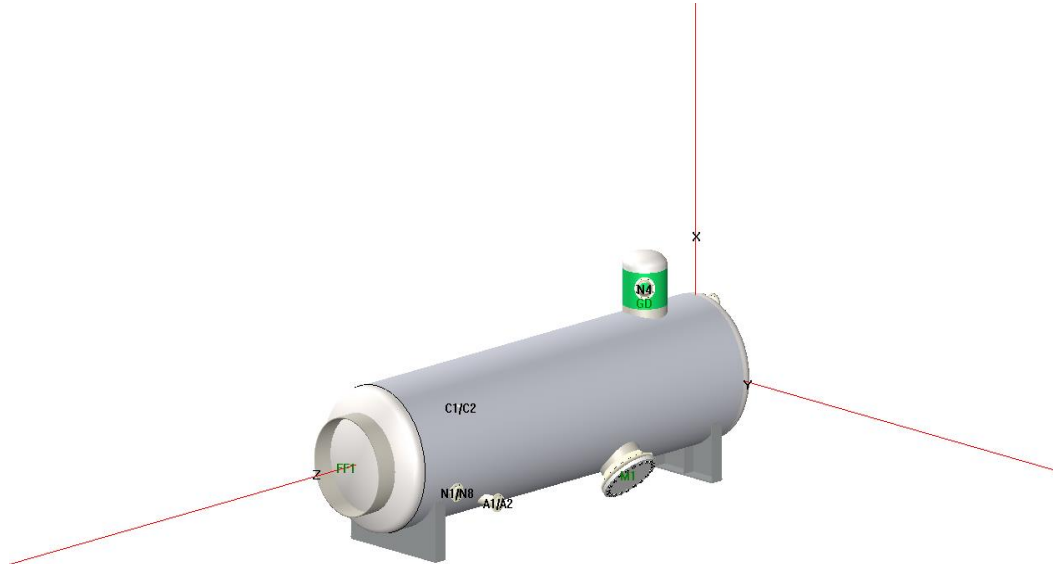


# Blue Diamond Design

#10 Pegasus Way NE

Calgary, Alberta

T2E 8M5



## COMPRESS Pressure Vessel Design Calculations

**Item:** Treator  
**Drawng No:** Treator  
**Customer:** Altec Inspection Ltd.  
**Designer:** Brian Munn, C.E.T.  
**Date:** Wednesday, June 17, 2020  
**Name:** 8009c-2 R0 - Treator

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## Revision History

Revisions			
No.	Date	Operator	Notes
0	6/ 2/2020	brianm	New vessel created ASME Section VIII Division 1 [COMPRESS 2020 Build 8000]
1	6/ 2/2020	brianm	Converted from ASME Section VIII Division 1, 2019 Edition to ASME Section VIII Division 1, 2001 Edition. During the conversion, changes may have been made to your vessel (some may be listed above). Please check your vessel carefully.

## Deficiencies Summary

**No deficiencies found.**

## Warnings Summary

### Warnings for [Firetube \(FF1\)](#)

The limits of reinforcement of Firetube (FF1) fall off of Left Head on to Shell. You may address this issue by relocating the nozzle or specifying a user defined radial limit of reinforcement by clicking on the Calculation Options button in the Detailed Nozzle Design dialog. (warning)

### Warnings for Vessel

Changes to steelmaking practices have increased the risk of brittle fracture at temperatures higher than the ASME impact test exemption temperatures. It is highly recommended that the following supplemental requirements be applied for SA-105, SA-106 B, SA-53 seamless, and SA-234: material composition should have a minimum Mn:C ratio of 5, and SA-105 flanges should require a grain size of 7 or finer. (warning)

### ASME B16.5 / B16.47 Flange Warnings Summary

Flange	Applicable Warnings
4" On Shell (N1/N8)	1
3" Nozzle (On Shell) (N3/N10)	1
2" Nozzle (On Shell) (N5/N15/N16/N17)	1
Gas Outlet (N4)	1
Anode Ports (A1/A2)	1
Manway (M1)	1
Oil Outlet (On Head) (N2)	1
Oil Level Controller (N6)	1
LSHH (N9)	1
Pressure Indicator (N14)	1
Oil Level Gauge (N12A)	1
2" Nozzles at Lowest Location (In Head) (N11/N12B/N13)	1
Interface Level Controller (N7)	1

No.	Warning
1	For Class 150 flanges, ASME B16.5 para. 5.4.2 recommends gaskets to be in accordance with Fig. E1, Group No. I.

## Nozzle Schedule

Specifications									
Nozzle mark	Identifier	Size	Materials		Impact Tested	Normalized	Fine Grain	Flange	Blind
<a href="#">A1/A2</a>	Anode Ports	5.5 OD x 0.75	Nozzle	SA-105	No	No	No	NPS 4 Class 150 LWN A105	No
<a href="#">C1/C2</a>	1" Coupling	NPS 1 Class 6000 - Threaded (2.8674" length)	Nozzle	SA-105	No	No	No	N/A	No
<a href="#">FF1</a>	Firetube	49 OD x 0.625	Nozzle	SA-516 70	No	Yes	No	N/A	No
			Pad	SA-516 70	No	Yes	No		
<a href="#">GD</a>	Gas Dome	NPS 24 XS	Nozzle	SA-106 B Smls pipe	No	No	No	N/A	No
			Pad	SA-516 70	No	Yes	No		
	<a href="#">Gas Dome Shell</a>	NPS 24 Sch 20 (Std)	Nozzle Pipe	SA-106 B Smls pipe	No	No	No	N/A	No
	<a href="#">Gas Dome Head</a>	OD = 24" x Thk = 0.25"	Ellipsoidal Head	SA-516 70	No	Yes	No	N/A	N/A
<a href="#">M1</a>	Manway	NPS 24 XS	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 24 Class 150 WN A105 N	NPS 24 Class 150 A105 N
			Pad	SA-516 70	No	Yes	No		
<a href="#">N1/N8</a>	4" On Shell	NPS 4 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 4 Class 150 WN A105 N	No
<a href="#">N11/N12B/N13</a>	2" Nozzles at Lowest Location (In Head)	NPS 2 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 2 Class 150 WN A105 N	No
<a href="#">N12A</a>	Oil Level Gauge	NPS 2 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 2 Class 150 WN A105 N	No
<a href="#">N14</a>	Pressure Indicator	NPS 2 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 2 Class 150 WN A105 N	No
<a href="#">N2</a>	Oil Outlet (On Head)	NPS 3 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 3 Class 150 WN A105 N	No
<a href="#">N3/N10</a>	3" Nozzle (On Shell)	NPS 3 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 3 Class 150 WN A105 N	No
<a href="#">N4</a>	Gas Outlet	NPS 6 Sch 80 (XS)	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 6 Class 150 WN A105 N	No
<a href="#">N5/N15/N16/N17</a>	2" Nozzle (On Shell)	NPS 2 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 2 Class 150 WN A105 N	No
<a href="#">N6</a>	Oil Level Controller	NPS 4 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 4 Class 150 WN A105 N	No
<a href="#">N7</a>	Interface Level Controller	NPS 4 Sch 160	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 4 Class 150 WN A105 N	No
<a href="#">N9</a>	LSHH	NPS 4 XXS	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 4 Class 150 WN A105 N	No

## Nozzle Summary

Dimensions												
Nozzle mark	OD (in)	t <sub>n</sub> (in)	Req t <sub>n</sub> (in)	A <sub>1</sub> ?	A <sub>2</sub> ?	Shell			Reinforcement Pad		Corr (in)	A <sub>a</sub> /A <sub>r</sub> (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t <sub>pad</sub> (in)		
<a href="#">A1/A2</a>	5.5	0.75	0.3046	Yes	Yes	0.375	0.3046		N/A	N/A	0.125	147.9
<a href="#">C1/C2</a>	2.25	0.47	0.1875	Yes	Yes	0.375	N/A		N/A	N/A	0.125	Exempt
<a href="#">FF1</a>	49	0.625	0.398	Yes	Yes	0.514*	0.3981		6	0.625	0.125	106.9
<a href="#">GD</a>	24	0.5	0.3481	Yes	Yes	0.375	0.3046		3	0.375	0.125	103.4
<a href="#">M1</a>	24	0.5	0.2208	Yes	Yes	0.375	0.3046		3	0.375	0.125	103.6
<a href="#">N1/N8</a>	4.5	0.531	0.3481	Yes	Yes	0.375	0.3046		N/A	N/A	0.125	106.3
<a href="#">N11/N12B/N13</a>	2.375	0.344	0.2969	Yes	Yes	0.493*	N/A		N/A	N/A	0.125	Exempt
<a href="#">N12A</a>	2.375	0.344	0.2969	Yes	Yes	0.493*	0.2909		N/A	N/A	0.125	177.3
<a href="#">N14</a>	2.375	0.344	0.2969	Yes	Yes	0.493*	0.2909		N/A	N/A	0.125	179.5
<a href="#">N2</a>	3.5	0.438	0.3589	Yes	Yes	0.493*	N/A		N/A	N/A	0.125	Exempt
<a href="#">N3/N10</a>	3.5	0.438	0.3481	Yes	Yes	0.375	N/A		N/A	N/A	0.125	Exempt
<a href="#">N4</a>	6.625	0.432	0.2229	Yes	Yes	0.375	0.195		N/A	N/A	0.125	270.7
<a href="#">N5/N15/N16/N17</a>	2.375	0.344	0.2969	Yes	Yes	0.375	N/A		N/A	N/A	0.125	Exempt
<a href="#">N6</a>	4.5	0.531	0.3799	Yes	Yes	0.493*	0.2909		N/A	N/A	0.125	225.8
<a href="#">N7</a>	4.5	0.531	0.3799	Yes	Yes	0.493*	0.2909		N/A	N/A	0.125	226.9
<a href="#">N9</a>	4.5	0.674	0.3799	Yes	Yes	0.493*	0.2909		N/A	N/A	0.125	257.7

\*Head minimum thickness after forming

Definitions	
t <sub>n</sub>	Nozzle thickness
Req t <sub>n</sub>	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 <sub>a</sub>	Area available per UG-37, governing condition
A <sub>r</sub>	Area required per UG-37, governing condition
Corr	Corrosion allowance on nozzle wall

## Pressure Summary

Component Summary						
Identifier	P Design (psi)	T Design (°F)	MDMT (°F)	MDMT Exemption		Impact Tested
<a href="#">Left Head</a>	100	200	-55	Note 1		No
<a href="#">Straight Flange on Left Head</a>	100	200	-55	Note 2		No
<a href="#">Shell</a>	100	200	-55	Note 3		No
<a href="#">Straight Flange on Right Head</a>	100	200	-55	Note 5		No
<a href="#">Right Head</a>	100	200	-55	Note 4		No
<a href="#">Saddle #1</a>	100	200	N/A	N/A		N/A
<a href="#">Anode Ports (A1/A2)</a>	100	200	-55	Note 6		No
<a href="#">1" Coupling (C1/C2)</a>	100	200	-55	Note 6		No
<a href="#">Firetube (FF1)</a>	100	200	-55	Nozzle	Note 7	No
				Pad	Note 8	No
<a href="#">Gas Dome (GD)</a>	100	200	-55	Nozzle	Note 6	No
				Pad	Note 9	No
<a href="#">Gas Dome Shell</a>	100	200	-155	Note 10		No
<a href="#">Straight Flange on Gas Dome Head</a>	100	200	-155	Note 12		No
<a href="#">Gas Dome Head</a>	100	200	-155	Note 11		No
<a href="#">Manway (M1)</a>	100	200	-55	Nozzle	Note 6	No
				Pad	Note 9	No
<a href="#">4" On Shell (N1/N8)</a>	100	200	-55	Note 6		No
<a href="#">2" Nozzles at Lowest Location (In Head) (N11/N12B/N13)</a>	100	200	-55	Note 13		No
<a href="#">Oil Level Gauge (N12A)</a>	100	200	-55	Note 13		No
<a href="#">Pressure Indicator (N14)</a>	100	200	-55	Note 13		No
<a href="#">Oil Outlet (On Head) (N2)</a>	100	200	-55	Note 13		No
<a href="#">3" Nozzle (On Shell) (N3/N10)</a>	100	200	-55	Note 6		No
<a href="#">Gas Outlet (N4)</a>	100	200	-55	Note 13		No
<a href="#">2" Nozzle (On Shell) (N5/N15/N16/N17)</a>	100	200	-55	Note 13		No
<a href="#">Oil Level Controller (N6)</a>	100	200	-55	Note 13		No
<a href="#">Interface Level Controller (N7)</a>	100	200	-55	Note 13		No
<a href="#">LSHH (N9)</a>	100	200	-55	Note 14		No

Chamber Summary	
Design MDMT	-20 °F
Rated MDMT	-55 °F @ 100 psi
MAWP hot & corroded	100 psi
(1) This pressure chamber is not designed for external pressure.	



Notes for Maximum Pressure Rating	
Note #	Details
1.	Option to calculate MAP was not selected. See the Calculation->General tab of the Set Mode dialog.
2.	Option to calculate MAWP was not selected. See the Calculation->General tab of the Set Mode dialog.

Notes for MDMT Rating		
Note #	Exemption	Details
1.	<a href="#">Straight Flange</a> governs MDMT	
2.	Material impact test exemption temperature from Fig UCS-66 Curve D = -55°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 67°F, (coincident ratio = 0.4618) Rated MDMT of -152°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in
3.	Material impact test exemption temperature from Fig UCS-66 Curve D = -55°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 28.1°F, (coincident ratio = 0.7186) Rated MDMT of -113.1°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in
4.	<a href="#">Straight Flange</a> governs MDMT	
5.	Material impact test exemption temperature from Fig UCS-66 Curve D = -55°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 60.7°F, (coincident ratio = 0.4882) Rated MDMT of -145.7°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in
6.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 28.1°F, (coincident ratio = 0.7186) Rated MDMT of -78.1°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in.
7.	Nozzle impact test exemption temperature from Fig UCS-66 Curve D = -48°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 29.8°F, (coincident ratio = 0.7019) Rated MDMT of -107.8°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.625 in.
8.	Pad impact test exemption temperature from Fig UCS-66 Curve D = -48°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 29.8°F, (coincident ratio = 0.7019) Rated MDMT of -107.8°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.625 in.
9.	Pad impact test exemption temperature from Fig UCS-66 Curve D = -55°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 28.1°F, (coincident ratio = 0.7186) Rated MDMT of -113.1°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.375 in.
10.	Material is impact test exempt to -155°F per UCS-66(b)(3) (coincident ratio = 0.3447)	
11.	<a href="#">Straight Flange</a> governs MDMT	
12.	Material is impact test exempt to -155°F per UCS-66(b)(3) (coincident ratio = 0.2395)	
13.	Flange rating governs: Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	
14.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -7.67°F 30°F MDMT reduction per UCS-68(c) applies. Fig UCS-66.1 MDMT reduction = 70.1°F, (coincident ratio = 0.4508) Rated MDMT of -107.77°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.493 in.

## Settings Summary

COMPRESS 2020 Build 8000	
ASME Section VIII Division 1, 2001 Edition	
Units	U.S. Customary
Datum Line Location	0.00" from right seam
Vessel Design Mode	Rating Mode (Analysis)
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	0.25"
Juncture calculations for $\alpha > 30$ only	Yes
Preheat P-No 1 Materials $> 1.25"$ and $\leq 1.50"$ 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	RT1
UG-116(f) Postweld heat treatment	HT
Code Cases\Interpretations	
Use Code Case 2901	No
Apply interpretation VIII-1-83-66	Yes
Apply interpretation VIII-1-86-175	Yes
Apply interpretation VIII-1-83-115	Yes

Apply interpretation VIII-1-01-37	Yes
Apply interpretation VIII-1-04-08	Yes
Apply interpretation VIII-1-01-150	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
<b>UG-22 Loadings</b>	
UG-22(a) Internal or External Design Pressure	Yes
UG-22(b) Weight of the vessel and normal contents under operating or test conditions	Yes
UG-22(c) Superimposed static reactions from weight of attached equipment (external loads)	No
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs	Yes
UG-22(f) Wind reactions	No
UG-22(f) Seismic reactions	Yes
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	Blue Diamond Design Corporation
License	Commercial
License Key ID	33137
Support Expires	October 18, 2020

## 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	
<a href="#">Left Head</a>	N/A	Seamless No RT	N/A	N/A	B	Full UW-11(a) / Type 1	RT1
<a href="#">Shell</a>	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
<a href="#">Gas Dome Head</a>	N/A	Seamless No RT	B	Full UW-11(a) / Type 1	N/A	N/A	RT1
<a href="#">Right Head</a>	N/A	Seamless No RT	B	Full UW-11(a) / Type 1	N/A	N/A	RT1
Nozzle	Longitudinal Seam		Nozzle to Vessel Circumferential Seam		Nozzle free end Circumferential Seam		
<a href="#">Firetube (FF1)</a>	A	User Defined (E = 1.00)	D	N/A / Type 7	N/A	N/A	RT1
<a href="#">4" On Shell (N1/N8)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">3" Nozzle (On Shell) (N3/N10)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">2" Nozzle (On Shell) (N5/N15/N16/N17)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">Gas Dome (GD)</a>	N/A	Seamless No RT	D	N/A / Type 7	B	Full UW-11(a) / Type 1	RT1
<a href="#">Gas Dome Shell</a>	N/A	Seamless No RT	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
<a href="#">Gas Outlet (N4)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">Anode Ports (A1/A2)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
<a href="#">Manway (M1)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT1
<a href="#">1" Coupling (C1/C2)</a>	N/A	Seamless No RT	D	N/A / Type 7	N/A	N/A	N/A
<a href="#">Oil Outlet (On Head) (N2)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">Oil Level Controller (N6)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">LSHH (N9)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">Pressure Indicator (N14)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">Oil Level Gauge (N12A)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">2" Nozzles at Lowest Location (In Head) (N11/N12B/N13)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">Interface Level Controller (N7)</a>	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
Nozzle Flange	Longitudinal Seam		Flange Face		Nozzle to Flange Circumferential Seam		
<a href="#">ASME B16.5/16.47 flange attached to 4" On Shell (N1/N8)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">ASME B16.5/16.47 flange attached to 3" Nozzle (On Shell) (N3/N10)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">ASME B16.5/16.47 flange attached to 2" Nozzle (On Shell) (N5/N15/N16/N17)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
	N/A	Seamless No RT	N/A	N/A / Gasketed	C		N/A

<a href="#">ASME B16.5/16.47 flange attached to Gas Outlet (N4)</a>						UW-11(a)(4) exempt / Type 1	
<a href="#">ASME B16.5/16.47 flange attached to Anode Ports (A1/A2)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
<a href="#">ASME B16.5/16.47 flange attached to Manway (M1)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
<a href="#">ASME B16.5/16.47 flange attached to Oil Outlet (On Head) (N2)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">ASME B16.5/16.47 flange attached to Oil Level Controller (N6)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">ASME B16.5/16.47 flange attached to LSHH (N9)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">ASME B16.5/16.47 flange attached to Pressure Indicator (N14)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">ASME B16.5/16.47 flange attached to Oil Level Gauge (N12A)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">ASME B16.5/16.47 flange attached to 2" Nozzles at Lowest Location (In Head) (N11/N12B/N13)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
<a href="#">ASME B16.5/16.47 flange attached to Interface Level Controller (N7)</a>	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
UG-116(e) Required Marking: <b>RT1</b>							

## Thickness Summary

Component Data								
Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
<a href="#">Left Head</a>	SA-516 70	72 OD	13.6784	0.514*	0.3981	0.125	1.00	Internal
<a href="#">Straight Flange on Left Head</a>	SA-516 70	72 OD	2	0.514	0.3047	0.125	1.00	Internal
<a href="#">Shell</a>	SA-516 70	72 OD	240	0.375	0.3047	0.125	1.00	Internal
<a href="#">Straight Flange on Right Head</a>	SA-516 70	72 OD	2	0.493	0.3047	0.125	1.00	Internal
<a href="#">Right Head</a>	SA-516 70	72 OD	13.6695	0.493*	0.398	0.125	1.00	Internal
<a href="#">Straight Flange on Gas Dome Head</a>	SA-516 70	24 OD	2	0.375	0.1849	0.125	1.00	Internal
<a href="#">Gas Dome Head</a>	SA-516 70	24 OD	6.125	0.25*	0.184	0.125	1.00	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

## 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 <sup>2</sup>
							New	Corroded	New	Corroded	
<a href="#">Left Head</a>	503.4	383.6	0	0	0	0	0	0	1,905.5	1,934.2	26
<a href="#">Shell</a>	5,629	3,759.4	0	0	0	0	0	0	35,007.7	35,262.7	370
<a href="#">Right Head</a>	736.3	552.1	0	0	0	0	0	0	1,442.3	1,466.5	39
<a href="#">Saddle #1</a>	784	784	0	0	0	0	0	0	0	0	66
<b>TOTAL:</b>	<b>7,652.7</b>	<b>5,479.1</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>38,355.4</b>	<b>38,663.4</b>	<b>501</b>

\*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 <sup>2</sup>
	New	Corroded	New	Corroded						
<a href="#">Left Head</a>	0	0	517.6	448.8	0	0	0	0	0	8
<a href="#">Shell</a>	0	0	1,242.6	1,126.8	0	0	0	0	0	38
<a href="#">Right Head</a>	0	0	100.2	93.4	0	0	0	0	0	6
<b>TOTAL:</b>	<b>0</b>	<b>0</b>	<b>1,860.5</b>	<b>1,669</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>52</b>

Vessel Totals		
	New	Corroded
Operating Weight (lb)	9,513	7,148
Empty Weight (lb)	9,513	7,148
Test Weight (lb)	47,869	45,811
Surface Area (ft <sup>2</sup> )	553	-
Capacity** (US gal)	4,487	4,522
**The vessel capacity does not include volume of nozzle, piping or other attachments.		

Vessel Lift Condition	
Vessel Lift Weight, New (lb)	9,513
Center of Gravity from Datum (in)	117.9827

## Hydrostatic Test

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

$$\begin{aligned}
 \text{Gauge pressure at } 70^{\circ}\text{F} &= \\
 &= 1.3 \cdot \text{MAWP} \cdot \text{LSR} \\
 &= 1.3 \cdot 100 \cdot 1 \\
 &= 130 \text{ psi}
 \end{aligned}$$

Horizontal shop hydrostatic test							
Identifier	Local test pressure (psi)	Test liquid static head (psi)	UG-99(b) stress ratio	UG-99(b) pressure factor	Stress during test (psi)	Allowable test stress (psi)	Stress excessive?
Left Head (1)	133.551	3.551	1	1.30	8,574	34,200	No
Straight Flange on Left Head	133.551	3.551	1	1.30	9,287	34,200	No
Shell	133.556	3.556	1	1.30	12,754	34,200	No
Straight Flange on Gas Dome Head	130.212	0.212	1	1.30	4,101	34,200	No
Gas Dome Head	130.212	0.212	1	1.30	5,508	34,200	No
Straight Flange on Right Head	133.551	3.551	1	1.30	9,685	34,200	No
Right Head	133.551	3.551	1	1.30	8,940	34,200	No
1" Coupling (C1/C2)	131.427	1.427	1	1.30	13,244	51,300	No
2" Nozzle (On Shell) (N5/N15/N16/N17)	133.646	3.646	1	1.30	14,881	51,300	No
2" Nozzles at Lowest Location (In Head) (N11/N12B/N13)	133.239	3.239	1	1.30	12,284	51,300	No
3" Nozzle (On Shell) (N3/N10)	133.714	3.714	1	1.30	15,142	51,300	No
4" On Shell (N1/N8)	132.837	2.837	1	1.30	17,000	51,300	No
Anode Ports (A1/A2)	133.244	3.244	1	1.30	12,658	51,300	No
Firetube (FF1)	133.131	3.131	1	1.30	19,715	51,300	No
Gas Dome (GD)	130.97	0.97	1	1.30	26,011	51,300	No
Gas Dome Shell	130.862	0.862	1	1.30	4,701	31,500	No
Gas Outlet (N4)	130.533	0.533	1	1.30	8,332	47,250	No
Interface Level Controller (N7)	132.839	2.839	1	1.30	10,138	51,300	No
LSHH (N9)	131.262	1.262	1	1.30	14,145	51,300	No
Manway (M1)	133.712	3.712	1	1.30	26,454	51,300	No
Oil Level Controller (N6)	131.664	1.664	1	1.30	10,081	51,300	No
Oil Level Gauge (N12A)	131.47	1.47	1	1.30	10,008	51,300	No
Oil Outlet (On Head) (N2)	132.425	2.425	1	1.30	9,937	51,300	No
Pressure Indicator (N14)	131.236	1.236	1	1.30	12,278	51,300	No

(1) Left Head limits the UG-99(b) stress ratio.  
 (2)  $P_L$  stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.  
 (3)  $1.5 \cdot 0.9 \cdot S_y$  used as the basis for the maximum local primary membrane stress at the nozzle intersection  $P_L$ .  
 (4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated.



The test temperature of 70 °F is warmer than the minimum recommended temperature of -25 °F so the brittle fracture provision of UG-99(h) has been met.

**Left Head**

ASME Section VIII Division 1, 2001 Edition				
<b>Component</b>		F&D Head		
<b>Material</b>		SA-516 70 (II-D p. 14, ln. 30)		
<b>Attached To</b>		Shell		
<b>Impact Tested</b>	<b>Normalized</b>	<b>Fine Grain Practice</b>	<b>PWHT</b>	<b>Maximize MDMT/ No MAWP</b>
No	Yes	No	Yes	No
		<b>Design Pressure (psi)</b>	<b>Design Temperature (°F)</b>	<b>Design MDMT (°F)</b>
<b>Internal</b>		100	200	-20
Static Liquid Head				
<b>Condition</b>		<b>P<sub>s</sub> (psi)</b>	<b>H<sub>s</sub> (in)</b>	<b>SG</b>
<b>Test horizontal</b>		3.55	98.361	1
Dimensions				
<b>Outer Diameter</b>		72"		
<b>Crown Radius L</b>		66"		
<b>Knuckle Radius r</b>		5"		
<b>Minimum Thickness</b>		0.514"		
<b>Corrosion</b>	<b>Inner</b>	0.125"		
	<b>Outer</b>	0"		
<b>Length L<sub>sf</sub></b>		2"		
<b>Nominal Thickness t<sub>sf</sub></b>		0.514"		
Weight and Capacity				
		<b>Weight (lb)<sup>1</sup></b>	<b>Capacity (US gal)<sup>1</sup></b>	
<b>New</b>		503.37	172.36	
<b>Corroded</b>		383.58	175.21	
Radiography				
<b>Category A joints</b>		Seamless No RT		
<b>Head to shell seam</b>		Full UW-11(a) Type 1		

<sup>1</sup> includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	<u>0.3981"</u>
<u>Straight Flange</u> governs MDMT	-55 °F

Factor M		
M = 1/4*[3 + (L / r) <sup>1/2</sup> ]		
Corroded	M = 1/4*[3 + (66.125 / 5.125) <sup>1/2</sup> ]	1.648
New	M = 1/4*[3 + (66 / 5) <sup>1/2</sup> ]	1.6583

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

$$\begin{aligned}
 t &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) + \text{Corrosion} \\
 &= 100 \cdot 66.514 \cdot 1.648 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1.648 - 0.2)) + 0.125 \\
 &= \underline{0.398"}
 \end{aligned}$$

**% Extreme fiber elongation - UCS-79(d)**

$$\begin{aligned}
 \text{EFE} &= (75 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (75 \cdot 0.514 / 5.257) \cdot (1 - 5.257 / \infty) \\
 &= 7.3331\%
 \end{aligned}$$

### Straight Flange on Left Head

ASME Section VIII Division 1, 2001 Edition				
<b>Component</b>		Cylinder		
<b>Material</b>		SA-516 70 (II-D p. 14, ln. 30)		
<b>Impact Tested</b>	<b>Normalized</b>	<b>Fine Grain Practice</b>	<b>PWHT</b>	<b>Maximize MDMT/ No MAWP</b>
No	Yes	No	Yes	No
		<b>Design Pressure (psi)</b>	<b>Design Temperature (°F)</b>	<b>Design MDMT (°F)</b>
<b>Internal</b>		100	200	-20
Static Liquid Head				
<b>Condition</b>		<b>P<sub>s</sub> (psi)</b>	<b>H<sub>s</sub> (in)</b>	<b>SG</b>
<b>Test horizontal</b>		3.55	98.361	1
Dimensions				
<b>Outer Diameter</b>		72"		
<b>Length</b>		2"		
<b>Nominal Thickness</b>		0.514"		
<b>Corrosion</b>	<b>Inner</b>	0.125"		
	<b>Outer</b>	0"		
Weight and Capacity				
		<b>Weight (lb)</b>		<b>Capacity (US gal)</b>
<b>New</b>		65.34		34.25
<b>Corroded</b>		49.53		34.49
Radiography				
<b>Longitudinal seam</b>		Seamless No RT		
<b>Right Circumferential seam</b>		Full UW-11(a) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	<a href="#">0.3047"</a>
Rated MDMT	-55 °F

UCS-66 Material Toughness Requirements	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve D =	-55°F
$t_r = 100*36 / (20,000*1 + 0.4*100) =$	0.1796"
Stress ratio = $t_r * E^* / (t_n - c) = 0.1796*1 / (0.514 - 0.125) =$	0.4618
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	67°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -55 - 67 - 30, -55 ] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

### Design thickness, (at 200 °F) Appendix 1-1

$$\begin{aligned}
 t &= P * R_o / (S * E + 0.40 * P) + \text{Corrosion} \\
 &= 100 * 36 / (20,000 * 1.00 + 0.40 * 100) + 0.125 \\
 &= \underline{0.3047"}
 \end{aligned}$$

### % Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 EFE &= (50 * t / R_f) * (1 - R_f / R_o) \\
 &= (50 * 0.514 / 35.743) * (1 - 35.743 / \infty) \\
 &= 0.719\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.389) \\
 &= 0.001351 \\
 B &= 13,406 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cHC} &= \min(B, S) = 13,406 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.514) \\
 &= 0.001785 \\
 B &= 14,519 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cHN} &= \min(B, S) = 14,519 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.514) \\
 &= 0.001785 \\
 B &= 14,519 \text{ psi}
 \end{aligned}$$

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

$$S_{\text{CCN}} = \min(B, S) = 14,519 \text{ psi}$$

**Allowable Compressive Stress, Cold and Corroded-  $S_{\text{CC}}$ , (table CS-2)**

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (36 / 0.389) \\ &= 0.001351 \end{aligned}$$

$$B = 13,406 \text{ psi}$$

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

$$S_{\text{CC}} = \min(B, S) = 13,406 \text{ psi}$$

**Allowable Compressive Stress, Vacuum and Corroded-  $S_{\text{VC}}$ , (table CS-2)**

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (36 / 0.389) \\ &= 0.001351 \end{aligned}$$

$$B = 13,406 \text{ psi}$$

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

$$S_{\text{VC}} = \min(B, S) = 13,406 \text{ psi}$$

## Right Head

ASME Section VIII Division 1, 2001 Edition				
<b>Component</b>		F&D Head		
<b>Material</b>		SA-516 70 (II-D p. 14, ln. 30)		
<b>Attached To</b>		Shell		
<b>Impact Tested</b>	<b>Normalized</b>	<b>Fine Grain Practice</b>	<b>PWHT</b>	<b>Maximize MDMT/ No MAWP</b>
No	Yes	No	Yes	No
		<b>Design Pressure (psi)</b>	<b>Design Temperature (°F)</b>	<b>Design MDMT (°F)</b>
<b>Internal</b>		100	200	-20
Static Liquid Head				
<b>Condition</b>		<b>P<sub>s</sub> (psi)</b>	<b>H<sub>s</sub> (in)</b>	<b>SG</b>
<b>Test horizontal</b>		3.55	98.382	1
Dimensions				
<b>Outer Diameter</b>		72"		
<b>Crown Radius L</b>		66"		
<b>Knuckle Radius r</b>		5"		
<b>Minimum Thickness</b>		0.493"		
<b>Corrosion</b>	<b>Inner</b>	0.125"		
	<b>Outer</b>	0"		
<b>Length L<sub>sf</sub></b>		2"		
<b>Nominal Thickness t<sub>sf</sub></b>		0.493"		
Weight and Capacity				
		<b>Weight (lb)<sup>1</sup></b>	<b>Capacity (US gal)<sup>1</sup></b>	
<b>New</b>		736.33	172.66	
<b>Corroded</b>		552.12	175.52	
Radiography				
<b>Category A joints</b>		Seamless No RT		
<b>Head to shell seam</b>		Full UW-11(a) Type 1		

<sup>1</sup> includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	<u>0.398"</u>
<u>Straight Flange</u> governs MDMT	-55 °F

Factor M		
M = 1/4*[3 + (L / r) <sup>1/2</sup> ]		
Corroded	M = 1/4*[3 + (66.125 / 5.125) <sup>1/2</sup> ]	1.648
New	M = 1/4*[3 + (66 / 5) <sup>1/2</sup> ]	1.6583

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

$$\begin{aligned}
 t &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) + \text{Corrosion} \\
 &= 100 \cdot 66.493 \cdot 1.648 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1.648 - 0.2)) + 0.125 \\
 &= \underline{0.398"}
 \end{aligned}$$

**% Extreme fiber elongation - UCS-79(d)**

$$\begin{aligned}
 EFE &= (75 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (75 \cdot 0.493 / 5.2465) \cdot (1 - 5.2465 / \infty) \\
 &= 7.0476\%
 \end{aligned}$$



### Straight Flange on Right Head

ASME Section VIII Division 1, 2001 Edition				
<b>Component</b>		Cylinder		
<b>Material</b>		SA-516 70 (II-D p. 14, ln. 30)		
<b>Impact Tested</b>	<b>Normalized</b>	<b>Fine Grain Practice</b>	<b>PWHT</b>	<b>Maximize MDMT/ No MAWP</b>
No	Yes	No	Yes	No
		<b>Design Pressure (psi)</b>	<b>Design Temperature (°F)</b>	<b>Design MDMT (°F)</b>
<b>Internal</b>		100	200	-20
Static Liquid Head				
<b>Condition</b>		<b>P<sub>s</sub> (psi)</b>	<b>H<sub>s</sub> (in)</b>	<b>SG</b>
<b>Test horizontal</b>		3.55	98.382	1
Dimensions				
<b>Outer Diameter</b>		72"		
<b>Length</b>		2"		
<b>Nominal Thickness</b>		0.493"		
<b>Corrosion</b>	<b>Inner</b>	0.125"		
	<b>Outer</b>	0"		
Weight and Capacity				
		<b>Weight (lb)</b>		<b>Capacity (US gal)</b>
<b>New</b>		62.68		34.29
<b>Corroded</b>		46.87		34.53
Radiography				
<b>Longitudinal seam</b>		Seamless No RT		
<b>Left Circumferential seam</b>		Full UW-11(a) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	<a href="#">0.3047"</a>
Rated MDMT	-55 °F

UCS-66 Material Toughness Requirements	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve D =	-55 °F
$t_r = 100*36 / (20,000*1 + 0.4*100) =$	0.1796"
Stress ratio = $t_r * E^* / (t_n - c) = 0.1796*1 / (0.493 - 0.125) =$	0.4882
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	60.7 °F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30 °F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -55 - 60.7 - 30, -55 ] =$	-55 °F
Material is exempt from impact testing at the Design MDMT of -20 °F.	

### Design thickness, (at 200 °F) Appendix 1-1

$$\begin{aligned}
 t &= P * R_o / (S * E + 0.40 * P) + \text{Corrosion} \\
 &= 100 * 36 / (20,000 * 1.00 + 0.40 * 100) + 0.125 \\
 &= \underline{0.3047"}
 \end{aligned}$$

### % Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 EFE &= (50 * t / R_f) * (1 - R_f / R_o) \\
 &= (50 * 0.493 / 35.7535) * (1 - 35.7535 / \infty) \\
 &= 0.6894\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.368) \\
 &= 0.001278 \\
 B &= 13,194 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cHC} &= \min(B, S) = 13,194 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.493) \\
 &= 0.001712 \\
 B &= 14,346 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cHN} &= \min(B, S) = 14,346 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.493) \\
 &= 0.001712 \\
 B &= 14,346 \text{ psi}
 \end{aligned}$$

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

$$S_{\text{CCN}} = \min(B, S) = 14,346 \text{ psi}$$

**Allowable Compressive Stress, Cold and Corroded-  $S_{\text{CC}}$ , (table CS-2)**

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (36 / 0.368) \\ &= 0.001278 \end{aligned}$$

$$B = 13,194 \text{ psi}$$

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

$$S_{\text{CC}} = \min(B, S) = 13,194 \text{ psi}$$

**Allowable Compressive Stress, Vacuum and Corroded-  $S_{\text{VC}}$ , (table CS-2)**

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (36 / 0.368) \\ &= 0.001278 \end{aligned}$$

$$B = 13,194 \text{ psi}$$

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

$$S_{\text{VC}} = \min(B, S) = 13,194 \text{ psi}$$

## Shell

ASME Section VIII Division 1, 2001 Edition				
<b>Component</b>		Cylinder		
<b>Material</b>		SA-516 70 (II-D p. 14, ln. 30)		
<b>Impact Tested</b>	<b>Normalized</b>	<b>Fine Grain Practice</b>	<b>PWHT</b>	<b>Maximize MDMT/ No MAWP</b>
No	Yes	No	Yes	No
		<b>Design Pressure (psi)</b>	<b>Design Temperature (°F)</b>	<b>Design MDMT (°F)</b>
<b>Internal</b>		100	200	-20
Static Liquid Head				
<b>Condition</b>		<b>P<sub>s</sub> (psi)</b>	<b>H<sub>s</sub> (in)</b>	<b>SG</b>
<b>Test horizontal</b>		3.56	98.5	1
Dimensions				
<b>Outer Diameter</b>		72"		
<b>Length</b>		240"		
<b>Nominal Thickness</b>		0.375"		
<b>Corrosion</b>	<b>Inner</b>	0.125"		
	<b>Outer</b>	0"		
Weight and Capacity				
		<b>Weight (lb)</b>		<b>Capacity (US gal)</b>
<b>New</b>		5,629.03		4,142.47
<b>Corroded</b>		3,759.35		4,171.59
Radiography				
<b>Longitudinal seam</b>		Full UW-11(a) Type 1		
<b>Left Circumferential seam</b>		Full UW-11(a) Type 1		
<b>Right Circumferential seam</b>		Full UW-11(a) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	<a href="#">0.3047"</a>
Rated MDMT	-55 °F

UCS-66 Material Toughness Requirements	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve D =	-55 °F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1 °F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30 °F
MDMT = $\max[\text{MDMT} - T_R - T_{PWHT}, -55] = \max[-55 - 28.1 - 30, -55] =$	-55 °F
Material is exempt from impact testing at the Design MDMT of -20 °F.	

### Design thickness, (at 200 °F) Appendix 1-1

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 100 \cdot 36 / (20,000 \cdot 1.00 + 0.40 \cdot 100) + 0.125 \\
 &= \underline{0.3047"}
 \end{aligned}$$

### % Extreme fiber elongation - UCS-79(d)

$$\begin{aligned}
 EFE &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (50 \cdot 0.375 / 35.8125) \cdot (1 - 35.8125 / \infty) \\
 &= 0.5236\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.25) \\
 &= 0.000868 \\
 B &= 11,676 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cHC} &= \min(B, S) = 11,676 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.375) \\
 &= 0.001302 \\
 B &= 13,266 \text{ psi} \\
 S &= 20,000 / 1.00 = 20,000 \text{ psi} \\
 S_{cHN} &= \min(B, S) = 13,266 \text{ psi}
 \end{aligned}$$

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

$$\begin{aligned}
 A &= 0.125 / (R_o / t) \\
 &= 0.125 / (36 / 0.375) \\
 &= 0.001302 \\
 B &= 13,266 \text{ psi}
 \end{aligned}$$

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

$$S_{\text{CCN}} = \min(B, S) = 13,266 \text{ psi}$$

**Allowable Compressive Stress, Cold and Corroded-  $S_{\text{CC}}$ , (table CS-2)**

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (36 / 0.25) \\ &= 0.000868 \end{aligned}$$

$$B = 11,676 \text{ psi}$$

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

$$S_{\text{CC}} = \min(B, S) = 11,676 \text{ psi}$$

**Allowable Compressive Stress, Vacuum and Corroded-  $S_{\text{cVC}}$ , (table CS-2)**

$$\begin{aligned} A &= 0.125 / (R_o / t) \\ &= 0.125 / (36 / 0.25) \\ &= 0.000868 \end{aligned}$$

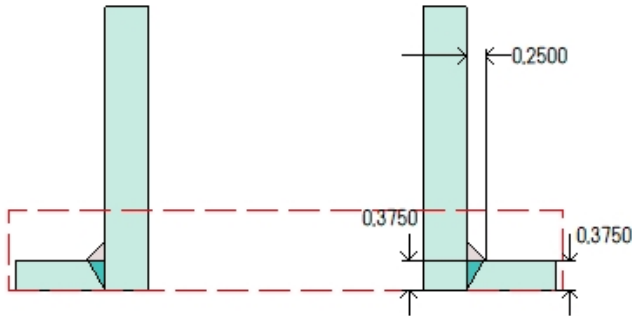
$$B = 11,676 \text{ psi}$$

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

$$S_{\text{cVC}} = \min(B, S) = 11,676 \text{ psi}$$

## 4" On Shell (N1/N8)

ASME Section VIII Division 1, 2001 Edition



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

### Location and Orientation

Located on	Shell
Orientation	90°
Nozzle center line offset to datum line	217"
End of nozzle to shell center	37.6535"
Offset from center, Lo	14"
Passes through a Category A joint	No

### Nozzle

Description	NPS 4 Sch 160
Access opening	No
Material specification	SA-106 B Smls pipe (II-D p. 10, ln. 15)
Inside diameter, new	3.438"
Pipe nominal wall thickness	0.531"
Pipe minimum wall thickness <sup>1</sup>	0.4646"
Corrosion allowance	0.125"
Opening chord length	4.0074"
Projection available outside vessel, Lpr	0.625"
Projection available outside vessel to flange face, Lf	3.625"
Local vessel minimum thickness	0.375"
Liquid static head included	0 psi
Longitudinal joint efficiency	1

### Welds

Inner fillet, Leg <sub>41</sub>	0.25"
Nozzle to vessel groove weld	0.375"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 4 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -20 - 28.1 - 30, -55 ] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
Impact test exempt per UCS-66(d) (NPS 4 or smaller pipe) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.3705	1.0988	0.623	0.4224	--	--	0.0534	0.3046	0.4646

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 <sub>41</sub> )	0.175	0.175	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(4.0074, 2.0037 + (0.531 - 0.125) + (0.375 - 0.125)) \\
 &= 4.0074 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.531 - 0.125) + 0) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 1.844 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0108 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

#### Area required per UG-37(c)

Allowable stresses: S<sub>n</sub> = 17,100, S<sub>v</sub> = 20,000 psi

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 4.0074 \cdot 0.1796 \cdot 0.5 + 2 \cdot 0.406 \cdot 0.1796 \cdot 0.5 \cdot (1 - 0.855) \\ &= \underline{0.3705} \text{ in}^2 \end{aligned}$$

#### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.623} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 4.0074 \cdot (1 \cdot 0.25 - 0.5 \cdot 0.1796) - 2 \cdot 0.406 \cdot (1 \cdot 0.25 - 0.5 \cdot 0.1796) \cdot (1 - 0.855) \\ &= 0.623 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.25 + 0.406) \cdot (1 \cdot 0.25 - 0.5 \cdot 0.1796) - 2 \cdot 0.406 \cdot (1 \cdot 0.25 - 0.5 \cdot 0.1796) \cdot (1 - 0.855) \\ &= 0.1913 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.4224} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.406 - 0.0108) \cdot 0.855 \cdot 0.25 \\ &= 0.4224 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.406 - 0.0108) \cdot 0.855 \cdot 0.625 \\ &= 0.4224 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.25^2 \cdot 0.855 \\ &= \underline{0.0534} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.623 + 0.4224 + 0.0534 \\ &= \underline{1.0988} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

#### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.25 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 \cdot t_{\min} = \underline{0.175} \text{ in}$

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

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

Wall thickness per UG-45(a):  $t_{r1} = 0.1358$  in ( $E = 1$ )

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.3046$  in

Wall thickness per UG-16(b):  $t_{r3} = 0.1875$  in

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3324$  in

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.3046$  in

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.3046$  in

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.3046$  in

Available nozzle wall thickness new,  $t_n = 0.875 \cdot 0.531 = 0.4646$  in

The nozzle neck thickness is adequate.

## Reinforcement check in the plane parallel to the longitudinal axis

### Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.6837	0.727	0.2512	0.4224	--	--	0.0534	0.3046	0.4646

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 <sub>41</sub> )	0.175	0.175	weld size is adequate

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.688, 1.844 + (0.531 - 0.125) + (0.375 - 0.125)) \\
 &= 3.688 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.531 - 0.125) + 0) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P * R_n / (S_n * E - 0.6 * P) \\
 &= 100 * 1.844 / (17,100 * 1 - 0.6 * 100) \\
 &= 0.0108 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P * R_o / (S * E + 0.4 * P) \\
 &= 100 * 36 / (20,000 * 1 + 0.4 * 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

#### Area required per UG-37(c)

Allowable stresses: S<sub>n</sub> = 17,100, S<sub>v</sub> = 20,000 psi

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.688 \cdot 0.1796 \cdot 1 + 2 \cdot 0.406 \cdot 0.1796 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{0.6837} \text{ in}^2 \end{aligned}$$

#### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.2512} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.688 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) - 2 \cdot 0.406 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) \cdot (1 - 0.855) \\ &= 0.2512 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.25 + 0.406) \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) - 2 \cdot 0.406 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) \cdot (1 - 0.855) \\ &= 0.084 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.4224} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.406 - 0.0108) \cdot 0.855 \cdot 0.25 \\ &= 0.4224 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.406 - 0.0108) \cdot 0.855 \cdot 0.625 \\ &= 0.4224 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.25^2 \cdot 0.855 \\ &= \underline{0.0534} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.2512 + 0.4224 + 0.0534 \\ &= \underline{0.727} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

#### UG-45 Nozzle Neck Thickness Check

$$\text{Wall thickness per UG-45(a): } t_{r1} = 0.1358 \text{ in (E = 1)}$$

$$\text{Wall thickness per UG-45(b)(1): } t_{r2} = 0.3046 \text{ in}$$

$$\text{Wall thickness per UG-16(b): } t_{r3} = 0.1875 \text{ in}$$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3324$  in

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.3046$  in

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.3046$  in

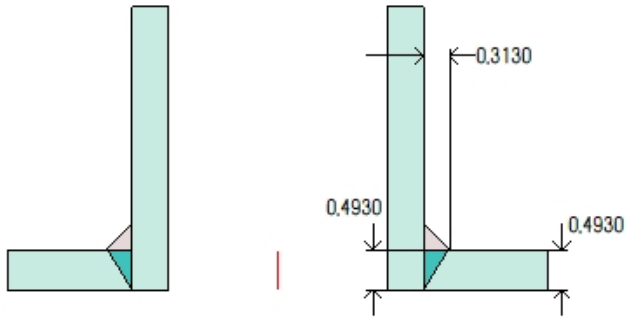
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.3046$  in

Available nozzle wall thickness new,  $t_n = 0.875 * 0.531 = 0.4646$  in

The nozzle neck thickness is adequate.

## Oil Outlet (On Head) (N2)

ASME Section VIII Division 1, 2001 Edition



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

### Location and Orientation

Located on	Right Head
Orientation	180°
End of nozzle to datum line	-19.1577"
Calculated as hillside	Yes
Distance to head center, R	3"
Passes through a Category A joint	No

### Nozzle

Description	NPS 3 Sch 160
Access opening	No
Material specification	SA-106 B Smls pipe (II-D p. 10, ln. 15)
Inside diameter, new	2.624"
Pipe nominal wall thickness	0.438"
Pipe minimum wall thickness <sup>1</sup>	0.3833"
Corrosion allowance	0.125"
Opening chord length	2.877"
Projection available outside vessel, L <sub>pr</sub>	0.75"
Projection available outside vessel to flange face, L <sub>f</sub>	3.5"
Local vessel minimum thickness	0.493"
Liquid static head included	0 psi
Longitudinal joint efficiency	1

### Welds

Inner fillet, Leg <sub>41</sub>	0.313"
Nozzle to vessel groove weld	0.493"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 3 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 * 1.437 / (17,100 * 1 - 0.6 * 100) =$	0.0084"
Stress ratio = $t_r * E^* / (t_n - c) = 0.0084 * 1 / (0.3833 - 0.125) =$	0.0327
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							<a href="#">0.314</a>	0.3833

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 <sub>41</sub> )	<a href="#">0.2191</a>	0.2191	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.877, 1.4385 + (0.438 - 0.125) + (0.493 - 0.125)) \\
 &= 2.877 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.493 - 0.125), 2.5*(0.438 - 0.125) + 0) \\
 &= 0.7825 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 1.437 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0084 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)(1)

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 100 \cdot 66.493 \cdot 1 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1 - 0.2)) \\
 &= 0.1659 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 100 \cdot 66.493 \cdot 1.648 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1.648 - 0.2)) \\
 &= 0.273 \text{ in}
 \end{aligned}$$

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

### **UW-16(c) Weld Check**

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.313 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.2191 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.313 = 0.2191 \text{ in}$

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.

Wall thickness per UG-45(a):  $t_{r1} = 0.1334 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.398 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.314 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.398 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.314 \text{ in}$

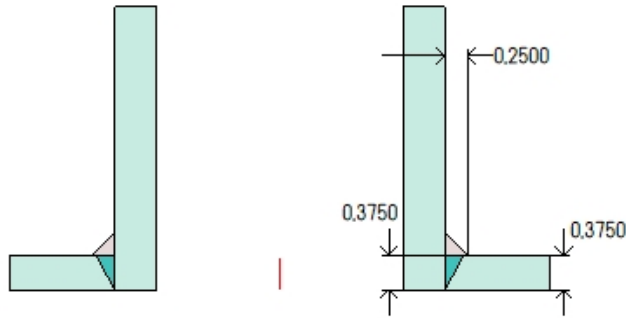
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.314 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.438 = 0.3833 \text{ in}$

The nozzle neck thickness is adequate.

### 3" Nozzle (On Shell) (N3/N10)

ASME Section VIII Division 1, 2001 Edition



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

#### Location and Orientation

Located on	Shell
Orientation	180°
Nozzle center line offset to datum line	7"
End of nozzle to shell center	40"
Passes through a Category A joint	No

#### Nozzle

Description	NPS 3 Sch 160
Access opening	No
Material specification	SA-106 B Smls pipe (II-D p. 10, ln. 15)
Inside diameter, new	2.624"
Pipe nominal wall thickness	0.438"
Pipe minimum wall thickness <sup>1</sup>	0.3833"
Corrosion allowance	0.125"
Projection available outside vessel, L <sub>pr</sub>	1.25"
Projection available outside vessel to flange face, L <sub>f</sub>	4"
Local vessel minimum thickness	0.375"
Liquid static head included	0 psi
Longitudinal joint efficiency	1

#### Welds

Inner fillet, Leg <sub>41</sub>	0.25"
Nozzle to vessel groove weld	0.375"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
<b>Description</b>	NPS 3 Class 150 WN A105 N
<b>Bolt Material</b>	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, In. 37)
<b>Blind included</b>	No
<b>Rated MDMT</b>	-55 °F
<b>Liquid static head</b>	0 psi
<b>MAWP rating</b>	260 psi @ 200 °F
<b>MAP rating</b>	285 psi @ 70 °F
<b>Hydrotest rating</b>	450 psi @ 70 °F
<b>PWHT performed</b>	Yes
<b>Impact Tested</b>	No
<b>Circumferential joint radiography</b>	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55 °F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55 °F	

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve B =	-20 °F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1 °F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30 °F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -20 - 28.1 - 30, -55 ] =$	-55 °F
Material is exempt from impact testing at the Design MDMT of -20 °F.	

UCS-66 Material Toughness Requirements Nozzle	
Impact test exempt per UCS-66(d) (NPS 4 or smaller pipe) =	-155 °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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							<a href="#">0.3046</a>	0.3833

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 <sub>41</sub> )	<a href="#">0.175</a>	0.175	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.874, 1.437 + (0.438 - 0.125) + (0.375 - 0.125)) \\
 &= 2.874 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.438 - 0.125) + 0) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 1.437 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0084 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.25 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.175 \text{ in}$

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

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

Wall thickness per UG-45(a):  $t_{r1} = 0.1334 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.3046 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.314 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.3046 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.3046 \text{ in}$

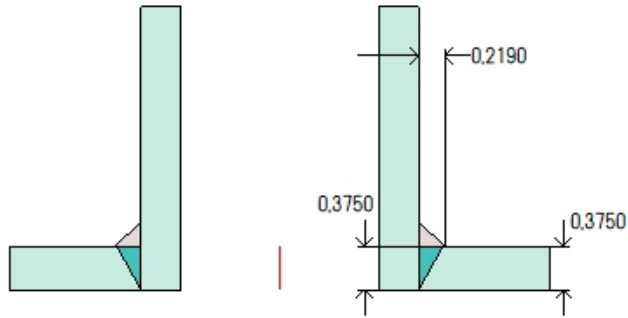
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.3046 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.438 = 0.3833 \text{ in}$

The nozzle neck thickness is adequate.

**2" Nozzle (On Shell) (N5/N15/N16/N17)**

**ASME Section VIII Division 1, 2001 Edition**



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

**Location and Orientation**

<b>Located on</b>	Shell
<b>Orientation</b>	180°
<b>Nozzle center line offset to datum line</b>	102.5"
<b>End of nozzle to shell center</b>	38.1421"
<b>Offset from center, Lo</b>	9"
<b>Passes through a Category A joint</b>	No

**Nozzle**

<b>Description</b>	NPS 2 Sch 160
<b>Access opening</b>	No
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	1.687"
<b>Pipe nominal wall thickness</b>	0.344"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.301"
<b>Corrosion allowance</b>	0.125"
<b>Opening chord length</b>	2.0012"
<b>Projection available outside vessel, Lpr</b>	0.5"
<b>Projection available outside vessel to flange face, Lf</b>	3"
<b>Local vessel minimum thickness</b>	0.375"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

**Welds**

Inner fillet, Leg <sub>41</sub>	0.219"
Nozzle to vessel groove weld	0.375"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 2 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 0.9685 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0057"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0057 \cdot 1 / (0.301 - 0.125) =$	0.0323
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							<a href="#">0.2598</a>	0.301

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 <sub>41</sub> )	<a href="#">0.1533</a>	0.1533	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.0012, 1.0006 + (0.344 - 0.125) + (0.375 - 0.125)) \\
 &= 2.0012 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.344 - 0.125) + 0) \\
 &= 0.5475 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 0.9685 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0057 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.219 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1533 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.219 = 0.1533 \text{ in}$

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

Wall thickness per UG-45(a):  $t_{r1} = 0.1307 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.3046 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.2598 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.3046 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.2598 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.2598 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.344 = 0.301 \text{ in}$

The nozzle neck thickness is adequate.

**Reinforcement check in the plane parallel to the longitudinal axis**

**Reinforcement Calculations for Internal Pressure**

UG-37 Area Calculation Summary (in <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							<a href="#">0.2598</a>	0.301

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 <sub>41</sub> )	<a href="#">0.1533</a>	0.1533	weld size is adequate

**Parallel Limit of reinforcement per UG-40**

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.937, 0.9685 + (0.344 - 0.125) + (0.375 - 0.125)) \\
 &= 1.937 \text{ in}
 \end{aligned}$$

**Outer Normal Limit of reinforcement per UG-40**

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.344 - 0.125) + 0) \\
 &= 0.5475 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 0.9685 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0057 \text{ in}
 \end{aligned}$$

**Required thickness t<sub>r</sub> from UG-37(a)**

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

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

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.1307$  in ( $E = 1$ )

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.3046$  in

Wall thickness per UG-16(b):  $t_{r3} = 0.1875$  in

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.2598$  in

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.3046$  in

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.2598$  in

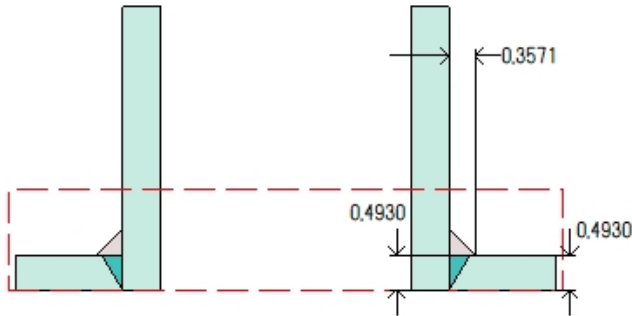
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.2598$  in

Available nozzle wall thickness new,  $t_n = 0.875 \cdot 0.344 = 0.301$  in

The nozzle neck thickness is adequate.

## Oil Level Controller (N6)

ASME Section VIII Division 1, 2001 Edition



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

### Location and Orientation

<b>Located on</b>	Right Head
<b>Orientation</b>	0°
<b>End of nozzle to datum line</b>	-18.6314"
<b>Calculated as hillside</b>	Yes
<b>Distance to head center, R</b>	18.5"
<b>Passes through a Category A joint</b>	No

### Nozzle

<b>Description</b>	NPS 4 Sch 160
<b>Access opening</b>	No
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	3.438"
<b>Pipe nominal wall thickness</b>	0.531"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.4646"
<b>Corrosion allowance</b>	0.125"
<b>Opening chord length</b>	3.8411"
<b>Projection available outside vessel, Lpr</b>	1.9781"
<b>Projection available outside vessel to flange face, Lf</b>	4.9781"
<b>Local vessel minimum thickness</b>	0.493"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

### Welds

Inner fillet, Leg <sub>41</sub>	0.3571"
Nozzle to vessel groove weld	0.493"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 4 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 1.844 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0108"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0108 \cdot 1 / (0.4646 - 0.125) =$	0.0319
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.6568	1.4832	0.7525	0.6217	--	--	0.109	0.3324	0.4646

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 <sub>41</sub> )	0.25	0.25	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.8411, 1.9206 + (0.531 - 0.125) + (0.493 - 0.125)) \\
 &= 3.8411 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.493 - 0.125), 2.5*(0.531 - 0.125) + 0) \\
 &= 0.92 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P * R_n / (S_n * E - 0.6 * P) \\
 &= 100 * 1.844 / (17,100 * 1 - 0.6 * 100) \\
 &= 0.0108 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)(1)

$$\begin{aligned}
 t_r &= P * L_o * M / (2 * S * E + P * (M - 0.2)) \\
 &= 100 * 66.493 * 1 / (2 * 20,000 * 1 + 100 * (1 - 0.2)) \\
 &= 0.1659 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P * L_o * M / (2 * S * E + P * (M - 0.2)) \\
 &= 100 * 66.493 * 1.648 / (2 * 20,000 * 1 + 100 * (1.648 - 0.2)) \\
 &= 0.273 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.8411 \cdot 0.1659 \cdot 1 + 2 \cdot 0.406 \cdot 0.1659 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{0.6568} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.7525} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.8411 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.406 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.7525 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.368 + 0.406) \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.406 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.2891 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.6217} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.406 - 0.0108) \cdot 0.855 \cdot 0.368 \\ &= 0.6217 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.406 - 0.0108) \cdot 0.855 \cdot 0.406 \\ &= 0.6859 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.3571^2 \cdot 0.855 \\ &= \underline{0.109} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.7525 + 0.6217 + 0.109 \\ &= \underline{1.4832} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.



### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.368 \text{ in}$

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

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.3571 = 0.25 \text{ in}$

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.

Wall thickness per UG-45(a):  $t_{r1} = 0.1358 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.398 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3324 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.398 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.3324 \text{ in}$

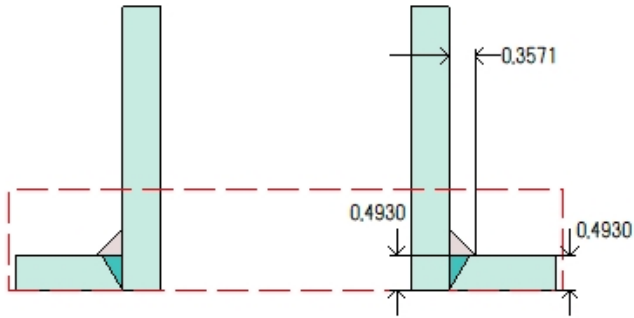
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.3324 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.531 = 0.4646 \text{ in}$

The nozzle neck thickness is adequate.

## Interface Level Controller (N7)

ASME Section VIII Division 1, 2001 Edition



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

### Location and Orientation

<b>Located on</b>	Right Head
<b>Orientation</b>	209°
<b>End of nozzle to datum line</b>	-18.219"
<b>Calculated as hillside</b>	Yes
<b>Distance to head center, R</b>	16.0629"
<b>Passes through a Category A joint</b>	No

### Nozzle

<b>Description</b>	NPS 4 Sch 160
<b>Access opening</b>	No
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	3.438"
<b>Pipe nominal wall thickness</b>	0.531"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.4646"
<b>Corrosion allowance</b>	0.125"
<b>Opening chord length</b>	3.8017"
<b>Projection available outside vessel, L<sub>pr</sub></b>	1"
<b>Projection available outside vessel to flange face, L<sub>f</sub></b>	4"
<b>Local vessel minimum thickness</b>	0.493"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

### Welds

Inner fillet, Leg <sub>41</sub>	0.3571"
Nozzle to vessel groove weld	0.493"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 4 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 1.844 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0108"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0108 \cdot 1 / (0.4646 - 0.125) =$	0.0319
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.6502	1.4752	0.7445	0.6217	--	--	0.109	0.3324	0.4646

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 <sub>41</sub> )	0.25	0.25	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.8017, 1.9009 + (0.531 - 0.125) + (0.493 - 0.125)) \\
 &= 3.8017 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.493 - 0.125), 2.5*(0.531 - 0.125) + 0) \\
 &= 0.92 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 1.844 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0108 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)(1)

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 100 \cdot 66.493 \cdot 1 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1 - 0.2)) \\
 &= 0.1659 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 100 \cdot 66.493 \cdot 1.648 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1.648 - 0.2)) \\
 &= 0.273 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.8017 \cdot 0.1659 \cdot 1 + 2 \cdot 0.406 \cdot 0.1659 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{0.6502} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.7445} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.8017 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.406 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.7445 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.368 + 0.406) \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.406 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.2891 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.6217} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.406 - 0.0108) \cdot 0.855 \cdot 0.368 \\ &= 0.6217 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.406 - 0.0108) \cdot 0.855 \cdot 1 \\ &= 0.6758 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.3571^2 \cdot 0.855 \\ &= \underline{0.109} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.7445 + 0.6217 + 0.109 \\ &= \underline{1.4752} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.368 \text{ in}$

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

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.3571 = 0.25 \text{ in}$

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.

Wall thickness per UG-45(a):  $t_{r1} = 0.1358 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.398 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3324 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.398 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.3324 \text{ in}$

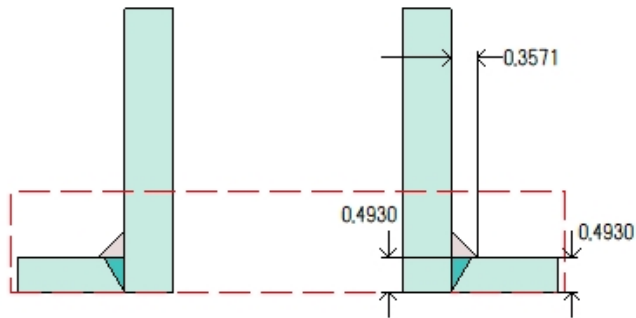
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.3324 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.531 = 0.4646 \text{ in}$

The nozzle neck thickness is adequate.

LSHH (N9)

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

Location and Orientation

Located on	Right Head
Orientation	0°
End of nozzle to datum line	-13.8292"
Calculated as hillside	Yes
Distance to head center, R	29.5"
Passes through a Category A joint	No

Nozzle

Description	NPS 4 XXS
Access opening	No
Material specification	SA-106 B Smls pipe (II-D p. 10, ln. 15)
Inside diameter, new	3.152"
Pipe nominal wall thickness	0.674"
Pipe minimum wall thickness <sup>1</sup>	0.5898"
Corrosion allowance	0.125"
Opening chord length	3.8004"
Projection available outside vessel, L <sub>pr</sub>	1"
Projection available outside vessel to flange face, L <sub>f</sub>	4"
Local vessel minimum thickness	0.493"
Liquid static head included	0 psi
Longitudinal joint efficiency	1

Welds

Inner fillet, Leg <sub>41</sub>	0.3571"
Nozzle to vessel groove weld	0.493"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 4 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, $t_g =$	0.493"
Exemption temperature from Fig UCS-66 Curve B =	-7.67°F
$t_r = 100 \cdot 66.493 \cdot 1 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1 - 0.2)) =$	0.1659"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1659 \cdot 1 / (0.493 - 0.125) =$	0.4508
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	70.1°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -7.67 - 70.1 - 30, -55 ] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
Impact test exempt per UCS-66(d) (NPS 4 or smaller pipe) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.6569	1.6929	0.7359	0.848	--	--	0.109	0.3324	0.5898

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

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

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(3.8004, 1.9002 + (0.674 - 0.125) + (0.493 - 0.125)) \\
 &= 3.8004 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.493 - 0.125), 2.5*(0.674 - 0.125) + 0) \\
 &= 0.92 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 1.701 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.01 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)(1)

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 100 \cdot 66.493 \cdot 1 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1 - 0.2)) \\
 &= 0.1659 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 100 \cdot 66.493 \cdot 1.648 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1.648 - 0.2)) \\
 &= 0.273 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 3.8004 \cdot 0.1659 \cdot 1 + 2 \cdot 0.549 \cdot 0.1659 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{0.6569} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.7359} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 3.8004 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.549 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.7359 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.368 + 0.549) \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.549 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.3385 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.848} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.549 - 0.01) \cdot 0.855 \cdot 0.368 \\ &= 0.848 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.549 - 0.01) \cdot 0.855 \cdot 1 \\ &= 0.9217 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.3571^2 \cdot 0.855 \\ &= \underline{0.109} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.7359 + 0.848 + 0.109 \\ &= \underline{1.6929} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.368 \text{ in}$

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

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.3571 = 0.25 \text{ in}$

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.

Wall thickness per UG-45(a):  $t_{r1} = 0.135 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.398 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3324 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.398 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.3324 \text{ in}$

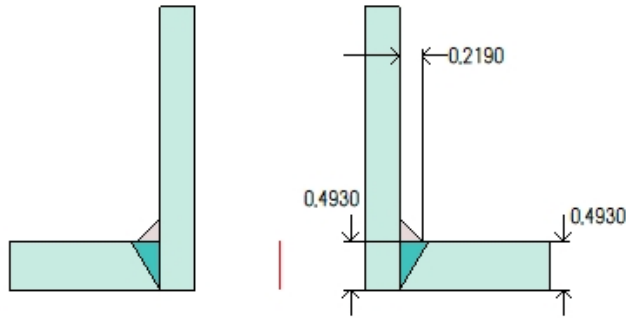
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.3324 \text{ in}$

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

The nozzle neck thickness is adequate.

**2" Nozzles at Lowest Location (In Head) (N11/N12B/N13)**

**ASME Section VIII Division 1, 2001 Edition**



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

**Location and Orientation**

<b>Located on</b>	Right Head
<b>Orientation</b>	211 °
<b>End of nozzle to datum line</b>	-11.6911"
<b>Calculated as hillside</b>	Yes
<b>Distance to head center, R</b>	30.3338"
<b>Passes through a Category A joint</b>	No

**Nozzle**

<b>Description</b>	NPS 2 Sch 160
<b>Access opening</b>	No
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	1.687"
<b>Pipe nominal wall thickness</b>	0.344"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.301"
<b>Corrosion allowance</b>	0.125"
<b>Opening chord length</b>	2.1792"
<b>Projection available outside vessel, L<sub>p</sub></b>	0.25"
<b>Projection available outside vessel to flange face, L<sub>f</sub></b>	2.75"
<b>Local vessel minimum thickness</b>	0.493"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

**Welds**

Inner fillet, Leg <sub>41</sub>	0.219"
Nozzle to vessel groove weld	0.493"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 2 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 0.9685 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0057"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0057 \cdot 1 / (0.301 - 0.125) =$	0.0323
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							<a href="#">0.2598</a>	0.301

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 <sub>41</sub> )	<a href="#">0.1533</a>	0.1533	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.1792, 1.0896 + (0.344 - 0.125) + (0.493 - 0.125)) \\
 &= 2.1792 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.493 - 0.125), 2.5*(0.344 - 0.125) + 0) \\
 &= 0.5475 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P*R_n / (S_n*E - 0.6*P) \\
 &= 100*0.9685 / (17,100*1 - 0.6*100) \\
 &= 0.0057 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)(1)

$$\begin{aligned}
 t_r &= P*L_o*M / (2*S*E + P*(M - 0.2)) \\
 &= 100*66.493*1 / (2*20,000*1 + 100*(1 - 0.2)) \\
 &= 0.1659 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P*L_o*M / (2*S*E + P*(M - 0.2)) \\
 &= 100*66.493*1.648 / (2*20,000*1 + 100*(1.648 - 0.2)) \\
 &= 0.273"
 \end{aligned}$$

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

### **UW-16(c) Weld Check**

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.219 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1533 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.219 = 0.1533 \text{ in}$

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.

Wall thickness per UG-45(a):  $t_{r1} = 0.1307 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.398 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.2598 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.398 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.2598 \text{ in}$

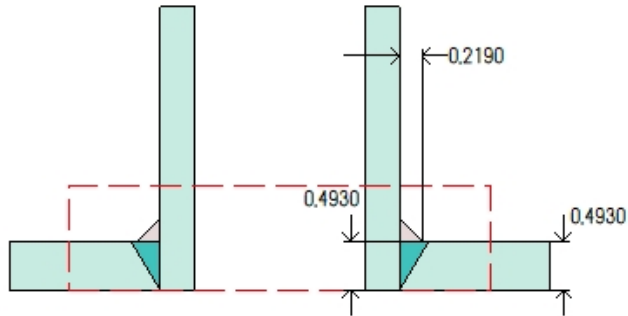
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.2598 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.344 = 0.301 \text{ in}$

The nozzle neck thickness is adequate.

## Oil Level Gauge (N12A)

ASME Section VIII Division 1, 2001 Edition



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

### Location and Orientation

<b>Located on</b>	Right Head
<b>Orientation</b>	341 °
<b>End of nozzle to datum line</b>	-14.5194"
<b>Calculated as hillside</b>	Yes
<b>Distance to head center, R</b>	24.3108"
<b>Passes through a Category A joint</b>	No

### Nozzle

<b>Description</b>	NPS 2 Sch 160
<b>Access opening</b>	No
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	1.687"
<b>Pipe nominal wall thickness</b>	0.344"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.301"
<b>Corrosion allowance</b>	0.125"
<b>Opening chord length</b>	2.0825"
<b>Projection available outside vessel, L<sub>pr</sub></b>	0.5"
<b>Projection available outside vessel to flange face, L<sub>f</sub></b>	3"
<b>Local vessel minimum thickness</b>	0.493"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

### Welds



Inner fillet, Leg <sub>41</sub>	0.219"
Nozzle to vessel groove weld	0.493"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 2 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 0.9685 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0057"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0057 \cdot 1 / (0.301 - 0.125) =$	0.0323
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)		
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45		
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>	
0.356	0.6314	0.408	0.1824	--	--	0.041	0.2598	0.301	

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 <sub>41</sub> )	0.1533	0.1533	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.0825, 1.0413 + (0.344 - 0.125) + (0.493 - 0.125)) \\
 &= 2.0825 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.493 - 0.125), 2.5*(0.344 - 0.125) + 0) \\
 &= 0.5475 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P * R_n / (S_n * E - 0.6 * P) \\
 &= 100 * 0.9685 / (17,100 * 1 - 0.6 * 100) \\
 &= 0.0057 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)(1)

$$\begin{aligned}
 t_r &= P * L_o * M / (2 * S * E + P * (M - 0.2)) \\
 &= 100 * 66.493 * 1 / (2 * 20,000 * 1 + 100 * (1 - 0.2)) \\
 &= 0.1659 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P * L_o * M / (2 * S * E + P * (M - 0.2)) \\
 &= 100 * 66.493 * 1.648 / (2 * 20,000 * 1 + 100 * (1.648 - 0.2)) \\
 &= 0.273 \text{ in}
 \end{aligned}$$

**Opening N9 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:  $S_n = 17,100$ ,  $S_v = 20,000$  psi

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 2.0825 \cdot 0.1659 \cdot 1 + 2 \cdot 0.219 \cdot 0.1659 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{0.356} \text{ in}^2 \end{aligned}$$

**Area available from FIG. UG-37.1**

$$A_1 = \text{larger of the following} = \underline{0.408} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2.0825 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.219 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.408 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.368 + 0.219) \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.219 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.2244 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.1824} \text{ in}^2$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.219 - 0.0057) \cdot 0.855 \cdot 0.5 \\ &= 0.1824 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot L_{pr} \\ &= 2 \cdot (0.219 - 0.0057) \cdot 0.855 \cdot 0.5 \\ &= 0.1824 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.219^2 \cdot 0.855 \\ &= \underline{0.041} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.408 + 0.1824 + 0.041 \\ &= \underline{0.6314} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.219 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1533 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.219 = 0.1533 \text{ in}$

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.

Wall thickness per UG-45(a):  $t_{r1} = 0.1307 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.398 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.2598 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.398 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.2598 \text{ in}$

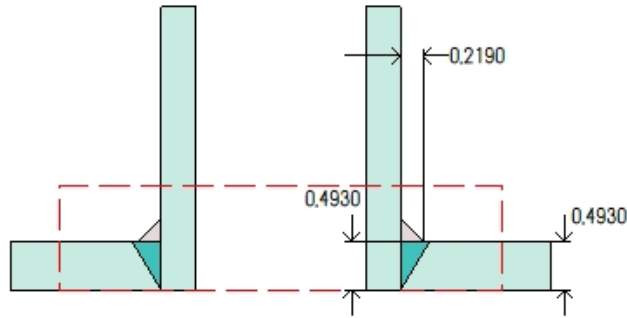
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.2598 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.344 = 0.301 \text{ in}$

The nozzle neck thickness is adequate.

**Pressure Indicator (N14)**

**ASME Section VIII Division 1, 2001 Edition**



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

**Location and Orientation**

<b>Located on</b>	Right Head
<b>Orientation</b>	345°
<b>End of nozzle to datum line</b>	-13.8436"
<b>Calculated as hillside</b>	Yes
<b>Distance to head center, R</b>	30.533"
<b>Passes through a Category A joint</b>	No

**Nozzle**

<b>Description</b>	NPS 2 Sch 160
<b>Access opening</b>	No
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	1.687"
<b>Pipe nominal wall thickness</b>	0.344"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.301"
<b>Corrosion allowance</b>	0.125"
<b>Opening chord length</b>	2.1831"
<b>Projection available outside vessel, L<sub>pr</sub></b>	2.5"
<b>Projection available outside vessel to flange face, L<sub>f</sub></b>	5"
<b>Local vessel minimum thickness</b>	0.493"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

**Welds**

Inner fillet, Leg <sub>41</sub>	0.219"
Nozzle to vessel groove weld	0.493"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
Description	NPS 2 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 0.9685 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0057"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0057 \cdot 1 / (0.301 - 0.125) =$	0.0323
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.3727	0.6691	0.4284	0.1997	--	--	0.041	0.2598	0.301

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 <sub>41</sub> )	0.1533	0.1533	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.1831, 1.0916 + (0.344 - 0.125) + (0.493 - 0.125)) \\
 &= 2.1831 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.493 - 0.125), 2.5*(0.344 - 0.125) + 0) \\
 &= 0.5475 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 0.9685 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0057 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)(1)

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 100 \cdot 66.493 \cdot 1 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1 - 0.2)) \\
 &= 0.1659 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> per Interpretation VIII-1-07-50

$$\begin{aligned}
 t_r &= P \cdot L_o \cdot M / (2 \cdot S \cdot E + P \cdot (M - 0.2)) \\
 &= 100 \cdot 66.493 \cdot 1.648 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1.648 - 0.2)) \\
 &= 0.273 \text{ in}
 \end{aligned}$$

**Opening N9 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:  $S_n = 17,100$ ,  $S_v = 20,000$  psi

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 2.1831 \cdot 0.1659 \cdot 1 + 2 \cdot 0.219 \cdot 0.1659 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{0.3727} \text{ in}^2 \end{aligned}$$

**Area available from FIG. UG-37.1**

$$A_1 = \text{larger of the following} = \underline{0.4284} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2.1831 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.219 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.4284 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.368 + 0.219) \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) - 2 \cdot 0.219 \cdot (1 \cdot 0.368 - 1 \cdot 0.1659) \cdot (1 - 0.855) \\ &= 0.2244 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.1997} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.219 - 0.0057) \cdot 0.855 \cdot 0.368 \\ &= 0.3356 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.219 - 0.0057) \cdot 0.855 \cdot 0.219 \\ &= 0.1997 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.219^2 \cdot 0.855 \\ &= \underline{0.041} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.4284 + 0.1997 + 0.041 \\ &= \underline{0.6691} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.



### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.219 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1533 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.219 = 0.1533 \text{ in}$

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.

Wall thickness per UG-45(a):  $t_{r1} = 0.1307 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.398 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.2598 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.398 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.2598 \text{ in}$

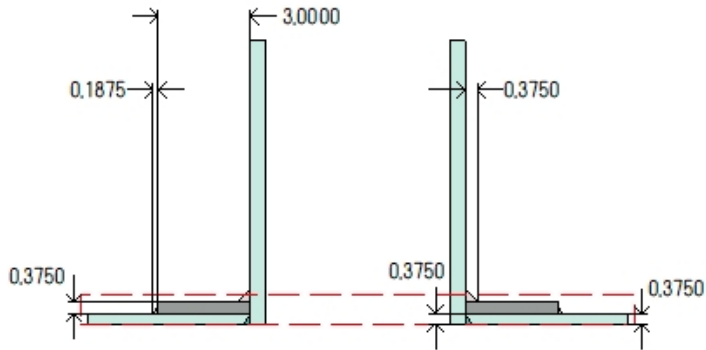
Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.2598 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.344 = 0.301 \text{ in}$

The nozzle neck thickness is adequate.

## Manway (M1)

### ASME Section VIII Division 1, 2001 Edition



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

#### Location and Orientation

<b>Located on</b>	Shell
<b>Orientation</b>	135°
<b>Nozzle center line offset to datum line</b>	82.5"
<b>End of nozzle to shell center</b>	45"
<b>Passes through a Category A joint</b>	No

#### Nozzle

<b>Description</b>	NPS 24 XS
<b>Access opening</b>	Yes
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	23"
<b>Pipe nominal wall thickness</b>	0.5"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.4375"
<b>Corrosion allowance</b>	0.125"
<b>Projection available outside vessel, L<sub>pr</sub></b>	3"
<b>Projection available outside vessel to flange face, L<sub>f</sub></b>	9"
<b>Local vessel minimum thickness</b>	0.375"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

#### Reinforcing Pad

<b>Material specification</b>	SA-516 70 (II-D p. 14, ln. 30) (normalized)
<b>Diameter, D<sub>p</sub></b>	30"

Thickness, $t_e$	0.375"
Is split	No
<b>Welds</b>	
Inner fillet, Leg <sub>41</sub>	0.375"
Outer fillet, Leg <sub>42</sub>	0.1875"
Nozzle to vessel groove weld	0.375"
Pad groove weld	0"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

<b>ASME B16.5-1996 Flange</b>	
Description	NPS 24 Class 150 WN A105 N
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, In. 37)
Blind included	Yes
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	23"
<b>Notes</b>	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

<b>UCS-66 Material Toughness Requirements Nozzle At Intersection</b>	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E' / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -20 - 28.1 - 30, -55 ] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 11.625 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0682"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0682 \cdot 1 / (0.4375 - 0.125) =$	0.2183
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155 °F
Material is exempt from impact testing at the Design MDMT of -20 °F.	

UCS-66 Material Toughness Requirements Pad	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve D =	-55 °F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1 °F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30 °F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -55 - 28.1 - 30, -55 ] =$	-55 °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 <sup>2</sup> )							UG-45 Summary (in)		
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45		
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>	
<a href="#">4.1962</a>	<a href="#">4.3482</a>	<a href="#">1.6282</a>	<a href="#">0.3279</a>	--	<a href="#">2.25</a>	<a href="#">0.1421</a>	<a href="#">0.1932</a>	0.4375	

UG-41 Weld Failure Path Analysis Summary (lb <sub>f</sub> )						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W <sub>1-1</sub>	Path 1-1 strength	Weld load W <sub>2-2</sub>	Path 2-2 strength	Weld load W <sub>3-3</sub>	Path 3-3 strength
<a href="#">52,261.68</a>	<a href="#">54,400</a>	<a href="#">253,167.94</a>	<a href="#">11,902.25</a>	<a href="#">257,942.03</a>	<a href="#">57,606.25</a>	<a href="#">226,076.86</a>

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to pad fillet (Leg <sub>41</sub> )	<a href="#">0.2625</a>	0.2625	weld size is adequate
Pad to shell fillet (Leg <sub>42</sub> )	<a href="#">0.125</a>	0.1312	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(23.25, 11.625 + (0.5 - 0.125) + (0.375 - 0.125)) \\
 &= 23.25 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.5 - 0.125) + 0.375) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 11.625 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0682 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.855$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 23.25 \cdot 0.1796 \cdot 1 + 2 \cdot 0.375 \cdot 0.1796 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{4.1962} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{1.6282} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 23.25 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) - 2 \cdot 0.375 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) \cdot (1 - 0.855) \\ &= 1.6282 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.25 + 0.375) \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) - 2 \cdot 0.375 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) \cdot (1 - 0.855) \\ &= 0.0803 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.3279} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.375 - 0.0682) \cdot 0.855 \cdot 0.25 \\ &= 0.3279 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= 2 \cdot (0.375 - 0.0682) \cdot (2.5 \cdot 0.375 + 0.375) \cdot 0.855 \\ &= 0.6886 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r3} \\ &= 0.3536^2 \cdot 0.855 \\ &= \underline{0.1069} \text{ in}^2 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned} A_{42} &= \text{Leg}^2 \cdot f_{r4} \\ &= 0.1875^2 \cdot 1 \\ &= \underline{0.0352} \text{ in}^2 \end{aligned}$$

$$\begin{aligned}
A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\
&= (30 - 23.25 - 2*0.375)*0.375*1 \\
&= \underline{2.25} \text{ in}^2
\end{aligned}$$

$$\begin{aligned}
\text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
&= 1.6282 + 0.3279 + 0.1069 + 0.0352 + 2.25 \\
&= \underline{4.3482} \text{ in}^2
\end{aligned}$$

As Area >= A the reinforcement is adequate.

### UW-16(c)(2) Weld Check

$$\begin{aligned}
\text{Inner fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t_e = 0.375 \text{ in} \\
t_{w(\min)} &= 0.7*t_{\min} = \underline{0.2625} \text{ in} \\
t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.375 = 0.2625 \text{ in}
\end{aligned}$$

$$\begin{aligned}
\text{Outer fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_e \text{ or } t = 0.25 \text{ in} \\
t_{w(\min)} &= 0.5*t_{\min} = \underline{0.125} \text{ in} \\
t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.1875 = 0.1313 \text{ in}
\end{aligned}$$

### UG-45 Nozzle Neck Thickness Check (Access Opening)

$$\text{Wall thickness req'd per UG-45(a): } t_{r1} = \underline{0.1932} \text{ in (E = 1)}$$

$$\text{Available nozzle wall thickness new, } t_n = 0.875*0.5 = 0.4375 \text{ in}$$

The nozzle neck thickness is adequate.

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

$$\text{Groove weld in tension: } 0.74*20,000 = 14,800 \text{ psi}$$

$$\text{Nozzle wall in shear: } 0.7*17,100 = 11,970 \text{ psi}$$

$$\text{Inner fillet weld in shear: } 0.49*17,100 = 8,379 \text{ psi}$$

$$\text{Outer fillet weld in shear: } 0.49*20,000 = 9,800 \text{ psi}$$

#### Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi / 2)*\text{Nozzle OD}*\text{Leg}*S_i = (\pi / 2)*24*0.375*8,379 = 118,455.32 \text{ lb}_f$$

(2) Outer fillet weld in shear

$$(\pi / 2)*\text{Pad OD}*\text{Leg}*S_o = (\pi / 2)*30*0.1875*9,800 = 86,590.15 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi / 2)*\text{Mean nozzle dia}*t_n*S_n = (\pi / 2)*23.625*0.375*11,970 = 166,577.8 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi / 2)*\text{Nozzle OD}*t_w*S_g = (\pi / 2)*24*0.25*14,800 = 139,486.71 \text{ lb}_f$$

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

$$\begin{aligned} W &= (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v \\ &= (4.1962 - 1.6282 + 2*0.375*0.855*(1*0.25 - 1*0.1796))*20,000 \\ &= \underline{52.261.68} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42})*S_v \\ &= (0.3279 + 2.25 + 0.1069 + 0.0352)*20,000 \\ &= \underline{54.400} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v \\ &= (0.3279 + 0 + 0.1069 + 0 + 2*0.375*0.25*0.855)*20,000 \\ &= \underline{11.902.25} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v \\ &= (0.3279 + 0 + 2.25 + 0.1069 + 0.0352 + 0 + 2*0.375*0.25*0.855)*20,000 \\ &= \underline{57.606.25} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or  $W_{1-1} = 52,261.68 \text{ lb}_f$   
Path 1-1 through (2) & (3) =  $86,590.15 + 166,577.8 = \underline{253.167.94} \text{ lb}_f$   
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

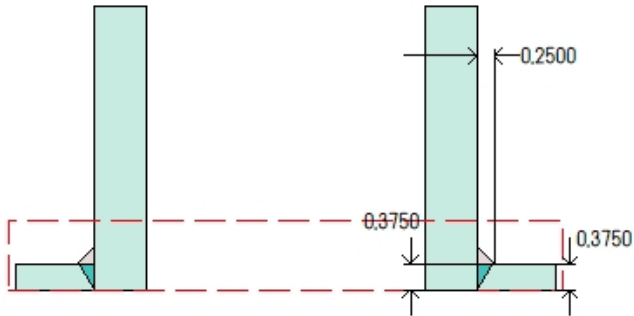
Load for path 2-2 lesser of W or  $W_{2-2} = 11,902.25 \text{ lb}_f$   
Path 2-2 through (1), (4) =  $118,455.32 + 139,486.71 = \underline{257.942.03} \text{ lb}_f$   
Path 2-2 is stronger than  $W_{2-2}$  so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or  $W_{3-3} = 52,261.68 \text{ lb}_f$   
Path 3-3 through (2), (4) =  $86,590.15 + 139,486.71 = \underline{226.076.86} \text{ lb}_f$   
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).



## Anode Ports (A1/A2)

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

### Location and Orientation

Located on	Shell
Orientation	90°
Nozzle center line offset to datum line	186.5"
End of nozzle to shell center	37.8008"
Offset from center, L <sub>o</sub>	25"
Passes through a Category A joint	No

### Nozzle

Access opening	No
Material specification	SA-105 (II-D p. 14, In. 17)
Inside diameter, new	4"
Nominal wall thickness	0.75"
Corrosion allowance	0.125"
Opening chord length	5.9509"
Projection available outside vessel, L <sub>pr</sub>	8.56"
Projection available outside vessel to flange face, L <sub>f</sub>	9.5"
Local vessel minimum thickness	0.375"
Liquid static head included	0 psi
Longitudinal joint efficiency	1

### Welds

Inner fillet, Leg <sub>41</sub>	0.25"
Nozzle to vessel groove weld	0.375"

ASME B16.5-1996 Flange	
Description	NPS 4 Class 150 LWN A105
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 37)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	260 psi @ 200°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	Yes
Impact Tested	No
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55°F	

UCS-66 Material Toughness Requirements Nozzle	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -20 - 28.1 - 30, -55 ] =$	-55°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.5345	1.7836	0.9532	0.7679	--	--	0.0625	0.3046	0.75

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 <sub>41</sub> )	0.175	0.175	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(5.9509, 2.9755 + (0.75 - 0.125) + (0.375 - 0.125)) \\
 &= 5.9509 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.75 - 0.125) + 0) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 2.125 / (20,000 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0107 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 5.9509 \cdot 0.1796 \cdot 0.5 + 2 \cdot 0.625 \cdot 0.1796 \cdot 0.5 \cdot (1 - 1) \\ &= \underline{0.5345} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.9532} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 5.9509 \cdot (1 \cdot 0.25 - 0.5 \cdot 0.1796) - 2 \cdot 0.625 \cdot (1 \cdot 0.25 - 0.5 \cdot 0.1796) \cdot (1 - 1) \\ &= 0.9532 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.25 + 0.625) \cdot (1 \cdot 0.25 - 0.5 \cdot 0.1796) - 2 \cdot 0.625 \cdot (1 \cdot 0.25 - 0.5 \cdot 0.1796) \cdot (1 - 1) \\ &= 0.2803 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.7679} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.625 - 0.0107) \cdot 1 \cdot 0.25 \\ &= 0.7679 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.625 - 0.0107) \cdot 1 \cdot 0.625 \\ &= 1.9197 \text{ in}^2 \end{aligned}$$

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

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.9532 + 0.7679 + 0.0625 \\ &= \underline{1.7836} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.25 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.175 \text{ in}$

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

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

Wall thickness per UG-45(a):  $t_{r1} = 0.1357 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.3046 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3508 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.3046 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.3046 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.3046 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.75 \text{ in}$

The nozzle neck thickness is adequate.

**Reinforcement check in the plane parallel to the longitudinal axis**

**Reinforcement Calculations for Internal Pressure**

UG-37 Area Calculation Summary (in <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.7635	1.1294	0.299	0.7679	--	--	0.0625	0.3046	0.75

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 <sub>41</sub> )	0.175	0.175	weld size is adequate

**Parallel Limit of reinforcement per UG-40**

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(4.25, 2.125 + (0.75 - 0.125) + (0.375 - 0.125)) \\
 &= 4.25 \text{ in}
 \end{aligned}$$

**Outer Normal Limit of reinforcement per UG-40**

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.75 - 0.125) + 0) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 2.125 / (20,000 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0107 \text{ in}
 \end{aligned}$$

**Required thickness t<sub>r</sub> from UG-37(a)**

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 4.25 \cdot 0.1796 \cdot 1 + 2 \cdot 0.625 \cdot 0.1796 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.7635} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.299} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 4.25 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) - 2 \cdot 0.625 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) \cdot (1 - 1) \\ &= 0.299 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.25 + 0.625) \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) - 2 \cdot 0.625 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) \cdot (1 - 1) \\ &= 0.1231 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.7679} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.625 - 0.0107) \cdot 1 \cdot 0.25 \\ &= 0.7679 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.625 - 0.0107) \cdot 1 \cdot 0.625 \\ &= 1.9197 \text{ in}^2 \end{aligned}$$

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

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.299 + 0.7679 + 0.0625 \\ &= \underline{1.1294} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.

### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{r1} = 0.1357$  in ( $E = 1$ )

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.3046$  in

Wall thickness per UG-16(b):  $t_{r3} = 0.1875$  in

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.3508$  in

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.3046$  in

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.3046$  in

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.3046$  in

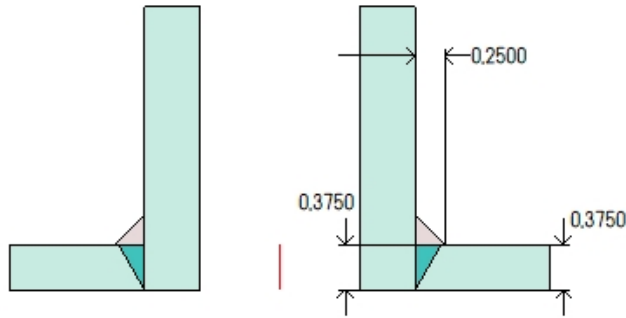
Available nozzle wall thickness new,  $t_n = 0.75$  in

The nozzle neck thickness is adequate.



## 1" Coupling (C1/C2)

### ASME Section VIII Division 1, 2001 Edition



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

#### Location and Orientation

<b>Located on</b>	Shell
<b>Orientation</b>	90°
<b>Nozzle center line offset to datum line</b>	205"
<b>End of nozzle to shell center</b>	28.1624"
<b>Offset from center, Lo</b>	-24"
<b>Passes through a Category A joint</b>	No

#### Nozzle

<b>Description</b>	NPS 1 Class 6000 - Threaded (2.8674" length)
<b>Access opening</b>	No
<b>Material specification</b>	SA-105 (II-D p. 14, ln. 17)
<b>Inside diameter, new</b>	1.31"
<b>Nominal wall thickness</b>	0.47"
<b>Corrosion allowance</b>	0.125"
<b>Opening chord length</b>	2.1012"
<b>Projection available outside vessel, L<sub>pr</sub></b>	0.3643"
<b>Local vessel minimum thickness</b>	0.375"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

#### Welds

<b>Inner fillet, Leg<sub>41</sub></b>	0.25"
<b>Nozzle to vessel groove weld</b>	0.375"

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[\text{MDMT} - T_R - T_{PWHT}, -55] = \max[-20 - 28.1 - 30, -55] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 0.78 / (20,000 \cdot 1 - 0.6 \cdot 100) =$	0.0039"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0039 \cdot 1 / (0.47 - 0.125) =$	0.0113
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°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 <sup>2</sup> )							UG-44 Summary (in)	
For P = 100 psi @ 200 °F							The nozzle passes UG-44	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							<a href="#">0.1875</a>	0.47

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 <sub>41</sub> )	<a href="#">0.175</a>	0.175	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(2.1012, 1.0506 + (0.47 - 0.125) + (0.375 - 0.125)) \\
 &= 2.1012 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.47 - 0.125) + 0) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P*R_n / (S_n*E - 0.6*P) \\
 &= 100*0.78 / (20,000*1 - 0.6*100) \\
 &= 0.0039 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*R_o / (S*E + 0.4*P) \\
 &= 100*36 / (20,000*1 + 0.4*100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

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

### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.25 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = 0.175 \text{ in}$

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

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-44 Thickness Check - ASME B16.11 Coupling

$$\begin{aligned}t_{a \text{ App 1-1}} &= P*R_o / (S_n*E + 0.4*P) + \text{Corrosion} \\ &= 100*1.125 / (20,000*1 + 0.4*100) + 0.125 \\ &= 0.1306 \text{ in}\end{aligned}$$

$$\begin{aligned}t_{a \text{ UG-44}} &= \max[ t_{a \text{ App 1-1}} , t_{b \text{ UG16}} ] \\ &= \max[ 0.1306 , 0.1875 ] \\ &= 0.1875 \text{ in}\end{aligned}$$

Available nozzle wall thickness new,  $t_n = 0.47 \text{ in}$

The nozzle neck thickness is adequate.

**Reinforcement check in the plane parallel to the longitudinal axis**

**Reinforcement Calculations for Internal Pressure**

UG-37 Area Calculation Summary (in <sup>2</sup> )							UG-44 Summary (in)	
For P = 100 psi @ 200 °F							The nozzle passes UG-44	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							<a href="#">0.1875</a>	0.47

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 <sub>41</sub> )	<a href="#">0.175</a>	0.175	weld size is adequate

**Parallel Limit of reinforcement per UG-40**

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(1.56, 0.78 + (0.47 - 0.125) + (0.375 - 0.125)) \\
 &= 1.56 \text{ in}
 \end{aligned}$$

**Outer Normal Limit of reinforcement per UG-40**

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.47 - 0.125) + 0) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_m &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 0.78 / (20,000 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0039 \text{ in}
 \end{aligned}$$

**Required thickness t<sub>r</sub> from UG-37(a)**

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

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

### UG-44 Thickness Check - ASME B16.11 Coupling

$$\begin{aligned}t_{a \text{ App 1-1}} &= P \cdot R_o / (S_n \cdot E + 0.4 \cdot P) + \text{Corrosion} \\ &= 100 \cdot 1.125 / (20,000 \cdot 1 + 0.4 \cdot 100) + 0.125 \\ &= 0.1306 \text{ in}\end{aligned}$$

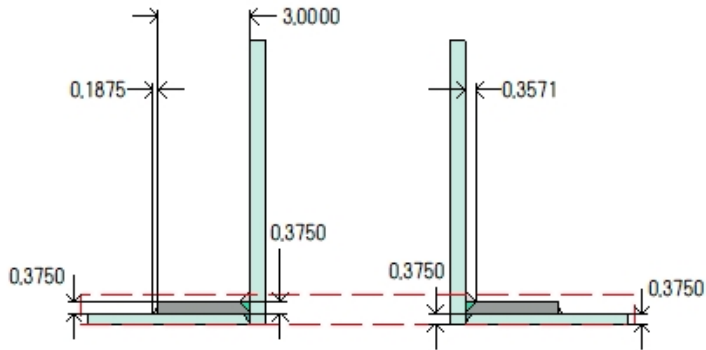
$$\begin{aligned}t_{a \text{ UG-44}} &= \max[ t_{a \text{ App 1-1}} , t_{b \text{ UG16}} ] \\ &= \max[ 0.1306 , 0.1875 ] \\ &= \underline{0.1875} \text{ in}\end{aligned}$$

Available nozzle wall thickness new,  $t_n = 0.47$  in

The nozzle neck thickness is adequate.

## Gas Dome (GD)

### ASME Section VIII Division 1, 2001 Edition



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

#### Location and Orientation

<b>Located on</b>	Shell
<b>Orientation</b>	0°
<b>Nozzle center line offset to datum line</b>	38.5"
<b>End of nozzle to shell center</b>	39"
<b>Passes through a Category A joint</b>	No

#### Nozzle

<b>Description</b>	NPS 24 XS
<b>Access opening</b>	No
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	23"
<b>Pipe nominal wall thickness</b>	0.5"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.4375"
<b>Corrosion allowance</b>	0.125"
<b>Projection available outside vessel, L<sub>pr</sub></b>	3"
<b>Local vessel minimum thickness</b>	0.375"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

#### Reinforcing Pad

<b>Material specification</b>	SA-516 70 (II-D p. 14, ln. 30) (normalized)
<b>Diameter, D<sub>p</sub></b>	30"
<b>Thickness, t<sub>e</sub></b>	0.375"

<b>Is split</b>	No
<b>Welds</b>	
<b>Inner fillet, Leg<sub>41</sub></b>	0.3571"
<b>Outer fillet, Leg<sub>42</sub></b>	0.1875"
<b>Nozzle to vessel groove weld</b>	0.375"
<b>Pad groove weld</b>	0.375"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

<b>UCS-66 Material Toughness Requirements Nozzle At Intersection</b>	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -20 - 28.1 - 30, -55 ] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

<b>UCS-66 Material Toughness Requirements Nozzle</b>	
$t_r = 100 \cdot 11.625 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0682"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0682 \cdot 1 / (0.4375 - 0.125) =$	0.2183
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

<b>UCS-66 Material Toughness Requirements Pad</b>	
Governing thickness, $t_g =$	0.375"
Exemption temperature from Fig UCS-66 Curve D =	-55°F
$t_r = 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.1796"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1796 \cdot 1 / (0.375 - 0.125) =$	0.7186
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	28.1°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -55 - 28.1 - 30, -55 ] =$	-55°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
<a href="#">4.1962</a>	<a href="#">4.3405</a>	<a href="#">1.6282</a>	<a href="#">0.3279</a>	--	<a href="#">2.25</a>	<a href="#">0.1344</a>	<a href="#">0.3046</a>	0.4375

UG-41 Weld Failure Path Analysis Summary (lb <sub>f</sub> )						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W <sub>1-1</sub>	Path 1-1 strength	Weld load W <sub>2-2</sub>	Path 2-2 strength	Weld load W <sub>3-3</sub>	Path 3-3 strength
<a href="#">52,261.68</a>	<a href="#">54,246</a>	<a href="#">253,167.94</a>	<a href="#">11,748.25</a>	<a href="#">461,517.84</a>	<a href="#">57,452.25</a>	<a href="#">226,076.86</a>

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg <sub>41</sub> )	<a href="#">0.25</a>	0.25	weld size is adequate
Pad to shell fillet (Leg <sub>42</sub> )	<a href="#">0.125</a>	0.1312	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(23.25, 11.625 + (0.5 - 0.125) + (0.375 - 0.125)) \\
 &= 23.25 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.375 - 0.125), 2.5*(0.5 - 0.125) + 0.375) \\
 &= 0.625 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 11.625 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0682 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 36 / (20,000 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.1796 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 0.855$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 23.25 \cdot 0.1796 \cdot 1 + 2 \cdot 0.375 \cdot 0.1796 \cdot 1 \cdot (1 - 0.855) \\ &= \underline{4.1962} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{1.6282} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 23.25 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) - 2 \cdot 0.375 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) \cdot (1 - 0.855) \\ &= 1.6282 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.25 + 0.375) \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) - 2 \cdot 0.375 \cdot (1 \cdot 0.25 - 1 \cdot 0.1796) \cdot (1 - 0.855) \\ &= 0.0803 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.3279} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.375 - 0.0682) \cdot 0.855 \cdot 0.25 \\ &= 0.3279 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= 2 \cdot (0.375 - 0.0682) \cdot (2.5 \cdot 0.375 + 0.375) \cdot 0.855 \\ &= 0.6886 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r3} \\ &= 0.3407^2 \cdot 0.855 \\ &= \underline{0.0992} \text{ in}^2 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned} A_{42} &= \text{Leg}^2 \cdot f_{r4} \\ &= 0.1875^2 \cdot 1 \\ &= \underline{0.0352} \text{ in}^2 \end{aligned}$$

$$\begin{aligned}
A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\
&= (30 - 23.25 - 2*0.375)*0.375*1 \\
&= \underline{2.25} \text{ in}^2
\end{aligned}$$

$$\begin{aligned}
\text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
&= 1.6282 + 0.3279 + 0.0992 + 0.0352 + 2.25 \\
&= \underline{4.3405} \text{ in}^2
\end{aligned}$$

As Area >= A the reinforcement is adequate.

### UW-16(c)(2) Weld Check

$$\begin{aligned}
\text{Inner fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t_e = 0.375 \text{ in} \\
t_{c(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.25} \text{ in} \\
t_{c(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.3571 = 0.25 \text{ in}
\end{aligned}$$

$$\begin{aligned}
\text{Outer fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_e \text{ or } t = 0.25 \text{ in} \\
t_{w(\min)} &= 0.5*t_{\min} = \underline{0.125} \text{ in} \\
t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.1875 = 0.1313 \text{ in}
\end{aligned}$$

### UG-45 Nozzle Neck Thickness Check

$$\begin{aligned}
\text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.1932 \text{ in (E =1)} \\
\text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 0.3046 \text{ in} \\
\text{Wall thickness per UG-16(b):} & \quad t_{r3} = 0.1875 \text{ in} \\
\text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 0.4531 \text{ in} \\
\text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 0.3046 \text{ in} \\
\text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 0.3046 \text{ in}
\end{aligned}$$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = \underline{0.3046}$  in

Available nozzle wall thickness new,  $t_n = 0.875*0.5 = 0.4375$  in

The nozzle neck thickness is adequate.

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

$$\begin{aligned}
\text{Groove weld in tension:} & \quad 0.74*20,000 = 14,800 \text{ psi} \\
\text{Nozzle wall in shear:} & \quad 0.7*17,100 = 11,970 \text{ psi} \\
\text{Inner fillet weld in shear:} & \quad 0.49*17,100 = 8,379 \text{ psi} \\
\text{Outer fillet weld in shear:} & \quad 0.49*20,000 = 9,800 \text{ psi} \\
\text{Upper groove weld in tension:} & \quad 0.74*20,000 = 14,800 \text{ psi}
\end{aligned}$$

### Strength of welded joints:

$$\begin{aligned}
(1) \text{ Inner fillet weld in shear} \\
(\pi / 2)*\text{Nozzle OD}*\text{Leg}*S_i &= (\pi / 2)*24*0.3571*8,379 = 112,801.05 \text{ lb}_f
\end{aligned}$$

$$(2) \text{ Outer fillet weld in shear}$$

$$(\pi / 2) * \text{Pad OD} * \text{Leg} * S_o = (\pi / 2) * 30 * 0.1875 * 9,800 = 86,590.15 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi / 2) * \text{Mean nozzle dia} * t_n * S_n = (\pi / 2) * 23.625 * 0.375 * 11,970 = 166,577.8 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 24 * 0.25 * 14,800 = 139,486.71 \text{ lb}_f$$

(6) Upper groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 24 * 0.375 * 14,800 = 209,230.07 \text{ lb}_f$$

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

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * f_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (4.1962 - 1.6282 + 2 * 0.375 * 0.855 * (1 * 0.25 - 1 * 0.1796)) * 20,000 \\ &= \underline{52.261.68} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.3279 + 2.25 + 0.0992 + 0.0352) * 20,000 \\ &= \underline{54.246} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.3279 + 0 + 0.0992 + 0 + 2 * 0.375 * 0.25 * 0.855) * 20,000 \\ &= \underline{11.748.25} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.3279 + 0 + 2.25 + 0.0992 + 0.0352 + 0 + 2 * 0.375 * 0.25 * 0.855) * 20,000 \\ &= \underline{57.452.25} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or  $W_{1-1} = 52,261.68 \text{ lb}_f$

Path 1-1 through (2) & (3) =  $86,590.15 + 166,577.8 = \underline{253.167.94} \text{ lb}_f$

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  $W_{2-2} = 11,748.25 \text{ lb}_f$

Path 2-2 through (1), (4), (6) =  $112,801.05 + 139,486.71 + 209,230.07 = \underline{461.517.84} \text{ lb}_f$

Path 2-2 is stronger than  $W_{2-2}$  so it is acceptable per UG-41(b)(1).

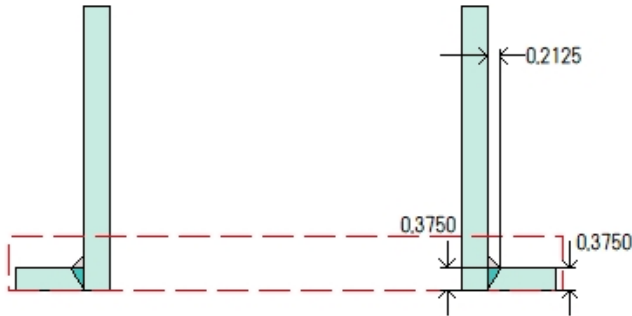
Load for path 3-3 lesser of W or  $W_{3-3} = 52,261.68 \text{ lb}_f$

Path 3-3 through (2), (4) =  $86,590.15 + 139,486.71 = \underline{226.076.86} \text{ lb}_f$

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

## Gas Outlet (N4)

ASME Section VIII Division 1, 2001 Edition



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

### Location and Orientation

<b>Located on</b>	Gas Dome Shell
<b>Orientation</b>	315°
<b>Nozzle center line offset to datum line</b>	0"
<b>End of nozzle to shell center</b>	18"
<b>Passes through a Category A joint</b>	No

### Nozzle

<b>Description</b>	NPS 6 Sch 80 (XS)
<b>Access opening</b>	No
<b>Material specification</b>	SA-106 B Smls pipe (II-D p. 10, ln. 15)
<b>Inside diameter, new</b>	5.761"
<b>Pipe nominal wall thickness</b>	0.432"
<b>Pipe minimum wall thickness<sup>1</sup></b>	0.378"
<b>Corrosion allowance</b>	0.125"
<b>Projection available outside vessel, L<sub>pr</sub></b>	2.5"
<b>Projection available outside vessel to flange face, L<sub>f</sub></b>	6"
<b>Local vessel minimum thickness</b>	0.3281"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

### Welds

<b>Inner fillet, Leg<sub>41</sub></b>	0.2125"
<b>Nozzle to vessel groove weld</b>	0.375"

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

ASME B16.5-1996 Flange	
<b>Description</b>	NPS 6 Class 150 WN A105 N
<b>Bolt Material</b>	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, In. 37)
<b>Blind included</b>	No
<b>Rated MDMT</b>	-55 °F
<b>Liquid static head</b>	0 psi
<b>MAWP rating</b>	260 psi @ 200 °F
<b>MAP rating</b>	285 psi @ 70 °F
<b>Hydrotest rating</b>	450 psi @ 70 °F
<b>PWHT performed</b>	Yes
<b>Impact Tested</b>	No
<b>Circumferential joint radiography</b>	None UW-11(c) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55 °F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (e) = -55 °F	

UCS-66 Material Toughness Requirements Nozzle At Intersection	
$t_r = 100 \cdot 12 / (17,100 \cdot 1 + 0.4 \cdot 100) =$	0.07"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.07 \cdot 1 / (0.3281 - 0.125) =$	0.3447
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155 °F
Material is exempt from impact testing at the Design MDMT of -20 °F.	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 3.0055 / (17,100 \cdot 1 - 0.6 \cdot 100) =$	0.0176"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0176 \cdot 1 / (0.378 - 0.125) =$	0.0697
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155 °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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
0.4208	1.1391	0.8	0.2939	--	--	0.0452	0.195	0.378

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 <sub>41</sub> )	0.1422	0.1488	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(6.011, 3.0055 + (0.432 - 0.125) + (0.3281 - 0.125)) \\
 &= 6.011 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.3281 - 0.125), 2.5*(0.432 - 0.125) + 0) \\
 &= 0.5078 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P \cdot R_n / (S_n \cdot E - 0.6 \cdot P) \\
 &= 100 \cdot 3.0055 / (17,100 \cdot 1 - 0.6 \cdot 100) \\
 &= 0.0176 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P \cdot R_o / (S \cdot E + 0.4 \cdot P) \\
 &= 100 \cdot 12 / (17,100 \cdot 1 + 0.4 \cdot 100) \\
 &= 0.07 \text{ in}
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 6.011 \cdot 0.07 \cdot 1 + 2 \cdot 0.307 \cdot 0.07 \cdot 1 \cdot (1 - 1) \\ &= \underline{0.4208} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{0.8} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 6.011 \cdot (1 \cdot 0.2031 - 1 \cdot 0.07) - 2 \cdot 0.307 \cdot (1 \cdot 0.2031 - 1 \cdot 0.07) \cdot (1 - 1) \\ &= 0.8 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.2031 + 0.307) \cdot (1 \cdot 0.2031 - 1 \cdot 0.07) - 2 \cdot 0.307 \cdot (1 \cdot 0.2031 - 1 \cdot 0.07) \cdot (1 - 1) \\ &= 0.1358 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.2939} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.307 - 0.0176) \cdot 1 \cdot 0.2031 \\ &= 0.2939 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t_n \\ &= 5 \cdot (0.307 - 0.0176) \cdot 1 \cdot 0.307 \\ &= 0.4442 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r2} \\ &= 0.2125^2 \cdot 1 \\ &= \underline{0.0452} \text{ in}^2 \end{aligned}$$

$$\begin{aligned} \text{Area} &= A_1 + A_2 + A_{41} \\ &= 0.8 + 0.2939 + 0.0452 \\ &= \underline{1.1391} \text{ in}^2 \end{aligned}$$

As Area  $\geq$  A the reinforcement is adequate.



### UW-16(c) Weld Check

Fillet weld:  $t_{\min} = \text{lesser of } 0.75 \text{ or } t_n \text{ or } t = 0.2031 \text{ in}$

$t_{c(\min)} = \text{lesser of } 0.25 \text{ or } 0.7 * t_{\min} = 0.1422 \text{ in}$

$t_{c(\text{actual})} = 0.7 * \text{Leg} = 0.7 * 0.2125 = 0.1488 \text{ in}$

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

Wall thickness per UG-45(a):  $t_{r1} = 0.1426 \text{ in (E = 1)}$

Wall thickness per UG-45(b)(1):  $t_{r2} = 0.195 \text{ in}$

Wall thickness per UG-16(b):  $t_{r3} = 0.1875 \text{ in}$

Standard wall pipe per UG-45(b)(4):  $t_{r4} = 0.37 \text{ in}$

The greater of  $t_{r2}$  or  $t_{r3}$ :  $t_{r5} = 0.195 \text{ in}$

The lesser of  $t_{r4}$  or  $t_{r5}$ :  $t_{r6} = 0.195 \text{ in}$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = 0.195 \text{ in}$

Available nozzle wall thickness new,  $t_n = 0.875 * 0.432 = 0.378 \text{ in}$

The nozzle neck thickness is adequate.

## Gas Dome Head

ASME Section VIII Division 1, 2001 Edition				
<b>Component</b>		Ellipsoidal Head		
<b>Material</b>		SA-516 70 (II-D p. 14, In. 30)		
<b>Attached To</b>		Gas Dome Shell		
<b>Impact Tested</b>	<b>Normalized</b>	<b>Fine Grain Practice</b>	<b>PWHT</b>	<b>Maximize MDMT/ No MAWP</b>
No	Yes	No	Yes	No
		<b>Design Pressure (psi)</b>	<b>Design Temperature (°F)</b>	<b>Design MDMT (°F)</b>
<b>Internal</b>		100	200	-20
Static Liquid Head				
<b>Condition</b>		<b>P<sub>s</sub> (psi)</b>	<b>H<sub>s</sub> (in)</b>	<b>SG</b>
<b>Test horizontal</b>		0.14	3.875	1
Dimensions				
<b>Outer Diameter</b>		24"		
<b>Head Ratio</b>		2		
<b>Minimum Thickness</b>		0.25"		
<b>Corrosion</b>	<b>Inner</b>	0.125"		
	<b>Outer</b>	0"		
<b>Length L<sub>sf</sub></b>		2"		
<b>Nominal Thickness t<sub>sf</sub></b>		0.375"		
Weight and Capacity				
		<b>Weight (lb)<sup>1</sup></b>		<b>Capacity (US gal)<sup>1</sup></b>
<b>New</b>		61.97		11.03
<b>Corroded</b>		33.97		11.43
Radiography				
<b>Category A joints</b>		Seamless No RT		
<b>Head to shell seam</b>		Full UW-11(a) Type 1		

<sup>1</sup> includes straight flange

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	<u>0.184"</u>
<u>Straight Flange</u> governs MDMT	-155 °F

Factor K		
K = (1/6)*[2 + (D / (2*h)) <sup>2</sup> ]		
Corroded	K = (1/6)*[2 + (23.75 / (2*6)) <sup>2</sup> ]	0.9862
New	K = (1/6)*[2 + (23.5 / (2*5.875)) <sup>2</sup> ]	1

**Design thickness for internal pressure, (Corroded at 200 °F) Appendix 1-4(c)**

$$\begin{aligned}
 t &= P \cdot D_o \cdot K / (2 \cdot S \cdot E + 2 \cdot P \cdot (K - 0.1)) + \text{Corrosion} \\
 &= 100 \cdot 24 \cdot 0.986183 / (2 \cdot 20,000 \cdot 1 + 2 \cdot 100 \cdot (0.986183 - 0.1)) + 0.125 \\
 &= \underline{0.1839"}
 \end{aligned}$$

**% Extreme fiber elongation - UCS-79(d)**

$$\begin{aligned}
 \text{EFE} &= (75 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (75 \cdot 0.375 / 4.1825) \cdot (1 - 4.1825 / \infty) \\
 &= 6.7244\%
 \end{aligned}$$

### Straight Flange on Gas Dome Head

ASME Section VIII Division 1, 2001 Edition				
<b>Component</b>		Cylinder		
<b>Material</b>		SA-516 70 (II-D p. 14, ln. 30)		
<b>Attached To</b>		Gas Dome Shell		
<b>Impact Tested</b>	<b>Normalized</b>	<b>Fine Grain Practice</b>	<b>PWHT</b>	<b>Maximize MDMT/ No MAWP</b>
No	Yes	No	Yes	No
		<b>Design Pressure (psi)</b>	<b>Design Temperature (°F)</b>	<b>Design MDMT (°F)</b>
<b>Internal</b>		100	200	-20
Static Liquid Head				
<b>Condition</b>		<b>P<sub>s</sub> (psi)</b>	<b>H<sub>s</sub> (in)</b>	<b>SG</b>
<b>Test horizontal</b>		0.21	5.875	1
Dimensions				
<b>Outer Diameter</b>		24"		
<b>Length</b>		2"		
<b>Nominal Thickness</b>		0.375"		
<b>Corrosion</b>	<b>Inner</b>	0.125"		
	<b>Outer</b>	0"		
Weight and Capacity				
		<b>Weight (lb)</b>	<b>Capacity (US gal)</b>	
<b>New</b>		15.75	3.68	
<b>Corroded</b>		10.56	3.76	
Radiography				
<b>Longitudinal seam</b>		Seamless No RT		
<b>Left Circumferential seam</b>		Full UW-11(a) Type 1		

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	<a href="#">0.1849"</a>
Rated MDMT	-155 °F

UCS-66 Material Toughness Requirements	
$t_r = 100 \cdot 12 / (20,000 \cdot 1 + 0.4 \cdot 100) =$	0.0599"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.0599 \cdot 1 / (0.375 - 0.125) =$	0.2395
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155 °F
Material is exempt from impact testing at the Design MDMT of -20 °F.	

**Design thickness, (at 200 °F) Appendix 1-1**

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 100 \cdot 12 / (20,000 \cdot 1.00 + 0.40 \cdot 100) + 0.125 \\
 &= \underline{0.1849"}
 \end{aligned}$$

**% Extreme fiber elongation - UCS-79(d)**

$$\begin{aligned}
 EFE &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\
 &= (50 \cdot 0.375 / 11.8125) \cdot (1 - 11.8125 / \infty) \\
 &= 1.5873\%
 \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

## Gas Dome Shell

ASME Section VIII Division 1, 2001 Edition				
<b>Component</b>		Nozzle Pipe		
<b>Material</b>		SA-106 B Smls pipe (II-D p. 10, ln. 15)		
<b>Pipe NPS and Schedule</b>		NPS 24 Sch 20 (Std)		
<b>Attached To</b>		Gas Dome (GD)		
<b>Impact Tested</b>	<b>Normalized</b>	<b>Fine Grain Practice</b>	<b>PWHT</b>	<b>Maximize MDMT/ No MAWP</b>
No	No	No	Yes	No
		<b>Design Pressure (psi)</b>	<b>Design Temperature (°F)</b>	<b>Design MDMT (°F)</b>
<b>Internal</b>		100	200	-20
Static Liquid Head				
<b>Condition</b>		<b>P<sub>s</sub> (psi)</b>	<b>H<sub>s</sub> (in)</b>	<b>SG</b>
<b>Test horizontal</b>		0.86	23.875	1
Dimensions				
<b>Outer Diameter</b>		24"		
<b>Length</b>		18"		
<b>Pipe Nominal Thickness</b>		0.375"		
<b>Pipe Minimum Thickness<sup>1</sup></b>		0.3281"		
<b>Corrosion</b>	<b>Inner</b>	0.125"		
	<b>Outer</b>	0"		
Weight and Capacity				
		<b>Weight (lb)</b>		<b>Capacity (US gal)</b>
<b>New</b>		138.12		33.08
<b>Corroded</b>		92.58		33.8
Radiography				
<b>Longitudinal seam</b>		Seamless No RT		
<b>Left Circumferential seam</b>		Full UW-11(a) Type 1		
<b>Right Circumferential seam</b>		Full UW-11(a) Type 1		

<sup>1</sup>Pipe minimum thickness = nominal thickness times pipe tolerance factor of 0.875.

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0.125" = 0.1875"
Design thickness due to internal pressure (t)	<u>0.1951"</u>
Rated MDMT	-155 °F

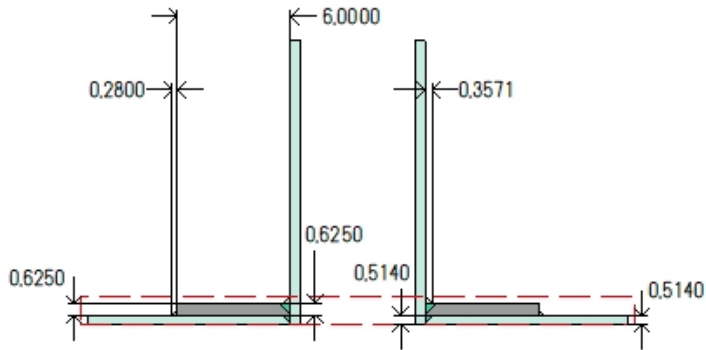
UCS-66 Material Toughness Requirements	
$t_r = 100 \cdot 12 / (17,100 \cdot 1 + 0.4 \cdot 100) =$	0.07"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.07 \cdot 1 / (0.3281 - 0.125) =$	0.3447
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155 °F
Material is exempt from impact testing at the Design MDMT of -20 °F.	

**Design thickness, (at 200 °F) Appendix 1-1**

$$\begin{aligned}
 t &= P \cdot R_o / (S \cdot E + 0.40 \cdot P) + \text{Corrosion} \\
 &= 100 \cdot 12 / (17,100 \cdot 1.00 + 0.40 \cdot 100) + 0.125 \\
 &= \underline{0.1951"}
 \end{aligned}$$

## Firetube (FF1)

### ASME Section VIII Division 1, 2001 Edition



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

#### Location and Orientation

<b>Located on</b>	Left Head
<b>Orientation</b>	0°
<b>End of nozzle to datum line</b>	262.9224"
<b>Calculated as hillside</b>	No
<b>Distance to head center, R</b>	0"
<b>Passes through a Category A joint</b>	No

#### Nozzle

<b>Access opening</b>	No
<b>Material specification</b>	SA-516 70 (II-D p. 14, In. 30) (normalized)
<b>Inside diameter, new</b>	47.75"
<b>Nominal wall thickness</b>	0.625"
<b>Corrosion allowance</b>	0.125"
<b>Projection available outside vessel, L<sub>pr</sub></b>	11.9206"
<b>Local vessel minimum thickness</b>	0.514"
<b>Liquid static head included</b>	0 psi
<b>Longitudinal joint efficiency</b>	1

#### Reinforcing Pad

<b>Material specification</b>	SA-516 70 (II-D p. 14, In. 30) (normalized)
<b>Diameter, D<sub>p</sub></b>	61"
<b>Thickness, t<sub>e</sub></b>	0.625"
<b>Is split</b>	No



Welds	
Inner fillet, Leg <sub>41</sub>	0.3571"
Outer fillet, Leg <sub>42</sub>	0.28"
Nozzle to vessel groove weld	0.514"
Pad groove weld	0.625"

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, $t_g =$	0.625"
Exemption temperature from Fig UCS-66 Curve D =	-48°F
$t_r = 100 \cdot 66.514 \cdot 1.648 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1.648 - 0.2)) =$	0.2731"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.2731 \cdot 1 / (0.514 - 0.125) =$	0.7019
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	29.8°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -48 - 29.8 - 30, -55 ] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = 100 \cdot 24 / (20,000 \cdot 1 - 0.6 \cdot 100) =$	0.1204"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.1204 \cdot 1 / (0.625 - 0.125) =$	0.2407
Stress ratio $\leq 0.35$ , MDMT per UCS-66(b)(3) =	-155°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Pad	
Governing thickness, $t_g =$	0.625"
Exemption temperature from Fig UCS-66 Curve D =	-48°F
$t_r = 100 \cdot 66.514 \cdot 1.648 / (2 \cdot 20,000 \cdot 1 + 100 \cdot (1.648 - 0.2)) =$	0.2731"
Stress ratio = $t_r \cdot E^* / (t_n - c) = 0.2731 \cdot 1 / (0.514 - 0.125) =$	0.7019
Reduction in MDMT, $T_R$ from Fig UCS-66.1 =	29.8°F
Reduction in MDMT, $T_{PWHT}$ from UCS-68(c) =	30°F
MDMT = $\max[ \text{MDMT} - T_R - T_{PWHT}, -55 ] = \max[ -48 - 29.8 - 30, -55 ] =$	-55°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 <sup>2</sup> )							UG-45 Summary (in)	
For P = 100 psi @ 200 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>5</sub>	A welds	t <sub>req</sub>	t <sub>min</sub>
<a href="#">13.1064</a>	<a href="#">14.0097</a>	<a href="#">5.5656</a>	<a href="#">0.7383</a>	--	<a href="#">7.5</a>	<a href="#">0.2058</a>	<a href="#">0.398</a>	0.625

UG-41 Weld Failure Path Analysis Summary (lb <sub>f</sub> )						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W <sub>1-1</sub>	Path 1-1 strength	Weld load W <sub>2-2</sub>	Path 2-2 strength	Weld load W <sub>3-3</sub>	Path 3-3 strength
<a href="#">153.135</a>	<a href="#">168.882</a>	<a href="#">796.211.52</a>	<a href="#">25.094</a>	<a href="#">1,424,448.71</a>	<a href="#">176.662</a>	<a href="#">706.052.21</a>

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg <sub>41</sub> )	<a href="#">0.25</a>	0.25	weld size is adequate
Pad to shell fillet (Leg <sub>42</sub> )	<a href="#">0.1945</a>	0.196	weld size is adequate

### Calculations for internal pressure 100 psi @ 200 °F

#### Parallel Limit of reinforcement per UG-40

$$\begin{aligned}
 L_R &= \text{MAX}(d, R_n + (t_n - C_n) + (t - C)) \\
 &= \text{MAX}(48, 24 + (0.625 - 0.125) + (0.514 - 0.125)) \\
 &= 48 \text{ in}
 \end{aligned}$$

#### Outer Normal Limit of reinforcement per UG-40

$$\begin{aligned}
 L_H &= \text{MIN}(2.5*(t - C), 2.5*(t_n - C_n) + t_e) \\
 &= \text{MIN}(2.5*(0.514 - 0.125), 2.5*(0.625 - 0.125) + 0.625) \\
 &= 0.9725 \text{ in}
 \end{aligned}$$

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

$$\begin{aligned}
 t_{rn} &= P*R_n / (S_n*E - 0.6*P) \\
 &= 100*24 / (20,000*1 - 0.6*100) \\
 &= 0.1204 \text{ in}
 \end{aligned}$$

#### Required thickness t<sub>r</sub> from UG-37(a)

$$\begin{aligned}
 t_r &= P*L_o*M / (2*S*E + P*(M - 0.2)) \\
 &= 100*66.514*1.648 / (2*20,000*1 + 100*(1.648 - 0.2)) \\
 &= 0.273"
 \end{aligned}$$

### Area required per UG-37(c)

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

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

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

$$f_{r3} = \text{lesser of } f_{r2} \text{ or } S_p / S_v = 1$$

$$f_{r4} = \text{lesser of } 1 \text{ or } S_p / S_v = 1$$

$$\begin{aligned} A &= d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}) \\ &= 48 \cdot 0.2731 \cdot 1 + 2 \cdot 0.5 \cdot 0.2731 \cdot 1 \cdot (1 - 1) \\ &= \underline{13.1064} \text{ in}^2 \end{aligned}$$

### Area available from FIG. UG-37.1

$$A_1 = \text{larger of the following} = \underline{5.5656} \text{ in}^2$$

$$\begin{aligned} &= d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 48 \cdot (1 \cdot 0.389 - 1 \cdot 0.2731) - 2 \cdot 0.5 \cdot (1 \cdot 0.389 - 1 \cdot 0.2731) \cdot (1 - 1) \\ &= 5.5656 \text{ in}^2 \\ &= 2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1}) \\ &= 2 \cdot (0.389 + 0.5) \cdot (1 \cdot 0.389 - 1 \cdot 0.2731) - 2 \cdot 0.5 \cdot (1 \cdot 0.389 - 1 \cdot 0.2731) \cdot (1 - 1) \\ &= 0.2062 \text{ in}^2 \end{aligned}$$

$$A_2 = \text{smaller of the following} = \underline{0.7383} \text{ in}^2$$

$$\begin{aligned} &= 5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t \\ &= 5 \cdot (0.5 - 0.1204) \cdot 1 \cdot 0.389 \\ &= 0.7383 \text{ in}^2 \\ &= 2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2} \\ &= 2 \cdot (0.5 - 0.1204) \cdot (2.5 \cdot 0.5 + 0.625) \cdot 1 \\ &= 1.4235 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} A_{41} &= \text{Leg}^2 \cdot f_{r3} \\ &= 0.357^2 \cdot 1 \\ &= \underline{0.1274} \text{ in}^2 \end{aligned}$$

(Part of the weld is outside of the limits)

$$\begin{aligned} A_{42} &= \text{Leg}^2 \cdot f_{r4} \\ &= 0.28^2 \cdot 1 \\ &= \underline{0.0784} \text{ in}^2 \end{aligned}$$

$$\begin{aligned}
A_5 &= (D_p - d - 2*t_n)*t_e*f_{r4} \\
&= (61 - 48 - 2*0.5)*0.625*1 \\
&= \underline{7.5} \text{ in}^2
\end{aligned}$$

$$\begin{aligned}
\text{Area} &= A_1 + A_2 + A_{41} + A_{42} + A_5 \\
&= 5.5656 + 0.7383 + 0.1274 + 0.0784 + 7.5 \\
&= \underline{14.0097} \text{ in}^2
\end{aligned}$$

As Area >= A the reinforcement is adequate.

### UW-16(c)(2) Weld Check

$$\begin{aligned}
\text{Inner fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t_e = 0.5 \text{ in} \\
t_{c(\min)} &= \text{lesser of } 0.25 \text{ or } 0.7*t_{\min} = \underline{0.25} \text{ in} \\
t_{c(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.3571 = 0.25 \text{ in}
\end{aligned}$$

$$\begin{aligned}
\text{Outer fillet: } t_{\min} &= \text{lesser of } 0.75 \text{ or } t_e \text{ or } t = 0.389 \text{ in} \\
t_{w(\min)} &= 0.5*t_{\min} = \underline{0.1945} \text{ in} \\
t_{w(\text{actual})} &= 0.7*\text{Leg} = 0.7*0.28 = 0.196 \text{ in}
\end{aligned}$$

### UG-45 Nozzle Neck Thickness Check

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

$$\begin{aligned}
\text{Wall thickness per UG-45(a):} & \quad t_{r1} = 0.2454 \text{ in (E =1)} \\
\text{Wall thickness per UG-45(b)(1):} & \quad t_{r2} = 0.398 \text{ in} \\
\text{Wall thickness per UG-16(b):} & \quad t_{r3} = 0.1875 \text{ in} \\
\text{Standard wall pipe per UG-45(b)(4):} & \quad t_{r4} = 0.4531 \text{ in} \\
\text{The greater of } t_{r2} \text{ or } t_{r3}: & \quad t_{r5} = 0.398 \text{ in} \\
\text{The lesser of } t_{r4} \text{ or } t_{r5}: & \quad t_{r6} = 0.398 \text{ in}
\end{aligned}$$

Required per UG-45 is the larger of  $t_{r1}$  or  $t_{r6} = \underline{0.398}$  in

Available nozzle wall thickness new,  $t_n = 0.625$  in

The nozzle neck thickness is adequate.

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

$$\begin{aligned}
\text{Groove weld in tension:} & \quad 0.74*20,000 = 14,800 \text{ psi} \\
\text{Nozzle wall in shear:} & \quad 0.7*20,000 = 14,000 \text{ psi} \\
\text{Inner fillet weld in shear:} & \quad 0.49*20,000 = 9,800 \text{ psi} \\
\text{Outer fillet weld in shear:} & \quad 0.49*20,000 = 9,800 \text{ psi} \\
\text{Upper groove weld in tension:} & \quad 0.74*20,000 = 14,800 \text{ psi}
\end{aligned}$$

### Strength of welded joints:

(1) Inner fillet weld in shear

$$(\pi / 2) * \text{Nozzle OD} * \text{Leg} * S_i = (\pi / 2) * 49 * 0.3571 * 9,800 = 269,359.24 \text{ lb}_f$$

(2) Outer fillet weld in shear

$$(\pi / 2) * \text{Pad OD} * \text{Leg} * S_o = (\pi / 2) * 61 * 0.28 * 9,800 = 262,926.17 \text{ lb}_f$$

(3) Nozzle wall in shear

$$(\pi / 2) * \text{Mean nozzle dia} * t_n * S_n = (\pi / 2) * 48.5 * 0.5 * 14,000 = 533,285.35 \text{ lb}_f$$

(4) Groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 49 * 0.389 * 14,800 = 443,126.04 \text{ lb}_f$$

(6) Upper groove weld in tension

$$(\pi / 2) * \text{Nozzle OD} * t_w * S_g = (\pi / 2) * 49 * 0.625 * 14,800 = 711,963.43 \text{ lb}_f$$

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

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * f_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (13.1064 - 5.5656 + 2 * 0.5 * 1 * (1 * 0.389 - 1 * 0.2731)) * 20,000 \\ &= \underline{153.135} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (0.7383 + 7.5 + 0.1274 + 0.0784) * 20,000 \\ &= \underline{168.882} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.7383 + 0 + 0.1274 + 0 + 2 * 0.5 * 0.389 * 1) * 20,000 \\ &= \underline{25.094} \text{ lb}_f \end{aligned}$$

$$\begin{aligned} W_{3-3} &= (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (0.7383 + 0 + 7.5 + 0.1274 + 0.0784 + 0 + 2 * 0.5 * 0.389 * 1) * 20,000 \\ &= \underline{176.662} \text{ lb}_f \end{aligned}$$

Load for path 1-1 lesser of W or  $W_{1-1} = 153,135 \text{ lb}_f$

Path 1-1 through (2) & (3) =  $262,926.17 + 533,285.35 = \underline{796,211.52} \text{ lb}_f$

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  $W_{2-2} = 25,094 \text{ lb}_f$

Path 2-2 through (1), (4), (6) =  $269,359.24 + 443,126.04 + 711,963.43 = \underline{1,424,448.71} \text{ lb}_f$

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  $W_{3-3} = 153,135 \text{ lb}_f$

Path 3-3 through (2), (4) =  $262,926.17 + 443,126.04 = \underline{706,052.21} \text{ lb}_f$

Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

**% Extreme fiber elongation - UCS-79(d)**

$$\begin{aligned} \text{EFE} &= (50 \cdot t / R_f) \cdot (1 - R_f / R_o) \\ &= (50 \cdot 0.625 / 24.1875) \cdot (1 - 24.1875 / \infty) \\ &= 1.292\% \end{aligned}$$

The extreme fiber elongation does not exceed 5%.

**Saddle #1**

ASME Section VIII Division 1, 2001 Edition		
Saddle Material	SA-36	
Saddle Construction	Web at edge of rib	
Welded to Vessel	Yes	
Saddle Allowable Stress, $S_s$	16,600 psi	
Saddle Yield Stress, $S_y$	36,000 psi	
Foundation Allowable Stress	1,658 psi	
Design Pressure	Left Saddle	Right Saddle
Operating	100 psi	
Test	133.56 psi	
Dimensions		
Right saddle distance to datum	16"	
Tangent To Tangent Length, L	244"	
Saddle separation, $L_s$	208"	
Vessel Radius, R	36"	
Tangent Distance Left, $A_l$	18"	
Tangent Distance Right, $A_r$	18"	
Saddle Height, $H_s$	48"	
Saddle Contact Angle, $\theta$	120°	
Web Plate Thickness, $t_s$	0.625"	
Base Plate Length, E	63.5"	
Base Plate Width, F	7.5"	
Base Plate Thickness, $t_b$	0.75"	
Number of Stiffening Ribs, n	4	
Largest Stiffening Rib Spacing, $d_i$	20.9583"	
Stiffening Rib Thickness, $t_w$	0.625"	
Saddle Width, b	7.5"	
Bolting		
Material	SA-307 B	
Bolt Allowable Shear	7,000 psi	
Description	1" coarse threaded	
Corrosion on root	0"	
Anchor Bolts per Saddle	2	

<b>Base coefficient of friction, <math>\mu</math></b>	0.45	
<b>Hole Diameter</b>	1.125"	
<b>Slotted Hole in Which Saddle</b>	Left Saddle	
<b>Slotted Hole Length</b>	0.5"	
<b>Weight</b>		
	<b>Operating, Corroded</b>	<b>Hydrotest</b>
<b>Weight on Left Saddle</b>	3,104 lb	23,721 lb
<b>Weight on Right Saddle</b>	3,260 lb	23,364 lb
<b>Weight of Saddle Pair</b>	784 lb	

<b>Notes</b>	
(1) Saddle calculations are based on the method presented in "Stresses in Large Cylindrical Pressure Vessels on Two Saddle Supports" by L.P. Zick.	



Stress Summary										
Load	Condition	Saddle	Bending + pressure between saddles (psi)				Bending + pressure at the saddle (psi)			
			S <sub>1</sub> (+)	allow (+)	S <sub>1</sub> (-)	allow (-)	S <sub>2</sub> (+)	allow (+)	S <sub>2</sub> (-)	allow (-)
Seismic	Operating	Right Saddle	<a href="#">7.306</a>	24,000	<a href="#">156</a>	14,011	<a href="#">7.151</a>	24,000	<a href="#">1</a>	14,011
		Left Saddle					<a href="#">7.151</a>	24,000	<a href="#">1</a>	14,011
Weight	Operating	Right Saddle	<a href="#">7.282</a>	20,000	<a href="#">132</a>	11,676	<a href="#">7.151</a>	20,000	<a href="#">1</a>	11,676
		Left Saddle					<a href="#">7.151</a>	20,000	<a href="#">1</a>	11,676
	Test	Right Saddle	<a href="#">6.986</a>	34,200	<a href="#">642</a>	13,266	<a href="#">6.350</a>	34,200	<a href="#">6</a>	13,266
		Left Saddle					<a href="#">6.350</a>	34,200	<a href="#">6</a>	13,266

Stress Summary										
Load	Condition	Saddle	Tangential shear (psi)		Circumferential stress (psi)		Stress over saddle (psi)		Splitting (psi)	
			S <sub>3</sub>	allow	S <sub>4</sub> (horns)	allow (+/-)	S <sub>5</sub>	allow	S <sub>6</sub>	allow
Seismic	Operating	Right Saddle	<a href="#">379</a>	16,000	<a href="#">-1.756</a>	30,000	<a href="#">2.214</a>	17,400	<a href="#">112</a>	11,067
		Left Saddle	<a href="#">361</a>	16,000	<a href="#">-1.672</a>	30,000	<a href="#">2.108</a>	17,400	<a href="#">106</a>	11,067
Weight	Operating	Right Saddle	<a href="#">320</a>	16,000	<a href="#">-1.482</a>	30,000	<a href="#">1.869</a>	17,400	<a href="#">94</a>	11,067
		Left Saddle	<a href="#">305</a>	16,000	<a href="#">-1.411</a>	30,000	<a href="#">1.779</a>	17,400	<a href="#">90</a>	11,067
	Test	Right Saddle	<a href="#">1.531</a>	27,360	<a href="#">-5.040</a>	34,200	<a href="#">7.452</a>	32,400	<a href="#">676</a>	32,400
		Left Saddle	<a href="#">1.554</a>	27,360	<a href="#">-5.117</a>	34,200	<a href="#">7.566</a>	32,400	<a href="#">687</a>	32,400

Seismic base shear on vessel	
Vessel is assumed to be a rigid structure.	
Method of seismic analysis	NBC Canada 2010
Location	Kelowna, British Columbia
Vertical seismic accelerations considered	No
Importance factor, $I_E$	1
Site Class	C
Spectral response acceleration value at 0.2 s, $S_a(0.2)$	0.28
Acceleration based site coefficient, $F_a$	1
Response modification factor, $R_p$	1
Seismic coefficient, $C_p$	1
Response factor, $A_r$	1
Vessel elevation, $h_x$	48"
Structure total height, $h_n$	84"
Weight on Saddle, $W_p$	6,364 lb <sub>f</sub>
Hazardous, toxic, or explosive contents	No
Equations	
$A_x = \min[ 1 + 2 \cdot h_x / h_n , 3 ]$	
$S_p = \min[ \max[ C_p \cdot A_r \cdot A_x / R_p , 0.7 ] , 4 ]$	
Lateral force $V_p$ from NBC Subsection 4.1.8.18.	
$V_p = (2 / 3) \cdot 0.3 \cdot F_a \cdot S_a(0.2) \cdot I_E \cdot S_p \cdot W_p$	
Results	
$A_x = \min[ 1 + 2 \cdot 48 / 84 , 3 ]$	2.14
$S_p = \min[ \max[ 1 \cdot 1 \cdot 2.14 / 1 , 0.7 ] , 4 ]$	2.14
$V_p = (2 / 3) \cdot 0.3 \cdot 1 \cdot 0.28 \cdot 1 \cdot 2.14 \cdot 6,364$	762.66 lb <sub>f</sub>

Saddle reactions due to weight + seismic			
$V_v$ = vertical seismic force acting on the saddle			
$V$ = horizontal seismic shear acting on the saddle (worst case if not slotted)			
Seismic longitudinal reaction, $Q_l$			
Seismic transverse reaction, $Q_t$			
Equations			
$Q_l = V \cdot H_s / L_s + V_v$			
$Q_t = V \cdot H_s / (R_o \cdot \sin(\theta / 2)) + V_v$			
$Q = W + \max[Q_t, Q_l]$			
Results			
Operating	Right Saddle	$Q_l = 762.66 \cdot 48 / 208 + 0$	176 lb <sub>f</sub>
		$Q_t = 390.68 \cdot 48 / (36 \cdot \sin(120 / 2)) + 0$	601.49 lb <sub>f</sub>
		$Q = 3,260 + \max[601.49, 176]$	3,861.49 lb <sub>f</sub>
	Left Saddle	$Q_l = 762.66 \cdot 48 / 208 + 0$	176 lb <sub>f</sub>
		$Q_t = 371.98 \cdot 48 / (36 \cdot \sin(120 / 2)) + 0$	572.71 lb <sub>f</sub>
		$Q = 3,104 + \max[572.71, 176]$	3,676.71 lb <sub>f</sub>

### Load Case 1: Seismic, Operating

#### Longitudinal stress between saddles (Seismic, Operating, right saddle loading and geometry govern)

$$S_1 = \pm 3 \cdot K_1 \cdot Q \cdot (L / 12) / (\pi \cdot R^2 \cdot t)$$

$$= 3 \cdot 0.6701 \cdot 3,861.49 \cdot (244 / 12) / (\pi \cdot 35.875^2 \cdot 0.25)$$

$$= 156 \text{ psi}$$

$$S_p = P \cdot R / (2 \cdot t)$$

$$= 100 \cdot 35.75 / (2 \cdot 0.25)$$

$$= 7,150 \text{ psi}$$

Maximum tensile stress  $S_{1t} = S_1 + S_p = 7,306$  psi  
 Maximum compressive stress (shut down)  $S_{1c} = S_1 = 156$  psi

Tensile stress is acceptable ( $\leq 1.2 \cdot S \cdot E = 24,000$  psi)  
 Compressive stress is acceptable ( $\leq 1.2 \cdot S_c = 14,011$  psi)

#### Longitudinal stress at the right saddle (Seismic, Operating)

$$L_e = 2 \cdot (\text{Left head depth}) / 3 + L + 2 \cdot (\text{Right head depth}) / 3$$

$$= 2 \cdot 13.6784 / 3 + 244 + 2 \cdot 13.6695 / 3$$

$$= 262.2319 \text{ in}$$

$$w = W_t / L_e = 6,364 / 262.2319 = 24.27 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$M_q = w \cdot (2 \cdot H \cdot A_r / 3 + A_r^2 / 2 - (R^2 - H^2) / 4)$$

$$= 24.27 * (2 * 13.6695 * 18 / 3 + 18^2 / 2 - (36^2 - 13.6695^2) / 4)$$

$$= 1,183 \text{ lb}_f\text{-in}$$

$$S_2 = \pm M_0 * K_1' / (\pi * R^2 * t)$$

$$= 1,183 * 1 / (\pi * 35.875^2 * 0.25)$$

$$= 1 \text{ psi}$$

$$S_p = P * R / (2 * t)$$

$$= 100 * 35.75 / (2 * 0.25)$$

$$= 7,150 \text{ psi}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = 7.151$  psi  
 Maximum compressive stress (shut down)  $S_{2c} = S_2 = 1$  psi

Tensile stress is acceptable ( $\leq 1.2 * S = 24,000$  psi)  
 Compressive stress is acceptable ( $\leq 1.2 * S_c = 14,011$  psi)

### Tangential shear stress in the shell (right saddle, Seismic, Operating)

$$S_3 = K_{2.3} * Q / (R * t)$$

$$= 0.8799 * 3,861.49 / (35.875 * 0.25)$$

$$= 379 \text{ psi}$$

Tangential shear stress is acceptable ( $\leq 0.8 * S = 16,000$  psi)

### Tangential shear stress in the right head (Seismic, Operating)

$$S_3 = K_{2.3} * Q / (R * t_h)$$

$$= 0.8799 * 3,861.49 / (35.875 * 0.368)$$

$$= 257 \text{ psi}$$

Tangential shear stress is acceptable ( $\leq 0.8 * S = 16,000$  psi)

### Additional stress in the head used as a stiffener (right saddle, Seismic, Operating)

$$S_{3h} = K_{2.4} * Q / (R * t_h)$$

$$= 0.4011 * 3,861.49 / (35.875 * 0.368)$$

$$= 117 \text{ psi}$$

$$S_p = P * (L * M + 0.2 * t_h) / (2 * t_h)$$

$$= 100 * (66.125 * 1 + 0.2 * 0.368) / (2 * 0.368)$$

$$= 8,994 \text{ psi}$$

Total stress in the head =  $S_{3h} + S_p = 9,112$  psi

Stress in the head is acceptable ( $\leq 1.25 * S_h = 25,000$  psi)

### Circumferential stress at the right saddle horns (Seismic, Operating)

$$S_4 = -Q / (4 * t * (b + 1.56 * \text{Sqr}(R_o * t))) - 12 * K_3 * Q * R / (L * t^2)$$

$$= -3,861.49 / (4 * 0.25 * (7.5 + 1.56 * \text{Sqr}(36 * 0.25))) - 12 * 0.0132 * 3,861.49 * 35.875 / (244 * 0.25^2)$$

$$= -1.756 \text{ psi}$$

Circumferential stress at saddle horns is acceptable ( $\leq 1.5 * S_a = 30,000$  psi)

### Ring compression in shell over right saddle (Seismic, Operating)

$$S_5 = K_5 * Q / (t * (t_s + 1.56 * \text{Sqr}(R_o * t_c)))$$

$$= 0.7603 * 3,861.49 / (0.25 * (0.625 + 1.56 * \text{Sqr}(36 * 0.25)))$$

$$= \underline{2.214} \text{ psi}$$

Ring compression in shell is acceptable ( $\leq 0.5 * S_y = 17,400$  psi)

### Saddle splitting load (right, Seismic, Operating)

Area resisting splitting force = Web area + wear plate area

$$A_e = H_{\text{eff}} * t_s + t_p * W_p$$

$$= 11.25 * 0.625 + 0 * 0$$

$$= 7.0313 \text{ in}^2$$

$$S_6 = K_8 * Q / A_e$$

$$= 0.2035 * 3,861.49 / 7.0313$$

$$= \underline{112} \text{ psi}$$

Stress in saddle is acceptable ( $\leq (2 / 3) * S_s = 11,067$  psi)

### Longitudinal stress at the left saddle (Seismic, Operating)

$$L_e = 2 * (\text{Left head depth}) / 3 + L + 2 * (\text{Right head depth}) / 3$$

$$= 2 * 13.6784 / 3 + 244 + 2 * 13.6695 / 3$$

$$= 262.2319 \text{ in}$$

$$w = W_t / L_e = 6,364 / 262.2319 = 24.27 \text{ lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w * (2 * H * A_1 / 3 + A_1^2 / 2 - (R^2 - H^2) / 4)$$

$$= 24.27 * (2 * 13.6784 * 18 / 3 + 18^2 / 2 - (36^2 - 13.6784^2) / 4)$$

$$= 1,187.1 \text{ lb}_f\text{-in}$$

$$S_2 = \pm M_q * K_1' / (\pi * R^2 * t)$$

$$= 1,187.1 * 1 / (\pi * 35.875^2 * 0.25)$$

$$= 1 \text{ psi}$$

$$S_p = P * R / (2 * t)$$

$$= 100 * 35.75 / (2 * 0.25)$$

$$= 7,150 \text{ psi}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = \underline{7.151}$  psi

Maximum compressive stress (shut down)  $S_{2c} = S_2 = \underline{1}$  psi

Tensile stress is acceptable ( $\leq 1.2 * S = 24,000$  psi)

Compressive stress is acceptable ( $\leq 1.2 * S_c = 14,011$  psi)

### Tangential shear stress in the shell (left saddle, Seismic, Operating)

$$S_3 = K_{2.3} * Q / (R * t)$$

$$= 0.8799 * 3,676.71 / (35.875 * 0.25)$$

$$= \underline{361} \text{ psi}$$

Tangential shear stress is acceptable ( $\leq 0.8 * S = 16,000$  psi)

### Tangential shear stress in the left head (Seismic, Operating)

$$\begin{aligned}
S_3 &= K_{2.3} * Q / (R * t_h) \\
&= 0.8799 * 3,676.71 / (35.875 * 0.389) \\
&= \underline{232} \text{ psi}
\end{aligned}$$

Tangential shear stress is acceptable ( $\leq 0.8 * S = 16,000$  psi)

#### **Additional stress in the head used as a stiffener (left saddle, Seismic, Operating)**

$$\begin{aligned}
S_{3h} &= K_{2.4} * Q / (R * t_h) \\
&= 0.4011 * 3,676.71 / (35.875 * 0.389) \\
&= 106 \text{ psi}
\end{aligned}$$

$$\begin{aligned}
S_p &= P * (L * M + 0.2 * t_h) / (2 * t_h) \\
&= 100 * (66.125 * 1 + 0.2 * 0.389) / (2 * 0.389) \\
&= 8,509 \text{ psi}
\end{aligned}$$

Total stress in the head =  $S_{3h} + S_p = 8,615$  psi

Stress in the head is acceptable ( $\leq 1.25 * S_h = 25,000$  psi)

#### **Circumferential stress at the left saddle horns (Seismic, Operating)**

$$\begin{aligned}
S_4 &= -Q / (4 * t * (b + 1.56 * \text{Sqr}(R_o * t))) - 12 * K_3 * Q * R / (L * t^2) \\
&= -3,676.71 / (4 * 0.25 * (7.5 + 1.56 * \text{Sqr}(36 * 0.25))) - 12 * 0.0132 * 3,676.71 * 35.875 / (244 * 0.25^2) \\
&= \underline{-1.672} \text{ psi}
\end{aligned}$$

Circumferential stress at saddle horns is acceptable ( $\leq 1.5 * S_a = 30,000$  psi)

#### **Ring compression in shell over left saddle (Seismic, Operating)**

$$\begin{aligned}
S_5 &= K_5 * Q / (t * (t_s + 1.56 * \text{Sqr}(R_o * t_c))) \\
&= 0.7603 * 3,676.71 / (0.25 * (0.625 + 1.56 * \text{Sqr}(36 * 0.25))) \\
&= \underline{2.108} \text{ psi}
\end{aligned}$$

Ring compression in shell is acceptable ( $\leq 0.5 * S_y = 17,400$  psi)

#### **Saddle splitting load (left, Seismic, Operating)**

Area resisting splitting force = Web area + wear plate area

$$\begin{aligned}
A_e &= H_{eff} * t_s + t_p * W_p \\
&= 11.25 * 0.625 + 0 * 0 \\
&= 7.0313 \text{ in}^2
\end{aligned}$$

$$\begin{aligned}
S_6 &= K_8 * Q / A_e \\
&= 0.2035 * 3,676.71 / 7.0313 \\
&= \underline{106} \text{ psi}
\end{aligned}$$

Stress in saddle is acceptable ( $\leq (2 / 3) * S_s = 11,067$  psi)

### **Load Case 2: Weight, Operating**

#### **Longitudinal stress between saddles (Weight, Operating, right saddle loading and geometry govern)**

$$\begin{aligned}
S_1 &= \pm 3 * K_1 * Q * (L / 12) / (\pi * R^2 * t) \\
&= 3 * 0.6701 * 3,260 * (244 / 12) / (\pi * 35.875^2 * 0.25)
\end{aligned}$$

= 132 psi

$$\begin{aligned} S_p &= P \cdot R / (2 \cdot t) \\ &= 100 \cdot 35.75 / (2 \cdot 0.25) \\ &= 7,150 \text{ psi} \end{aligned}$$

Maximum tensile stress  $S_{1t} = S_1 + S_p = 7,282$  psi  
Maximum compressive stress (shut down)  $S_{1c} = S_1 = 132$  psi

Tensile stress is acceptable ( $\leq S \cdot E = 20,000$  psi)  
Compressive stress is acceptable ( $\leq S_c = 11,676$  psi)

### Longitudinal stress at the right saddle (Weight, Operating)

$$\begin{aligned} L_e &= 2 \cdot (\text{Left head depth}) / 3 + L + 2 \cdot (\text{Right head depth}) / 3 \\ &= 2 \cdot 13.6784 / 3 + 244 + 2 \cdot 13.6695 / 3 \\ &= 262.2319 \text{ in} \end{aligned}$$

$$w = W_t / L_e = 6,364 / 262.2319 = 24.27 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$\begin{aligned} M_q &= w \cdot (2 \cdot H \cdot A_r / 3 + A_r^2 / 2 - (R^2 - H^2) / 4) \\ &= 24.27 \cdot (2 \cdot 13.6695 \cdot 18 / 3 + 18^2 / 2 - (36^2 - 13.6695^2) / 4) \\ &= 1,183 \text{ lb}_f\text{-in} \end{aligned}$$

$$\begin{aligned} S_2 &= \pm M_q \cdot K_1' / (\pi \cdot R^2 \cdot t) \\ &= 1,183 \cdot 1 / (\pi \cdot 35.875^2 \cdot 0.25) \\ &= 1 \text{ psi} \end{aligned}$$

$$\begin{aligned} S_p &= P \cdot R / (2 \cdot t) \\ &= 100 \cdot 35.75 / (2 \cdot 0.25) \\ &= 7,150 \text{ psi} \end{aligned}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = 7,151$  psi  
Maximum compressive stress (shut down)  $S_{2c} = S_2 = 1$  psi

Tensile stress is acceptable ( $\leq S = 20,000$  psi)  
Compressive stress is acceptable ( $\leq S_c = 11,676$  psi)

### Tangential shear stress in the shell (right saddle, Weight, Operating)

$$\begin{aligned} S_3 &= K_{2.3} \cdot Q / (R \cdot t) \\ &= 0.8799 \cdot 3,260 / (35.875 \cdot 0.25) \\ &= 320 \text{ psi} \end{aligned}$$

Tangential shear stress is acceptable ( $\leq 0.8 \cdot S = 16,000$  psi)

### Tangential shear stress in the right head (Weight, Operating)

$$\begin{aligned} S_3 &= K_{2.3} \cdot Q / (R \cdot t_h) \\ &= 0.8799 \cdot 3,260 / (35.875 \cdot 0.368) \\ &= 217 \text{ psi} \end{aligned}$$

Tangential shear stress is acceptable ( $\leq 0.8 \cdot S = 16,000$  psi)

### Additional stress in the head used as a stiffener (right saddle, Weight, Operating)

$$\begin{aligned}
S_{3h} &= K_{2.4} * Q / (R * t_h) \\
&= 0.4011 * 3,260 / (35.875 * 0.368) \\
&= 99 \text{ psi}
\end{aligned}$$

$$\begin{aligned}
S_p &= P * (L * M + 0.2 * t_h) / (2 * t_h) \\
&= 100 * (66.125 * 1 + 0.2 * 0.368) / (2 * 0.368) \\
&= 8,994 \text{ psi}
\end{aligned}$$

Total stress in the head =  $S_{3h} + S_p = 9,093$  psi

Stress in the head is acceptable ( $\leq 1.25 * S_h = 25,000$  psi)

### Circumferential stress at the right saddle horns (Weight, Operating)

$$\begin{aligned}
S_4 &= -Q / (4 * t * (b + 1.56 * \text{Sqr}(R_o * t))) - 12 * K_3 * Q * R / (L * t^2) \\
&= -3,260 / (4 * 0.25 * (7.5 + 1.56 * \text{Sqr}(36 * 0.25))) - 12 * 0.0132 * 3,260 * 35.875 / (244 * 0.25^2) \\
&= -1.482 \text{ psi}
\end{aligned}$$

Circumferential stress at saddle horns is acceptable ( $\leq 1.5 * S_a = 30,000$  psi)

### Ring compression in shell over right saddle (Weight, Operating)

$$\begin{aligned}
S_5 &= K_5 * Q / (t * (t_s + 1.56 * \text{Sqr}(R_o * t_c))) \\
&= 0.7603 * 3,260 / (0.25 * (0.625 + 1.56 * \text{Sqr}(36 * 0.25))) \\
&= 1.869 \text{ psi}
\end{aligned}$$

Ring compression in shell is acceptable ( $\leq 0.5 * S_y = 17,400$  psi)

### Saddle splitting load (right, Weight, Operating)

Area resisting splitting force = Web area + wear plate area

$$\begin{aligned}
A_e &= H_{eff} * t_s + t_p * W_p \\
&= 11.25 * 0.625 + 0 * 0 \\
&= 7.0313 \text{ in}^2
\end{aligned}$$

$$\begin{aligned}
S_6 &= K_8 * Q / A_e \\
&= 0.2035 * 3,260 / 7.0313 \\
&= 94 \text{ psi}
\end{aligned}$$

Stress in saddle is acceptable ( $\leq (2 / 3) * S_s = 11,067$  psi)

### Longitudinal stress at the left saddle (Weight, Operating)

$$\begin{aligned}
L_e &= 2 * (\text{Left head depth}) / 3 + L + 2 * (\text{Right head depth}) / 3 \\
&= 2 * 13.6784 / 3 + 244 + 2 * 13.6695 / 3 \\
&= 262.2319 \text{ in}
\end{aligned}$$

$$w = W_t / L_e = 6,364 / 262.2319 = 24.27 \text{ lb}_f/\text{in}$$

Bending moment at the left saddle:

$$\begin{aligned}
M_q &= w * (2 * H * A_1 / 3 + A_1^2 / 2 - (R^2 - H^2) / 4) \\
&= 24.27 * (2 * 13.6784 * 18 / 3 + 18^2 / 2 - (36^2 - 13.6784^2) / 4) \\
&= 1,187.1 \text{ lb}_f\text{-in}
\end{aligned}$$



$$\begin{aligned}
S_2 &= \pm M_q * K_1' / (\pi * R^2 * t) \\
&= 1,187.1 * 1 / (\pi * 35.875^2 * 0.25) \\
&= 1 \text{ psi}
\end{aligned}$$

$$\begin{aligned}
S_p &= P * R / (2 * t) \\
&= 100 * 35.75 / (2 * 0.25) \\
&= 7,150 \text{ psi}
\end{aligned}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = 7.151$  psi  
Maximum compressive stress (shut down)  $S_{2c} = S_2 = 1$  psi

Tensile stress is acceptable ( $\leq S = 20,000$  psi)  
Compressive stress is acceptable ( $\leq S_c = 11,676$  psi)

### Tangential shear stress in the shell (left saddle, Weight, Operating)

$$\begin{aligned}
S_3 &= K_{2.3} * Q / (R * t) \\
&= 0.8799 * 3,104 / (35.875 * 0.25) \\
&= 305 \text{ psi}
\end{aligned}$$

Tangential shear stress is acceptable ( $\leq 0.8 * S = 16,000$  psi)

### Tangential shear stress in the left head (Weight, Operating)

$$\begin{aligned}
S_3 &= K_{2.3} * Q / (R * t_h) \\
&= 0.8799 * 3,104 / (35.875 * 0.389) \\
&= 196 \text{ psi}
\end{aligned}$$

Tangential shear stress is acceptable ( $\leq 0.8 * S = 16,000$  psi)

### Additional stress in the head used as a stiffener (left saddle, Weight, Operating)

$$\begin{aligned}
S_{3h} &= K_{2.4} * Q / (R * t_h) \\
&= 0.4011 * 3,104 / (35.875 * 0.389) \\
&= 89 \text{ psi}
\end{aligned}$$

$$\begin{aligned}
S_p &= P * (L * M + 0.2 * t_h) / (2 * t_h) \\
&= 100 * (66.125 * 1 + 0.2 * 0.389) / (2 * 0.389) \\
&= 8,509 \text{ psi}
\end{aligned}$$

Total stress in the head =  $S_{3h} + S_p = 8,599$  psi

Stress in the head is acceptable ( $\leq 1.25 * S_h = 25,000$  psi)

### Circumferential stress at the left saddle horns (Weight, Operating)

$$\begin{aligned}
S_4 &= -Q / (4 * t * (b + 1.56 * \text{Sqr}(R_o * t))) - 12 * K_3 * Q * R / (L * t^2) \\
&= -3,104 / (4 * 0.25 * (7.5 + 1.56 * \text{Sqr}(36 * 0.25))) - 12 * 0.0132 * 3,104 * 35.875 / (244 * 0.25^2) \\
&= -1.411 \text{ psi}
\end{aligned}$$

Circumferential stress at saddle horns is acceptable ( $\leq 1.5 * S_a = 30,000$  psi)

### Ring compression in shell over left saddle (Weight, Operating)

$$\begin{aligned}
S_5 &= K_5 * Q / (t * (t_s + 1.56 * \text{Sqr}(R_o * t_c))) \\
&= 0.7603 * 3,104 / (0.25 * (0.625 + 1.56 * \text{Sqr}(36 * 0.25))) \\
&= 1.779 \text{ psi}
\end{aligned}$$

Ring compression in shell is acceptable ( $\leq 0.5 \cdot S_y = 17,400$  psi)

### Saddle splitting load (left, Weight, Operating)

Area resisting splitting force = Web area + wear plate area

$$\begin{aligned} A_e &= H_{\text{eff}} \cdot t_s + t_p \cdot W_p \\ &= 11.25 \cdot 0.625 + 0 \cdot 0 \\ &= 7.0313 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} S_6 &= K_8 \cdot Q / A_e \\ &= 0.2035 \cdot 3,104 / 7.0313 \\ &= 90 \text{ psi} \end{aligned}$$

Stress in saddle is acceptable ( $\leq (2 / 3) \cdot S_s = 11,067$  psi)

### Load Case 3: Weight, Test

Longitudinal stress between saddles (Weight, Test, left saddle loading and geometry govern)

$$\begin{aligned} S_1 &= \pm 3 \cdot K_1 \cdot Q \cdot (L / 12) / (\pi \cdot R^2 \cdot t) \\ &= 3 \cdot 0.67 \cdot 23,721 \cdot (244 / 12) / (\pi \cdot 35.8125^2 \cdot 0.375) \\ &= 642 \text{ psi} \end{aligned}$$

$$\begin{aligned} S_p &= P \cdot R / (2 \cdot t) \\ &= 133.56 \cdot 35.625 / (2 \cdot 0.375) \\ &= 6,344 \text{ psi} \end{aligned}$$

Maximum tensile stress  $S_{1t} = S_1 + S_p = 6,986$  psi

Maximum compressive stress (shut down)  $S_{1c} = S_1 = 642$  psi

Tensile stress is acceptable ( $\leq 0.9 \cdot S_y \cdot E = 34,200$  psi)

Compressive stress is acceptable ( $\leq S_c = 13,266$  psi)

### Longitudinal stress at the right saddle (Weight, Test)

$$\begin{aligned} L_e &= 2 \cdot (\text{Left head depth}) / 3 + L + 2 \cdot (\text{Right head depth}) / 3 \\ &= 2 \cdot 13.6784 / 3 + 244 + 2 \cdot 13.6695 / 3 \\ &= 262.2319 \text{ in} \end{aligned}$$

$$w = W_t / L_e = 47,085 / 262.2319 = 179.55 \text{ lb}_f/\text{in}$$

Bending moment at the right saddle:

$$\begin{aligned} M_q &= w \cdot (2 \cdot H \cdot A_r / 3 + A_r^2 / 2 - (R^2 - H^2) / 4) \\ &= 179.55 \cdot (2 \cdot 13.6695 \cdot 18 / 3 + 18^2 / 2 - (36^2 - 13.6695^2) / 4) \\ &= 8,752.9 \text{ lb}_f\text{-in} \end{aligned}$$

$$\begin{aligned} S_2 &= \pm M_q \cdot K_1' / (\pi \cdot R^2 \cdot t) \\ &= 8,752.9 \cdot 1 / (\pi \cdot 35.8125^2 \cdot 0.375) \\ &= 6 \text{ psi} \end{aligned}$$

$$\begin{aligned} S_p &= P \cdot R / (2 \cdot t) \\ &= 133.56 \cdot 35.625 / (2 \cdot 0.375) \\ &= 6,344 \text{ psi} \end{aligned}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = 6.350$  psi  
Maximum compressive stress (shut down)  $S_{2c} = S_2 = 6$  psi

Tensile stress is acceptable ( $\leq 0.9 \cdot S_y = 34,200$  psi)  
Compressive stress is acceptable ( $\leq S_c = 13,266$  psi)

#### **Tangential shear stress in the shell (right saddle, Weight, Test)**

$$\begin{aligned} S_3 &= K_{2.3} \cdot Q / (R \cdot t) \\ &= 0.8799 \cdot 23,364 / (35.8125 \cdot 0.375) \\ &= 1.531 \text{ psi} \end{aligned}$$

Tangential shear stress is acceptable ( $\leq 0.8 \cdot (0.9 \cdot S_y) = 27,360$  psi)

#### **Tangential shear stress in the right head (Weight, Test)**

$$\begin{aligned} S_3 &= K_{2.3} \cdot Q / (R \cdot t_h) \\ &= 0.8799 \cdot 23,364 / (35.8125 \cdot 0.493) \\ &= 1.164 \text{ psi} \end{aligned}$$

Tangential shear stress is acceptable ( $\leq 0.8 \cdot (0.9 \cdot S_y) = 27,360$  psi)

#### **Additional stress in the head used as a stiffener (right saddle, Weight, Test)**

$$\begin{aligned} S_{3h} &= K_{2.4} \cdot Q / (R \cdot t_h) \\ &= 0.4011 \cdot 23,364 / (35.8125 \cdot 0.493) \\ &= 531 \text{ psi} \end{aligned}$$

$$\begin{aligned} S_p &= P \cdot (L \cdot M + 0.2 \cdot t_h) / (2 \cdot t_h) \\ &= 133.56 \cdot (66 \cdot 1 + 0.2 \cdot 0.493) / (2 \cdot 0.493) \\ &= 8,953 \text{ psi} \end{aligned}$$

Total stress in the head =  $S_{3h} + S_p = 9,484$  psi

Stress in the head is acceptable ( $\leq 0.9 \cdot S_y = 34,200$  psi)

#### **Circumferential stress at the right saddle horns (Weight, Test)**

$$\begin{aligned} S_4 &= -Q / (4 \cdot t \cdot (b + 1.56 \cdot \text{Sqr}(R_o \cdot t))) - 12 \cdot K_3 \cdot Q \cdot R / (L \cdot t^2) \\ &= -23,364 / (4 \cdot 0.375 \cdot (7.5 + 1.56 \cdot \text{Sqr}(36 \cdot 0.375))) - 12 \cdot 0.0132 \cdot 23,364 \cdot 35.8125 / (244 \cdot 0.375^2) \\ &= -5.040 \text{ psi} \end{aligned}$$

Circumferential stress at saddle horns is acceptable ( $\leq 0.9 \cdot S_y = 34,200$  psi)

#### **Ring compression in shell over right saddle (Weight, Test)**

$$\begin{aligned} S_5 &= K_5 \cdot Q / (t \cdot (t_s + 1.56 \cdot \text{Sqr}(R_o \cdot t_c))) \\ &= 0.7603 \cdot 23,364 / (0.375 \cdot (0.625 + 1.56 \cdot \text{Sqr}(36 \cdot 0.375))) \\ &= 7.452 \text{ psi} \end{aligned}$$

Ring compression in shell is acceptable ( $\leq 0.9 \cdot S_y = 32,400$  psi)

#### **Saddle splitting load (right, Weight, Test)**

Area resisting splitting force = Web area + wear plate area

$$A_e = H_{\text{eff}} \cdot t_s + t_p \cdot W_p$$

$$= 11.25 \cdot 0.625 + 0 \cdot 0$$

$$= 7.0313 \text{ in}^2$$

$$S_6 = K_8 \cdot Q / A_e$$

$$= 0.2035 \cdot 23,364 / 7.0313$$

$$= 676 \text{ psi}$$

Stress in saddle is acceptable ( $\leq 0.9 \cdot S_y = 32,400 \text{ psi}$ )

### Longitudinal stress at the left saddle (Weight, Test)

$$L_e = 2 \cdot (\text{Left head depth}) / 3 + L + 2 \cdot (\text{Right head depth}) / 3$$

$$= 2 \cdot 13.6784 / 3 + 244 + 2 \cdot 13.6695 / 3$$

$$= 262.2319 \text{ in}$$

$$w = W_t / L_e = 47,085 / 262.2319 = 179.55 \text{ lb}_f/\text{in}$$

Bending moment at the left saddle:

$$M_q = w \cdot (2 \cdot H \cdot A_1 / 3 + A_1^2 / 2 - (R^2 - H^2) / 4)$$

$$= 179.55 \cdot (2 \cdot 13.6784 \cdot 18 / 3 + 18^2 / 2 - (36^2 - 13.6784^2) / 4)$$

$$= 8,782.9 \text{ lb}_f\text{-in}$$

$$S_2 = \pm M_q \cdot K_1' / (\pi \cdot R^2 \cdot t)$$

$$= 8,782.9 \cdot 1 / (\pi \cdot 35.8125^2 \cdot 0.375)$$

$$= 6 \text{ psi}$$

$$S_p = P \cdot R / (2 \cdot t)$$

$$= 133.56 \cdot 35.625 / (2 \cdot 0.375)$$

$$= 6,344 \text{ psi}$$

Maximum tensile stress  $S_{2t} = S_2 + S_p = 6.350 \text{ psi}$   
 Maximum compressive stress (shut down)  $S_{2c} = S_2 = 6 \text{ psi}$

Tensile stress is acceptable ( $\leq 0.9 \cdot S_y = 34,200 \text{ psi}$ )  
 Compressive stress is acceptable ( $\leq S_c = 13,266 \text{ psi}$ )

### Tangential shear stress in the shell (left saddle, Weight, Test)

$$S_3 = K_{2.3} \cdot Q / (R \cdot t)$$

$$= 0.8799 \cdot 23,721 / (35.8125 \cdot 0.375)$$

$$= 1.554 \text{ psi}$$

Tangential shear stress is acceptable ( $\leq 0.8 \cdot (0.9 \cdot S_y) = 27,360 \text{ psi}$ )

### Tangential shear stress in the left head (Weight, Test)

$$S_3 = K_{2.3} \cdot Q / (R \cdot t_h)$$

$$= 0.8799 \cdot 23,721 / (35.8125 \cdot 0.514)$$

$$= 1.134 \text{ psi}$$

Tangential shear stress is acceptable ( $\leq 0.8 \cdot (0.9 \cdot S_y) = 27,360 \text{ psi}$ )

### Additional stress in the head used as a stiffener (left saddle, Weight, Test)

$$S_{3h} = K_{2.4} \cdot Q / (R \cdot t_h)$$

$$= 0.4011 \cdot 23,721 / (35.8125 \cdot 0.514)$$

= 517 psi

$$\begin{aligned} S_p &= P(LM + 0.2t_h) / (2t_h) \\ &= 133.56(66 \cdot 1 + 0.2 \cdot 0.514) / (2 \cdot 0.514) \\ &= 8,588 \text{ psi} \end{aligned}$$

Total stress in the head =  $S_{3h} + S_p = 9,105$  psi

Stress in the head is acceptable ( $\leq 0.9 \cdot S_y = 34,200$  psi)

#### **Circumferential stress at the left saddle horns (Weight, Test)**

$$\begin{aligned} S_4 &= -Q / (4t(b + 1.56 \cdot \text{Sqr}(R_o \cdot t))) - 12K_3 \cdot Q \cdot R / (L \cdot t^2) \\ &= -23,721 / (4 \cdot 0.375(7.5 + 1.56 \cdot \text{Sqr}(36 \cdot 0.375))) - 12 \cdot 0.0132 \cdot 23,721 \cdot 35.8125 / (244 \cdot 0.375^2) \\ &= -5.117 \text{ psi} \end{aligned}$$

Circumferential stress at saddle horns is acceptable ( $\leq 0.9 \cdot S_y = 34,200$  psi)

#### **Ring compression in shell over left saddle (Weight, Test)**

$$\begin{aligned} S_5 &= K_5 \cdot Q / (t(t_s + 1.56 \cdot \text{Sqr}(R_o \cdot t_c))) \\ &= 0.7603 \cdot 23,721 / (0.375(0.625 + 1.56 \cdot \text{Sqr}(36 \cdot 0.375))) \\ &= 7.566 \text{ psi} \end{aligned}$$

Ring compression in shell is acceptable ( $\leq 0.9 \cdot S_y = 32,400$  psi)

#### **Saddle splitting load (left, Weight, Test)**

Area resisting splitting force = Web area + wear plate area

$$\begin{aligned} A_e &= H_{\text{eff}} \cdot t_s + t_p \cdot W_p \\ &= 11.25 \cdot 0.625 + 0 \cdot 0 \\ &= 7.0313 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} S_6 &= K_8 \cdot Q / A_e \\ &= 0.2035 \cdot 23,721 / 7.0313 \\ &= 687 \text{ psi} \end{aligned}$$

Stress in saddle is acceptable ( $\leq 0.9 \cdot S_y = 32,400$  psi)

#### **Shear stress in anchor bolting, one end slotted**

Maximum seismic or wind base shear = 762.66 lb<sub>f</sub>

Thermal expansion base shear =  $W \cdot \mu = 3,496 \cdot 0.45 = 1,573.2$  lb<sub>f</sub>  
Corroded root area for a 1" coarse threaded bolt = 0.551 in<sup>2</sup> ( 2 per saddle )

Bolt shear stress =  $1,573.2 / (0.551 \cdot 1 \cdot 2) = 1,428$  psi

Anchor bolt stress is acceptable ( $\leq 7,000$  psi)

#### **Shear stress in anchor bolting, transverse**

Maximum seismic or wind base shear = 762.66 lb<sub>f</sub>  
Corroded root area for a 1" coarse threaded bolt = 0.551 in<sup>2</sup> ( 2 per saddle )

Bolt shear stress =  $762.66 / (0.551 \cdot 2 \cdot 2) = 346$  psi

Anchor bolt stress is acceptable ( $\leq 7,000$  psi)

### Web plate buckling check (Escoe pg 251)

Allowable compressive stress  $S_c$  is the lesser of 16,600 or 29,835 psi: (16,600)

$$\begin{aligned} S_c &= K_f \pi^2 E / (12(1 - 0.3^2)(d_i / t_s)^2) \\ &= 1.28 \pi^2 29E+06 / (12(1 - 0.3^2)(20.9583 / 0.625)^2) \\ &= 29,835 \text{ psi} \end{aligned}$$

Allowable compressive load on the saddle

$$\begin{aligned} b_e &= d_i t_s / (d_i t_s + 2 t_w (b - 1)) \\ &= 20.9583 * 0.625 / (20.9583 * 0.625 + 2 * 0.625 * (7.5 - 1)) \\ &= 0.6172 \end{aligned}$$

$$\begin{aligned} F_b &= n(A_s + 2 b_e t_s) S_c \\ &= 4(4.2969 + 2 * 0.6172 * 0.625) * 16,600 \\ &= 336,538.27 \text{ lb}_f \end{aligned}$$

Saddle loading of 24,113  $\text{lb}_f$  is  $\leq F_b$ ; satisfactory.

### Primary bending + axial stress in the saddle due to end loads (assumes one saddle slotted)

$$\begin{aligned} \sigma_b &= V(H_s - x_o) y / I + Q / A \\ &= 762.66(48 - 29.7718) * 5.3125 / 189.11 + 3,861.49 / 56.1586 \\ &= 459 \text{ psi} \end{aligned}$$

The primary bending + axial stress in the saddle  $\leq S_s = 16,600$  psi; satisfactory.

### Secondary bending + axial stress in the saddle due to end loads (includes thermal expansion, assumes one saddle slotted)

$$\begin{aligned} \sigma_b &= V(H_s - x_o) y / I + Q / A \\ &= 2,335.86(48 - 29.7718) * 5.3125 / 189.11 + 3,676.71 / 56.1586 \\ &= 1,262 \text{ psi} \end{aligned}$$

The secondary bending + axial stress in the saddle  $\leq 2 S_y = 72,000$  psi; satisfactory.

### Saddle base plate thickness check (Roark sixth edition, Table 26, case 7a)

where  $a = 20.9583$ ,  $b = 6.875$  in

$$\begin{aligned} t_b &= (\beta_1 q b^2 / (1.5 S_a))^{0.5} \\ &= (3 * 51 * 6.875^2 / (1.5 * 16,600))^{0.5} \\ &= 0.537 \text{ in} \end{aligned}$$

The base plate thickness of 0.75 in is adequate.

### Foundation bearing check

$$\begin{aligned} S_f &= Q_{\max} / (F * E) \\ &= 24,113 / (7.5 * 63.5) \\ &= 51 \text{ psi} \end{aligned}$$

Concrete bearing stress  $\leq 1,658$  psi ; satisfactory.

### Slotted hole length (Process Industry Practices VEFV1100)

$$\begin{aligned}\Delta_t &= \max[ \text{abs}( T_{\text{amb}} - T_s ), \text{abs}( T_{\text{amb}} - \text{MDMT} ) ] \\ &= \max[ \text{abs}( 70 - 200 ), \text{abs}( 70 - -20 ) ] \\ &= 130^\circ\text{F}\end{aligned}$$

$$\begin{aligned}S_L &= 2 * L_s * \alpha * \Delta_t \\ &= 2 * 208 * 6.7\text{E-}06 * 130 \\ &= 0.3623\text{"}\end{aligned}$$

Actual slot length is greater than or equal to the minimum ( $0.5" \geq 0.3623"$ ); satisfactory.

## Seismic Code

Seismic calculations are reported in the saddle report.