirements Nozzle	
$t_r = \frac{40.27 \cdot 5.21}{16{,}700 \cdot 1 - 0.6 \cdot 40.27} =$	0.0126"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0126 \cdot 1}{0.1444 - 0} =$	0.0872
Impact test exempt per UHA-51(g) (coincident ratio = 0.0872)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UHA-51 Material Toughness Requirements Pad	
$t_r = \frac{40.27 \cdot 25.8}{20{,}000 \cdot 1 - 0.6 \cdot 40.27} =$	0.052"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.052 \cdot 1}{0.1875 - 0} =$	0.2774
Impact test exempt per UHA-51(g) (coincident ratio = 0.2774)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

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 = 86.43 psi @ 300 °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}
1.2373	1.2374	0.7183	0.1143	–	0.3579	0.0469	0.1183	0.1444

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
10,191.06	9,810.2	55,736.26	3,781.38	98,361.6	10,843.51	67,947.08

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0945	0.1312	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0675	0.0937	weld size is adequate

Calculations for internal pressure 86.43 psi @ 300 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d, R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[10.42, 5.21 + (0.165 - 0) + (0.1875 - 0)\right]$$
$$= 10.42 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.165 - 0) + 0.135\right]$$
$$= 0.4688 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{86.4343 \cdot 5.21}{16{,}700 \cdot 1 - 0.6 \cdot 86.4343}$$
$$= 0.027 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$
$$= \frac{86.4343 \cdot 25.8}{18{,}900 \cdot 1 - 0.6 \cdot 86.4343}$$
$$= 0.1183 \text{ in}$$

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

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{86.4343 \cdot 25.8}{18{,}900 \cdot 0.7 - 0.6 \cdot 86.4343}$$

$$= 0.1692 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 18,900, S_p = 16,700 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.8836

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.8836

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.8836

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.8836

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

$$= 10.42 \cdot 0.1183 \cdot 1 + 2 \cdot 0.165 \cdot 0.1183 \cdot 1 \cdot (1 - 0.8836)$$

$$= 1.2373 \text{ in}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.7183 in^2

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

$$= 10.42 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1183) - 2 \cdot 0.165 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1183) \cdot (1 - 0.8836)$$

$$= 0.7183 \text{ in}^2$$

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

$$= 2 \cdot (0.1875 + 0.165) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1183) - 2 \cdot 0.165 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1183) \cdot (1 - 0.8836)$$

$$= 0.0461 \text{ in}^2$$

A_2 = smaller of the following= 0.1143 in^2

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

$$= 5 \cdot (0.165 - 0.027) \cdot 0.8836 \cdot 0.1875$$

$$= 0.1143 \text{ in}^2$$

$$= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2}$$

$$= 2 \cdot (0.165 - 0.027) \cdot (2.5 \cdot 0.165 + 0.135) \cdot 0.8836$$

$$= 0.1335 \text{ in}^2$$

$A_{41} = Leg^2 \cdot f_{r3}$

$= 0.1875^{\ 2} \cdot 0.8836$

$=$ 0.0311 in^2

$A_{42} = Leg^2 \cdot f_{r4}$

$= 0.1339^{\ 2} \cdot 0.8836$

$=$ 0.0158 in^2

$A_5 = (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$

$= (13.75 - 10.42 - 2 \cdot 0.165) \cdot 0.135 \cdot 0.8836$

$=$ 0.3579 in^2

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$

$= 0.7183 + 0.1143 + 0.0311 + 0.0158 + 0.3579$

$=$ 1.2374 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min[0.75, t_n, t_e] =$ 0.135 in

$t_{c(\min)} = \min[0.25, 0.7 \cdot t_{\min}] =$ 0.0945 in

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

Outer fillet: $t_{\min} = \min[0.75, t_e, t] =$ 0.135 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0675 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1339 = 0.0937$ in

UG-45 Nozzle Neck Thickness Check

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

$$= \frac{86.4343 \cdot 5.21}{16{,}700 \cdot 1 - 0.6 \cdot 86.4343} + 0$$

$= 0.027$ in

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

$= \max[0.027, 0]$

$= 0.027$ in

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{86.4343 \cdot 25.8}{18{,}900 \cdot 1 - 0.6 \cdot 86.4343} + 0$$

$= 0.1183$ in

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

$= \max[0.1183, 0.0625]$

$= 0.1183$ in

$$t_b = \min\left[t_{t3}, t_{b1}\right]$$
$$= \min\left[0.3194, 0.1183\right]$$
$$= 0.1183 \text{ in}$$

$$t_{\text{UG-45}} = \max\left[t_a, t_b\right]$$
$$= \max\left[0.027, 0.1183\right]$$
$$= \underline{0.1183} \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.165$ = 0.1444 in

The nozzle neck thickness is adequate.

Allowable stresses in joints UG-45 and UW-15(c)

Groove weld in tension:	$0.74 \cdot 18{,}900$ =	13,986 psi
Nozzle wall in shear:	$0.7 \cdot 16{,}700$ =	11,690 psi
Inner fillet weld in shear:	$0.49 \cdot 16{,}700$ =	8,183 psi
Outer fillet weld in shear:	$0.49 \cdot 16{,}700$ =	8,183 psi
Upper groove weld in tension:	$0.74 \cdot 16{,}700$ =	12,358 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 10.75 \cdot 0.1875 \cdot 8{,}183$ = 25,908.49 lb$_f$

(2) Outer fillet weld in shear
$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 13.75 \cdot 0.1339 \cdot 8{,}183$ = 23,665.5 lb$_f$

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 10.585 \cdot 0.165 \cdot 11{,}690$ = 32,070.76 lb$_f$

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 10.75 \cdot 0.1875 \cdot 13{,}986$ = 44,281.58 lb$_f$

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 10.75 \cdot 0.135 \cdot 12{,}358$ = 28,171.52 lb$_f$

Loading on welds per UG-41(b)(1)

$W = (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$
$= (1.2373 - 0.7183 + 2 \cdot 0.165 \cdot 0.8836 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1183)) \cdot 18{,}900$
$= \underline{10{,}191.06}$ lb$_f$

$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$
$= (0.1143 + 0.3579 + 0.0311 + 0.0158) \cdot 18{,}900$
$= \underline{9{,}810.2}$ lb$_f$

$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$
$= (0.1143 + 0 + 0.0311 + 0 + 2 \cdot 0.165 \cdot 0.1875 \cdot 0.8836) \cdot 18{,}900$
$= \underline{3{,}781.38}$ lb$_f$

$W_{3\text{-}3}$ = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$

= $(0.1143 + 0 + 0.3579 + 0.0311 + 0.0158 + 0 + 2 \cdot 0.165 \cdot 0.1875 \cdot 0.8836) \cdot 18{,}900$

= 10,843.51 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 9,810.2 lb_f
Path 1-1 through (2) & (3) = 23,665.5 + 32,070.76 = 55,736.26 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 $W_{2\text{-}2}$ = 3,781.38 lb_f
Path 2-2 through (1), (4), (6) = 25,908.49 + 44,281.58 + 28,171.52 = 98,361.6 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 $W_{3\text{-}3}$ = 10,191.06 lb_f
Path 3-3 through (2), (4) = 23,665.5 + 44,281.58 = 67,947.08 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 90.26 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}
1.2229	1.223	0.7334	0.107	--	0.3382	0.0444	0.1167	0.1444

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
10,179.74	9,791.5	55,736.26	3,761.31	100,938.83	10,824.81	70,524.32

Calculations for internal pressure 90.26 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d, R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[10.42, 5.21 + (0.165 - 0) + (0.1875 - 0)\right]$$
$$= 10.42 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.165 - 0) + 0.135\right]$$
$$= 0.4688 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{90.2585 \cdot 5.21}{16{,}700 \cdot 1 - 0.6 \cdot 90.2585}$$
$$= 0.0283 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$
$$= \frac{90.2585 \cdot 25.8}{20{,}000 \cdot 1 - 0.6 \cdot 90.2585}$$
$$= 0.1168 \text{ in}$$

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

t_r = $\dfrac{P \cdot R}{S \cdot E - 0.6 \cdot P}$

= $\dfrac{90.2585 \cdot 25.8}{20{,}000 \cdot 0.7 - 0.6 \cdot 90.2585}$

= 0.167 in

Area required per UG-37(c)

Allowable stresses: S_n = 16,700, S_v = 20,000, S_p = 16,700 psi

f_{r1} = lesser of 1 or $\dfrac{S_n}{S_v}$ = 0.835

f_{r2} = lesser of 1 or $\dfrac{S_n}{S_v}$ = 0.835

f_{r3} = lesser of f_{r2} or $\dfrac{S_p}{S_v}$ = 0.835

f_{r4} = lesser of 1 or $\dfrac{S_p}{S_v}$ = 0.835

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

= $10.42 \cdot 0.1168 \cdot 1 + 2 \cdot 0.165 \cdot 0.1168 \cdot 1 \cdot (1 - 0.835)$

= 1.2229 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.7334 in^2

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

= $10.42 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1168) - 2 \cdot 0.165 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1168) \cdot (1 - 0.835)$

= 0.7334 in^2

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

= $2 \cdot (0.1875 + 0.165) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1168) - 2 \cdot 0.165 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1168) \cdot (1 - 0.835)$

= 0.046 in^2

A_2 = smaller of the following= 0.107 in^2

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

= $5 \cdot (0.165 - 0.0283) \cdot 0.835 \cdot 0.1875$

= 0.107 in^2

= $2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2}$

= $2 \cdot (0.165 - 0.0283) \cdot (2.5 \cdot 0.165 + 0.135) \cdot 0.835$

= 0.125 in^2

A_{41} = $Leg^2 \cdot f_{r3}$

= $0.1875^{\ 2} \cdot 0.835$

= 0.0294 in^2

$A_{42} = Leg^2 \cdot f_{r4}$

$= 0.1339^{\ 2} \cdot 0.835$

$= 0.015$ in^2

$A_5 = (D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$

$= (13.75 - 10.42 - 2 \cdot 0.165) \cdot 0.135 \cdot 0.835$

$= 0.3382$ in^2

$Area = A_1 + A_2 + A_{41} + A_{42} + A_5$

$= 0.7334 + 0.107 + 0.0294 + 0.015 + 0.3382$

$= 1.223$ in^2

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$= \frac{90.2585 \cdot 5.21}{16{,}700 \cdot 1 - 0.6 \cdot 90.2585} + 0$$

$$= 0.0283 \text{ in}$$

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

$$= \max\left[0.0283, 0\right]$$

$$= 0.0283 \text{ in}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$

$$= \frac{90.2585 \cdot 25.8}{20{,}000 \cdot 1 - 0.6 \cdot 90.2585} + 0$$

$$= 0.1167 \text{ in}$$

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

$$= \max\left[0.1167, 0.0625\right]$$

$$= 0.1167 \text{ in}$$

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

$$= \min\left[0.3194, 0.1167\right]$$

$$= 0.1167 \text{ in}$$

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

$$= \max\left[0.0283, 0.1167\right]$$

$$= 0.1167 \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.165 = 0.1444$ 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:	$0.7 \cdot 16{,}700$	= 11,690 psi
Inner fillet weld in shear:	$0.49 \cdot 16{,}700$	= 8,183 psi
Outer fillet weld in shear:	$0.49 \cdot 16{,}700$	= 8,183 psi
Upper groove weld in tension:	$0.74 \cdot 16{,}700$	= 12,358 psi

Strength of welded joints:

(1) Inner fillet weld in shear

$$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 10.75 \cdot 0.1875 \cdot 8{,}183 = 25{,}908.49 \text{ lb}_\text{f}$$

(2) Outer fillet weld in shear

$$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 13.75 \cdot 0.1339 \cdot 8{,}183 = 23{,}665.5 \text{ lb}_\text{f}$$

(3) Nozzle wall in shear

$$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 10.585 \cdot 0.165 \cdot 11{,}690 = 32{,}070.76 \text{ lb}_\text{f}$$

(4) Groove weld in tension

$$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 10.75 \cdot 0.1875 \cdot 14{,}800 = 46{,}858.82 \text{ lb}_\text{f}$$

(6) Upper groove weld in tension

$$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 10.75 \cdot 0.135 \cdot 12{,}358 = 28{,}171.52 \text{ lb}_\text{f}$$

Loading on welds per UG-41(b)(1)

$$W = (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$$
$$= (1.2229 - 0.7334 + 2 \cdot 0.165 \cdot 0.835 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1168)) \cdot 20{,}000$$
$$= 10{,}179.74 \text{ lb}_\text{f}$$

$$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$$
$$= (0.107 + 0.3382 + 0.0294 + 0.015) \cdot 20{,}000$$
$$= 9{,}791.5 \text{ lb}_\text{f}$$

$$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$$
$$= (0.107 + 0 + 0.0294 + 0 + 2 \cdot 0.165 \cdot 0.1875 \cdot 0.835) \cdot 20{,}000$$
$$= 3{,}761.31 \text{ lb}_\text{f}$$

$$W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$$
$$= (0.107 + 0 + 0.3382 + 0.0294 + 0.015 + 0 + 2 \cdot 0.165 \cdot 0.1875 \cdot 0.835) \cdot 20{,}000$$
$$= 10{,}824.81 \text{ lb}_\text{f}$$

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 9,791.5 lb_f
Path 1-1 through (2) & (3) = 23,665.5 + 32,070.76 = 55,736.26 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 $W_{2\text{-}2}$ = 3,761.31 lb_f
Path 2-2 through (1), (4), (6) = 25,908.49 + 46,858.82 + 28,171.52 = 100,938.83 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 $W_{3\text{-}3}$ = 10,179.74 lb_f
Path 3-3 through (2), (4) = 23,665.5 + 46,858.82 = 70,524.32 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 15.71 psi @ 300 °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}
0.8252	0.8254	0.3082	0.1124	–	0.3579	0.0469	0.0625	0.1444

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0945	0.1312	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0675	0.0937	weld size is adequate

Calculations for external pressure 15.71 psi @ 300 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d, R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[10.42, 5.21 + (0.165 - 0) + (0.1875 - 0)\right]$$
$$= 10.42 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.165 - 0) + 0.135\right]$$
$$= 0.4688 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0294 in

From UG-37(d)(1) required thickness t_r = 0.1578 in

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

Allowable stresses: S_n = 16,700, S_v = 18,900, S_p = 16,700 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.8836

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.8836

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.8836

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.8836

A = $0.5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$

= $0.5 \cdot (10.42 \cdot 0.1578 \cdot 1 + 2 \cdot 0.165 \cdot 0.1578 \cdot 1 \cdot (1 - 0.8836))$

= 0.8252 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.3082 in^2

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

= $10.42 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1578) - 2 \cdot 0.165 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1578) \cdot (1 - 0.8836)$

= $0.3082 \ \text{in}^2$

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

= $2 \cdot (0.1875 + 0.165) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1578) - 2 \cdot 0.165 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1578) \cdot (1 - 0.8836)$

= $0.0198 \ \text{in}^2$

A_2 = smaller of the following= 0.1124 in^2

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

= $5 \cdot (0.165 - 0.0294) \cdot 0.8836 \cdot 0.1875$

= $0.1124 \ \text{in}^2$

= $2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2}$

= $2 \cdot (0.165 - 0.0294) \cdot (2.5 \cdot 0.165 + 0.135) \cdot 0.8836$

= $0.1312 \ \text{in}^2$

A_{41} = $Leg^2 \cdot f_{r3}$

= $0.1875^{\ 2} \cdot 0.8836$

= 0.0311 in^2

A_{42} = $Leg^2 \cdot f_{r4}$

= $0.1339^{\ 2} \cdot 0.8836$

= 0.0158 in^2

A_5 = $(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$

= $(13.75 - 10.42 - 2 \cdot 0.165) \cdot 0.135 \cdot 0.8836$

= 0.3579 in^2

$Area$ = $A_1 + A_2 + A_{41} + A_{42} + A_5$

= $0.3082 + 0.1124 + 0.0311 + 0.0158 + 0.3579$

= 0.8254 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min}$ = $\min\,[0.75, t_n, t_e]$ = 0.135 in

$t_{c(\min)}$ = $\min\,[0.25, 0.7 \cdot t_{\min}]$ = 0.0945 in

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

Outer fillet: $t_{\min} = \min[0.75, t_e, t] =$ 0.135 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0675 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.1339 = 0.0937$ in

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}} = 0.0294$ in

$t_a = \max[t_{a\text{UG-28}}, t_{a\text{UG-22}}]$

$= \max[0.0294, 0]$

$= 0.0294$ in

$t_{b2} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$

$= \frac{15.7101 \cdot 25.8}{18{,}900 \cdot 1 - 0.6 \cdot 15.7101} + 0$

$= 0.0215$ in

$t_{b2} = \max[t_{b2}, t_{b\text{UG16}}]$

$= \max[0.0215, 0.0625]$

$= 0.0625$ in

$t_b = \min[t_{b3}, t_{b2}]$

$= \min[0.3194, 0.0625]$

$= 0.0625$ in

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

$= \max[0.0294, 0.0625]$

$=$ 0.0625 in

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.165 =$ 0.1444 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 300 °F) UG-28(c)

$\frac{L}{D_o} = \frac{6.5619}{10.75} = 0.6104$

$\frac{D_o}{t} = \frac{10.75}{0.0294} = 366.2566$

From table G: $A = 0.000326$

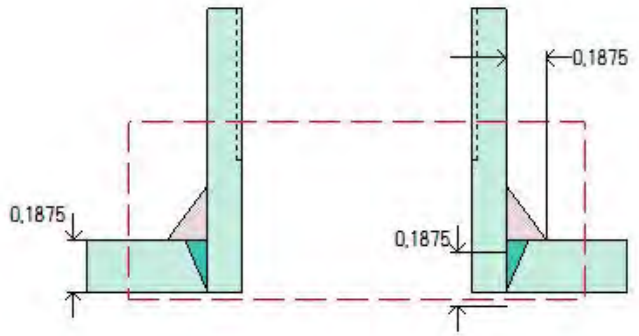
From table HA-3: $B = 4{,}315.2581$ psi

$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 4{,}315.26}{3 \cdot (10.75 / 0.0294)} = 15.71$ psi

Design thickness for external pressure P_a = 15.71 psi

$t_a = t + \text{Corrosion} = 0.0294 + 0 =$ 0.0294"

Nozzle P3 (P3)

ASME Section VIII Division 1, 2019 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Cylinder #1
Orientation	0°
Nozzle center line offset to datum line	16.625"
End of nozzle to shell center	26.7908"
Passes through a Category A joint	No
Nozzle	
Service	Pressure Relief Valve (PRV)
Description	NPS 0.75 Class 3000 - Threaded Half Coupling
Access opening	No
Material specification	SA-182 F304L <= 5 (II-D p. 84, ln. 29)
Inside diameter, new	1.06"
Nominal wall thickness	0.16"
Corrosion allowance	0"
Projection available outside vessel, Lpr	0.8033"
Local vessel minimum thickness	0.1875"
Liquid static head included	0 psi
Longitudinal joint efficiency	1
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.1875"

UHA-51 Material Toughness Requirements Nozzle	
$t_r = \frac{40.27 \cdot 0.53}{16{,}700 \cdot 1 - 0.6 \cdot 40.27} =$	0.0013"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0013 \cdot 1}{0.16 - 0} =$	0.008
Impact test exempt per UHA-51(g) (coincident ratio = 0.008)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-44 Summary (in)	
For P = 136.76 psi @ 300 °F							The nozzle passes UG-44	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.16

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})	0.0937	0.1312	weld size is adequate

Calculations for internal pressure 136.76 psi @ 300 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d, R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[1.06, 0.53 + (0.16 - 0) + (0.1875 - 0)\right]$$
$$= 1.06 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.16 - 0) + 0\right]$$
$$= 0.4 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{136.7576 \cdot 0.53}{16{,}700 \cdot 1 - 0.6 \cdot 136.7576}$$
$$= 0.0044 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$
$$= \frac{136.7576 \cdot 25.8}{18{,}900 \cdot 1 - 0.6 \cdot 136.7576}$$
$$= 0.1875 \text{ in}$$

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

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{136.7576 \cdot 25.8}{18{,}900 \cdot 0.7 - 0.6 \cdot 136.7576}$$

$$= 0.2684 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min[0.75, t_n, t] =$ 0.16 in

$t_{c(\min)} = \min[0.09375, 0.7 \cdot t_{\min}] =$ 0.0937 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-44 Thickness Check - ASME B16.11 Coupling

$$t_{a\text{App 1-1}} = \frac{P \cdot R_o}{S_n \cdot E + 0.4 \cdot P} + \text{Corrosion}$$

$$= \frac{136.7576 \cdot 0.69}{16{,}700 \cdot 1 + 0.4 \cdot 136.7576} + 0$$

$$= 0.0056 \text{ in}$$

$$t_{a\text{UG-44}} = \max[t_{a\text{App 1-1}},\ t_{b\text{UG16}}]$$

$$= \max[0.0056,\ 0.0625]$$

$$= 0.0625 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.16 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-44 Summary (in)	
For P = 144.72 psi @ 70 °F							The nozzle passes UG-44	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.16

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

Calculations for internal pressure 144.72 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= \max\left[d, R_n + (t_n - C_n) + (t - C)\right] \\ &= \max\left[1.06, 0.53 + (0.16 - 0) + (0.1875 - 0)\right] \\ &= 1.06 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right] \\ &= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.16 - 0) + 0\right] \\ &= 0.4 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} \\ &= \frac{144.7199 \cdot 0.53}{16{,}700 \cdot 1 - 0.6 \cdot 144.7199} \\ &= 0.0046 \text{ in} \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} \\ &= \frac{144.7199 \cdot 25.8}{20{,}000 \cdot 1 - 0.6 \cdot 144.7199} \\ &= 0.1875 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_r &= \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} \\ &= \frac{144.7199 \cdot 25.8}{20{,}000 \cdot 0.7 - 0.6 \cdot 144.7199} \\ &= 0.2684 \text{ in} \end{aligned}$$

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

UG-44 Thickness Check - ASME B16.11 Coupling

$$t_{a\text{App 1-1}} = \frac{P \cdot R_o}{S_n \cdot E + 0.4 \cdot P} + \text{Corrosion}$$

$$= \frac{144.7199 \cdot 0.69}{16{,}700 \cdot 1 + 0.4 \cdot 144.7199} + 0$$

$$= 0.006 \quad \text{in}$$

$$t_{a\text{UG-44}} = \max\left[t_{a\text{App 1-1}},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.006,\ 0.0625\right]$$

$$= \underline{0.0625} \quad \text{in}$$

Available nozzle wall thickness new, t_n = 0.16 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 23.85 psi @ 300 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.16

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0937	0.1312	weld size is adequate

Calculations for external pressure 23.85 psi @ 300 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= \max\left[d, R_n + (t_n - C_n) + (t - C)\right] \\ &= \max\left[1.06, 0.53 + (0.16 - 0) + (0.1875 - 0)\right] \\ &= 1.06 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right] \\ &= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.16 - 0) + 0\right] \\ &= 0.4 \text{ in} \end{aligned}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0047 in

From UG-37(d)(1) required thickness t_r = 0.1875 in

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75, t_n, t\right] =$ 0.16 in

$t_{c(\min)} = \min\left[0.09375, 0.7 \cdot t_{\min}\right] =$ 0.0937 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

$$t_{a\text{UG-28}} = 0.0047 \text{ in}$$

$$\begin{aligned} t_a &= \max\left[t_{a\text{UG-28}}, t_{a\text{UG-22}}\right] \\ &= \max\left[0.0047, 0\right] \\ &= 0.0047 \text{ in} \end{aligned}$$

t_{b2} = $\dfrac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$

= $\dfrac{23.8478 \cdot 25.8}{18{,}900 \cdot 1 - 0.6 \cdot 23.8478} + 0$

= 0.0326 in

$t_{b2} = \max\left[t_{b2}, t_{b\text{UG16}}\right]$

$= \max\left[0.0326, 0.0625\right]$

$= 0.0625 \text{ in}$

$t_b = \min\left[t_{b3}, t_{b2}\right]$

$= \min\left[0.1225, 0.0625\right]$

$= 0.0625 \text{ in}$

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

$= \max\left[0.0047, 0.0625\right]$

$= 0.0625 \text{ in}$

Available nozzle wall thickness new, t_n = 0.16 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 300 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{0.8124}{1.38} = 0.5887$$

$$\frac{D_o}{t} = \frac{1.38}{0.0047} = 295.9207$$

From table G: $A = 0.000453$

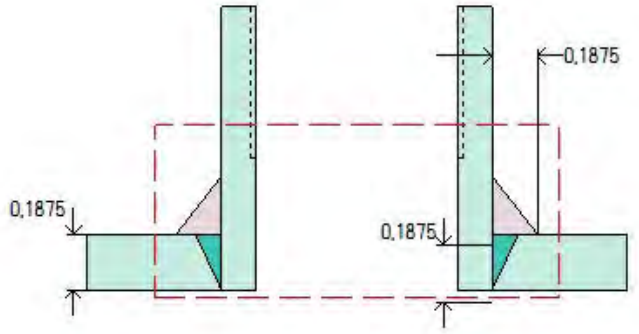
From table HA-3: $B = 5{,}292.8081 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 5{,}292.81}{3 \cdot (1.38 / 0.0047)} = 23.85 \text{ psi}$$

Design thickness for external pressure P_a = 23.85 psi

$t_a = t + \text{Corrosion} = 0.0047 + 0 = 0.0047"$

Nozzle P6 (P6)

ASME Section VIII Division 1, 2019 Edition

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

Location and Orientation	
Located on	Cylinder #1
Orientation	180°
Nozzle center line offset to datum line	16.625"
End of nozzle to shell center	26.7339"
Passes through a Category A joint	No

Nozzle	
Service	Drain (DRN)
Description	NPS 0.5 Class 3000 - Threaded Half Coupling
Access opening	No
Material specification	SA-182 F304L <= 5 (II-D p. 84, ln. 29)
Inside diameter, new	0.84"
Nominal wall thickness	0.14"
Corrosion allowance	0"
Projection available outside vessel, Lpr	0.7464"
Local vessel minimum thickness	0.1875"
Liquid static head included	0 psi
Longitudinal joint efficiency	1

Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.1875"

UHA-51 Material Toughness Requirements Nozzle	
$t_r = \frac{40.27 \cdot 0.42}{16{,}700 \cdot 1 - 0.6 \cdot 40.27} =$	0.001"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.001 \cdot 1}{0.14 - 0} =$	0.0073
Impact test exempt per UHA-51(g) (coincident ratio = 0.0073)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for MAWP

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2)							UG-44 Summary (in)	
For P = 136.76 psi @ 300 °F							The nozzle passes UG-44	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.14

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})	0.0937	0.1312	weld size is adequate

Calculations for internal pressure 136.76 psi @ 300 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d, R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[0.84, 0.42 + (0.14 - 0) + (0.1875 - 0)\right]$$
$$= 0.84 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.14 - 0) + 0\right]$$
$$= 0.35 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{136.7576 \cdot 0.42}{16{,}700 \cdot 1 - 0.6 \cdot 136.7576}$$
$$= 0.0035 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$
$$= \frac{136.7576 \cdot 25.8}{18{,}900 \cdot 1 - 0.6 \cdot 136.7576}$$
$$= 0.1875 \text{ in}$$

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

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$

$$= \frac{136.7576 \cdot 25.8}{18{,}900 \cdot 0.7 - 0.6 \cdot 136.7576}$$

$$= 0.2684 \text{ in}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min[0.75, t_n, t] =$ 0.14 in

$t_{c(\min)} = \min[0.09375, 0.7 \cdot t_{\min}] =$ 0.0937 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-44 Thickness Check - ASME B16.11 Coupling

$$t_{a\text{App 1-1}} = \frac{P \cdot R_o}{S_n \cdot E + 0.4 \cdot P} + \text{Corrosion}$$

$$= \frac{136.7576 \cdot 0.56}{16{,}700 \cdot 1 + 0.4 \cdot 136.7576} + 0$$

$$= 0.0046 \text{ in}$$

$$t_{a\text{UG-44}} = \max[t_{a\text{App 1-1}},\ t_{b\text{UG16}}]$$

$$= \max[0.0046,\ 0.0625]$$

$$= 0.0625 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.14 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-44 Summary (in)	
For P = 144.72 psi @ 70 °F							The nozzle passes UG-44	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.14

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

Calculations for internal pressure 144.72 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= \max\left[d, R_n + (t_n - C_n) + (t - C)\right] \\ &= \max\left[0.84, 0.42 + (0.14 - 0) + (0.1875 - 0)\right] \\ &= 0.84 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right] \\ &= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.14 - 0) + 0\right] \\ &= 0.35 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_{rn} &= \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P} \\ &= \frac{144.7199 \cdot 0.42}{16{,}700 \cdot 1 - 0.6 \cdot 144.7199} \\ &= 0.0037 \text{ in} \end{aligned}$$

Required thickness t_r from UG-37(a)

$$\begin{aligned} t_r &= \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} \\ &= \frac{144.7199 \cdot 25.8}{20{,}000 \cdot 1 - 0.6 \cdot 144.7199} \\ &= 0.1875 \text{ in} \end{aligned}$$

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

$$\begin{aligned} t_r &= \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} \\ &= \frac{144.7199 \cdot 25.8}{20{,}000 \cdot 0.7 - 0.6 \cdot 144.7199} \\ &= 0.2684 \text{ in} \end{aligned}$$

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

UG-44 Thickness Check - ASME B16.11 Coupling

$$t_{a\text{App 1-1}} = \frac{P \cdot R_o}{S_n \cdot E + 0.4 \cdot P} + \text{Corrosion}$$

$$= \frac{144.7199 \cdot 0.56}{16{,}700 \cdot 1 + 0.4 \cdot 144.7199} + 0$$

$$= 0.0048 \quad \text{in}$$

$$t_{a\text{UG-44}} = \max\left[t_{a\text{App 1-1}},\ t_{b\text{UG16}}\right]$$

$$= \max\left[0.0048,\ 0.0625\right]$$

$$= \underline{0.0625} \quad \text{in}$$

Available nozzle wall thickness new, t_n = 0.14 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 23.85 psi @ 300 °F							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.14

UG-41 Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0937	0.1312	weld size is adequate

Calculations for external pressure 23.85 psi @ 300 °F

Parallel Limit of reinforcement per UG-40

$$\begin{aligned} L_R &= \max\left[d, R_n + (t_n - C_n) + (t - C)\right] \\ &= \max\left[0.84, 0.42 + (0.14 - 0) + (0.1875 - 0)\right] \\ &= 0.84 \text{ in} \end{aligned}$$

Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned} L_H &= \min\left[2.5 \cdot (t - C), 2.5 \cdot (t_n - C_n) + t_e\right] \\ &= \min\left[2.5 \cdot (0.1875 - 0), 2.5 \cdot (0.14 - 0) + 0\right] \\ &= 0.35 \text{ in} \end{aligned}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0039 in

From UG-37(d)(1) required thickness t_r = 0.1875 in

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[0.75, t_n, t\right] =$ 0.14 in

$t_{c(\min)} = \min\left[0.09375, 0.7 \cdot t_{\min}\right] =$ 0.0937 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

$$t_{a\text{UG-28}} = 0.0039 \text{ in}$$

$$\begin{aligned} t_a &= \max\left[t_{a\text{UG-28}}, t_{a\text{UG-22}}\right] \\ &= \max\left[0.0039, 0\right] \\ &= 0.0039 \text{ in} \end{aligned}$$

$t_{b2} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$

$= \frac{23.8478 \cdot 25.8}{18{,}900 \cdot 1 - 0.6 \cdot 23.8478} + 0$

$= 0.0326 \text{ in}$

$t_{b2} = \max\left[t_{b2}, t_{b\text{UG16}}\right]$

$= \max\left[0.0326, 0.0625\right]$

$= 0.0625 \text{ in}$

$t_b = \min\left[t_{b3}, t_{b2}\right]$

$= \min\left[0.1164, 0.0625\right]$

$= 0.0625 \text{ in}$

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

$= \max\left[0.0039, 0.0625\right]$

$= 0.0625 \text{ in}$

Available nozzle wall thickness new, t_n = 0.14 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 300 °F) UG-28(c)

$\frac{L}{D_o} = \frac{0.7525}{1.12} = 0.6718$

$\frac{D_o}{t} = \frac{1.12}{0.0039} = 285.9271$

From table G: $A = 0.000419$

From table HA-3: $B = 5{,}112.9845 \text{ psi}$

$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 5{,}112.98}{3 \cdot (1.12 / 0.0039)} = 23.84 \text{ psi}$

Design thickness for external pressure P_a = 23.84 psi

$t_a = t + \text{Corrosion} = 0.0039 + 0 = 0.0039"$

Straight Flange on F&D Head #2

ASME Section VIII Division 1, 2019 Edition				
Component		Cylinder		
Material		SA-240 304 (II-D p. 88, ln. 37)		
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		25	300	-20
External		15	300	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		1.9	52.5908	1
Dimensions				
Inner Diameter		51.6"		
Length		1"		
Nominal Thickness		0.2"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		9.44		9.05
Corroded		9.44		9.05
Radiography				
Longitudinal seam		None UW-11(c) Type 1		
Left Circumferential seam		None UW-11(c) Type 1		

Results Summary	
Governing condition	External pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0489"
Design thickness due to external pressure (t_e)	0.1548"
Maximum allowable working pressure (MAWP)	102.08 psi
Maximum allowable pressure (MAP)	108.02 psi
Maximum allowable external pressure (MAEP)	27.19 psi
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \frac{40.27 \cdot 25.8}{20{,}000 \cdot 0.7 - 0.6 \cdot 40.27} =$	0.0743"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0743 \cdot 0.8}{0.2 - 0} =$	0.2974
Impact test exempt per UHA-51(g) (coincident ratio = 0.2974)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 300 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{25 \cdot 25.8}{18{,}900 \cdot 0.70 - 0.60 \cdot 25} + 0 = \underline{0.0489}"$$

Maximum allowable working pressure, (at 300 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{18{,}900 \cdot 0.70 \cdot 0.2}{25.8 + 0.60 \cdot 0.2} - 0 = \underline{102.08} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 0.70 \cdot 0.2}{25.8 + 0.60 \cdot 0.2} = \underline{108.02} \text{ psi}$$

External Pressure, (Corroded & at 300 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{40.651}{52} = 0.7818$$

$$\frac{D_o}{t} = \frac{52}{0.1548} = 335.9886$$

From table G: $A = 0.000287$

From table HA-1: $B = 3{,}779.872$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 3{,}779.87}{3 \cdot (52 / 0.1548)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.1548 + 0 = \underline{0.1548}"$$

Maximum Allowable External Pressure, (Corroded & at 300 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{40.651}{52} = 0.7818$$

$$\frac{D_o}{t} = \frac{52}{0.2} = 260.0000$$

From table G: $A = 0.000412$

From table HA-1: $B = 5{,}302.6411$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 5{,}302.64}{3 \cdot (52 / 0.2)} = \underline{27.19} \text{ psi}$$

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

$$EFE = \left(\frac{50 \cdot t}{R_f} \right) \cdot \left(1 - \frac{R_f}{R_o} \right) = \left(\frac{50 \cdot 0.2}{25.9} \right) \cdot \left(1 - \frac{25.9}{\infty} \right) = 0.3861\,\%$$

F&D Head #2

ASME Section VIII Division 1, 2019 Edition				
Component		F&D Head		
Material		SA-240 304 (II-D p. 88, ln. 37)		
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		25	300	-20
External		15	300	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		1.9	52.5908	1
Dimensions				
Inner Diameter		51.6"		
Crown Radius L		51.6"		
Knuckle Radius r		1"		
Minimum Thickness		0.2"		
Corrosion	**Inner**	0"		
	Outer	0"		
Length L_{sf}		1"		
Nominal Thickness t_{sf}		0.2"		
Weight and Capacity				
		Weight (lb)[1]	**Capacity (US gal)[1]**	
New		145.36	46.32	
Corroded		145.36	46.32	
Radiography				
Category A joints		None UW-11(c) Type 1		
Head to shell seam		None UW-11(c) Type 1		

[1] includes straight flange

Results Summary	
Governing condition	external pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.1242"
Design thickness due to external pressure (t_e)	0.1563"
Maximum allowable working pressure (MAWP)	40.27 psi
Maximum allowable pressure (MAP)	42.62 psi
Maximum allowable external pressure (MAEP)	22.11 psi
Rated MDMT	-320°F

Note: Endnote 90 used to determine allowable stress.

UHA-51 Material Toughness Requirements	
$t_r = \frac{40.27 \cdot 51.6 \cdot 1}{2 \cdot 20{,}000 \cdot 0.7 - 0.2 \cdot 40.27} =$	0.0742"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0742 \cdot 0.8}{0.2 - 0} =$	0.297
Impact test exempt per UHA-51(g) (coincident ratio = 0.297)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Factor M		
$M = \frac{1}{4} \cdot \left[3 + \left(\frac{L}{r}\right)^{\frac{1}{2}}\right]$		
Corroded	$M = \frac{1}{4} \cdot \left[3 + \left(\frac{51.6}{1}\right)^{\frac{1}{2}}\right]$	2.5458
New	$M = \frac{1}{4} \cdot \left[3 + \left(\frac{51.6}{1}\right)^{\frac{1}{2}}\right]$	2.5458

Design thickness for internal pressure, (Corroded at 300 °F) Appendix 1-4(d)

$$t = \frac{P \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{25 \cdot 51.6 \cdot 2.5458}{2 \cdot 18{,}900 \cdot 0.7 - 0.2 \cdot 25} + 0 = 0.1241\text{"}$$

Maximum allowable working pressure, (Corroded at 300 °F) Appendix 1-4(d)

$$P = \frac{2 \cdot S \cdot E \cdot t}{L \cdot M + 0.2 \cdot t} - P_s = \frac{2 \cdot 18{,}900 \cdot 0.7 \cdot 0.2}{51.6 \cdot 2.5458 + 0.2 \cdot 0.2} - 0 = 40.27 \text{ psi}$$

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

$$P = \frac{2 \cdot S \cdot E \cdot t}{L \cdot M + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 0.7 \cdot 0.2}{51.6 \cdot 2.5458 + 0.2 \cdot 0.2} - 0 = 42.62 \text{ psi}$$

Design thickness for external pressure, (Corroded at 300 °F) UG-33(e)

Equivalent outside spherical radius (R_o) = Outside crown radius $= 51.8 \text{ in}$

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{51.8 \ / \ 0.156236} = 0.000377$$

From Table HA-1:B = 4,973.2519 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{4{,}973.2519}{51.8 \ / \ 0.1562} = 15 \text{ psi}$$

t = 0.1562" + Corrosion = 0.1562" + 0" = 0.1562"

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

$$t = \frac{1.67 \cdot P_e \cdot L \cdot M}{2 \cdot S \cdot E - 0.2 \cdot 1.67 \cdot P_e} + \text{Corrosion} = \frac{1.67 \cdot 15 \cdot 51.6 \cdot 2.5458}{2 \cdot 18{,}900 \cdot 1 - 0.2 \cdot 1.67 \cdot 15} + 0 = 0.0871\text{”}$$

The head external pressure design thickness (t_e) is 0.1562".

Maximum Allowable External Pressure, (Corroded at 300 °F) UG-33(e)

Equivalent outside spherical radius (R_o) = Outside crown radius $= 51.8 \text{ in}$

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{51.8 \ / \ 0.2} = 0.000483$$

From Table HA-1:B = 5,726.9877 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{5{,}726.9877}{51.8 \ / \ 0.2} = 22.1119 \text{ psi}$$

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

$$P = \frac{2 \cdot S \cdot E \cdot t}{(L \cdot M + 0.2 \cdot t) \cdot 1.67} = \frac{2 \cdot 18{,}900 \cdot 1 \cdot 0.2}{(51.6 \cdot 2.5458 + 0.2 \cdot 0.2) \cdot 1.67} = 34.45 \text{ psi}$$

The maximum allowable external pressure (MAEP) is 22.11 psi.

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

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 0.2}{1.1}\right) \cdot \left(1 - \frac{1.1}{\infty}\right) = 13.6364 \, \%$$