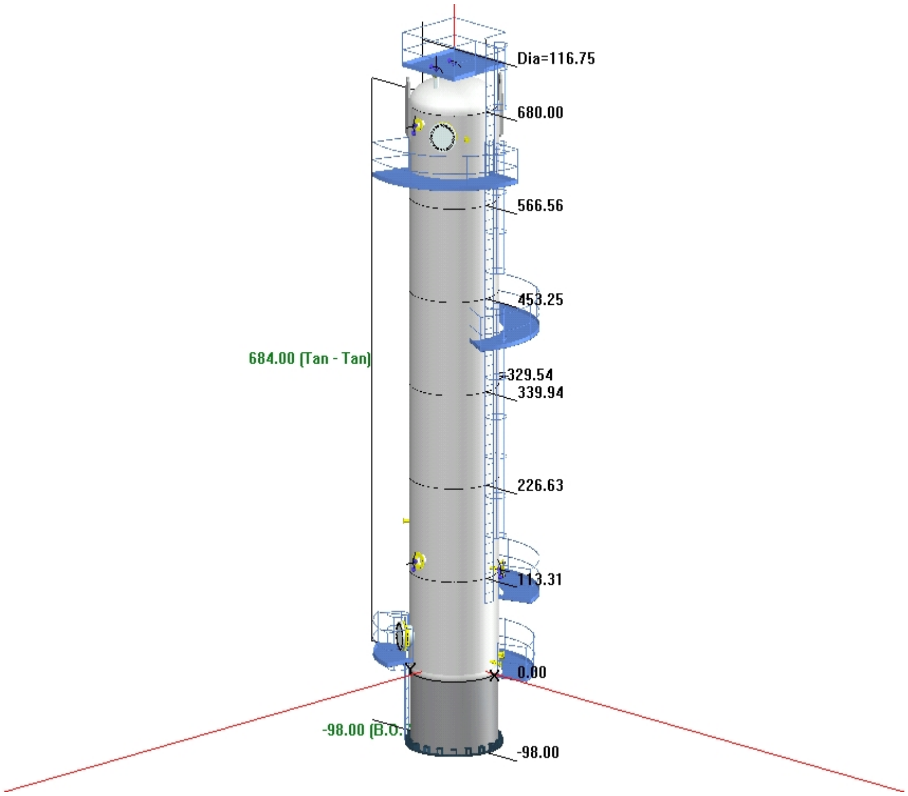
Your Company Name Here

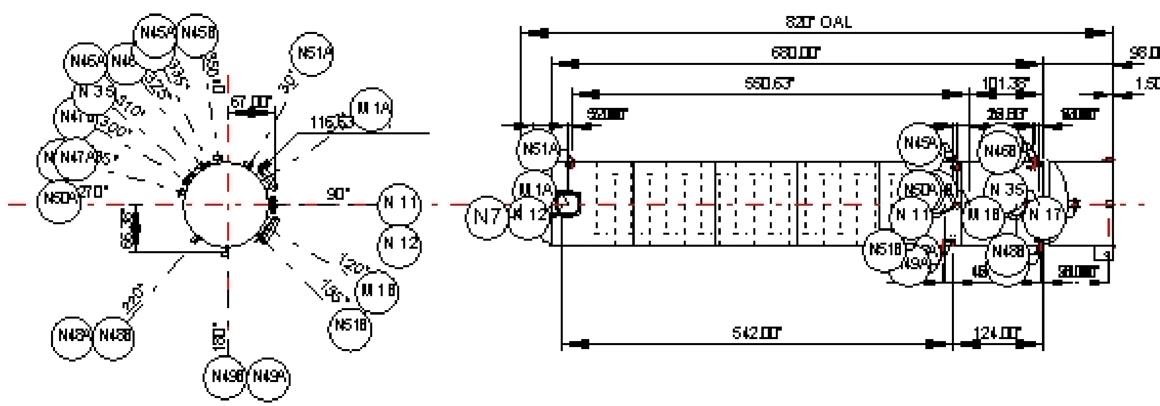
Your Address Here



COMPRESS Pressure Vessel Calculations Rev 1

Contact: Engineer's Name Here
Item: Example Amine Absorber
Drawing No: 12345-1 Rev 3
Customer:
Size: 114"ID x 57'-0" Tan/Tan x 400 psig DP @ -20/400 F.
Date: Monday, February 5, 2007

Vessel is 114"ID x 57'-0" Tan/Tan x 400 psig DP @ -20/400 F.
LIFT LUG CALCULATION INCLUDED



DESIGN DATA

Design Pressure	400.0 psi
Vacuum Pressure	0.0 psi
Test Pressure (Shop)	539.4 psi
Test Pressure (Field)	539.4 psi
Design Temperature	400.0 °F
MDMT	-20.0 °F
Corrosion Allowance	0.0000"
Radiography	RT1
PWHT	None

Estimated Weights

Dry: 182,003 lb Wet 182,003 lb

Materials

Cylinder(s): SA-516 70
Head(s): SA-516 70
Transition(s):
Support: SA-516 70

MARK	NOZZLE	SIZE&SCH	FLANGE	MARK	NOZZLE	SIZE&SCH	FLANGE
N49A	N49A NPS 2 RF		2" WN A350 LF	N47B	N47B NPS 2 R		2" WN A350 LF
N45A	N45A NPS 2 R		2" WN A350 LF	N46B	N46B NPS 3 RF		3" WN A350 LF
N51B	N51B NPS 2 RF		2" WN A350 LF	N45B	N45B NPS 2 R		2" WN A350 LF
N11	N11 NPS 12 R	12" X Heavy	12" WN A105 C	N35	N35 NPS 2 RF		2" WN A350 LF
M1A	M1A NPS 24 R		24" WN A105 C	N18	N18 NPS 2 RF		2" WN A350 LF
N51A	N51A NPS 2 RF		2" WN A350 LF	N47A	N47A NPS 2 R		2" WN A350 LF
N12	N12 NPS 8 RF	8" Sch 80 (XS)	8" WN A105 C	N46A	N46A NPS 3 RF		3" WN A350 LF
N7	N7 NPS 12 RF	12" X Heavy	12" WN A105 C	N48A	N48A NPS 2 RF		2" WN A350 LF
N6	N6 NPS 6 RFWN	6" Sch 80 (XS)	6" WN A105 C	N50A	N50A NPS 3 RF		3" WN A350 LF

NOZZLE SCHEDULE

REV	DATE	DESCRIPT
0	11/08/20	FOR APP

REVISIONS

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

DWN BY:
CHK BY:
145685-1

General Arran

DWG NO. DATE: Rev 0

Amine Absorber.CW6

MARK	NOZZLE	SIZE & SCH	FLANGE
N17	N17 NPS 8 RF	8" Sch 80 (XS)	8" WN A105 Cl
N438	N438 NPS 2 RF		2" WN A350 LF
M18	M18 NPS 24 R		24" WN A105 C
N508	N508 NPS 3 RF		3" WN A350 LF
N498	N498 NPS 2 RF		2" WN A350 LF

NOZZLE SCHEDULE

REV	DATE	DESCRIPT
0	11/06/20	FOR APP

REVISIONS

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

DWN BY:
CHK BY:
145685-1

General Arran
DWG NO.
DATE:
Rev
0

Deficiencies Summary

Deficiencies for N12 NPS 8 RFWN S/XH(0.5"wt) Amine Feed Nozzle (N12)
UG-45(c): The total combined shear stress (12636psi) is greater than the allowable ($0.7*S_n$ = 0.7*17100 = 11970 psi)

Deficiencies for N17 NPS 8 RFWN S/XH(0.5"wt) Amine Outlet Nozzle (N17)
UG-45(c): The total combined shear stress (12636psi) is greater than the allowable ($0.7*S_n$ = 0.7*17100 = 11970 psi)

Deficiencies for N45A NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle (N45A)
UG-45(c): The total combined shear stress (30360psi) is greater than the allowable ($0.7*S_n$ = 0.7*20000 = 14000 psi)

Deficiencies for N6 NPS 6 RFWN(0.432"wt) S/80 Purge Nozzle (N6)
UG-45(c): The total combined shear stress (17941psi) is greater than the allowable ($0.7*S_n$ = 0.7*17100 = 11970 psi)

Deficiencies for Tailing Lug
The local stresses for the lug have not been calculated.
The base ring section and stiffener beam are over stressed from the tail lug loading.

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
M1A	M1A NPS 24 RFWN (1.25"wt. 23.25"ID) Manway	23.25 IDx1.25	SA-516 70	Yes	Yes	No	SA-516 70	Yes	Yes	No	WN A105 Class 300
M1B	M1B NPS 24 RFWN (1.25"wt. 23.25"ID) Manway	23.25 IDx1.25	SA-516 70	Yes	Yes	No	SA-516 70	Yes	Yes	No	WN A105 Class 300
N11	N11 NPS 12 RFWN S/XH(0.5"wt) Vapor Feed Nozzle	12" X Heavy	SA-106 B Smls pipe	No	No	No	SA-516 70	Yes	Yes	No	WN A105 Class 300
N12	N12 NPS 8 RFWN S/XH(0.5"wt) Amine Feed Nozzle	8" Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	SA-516 70	Yes	Yes	No	WN A105 Class 300
N17	N17 NPS 8 RFWN S/XH(0.5"wt) Amine Outlet Nozzle	8" Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	SA-516 70	Yes	Yes	No	WN A105 Class 300
N18	N18 NPS 2 RFLWN(0.655"wt) HC liquid Outlet Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N35	N35 NPS 2 RFLWN(0.655"wt) Steam Out Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N45A	N45A NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N45B	N45B NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N46A	N46A NPS 3 RFLWN(0.810"wt) LT-17 Nozzle	3.00 IDx0.81	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N46B	N46B NPS 3 RFLWN(0.810"wt) LT-17 Nozzle	3.00 IDx0.81	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N47A	N47A NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N47B	N47B NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N48A	N48A NPS 2 RFLWN(0.655"wt) LG-105 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N48B	N48B NPS 2 RFLWN(0.655"wt) LG-105 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	Yes	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N49A	N49A NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N49B	N49B NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N50A	N50A NPS 3 RFLWN(0.81"wt) LT-16 Nozzle	3.00 IDx0.81	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N50B	N50B NPS 3 RFLWN(0.81"wt) LT-16 Nozzle	3.00 IDx0.81	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N51A	N51A NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1	No	No	No	N/A	N/A	N/A	N/A	LWN A350 LF2 Cl.1 Class 300
N51B				No	No	No	N/A	N/A	N/A	N/A	

	N51B NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle	2.00 IDx0.65	SA-350 LF2 Cl 1								LWN A350 LF2 Cl.1 Class 300
N6	N6 NPS 6 RFWN(0.432"wt) S/80 Purge Nozzle	6" Sch 80 (XS)	SA-106 B Smls pipe	No	No	No	SA-516 70	Yes	Yes	No	WN A105 Class 300
N7	N7 NPS 12 RFWN(0.500"wt) S/XH Vapor Outlet Nozzle	12" X Heavy	SA-106 B Smls pipe	No	No	No	SA-516 70	Yes	Yes	No	WN A105 Class 300

Nozzle Summary

Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
M1A	25.75	1.2500	0.2457	Yes	Yes	1.2500	1.2074		8.0000	1.2500	0.0000	100.0
M1B	25.75	1.2500	0.2457	Yes	Yes	1.2500	1.2074		8.0000	1.2500	0.0000	100.0
N11	12.75	0.5000	0.3750	Yes	Yes	1.2500	1.2499		5.0000	1.2500	0.0000	105.6
N12	8.63	0.5000	0.3286	Yes	Yes	1.2500	1.2499		3.0000	1.2500	0.0000	112.0
N17	8.63	0.5000	0.3310	Yes	Yes	1.1875*	1.1549		2.5000	1.2500	0.0000	100.0
N18	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N35	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N45A	3.31	0.6550	0.5786	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N45B	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N46A	4.62	0.8100	0.2257	Yes	Yes	1.2500	1.2012		N/A	N/A	0.0000	100.0
N46B	4.62	0.8100	0.2257	Yes	Yes	1.2500	1.2012		N/A	N/A	0.0000	100.0
N47A	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N47B	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N48A	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N48B	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N49A	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N49B	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N50A	4.62	0.8100	0.2257	Yes	Yes	1.2500	1.2012		N/A	N/A	0.0000	100.0
N50B	4.62	0.8100	0.2257	Yes	Yes	1.2500	1.2012		N/A	N/A	0.0000	100.0
N51A	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N51B	3.31	0.6550	0.1890	Yes	Yes	1.2500	N/A		N/A	N/A	0.0000	Exempt
N6	6.63	0.4320	0.3937	Yes	Yes	1.1875*	1.0708		3.0000	0.8750	0.0000	100.0
N7	12.75	0.5000	0.3750	Yes	Yes	1.1875*	1.0925		5.0000	1.0000	0.0000	100.0

t_n: Nozzle thickness
Req t_n: Nozzle thickness required per UG-45/UG-16
Nom t: Vessel wall thickness
Design t: Required vessel wall thickness due to pressure + corrosion allowance per UG-37
User t: Local vessel wall thickness (near opening)
A_a: Area available per UG-37, governing condition
A_r: Area required per UG-37, governing condition
Corr: Corrosion allowance on nozzle wall
* Head minimum thickness after forming

Pressure Summary

Pressure Summary for Chamber bounded by Bottom Ellipsoidal Head #2 and Top Ellipsoidal Head #1

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MDMT (°F)	MDMT Exemption	Total Corrosion Allowance (in)	Impact Test
Top Ellipsoidal Head #1	400.0	400.0	414.89	414.89	-40.0	Note 1	0.000	Yes
Straight Flange on Top Ellipsoidal Head #1	400.0	400.0	517.02	517.02	-40.0	Note 2	0.000	Yes
Cylinder #1	400.0	400.0	431.97	431.97	-24.0	Note 3	0.000	Yes
Cylinder #2	400.0	400.0	431.97	431.97	-24.0	Note 3	0.000	Yes
Cylinder #3	400.0	400.0	431.97	431.97	-24.0	Note 3	0.000	Yes
Cylinder #4	400.0	400.0	431.97	431.97	-24.0	Note 3	0.000	Yes
Cylinder #5	400.0	400.0	431.97	431.97	-24.0	Note 3	0.000	Yes
Cylinder #6	400.0	400.0	431.97	431.97	-24.0	Note 3	0.000	Yes
Straight Flange on Bottom Ellipsoidal Head #2	400.0	400.0	517.02	517.02	-40.0	Note 2	0.000	Yes
Bottom Ellipsoidal Head #2	400.0	400.0	414.89	414.89	-40.0	Note 4	0.000	Yes
M1A NPS 24 RFWN (1.25"wt. 23.25"ID) Manway (M1A)	400.0	400.0	417.43	417.43	-24.0	Nozzle Note 5; Pad note 6	0.000	Yes
M1B NPS 24 RFWN (1.25"wt. 23.25"ID) Manway (M1B)	400.0	400.0	417.43	417.43	-24.0	Nozzle Note 5; Pad note 6	0.000	Yes
N11 NPS 12 RFWN S/XH(0.5"wt) Vapor Feed Nozzle (N11)	400.0	400.0	431.93	431.93	-24.0	Nozzle Note 7; Pad note 6	0.000	No
N12 NPS 8 RFWN S/XH(0.5"wt) Amine Feed Nozzle (N12)	400.0	400.0	431.93	431.93	-24.0	Nozzle Note 8; Pad note 6	0.000	No
N17 NPS 8 RFWN S/XH(0.5"wt) Amine Outlet Nozzle (N17)	400.0	400.0	448.27	448.27	-30.0	Nozzle Note 8; Pad note 9	0.000	No
N18 NPS 2 RFLWN(0.655"wt) HC liquid Outlet Nozzle (N18)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N35 NPS 2 RFLWN(0.655"wt) Steam Out Nozzle (N35)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N45A NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle (N45A)	400.0	400.0	431.93	431.93	-55.0	Note 11	0.000	No
N45B NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle (N45B)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N46A NPS 3 RFLWN(0.810"wt) LT-17 Nozzle (N46A)	400.0	400.0	415.31	415.31	-55.0	Note 10	0.000	No
N46B NPS 3 RFLWN(0.810"wt) LT-17 Nozzle (N46B)	400.0	400.0	415.31	415.31	-55.0	Note 10	0.000	No
N47A NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle (N47A)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N47B NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle (N47B)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N48A NPS 2 RFLWN(0.655"wt) LG-105 Nozzle (N48A)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N48B NPS 2 RFLWN(0.655"wt) LG-105 Nozzle (N48B)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N49A NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle (N49A)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N49B NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle (N49B)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N50A NPS 3 RFLWN(0.81"wt) LT-16 Nozzle (N50A)	400.0	400.0	415.31	415.31	-55.0	Note 10	0.000	No
N50B NPS 3 RFLWN(0.81"wt) LT-16 Nozzle (N50B)	400.0	400.0	415.31	415.31	-55.0	Note 10	0.000	No
N51A NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle (N51A)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N51B NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle (N51B)	400.0	400.0	431.93	431.93	-55.0	Note 10	0.000	No
N6 NPS 6 RFWN(0.432"wt) S/80 Purge Nozzle (N6)	400.0	400.0	415.67	415.67	-28.6	Nozzle Note 12; Pad note 9	0.000	No
N7 NPS 12 RFWN(0.500"wt) S/XH Vapor Outlet Nozzle (N7)	400.0	400.0	424.10	424.10	-30.0	Nozzle Note 7; Pad note 9	0.000	No

Chamber design MDMT is -20.00°F

Chamber rated MDMT is -24.00°F @ 414.89 psi

Chamber MAWP hot & corroded is 414.89 psi @ 400.0°F

Chamber MAP cold & new is 414.89 psi @ 68.0°F

This pressure chamber is not designed for external pressure.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Straight Flange governs MDMT	
2.	Material is impact tested per UG-84 to -20 °F	UCS-66(i) reduction of 20 °F applied (ratio = 0.7999816).
3.	Material is impact tested per UG-84 to -20 °F	UCS-66(i) reduction of 4 °F applied (ratio = 0.9599779).
4.	Straight Flange governs MDMT	
5.	Nozzle is impact tested per UG-84 to -20 °F	UCS-66(i) reduction of 4 °F applied (ratio = 0.95998).
6.	Pad is impact tested per UG-84 to -20 °F	UCS-66(i) reduction of 4 °F applied (ratio = 0.95998).
7.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -13 °F Fig UCS-66.1 MDMT reduction = 44.3 °F, (coincident ratio = 0.57102) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.4375 in.
8.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -13 °F Fig UCS-66.1 MDMT reduction = 34.8 °F, (coincident ratio = 0.65227)	UCS-66 governing thickness = 0.4375 in.
9.	Pad is impact tested per UG-84 to -20 °F	UCS-66(i) reduction of 10 °F applied (ratio = 0.9).
10.	Flange rating governs: Flange impact tested to -55.00°F (UCS-66(g))	UG-84 provisions apply
11.	Nozzle is impact tested to -55 °F (UCS-66(g))	UCS-66 governing thickness = 0.655 in.
12.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -19.66 °F Fig UCS-66.1 MDMT reduction = 8.9 °F, (coincident ratio = 0.9112)	UCS-66 governing thickness = 0.378 in.

Design notes are available on the Settings Summary page.

Revision History

No.	Date	Operator	Notes
1	1/31/2007	Les Bildy	Converted from ASME Section VIII Division 1, 2001 Edition, A03 Addenda to ASME Section VIII Division 1, 2004 Edition, A06 Addenda. Default Forging Material Changed to A 105. During the conversion, changes may have been made to your vessel (some may be listed above). Please check your vessel carefully.

Settings Summary

COMPRESS Build 6252

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Design or Rating:	Get Thickness from Pressure
Minimum thickness:	1/16" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Design P, find nozzle MAWP and MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.3
Minimum nozzle projection:	2.0000"
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials > 1.25&#34 and <= 1.50" thick:	No

Butt welds are tapered per Figure UCS-66.3(a).

Hydro/Pneumatic Test

Shop Hydrotest Pressure:	1.3 times vessel MAWP
Test liquid specific gravity:	1.00
Field Hydrotest Pressure:	1.3 times vessel MAWP
Wind load present @ field:	33% of design
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116 (e) Radiography:	RT1
UG-116 (f) Postweld heat treatment:	None

Code Interpretations

Use Code Case 2547:	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
Disallow UG-20(f) exemptions:	No

UG-22 Loadings

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

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

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Joint E	Load
Top Ellipsoidal Head #1	SA-516 70	114.25 ID	29.75	1.1875*	1.1448	1.0000	Internal
Straight Flange on Top Ellipsoidal Head #1	SA-516 70	114.25 ID	2.00	1.5000	1.1564	1.0000	Internal
Cylinder #1	SA-516 70	114.25 ID	113.44	1.2500	1.1564	1.0000	Internal
Cylinder #2	SA-516 70	114.25 ID	113.31	1.2500	1.1564	1.0000	Internal
Cylinder #3	SA-516 70	114.25 ID	113.31	1.2500	1.1564	1.0000	Internal
Cylinder #4	SA-516 70	114.25 ID	113.31	1.2500	1.1564	1.0000	Internal
Cylinder #5	SA-516 70	114.25 ID	113.31	1.2500	1.1564	1.0000	Internal
Cylinder #6	SA-516 70	114.25 ID	113.31	1.2500	1.1564	1.0000	Internal
Straight Flange on Bottom Ellipsoidal Head #2	SA-516 70	114.25 ID	2.00	1.5000	1.1564	1.0000	Internal
Bottom Ellipsoidal Head #2	SA-516 70	114.25 ID	29.75	1.1875*	1.1448	1.0000	Internal
Support Skirt	SA-516 70	114.00 ID	89.71	0.6250	0.0941	0.5500	Weight

Nominal t:	Vessel wall nominal thickness
Design t:	Required vessel thickness due to governing loading + corrosion
Joint E:	Longitudinal seam joint efficiency
*	Head minimum thickness after forming

Load

internal:	Circumferential stress due to internal pressure governs
external:	External pressure governs
Wind:	Combined longitudinal stress of pressure + weight + wind governs
Seismic:	Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements						
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid
Top Ellipsoidal Head #1	5,439.68	5,439.68	423.53	520.15	0.00	0.00	7,755.39
Cylinder #1	14,353.18	14,353.18	884.73	1,474.36	0.00	0.00	41,886.58
Cylinder #2	14,544.75	14,544.75	883.90	1,472.71	0.00	0.00	41,749.35
Cylinder #3	14,544.75	14,544.75	883.90	1,472.71	0.00	0.00	41,749.35
Cylinder #4	14,544.75	14,544.75	883.90	1,472.71	0.00	0.00	41,749.35
Cylinder #5	14,472.50	14,472.50	883.90	1,472.71	0.00	0.00	41,770.62
Cylinder #6	14,330.40	14,330.40	883.90	1,472.71	0.00	0.00	41,840.00
Bottom Ellipsoidal Head #2	5,474.54	5,474.54	423.53	520.15	0.00	0.00	7,744.84
Support Skirt	5,713.89	5,713.89	0.00	0.00	0.00	0.00	0.00
Skirt Base Ring #1	2,325.00	2,325.00	0.00	0.00	0.00	0.00	0.00
TOTAL:	**105,743.43**	**105,743.43**	**6,151.30**	**9,878.20**	**0.00**	**0.00**	**266,245.44**

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

Component	Weight (lb) Contributed by Attachments								
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads
	New	Corroded	New	Corroded					
Top Ellipsoidal Head #1	0.00	0.00	356.02	356.02	0.00	1,883.66	0.00	0.00	0.00
Cylinder #1	0.00	0.00	2,165.49	2,165.49	0.00	2,214.15	4,051.76	1,915.64	0.00
Cylinder #2	0.00	0.00	0.00	0.00	0.00	236.07	5,402.34	0.00	0.00
Cylinder #3	0.00	0.00	0.00	0.00	0.00	2,287.64	6,752.93	0.00	0.00
Cylinder #4	0.00	0.00	0.00	0.00	0.00	236.07	6,752.93	0.00	15,000.00
Cylinder #5	0.00	0.00	466.62	466.62	0.00	342.18	2,701.17	0.00	0.00
Cylinder #6	0.00	0.00	2,228.32	2,228.32	0.00	2,743.00	0.00	0.00	0.00
Bottom Ellipsoidal Head #2	0.00	0.00	152.59	152.59	0.00	204.17	0.00	0.00	0.00
Support Skirt	0.00	0.00	0.00	0.00	0.00	1,740.99	0.00	396.80	0.00
TOTAL:	**0.00**	**0.00**	**5,369.05**	**5,369.05**	**0.00**	**11,887.92**	**25,661.13**	**2,312.44**	**15,000.00**

Vessel operating weight, Corroded: 182,003 lb
Vessel operating weight, New: 182,003 lb
Vessel empty weight, Corroded: 182,003 lb
Vessel empty weight, New: 182,003 lb
Vessel test weight, New: 448,249 lb

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 182,004 lb
Center of Gravity: 329.54"

Vessel Capacity

Vessel Capacity** (New): 31,899 US gal
Vessel Capacity** (Corroded): 31,899 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

Shop test pressure determination for Chamber bounded by Bottom Ellipsoidal Head #2 and Top Ellipsoidal Head #1 based on MAWP per UG-99(b)

Shop hydrostatic test gauge pressure is 539.360 psi at 68.00 °F (the chamber MAWP = 414.892 psi)

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

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
Top Ellipsoidal Head #1 (1)	543.788	4.428	1.0000	1.30	23,543	34,200	No
Straight Flange on Top Ellipsoidal Head #1	543.788	4.428	1.0000	1.30	20,980	34,200	No
Cylinder #1	543.788	4.428	1.0000	1.30	25,122	34,200	No
Cylinder #2	543.788	4.428	1.0000	1.30	25,122	34,200	No
Cylinder #3	543.788	4.428	1.0000	1.30	25,122	34,200	No
Cylinder #4	543.788	4.428	1.0000	1.30	25,122	34,200	No
Cylinder #5	543.788	4.428	1.0000	1.30	25,122	34,200	No
Cylinder #6	543.788	4.428	1.0000	1.30	25,122	34,200	No
Straight Flange on Bottom Ellipsoidal Head #2	543.788	4.428	1.0000	1.30	20,980	34,200	No
Bottom Ellipsoidal Head #2	543.788	4.428	1.0000	1.30	23,543	34,200	No
M1A NPS 24 RFWN (1.25"wt. 23.25"ID) Manway (M1A)	540.930	1.570	1.0000	1.30	24,231	51,300	No
M1B NPS 24 RFWN (1.25"wt. 23.25"ID) Manway (M1B)	543.360	3.999	1.0000	1.30	24,340	51,300	No
N11 NPS 12 RFWN S/XH(0.5"wt) Vapor Feed Nozzle (N11)	541.938	2.578	1.0000	1.30	22,799	46,576	No
N12 NPS 8 RFWN S/XH(0.5"wt) Amine Feed Nozzle (N12)	541.864	2.503	1.0000	1.30	22,346	46,918	No
N17 NPS 8 RFWN S/XH(0.5"wt) Amine Outlet Nozzle (N17)	541.864	2.503	1.0000	1.30	23,296	47,250	No
N18 NPS 2 RFLWN(0.655"wt) HC liquid Outlet Nozzle (N18)	539.831	0.471	1.0000	1.30	27,013	45,837	No
N35 NPS 2 RFLWN(0.655"wt) Steam Out Nozzle (N35)	540.399	1.039	1.0000	1.30	27,042	45,796	No
N45A NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle (N45A)	539.657	0.297	1.0000	1.30	27,005	45,850	No
N45B NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle (N45B)	539.657	0.297	1.0000	1.30	27,005	45,850	No
N46A NPS 3 RFLWN(0.810"wt) LT-17 Nozzle (N46A)	540.031	0.671	1.0000	1.30	27,693	45,321	No
N46B NPS 3 RFLWN(0.810"wt) LT-17 Nozzle (N46B)	540.031	0.671	1.0000	1.30	27,693	45,321	No
N47A NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle (N47A)	540.704	1.344	1.0000	1.30	27,057	45,775	No
N47B NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle (N47B)	540.704	1.344	1.0000	1.30	27,057	45,775	No
	543.585	4.224	1.0000	1.30	27,201	45,568	No

N48A NPS 2 RFLWN(0.655"wt) LG-105 Nozzle (N48A)							
N48B NPS 2 RFLWN(0.655"wt) LG-105 Nozzle (N48B)	543.585	4.224	1.0000	1.30	27,201	45,568	No
N49A NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle (N49A)	544.122	4.762	1.0000	1.30	27,228	45,529	No
N49B NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle (N49B)	544.122	4.762	1.0000	1.30	27,228	45,529	No
N50A NPS 3 RFLWN(0.81"wt) LT-16 Nozzle (N50A)	541.233	1.873	1.0000	1.30	27,755	45,233	No
N50B NPS 3 RFLWN(0.81"wt) LT-16 Nozzle (N50B)	541.233	1.873	1.0000	1.30	27,755	45,233	No
N51A NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle (N51A)	539.919	0.559	1.0000	1.30	27,018	45,831	No
N51B NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle (N51B)	543.446	4.086	1.0000	1.30	27,194	45,578	No
N6 NPS 6 RFWN(0.432"wt) S/80 Purge Nozzle (N6)	541.830	2.470	1.0000	1.30	23,335	47,250	No
N7 NPS 12 RFWN(0.500"wt) S/XH Vapor Outlet Nozzle (N7)	541.938	2.578	1.0000	1.30	25,078	45,844	No

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

The test temperature of 68.00 °F is warmer than the minimum recommended temperature of 6.00 °F so the brittle fracture provision of UG-99(h) has been met.

Field test pressure determination for Chamber bounded by Bottom Ellipsoidal Head #2 and Top Ellipsoidal Head #1 based on MAWP per UG-99(b)

Field hydrostatic test gauge pressure is 539.360 psi at 68.00 °F (the chamber MAWP = 414.892 psi)

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
Top Ellipsoidal Head #1 (1)	540.894	1.534	1.0000	1.30	23,418	34,200	No
Straight Flange on Top Ellipsoidal Head #1	540.894	1.534	1.0000	1.30	20,868	34,200	No
Cylinder #1	544.989	5.629	1.0000	1.30	25,178	34,200	No
Cylinder #2	549.079	9.719	1.0000	1.30	25,366	34,200	No
Cylinder #3	553.170	13.810	1.0000	1.30	25,555	34,200	No
Cylinder #4	557.260	17.900	1.0000	1.30	25,744	34,200	No
Cylinder #5	561.350	21.990	1.0000	1.30	25,933	34,200	No
Cylinder #6	565.440	26.080	1.0000	1.30	26,122	34,200	No
Straight Flange on Bottom Ellipsoidal Head #2	565.513	26.152	1.0000	1.30	21,818	34,200	No
Bottom Ellipsoidal Head #2	566.544	27.184	1.0000	1.30	24,528	34,200	No
M1A NPS 24 RFWN (1.25"wt. 23.25"ID) Manway (M1A)	542.144	2.784	1.0000	1.30	24,285	51,300	No
M1B NPS 24 RFWN (1.25"wt. 23.25"ID) Manway (M1B)	564.524	25.164	1.0000	1.30	25,288	50,985	No
N11 NPS 12 RFWN S/XH(0.5"wt) Vapor Feed Nozzle (N11)	560.743	21.383	1.0000	1.30	23,590	45,338	No
N12 NPS 8 RFWN S/XH(0.5"wt) Amine Feed Nozzle (N12)	541.537	2.177	1.0000	1.30	22,333	46,939	No
N17 NPS 8 RFWN S/XH(0.5"wt) Amine Outlet Nozzle (N17)	567.245	27.885	1.0000	1.30	24,387	45,541	No
N18 NPS 2 RFLWN(0.655"wt) HC liquid Outlet Nozzle (N18)	565.332	25.972	1.0000	1.30	28,290	44,006	No
N35 NPS 2 RFLWN(0.655"wt) Steam Out Nozzle (N35)	565.296	25.936	1.0000	1.30	28,288	44,009	No
N45A NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle (N45A)	561.000	21.640	1.0000	1.30	28,073	44,317	No
N45B NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle (N45B)	565.116	25.755	1.0000	1.30	28,279	44,022	No
N46A NPS 3 RFLWN(0.810"wt) LT-17 Nozzle (N46A)	561.235	21.875	1.0000	1.30	28,780	43,778	No
	565.025	25.665	1.0000	1.30	28,975	43,503	No

N46B NPS 3 RFLWN(0.810"wt) LT-17 Nozzle (N46B)							
N47A NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle (N47A)	561.240	21.879	1.0000	1.30	28,085	44,300	No
N47B NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle (N47B)	561.817	22.457	1.0000	1.30	28,114	44,258	No
N48A NPS 2 RFLWN(0.655"wt) LG-105 Nozzle (N48A)	561.000	21.640	1.0000	1.30	28,073	44,317	No
N48B NPS 2 RFLWN(0.655"wt) LG-105 Nozzle (N48B)	565.368	26.008	1.0000	1.30	28,291	44,004	No
N49A NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle (N49A)	560.459	21.099	1.0000	1.30	28,046	44,356	No
N49B NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle (N49B)	565.368	26.008	1.0000	1.30	28,291	44,004	No
N50A NPS 3 RFLWN(0.81"wt) LT-16 Nozzle (N50A)	561.018	21.658	1.0000	1.30	28,769	43,794	No
N50B NPS 3 RFLWN(0.81"wt) LT-16 Nozzle (N50B)	565.314	25.954	1.0000	1.30	28,990	43,482	No
N51A NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle (N51A)	541.941	2.581	1.0000	1.30	27,119	45,686	No
N51B NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle (N51B)	559.268	19.908	1.0000	1.30	27,986	44,442	No
N6 NPS 6 RFWN(0.432"wt) S/80 Purge Nozzle (N6)	539.956	0.596	1.0000	1.30	23,254	47,250	No
N7 NPS 12 RFWN(0.500"wt) S/XH Vapor Outlet Nozzle (N7)	539.748	0.388	1.0000	1.30	24,977	45,991	No

Notes:
(1) Top Ellipsoidal Head #1 limits the UG-99 stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) VIII-2, AD-151.1(b) used as the basis for nozzle allowable test stress.

The test temperature of 68.00 °F is warmer than the minimum recommended temperature of 6.00 °F so the brittle fracture provision of UG-99(h) has been met.

Engineering Notes

1. ***Fireproofing material on the vessel skirt is assumed to be added after vessel erection***. The skirt fireproofing estimated density is 200#/cu. ft.

2. The vessel skirt thickness has been increased to 0.625 inches from 0.5 inches as originally submitted.

3. The baseplate ID and OD, bolt circle and chair heights have been retained from the original design.
The standard dimensions may not be met per dwg C-510-1 Rev 2

4. Grating is 20 lbs/sq ft, railing is 12 lbs/ft and ladders are 25 lbs/ft.

5. The pressure vessel software COMPRESS includes a lifting and tailing lug design option. The lift lug is included with this set of calculations.

Cylinder #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component:	Cylinder
Material specification:	SA-516 70 (II-D p. 14, ln. 20)

Material is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.9599779).

Internal design pressure: P = 400 psi @ 400°F

Static liquid head:

P_{th} = 4.4279 psi (SG=1.0000, H_s=122.6653", Horizontal test head)
P_{tv} = 5.6290 psi (SG=1.0000, H_s=155.9400", Vertical test head)

Corrosion allowance:	Inner C = 0.0000"	Outer C = 0.0000"

Design MDMT = -20.00°F	Impact test performed
Rated MDMT = -24.00°F	Material is normalized
	Material is not produced to Fine Grain Practice
	PWHT is not performed

Radiography:	Longitudinal joint -	Full UW-11(a) Type 1
	Top circumferential joint -	Full UW-11(a) Type 1
	Bottom circumferential joint -	Full UW-11(a) Type 1

Estimated weight:	New = 14561.1113 lb	corr = 14561.1113 lb
Capacity:	New = 5012.4935 gal	corr = 5012.4935 gal

ID = 114.2500"
Length L_c = 113.4400"
t = 1.2500"

Insulation thk:	2.0000"	density:	15.0000 lb/ft³	Weight:	734.7292 lb
Insulation Support Spacing:	96.0000"	Individual Support Weight:	150.0000 lb	Total Support Weight:	150.0000 lb
Lining/Refractory thickness:	0.1250"	density:	501.1200 lb/ft³	Weight:	1474.3646 lb

Design thickness, (at 400.00°F) UG-27(c)(1)

t = P*R/(S*E - 0.60*P) + Corrosion
= 400.00*57.1250/(20000*1.00 - 0.60*400.00) + 0.0000
= 1.1564"

Maximum allowable working pressure, (at 400.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t) - P_s
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500) - 0.0000
= 431.9655 psi

Maximum allowable pressure, (at 68.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t)
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500)
= 431.9655 psi

% Extreme fiber elongation - UCS-79(d)

$= (50 * t / R_f) * (1 - R_f / R_o)$
$= (50 * 1.2500 / 57.7500) * (1 - 57.7500 / \infty)$
$= 1.0823$ %

Design thickness = 1.1564"

The governing condition is due to internal pressure.

The cylinder thickness of 1.2500" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5655	0.5625
Operating, Hot & New	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5655	0.5625
Hot Shut Down, Corroded	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0050	0.0093
Hot Shut Down, New	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0050	0.0093
Empty, Corroded	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0044	0.0081
Empty, New	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0044	0.0081
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0050	0.0093

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

A = $0.125 / (R_o / t)$
= 0.125 / (58.3750 / 1.2500)
= 0.002677
B = 13877.5869 psi
S = 20000.0000 / 1.0000
= 20000.0000 psi
S_{cHC} = 13877.5869 psi

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

S_{cHN} = S_{cHC}
= 13877.5869 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (58.3750 / 1.2500)
= 0.002677
B = 15853.0967 psi
S = 20000.0000 / 1.0000
= 20000.0000 psi
S_{cCN} = 15853.0967 psi

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

S_{cCC} = S_{cCN}
= 15853.0967 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 15853.0967 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cVC} = 15853.0967 psi

Operating, Hot & Corroded, Bottom Seam

t_p = P*R/(2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = M/(π*R_m^2*S_t*K_s*E_c) (bending)
= 311827/(π*57.7500²*20000*1.0000*1.00)
= 0.0015"

t_w = W/(2*π*R_m*S_t*K_s*E_c) (Weight)
= 35979/(2*π*57.7500*20000*1.0000*1.00)
= 0.0050"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.568974 + 0.001488 - (0.004958)
= 0.5655"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0.001488 + (0.004958) - (0.568974)|
= 0.5625"

Maximum allowable working pressure, Longitudinal Stress

P = 2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))
= 2*20000*1.0000*1.00*(1.2500-0.001488+(0.004958)) / (57.1250 - 0.40*(1.2500-0.001488+(0.004958)))
= 885.47 psi

Operating, Hot & New, Bottom Seam

t_p = P*R/(2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = M/(π*R_m^2*S_t*K_s*E_c) (bending)
= 311827/(π*57.7500²*20000*1.0000*1.00)
= 0.0015"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $35979/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0050"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001488 - (0.004958)
= 0.5655"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001488 + (0.004958) - (0.568974)|
= 0.5625"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001488+(0.004958)) / (57.1250 - 0.40*(1.2500-0.001488+(0.004958)))
= 885.47 psi

Hot Shut Down, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $311827/(\pi*57.7500^2*13878*1.0000)$
= 0.0021"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $35979/(2*\pi*57.7500*13878*1.0000)$
= 0.0071"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002145 - (0.007145)|
= 0.0050"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002145 + (0.007145) - (0.000000)
= 0.0093"

Hot Shut Down, New, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $311827/(\pi*57.7500^2*13878*1.0000)$
= 0.0021"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $35979/(2*\pi*57.7500*13878*1.0000)$
= 0.0071"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002145 - (0.007145)|
= 0.0050"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002145 + (0.007145) - (0.000000)

= 0.0093"

Empty, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)

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

= $311827/(\pi*57.7500^2*15853*1.0000)$

= 0.0019"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $35979/(2*\pi*57.7500*15853*1.0000)$

= 0.0063"

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

= |0.000000 + 0.001877 - (0.006255)|

= 0.0044"

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

= 0.001877 + (0.006255) - (0.000000)

= 0.0081"

Empty, New, Bottom Seam

t_p = 0.0000" (Pressure)

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

= $311827/(\pi*57.7500^2*15853*1.0000)$

= 0.0019"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $35979/(2*\pi*57.7500*15853*1.0000)$

= 0.0063"

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

= |0.000000 + 0.001877 - (0.006255)|

= 0.0044"

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

= 0.001877 + (0.006255) - (0.000000)

= 0.0081"

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

t_p = 0.0000" (Pressure)

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

= $311827/(\pi*57.7500^2*13878*1.0000)$

= 0.0021"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $35979/(2*\pi*57.7500*13878*1.0000)$

= 0.0071"

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

= |0.000000 + 0.002145 - (0.007145)|

= 0.0050"

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

$= 0.002145 + (0.007145) - (0.000000)$

$=$ 0.0093"

Cylinder #2

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component:	Cylinder
Material specification:	SA-516 70 (II-D p. 14, ln. 20)

Material is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.9599779).

Internal design pressure: P = 400 psi @ 400°F

Static liquid head:

P_{th} = 4.4279 psi (SG=1.0000, H_s=122.6653", Horizontal test head)
P_{tv} = 9.7192 psi (SG=1.0000, H_s=269.2525", Vertical test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F	Impact test performed
Rated MDMT = -24.00°F	Material is normalized
	Material is not produced to Fine Grain Practice
	PWHT is not performed

Radiography:	Longitudinal joint -	Full UW-11(a) Type 1
	Top circumferential joint -	Full UW-11(a) Type 1
	Bottom circumferential joint -	Full UW-11(a) Type 1

Estimated weight:	New = 14544.7461 lb	corr = 14544.7461 lb
Capacity:	New = 5006.8598 gal	corr = 5006.8598 gal

ID = 114.2500"
Length L_c = 113.3125"
t = 1.2500"

Insulation thk:	2.0000"	density:	15.0000 lb/ft³	Weight:	733.9034 lb
Insulation Support Spacing:	96.0000"	Individual Support Weight:	150.0000 lb	Total Support Weight:	150.0000 lb
Lining/Refractory thickness:	0.1250"	density:	501.1200 lb/ft³	Weight:	1472.7075 lb

Design thickness, (at 400.00°F) UG-27(c)(1)

t = P*R/(S*E - 0.60*P) + Corrosion
= 400.00*57.1250/(20000*1.00 - 0.60*400.00) + 0.0000
= 1.1564"

Maximum allowable working pressure, (at 400.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t) - P_s
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500) - 0.0000
= 431.9655 psi

Maximum allowable pressure, (at 68.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t)
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500)
= 431.9655 psi

% Extreme fiber elongation - UCS-79(d)

= $(50 * t / R_f) * (1 - R_f / R_o)$
= (50 * 1.2500 / 57.7500) * (1 - 57.7500 / ∞)
= 1.0823 %

Design thickness = 1.1564"

The governing condition is due to internal pressure.

The cylinder thickness of 1.2500" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5625	0.5595
Operating, Hot & New	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5625	0.5595
Hot Shut Down, Corroded	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0094	0.0137
Hot Shut Down, New	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0094	0.0137
Empty, Corroded	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0082	0.0120
Empty, New	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0082	0.0120
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0094	0.0137

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

A = $0.125 / (R_o / t)$
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 13877.5869 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cHC} = 13877.5869 psi

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

S_{cHN} = S_{cHC}
= 13877.5869 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 15853.0967 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cCN} = 15853.0967 psi

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

S_{cCC} = S_{cCN}
= 15853.0967 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 15853.0967 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cVC} = 15853.0967 psi

Operating, Hot & Corroded, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= $311827/(\pi*57.7500^2*20000*1.0000*1.00)$
= 0.0015"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $58133/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0080"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001488 - (0.008011)
= 0.5625"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001488 + (0.008011) - (0.568974)|
= 0.5595"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001488+(0.008011)) / (57.1250 - 0.40*(1.2500-0.001488+(0.008011)))
= 887.65 psi

Operating, Hot & New, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= $311827/(\pi*57.7500^2*20000*1.0000*1.00)$
= 0.0015"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $58133/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0080"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001488 - (0.008011)
= 0.5625"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001488 + (0.008011) - (0.568974)|
= 0.5595"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001488+(0.008011)) / (57.1250 - 0.40*(1.2500-0.001488+(0.008011)))
= 887.65 psi

Hot Shut Down, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $311827/(\pi*57.7500^2*13878*1.0000)$
= 0.0021"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $58133/(2*\pi*57.7500*13878*1.0000)$
= 0.0115"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002145 - (0.011545)|
= 0.0094"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002145 + (0.011545) - (0.000000)
= 0.0137"

Hot Shut Down, New, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $311827/(\pi*57.7500^2*13878*1.0000)$
= 0.0021"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $58133/(2*\pi*57.7500*13878*1.0000)$
= 0.0115"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002145 - (0.011545)|
= 0.0094"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002145 + (0.011545) - (0.000000)

$= \underline{0.0137"}$

Empty, Corroded, Bottom Seam

$t_p = 0.0000"$ (Pressure)

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

$= 311827/(\pi*57.7500^2*15853*1.0000)$

$= 0.0019"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)

$= 58133/(2*\pi*57.7500*15853*1.0000)$

$= 0.0101"$

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

$= |0.000000 + 0.001877 - (0.010106)|$

$= \underline{0.0082"}$

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

$= 0.001877 + (0.010106) - (0.000000)$

$= \underline{0.0120"}$

Empty, New, Bottom Seam

$t_p = 0.0000"$ (Pressure)

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

$= 311827/(\pi*57.7500^2*15853*1.0000)$

$= 0.0019"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)

$= 58133/(2*\pi*57.7500*15853*1.0000)$

$= 0.0101"$

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

$= |0.000000 + 0.001877 - (0.010106)|$

$= \underline{0.0082"}$

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

$= 0.001877 + (0.010106) - (0.000000)$

$= \underline{0.0120"}$

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

$t_p = 0.0000"$ (Pressure)

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

$= 311827/(\pi*57.7500^2*13878*1.0000)$

$= 0.0021"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)

$= 58133/(2*\pi*57.7500*13878*1.0000)$

$= 0.0115"$

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

$= |0.000000 + 0.002145 - (0.011545)|$

$= \underline{0.0094"}$

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

$= 0.002145 + (0.011545) - (0.000000)$

$=$ 0.0137"

Cylinder #3

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component: Cylinder
Material specification: SA-516 70 (II-D p. 14, ln. 20)
Material is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.9599779).

Internal design pressure: P = 400 psi @ 400°F

Static liquid head:

P_{th} =4.4279 psi (SG=1.0000, H_s=122.6653", Horizontal test head)
P_{tv} =13.8095 psi (SG=1.0000, H_s=382.5650", Vertical test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F
Rated MDMT = -24.00°F

Impact test performed
Material is normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography:	Longitudinal joint -	Full UW-11(a) Type 1
	Top circumferential joint -	Full UW-11(a) Type 1
	Bottom circumferential joint -	Full UW-11(a) Type 1

Estimated weight: New = 14544.7461 lb corr = 14544.7461 lb
Capacity: New = 5006.8598 gal corr = 5006.8598 gal
ID = 114.2500"
Length L_c = 113.3125"
t = 1.2500"

Insulation thk:	2.0000"	density:	15.0000 lb/ft³	Weight:	733.9034 lb
Insulation Support Spacing:	96.0000"	Individual Support Weight:	150.0000 lb	Total Support Weight:	150.0000 lb
Lining/Refractory thickness:	0.1250"	density:	501.1200 lb/ft³	Weight:	1472.7075 lb

Design thickness, (at 400.00°F) UG-27(c)(1)

t = P*R/(S*E - 0.60*P) + Corrosion
= 400.00*57.1250/(20000*1.00 - 0.60*400.00) + 0.0000
= 1.1564"

Maximum allowable working pressure, (at 400.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t) - P_s
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500) - 0.0000
= 431.9655 psi

Maximum allowable pressure, (at 68.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t)
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500)
= 431.9655 psi

% Extreme fiber elongation - UCS-79(d)

= (50 * t / R_f) * (1 - R_f / R_o)
= (50 * 1.2500 / 57.7500) * (1 - 57.7500 / ∞)
= 1.0823 %

Design thickness = 1.1564"

The governing condition is due to internal pressure.

The cylinder thickness of 1.2500" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5589	0.5558
Operating, Hot & New	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5589	0.5558
Hot Shut Down, Corroded	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0145	0.0190
Hot Shut Down, New	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0145	0.0190
Empty, Corroded	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0127	0.0167
Empty, New	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0127	0.0167
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0145	0.0190

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

A = 0.125 / (R_o / t)
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 13877.5869 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cHC} = 13877.5869 psi

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

S_{cHN} = S_{cHC}
= 13877.5869 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 15853.0967 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cCN} = 15853.0967 psi

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

S_{cCC} = S_{cCN}
= 15853.0967 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.3750 / 1.2500)
= 0.002677
B = 15853.0967 psi
S = 20000.0000 / 1.0000
= 20000.0000 psi
S_{cVC} = 15853.0967 psi

Operating, Hot & Corroded, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $330523/(\pi*57.7500^2*20000*1.0000*1.00)$
= 0.0016"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $84358/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0116"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001577 - (0.011624)
= 0.5589"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001577 + (0.011624) - (0.568974)|
= 0.5558"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001577+(0.011624)) / (57.1250 - 0.40*(1.2500-0.001577+(0.011624)))
= 890.16 psi

Operating, Hot & New, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $330523/(\pi*57.7500^2*20000*1.0000*1.00)$
= 0.0016"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $84358/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0116"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001577 - (0.011624)
= 0.5589"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001577 + (0.011624) - (0.568974)|
= 0.5558"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001577+(0.011624)) / (57.1250 - 0.40*(1.2500-0.001577+(0.011624)))
= 890.16 psi

Hot Shut Down, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $330523/(\pi*57.7500^2*13878*1.0000)$
= 0.0023"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $84358/(2*\pi*57.7500*13878*1.0000)$
= 0.0168"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002273 - (0.016752)|
= 0.0145"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002273 + (0.016752) - (0.000000)
= 0.0190"

Hot Shut Down, New, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $330523/(\pi*57.7500^2*13878*1.0000)$
= 0.0023"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $84358/(2*\pi*57.7500*13878*1.0000)$
= 0.0168"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002273 - (0.016752)|
= 0.0145"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002273 + (0.016752) - (0.000000)

= 0.0190"

Empty, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m{}^2*S_c*K_s)$ (bending)
= $330523/(\pi*57.7500^2*15853*1.0000)$
= 0.0020"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $84358/(2*\pi*57.7500*15853*1.0000)$
= 0.0147"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.001990 - (0.014665)|
= 0.0127"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.001990 + (0.014665) - (0.000000)
= 0.0167"

Empty, New, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m{}^2*S_c*K_s)$ (bending)
= $330523/(\pi*57.7500^2*15853*1.0000)$
= 0.0020"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $84358/(2*\pi*57.7500*15853*1.0000)$
= 0.0147"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.001990 - (0.014665)|
= 0.0127"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.001990 + (0.014665) - (0.000000)
= 0.0167"

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

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m{}^2*S_c*K_s)$ (bending)
= $330523/(\pi*57.7500^2*13878*1.0000)$
= 0.0023"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $84358/(2*\pi*57.7500*13878*1.0000)$
= 0.0168"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002273 - (0.016752)|
= 0.0145"

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

$= 0.002273 + (0.016752) - (0.000000)$

$=$ 0.0190"

Cylinder #4

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component: Cylinder
Material specification: SA-516 70 (II-D p. 14, ln. 20)
Material is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.9599779).

Internal design pressure: P = 400 psi @ 400°F

Static liquid head:

P_{th} = 4.4279 psi (SG=1.0000, H_s=122.6653", Horizontal test head)
P_{tv} = 17.8997 psi (SG=1.0000, H_s=495.8775", Vertical test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F
Rated MDMT = -24.00°F

Impact test performed
Material is normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography:	Longitudinal joint -	Full UW-11(a) Type 1
	Top circumferential joint -	Full UW-11(a) Type 1
	Bottom circumferential joint -	Full UW-11(a) Type 1

Estimated weight: New = 14544.7461 lb corr = 14544.7461 lb
Capacity: New = 5006.8598 gal corr = 5006.8598 gal
ID = 114.2500"
Length L_c = 113.3125"
t = 1.2500"

Insulation thk:	2.0000"	density:	15.0000 lb/ft³	Weight:	733.9034 lb
Insulation Support Spacing:	96.0000"	Individual Support Weight:	150.0000 lb	Total Support Weight:	150.0000 lb
Lining/Refractory thickness:	0.1250"	density:	501.1200 lb/ft³	Weight:	1472.7075 lb

Design thickness, (at 400.00°F) UG-27(c)(1)

t = P*R/(S*E - 0.60*P) + Corrosion
= 400.00*57.1250/(20000*1.00 - 0.60*400.00) + 0.0000
= 1.1564"

Maximum allowable working pressure, (at 400.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t) - P_s
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500) - 0.0000
= 431.9655 psi

Maximum allowable pressure, (at 68.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t)
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500)
= 431.9655 psi

% Extreme fiber elongation - UCS-79(d)

= $(50 * t / R_f) * (1 - R_f / R_o)$
= (50 * 1.2500 / 57.7500) * (1 - 57.7500 / ∞)
= 1.0823 %

Design thickness = 1.1564"

The governing condition is due to internal pressure.

The cylinder thickness of 1.2500" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5536	0.5505
Operating, Hot & New	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5536	0.5505
Hot Shut Down, Corroded	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0221	0.0267
Hot Shut Down, New	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0221	0.0267
Empty, Corroded	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0194	0.0233
Empty, New	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0194	0.0233
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0221	0.0267

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

A = $0.125 / (R_o / t)$
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 13877.5869 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cHC} = 13877.5869 psi

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

S_{cHN} = S_{cHC}
= 13877.5869 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 15853.0967 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cCN} = 15853.0967 psi

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

S_{cCC} = S_{cCN}
= 15853.0967 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.3750 / 1.2500)
= 0.002677

B = 15853.0967 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cVC} = 15853.0967 psi

Operating, Hot & Corroded, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $330523/(\pi*57.7500^2*20000*1.0000*1.00)$
= 0.0016"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $122862/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0169"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001577 - (0.016930)
= 0.5536"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001577 + (0.016930) - (0.568974)|
= 0.5505"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001577+(0.016930)) / (57.1250 - 0.40*(1.2500-0.001577+(0.016930)))
= 893.94 psi

Operating, Hot & New, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $330523/(\pi*57.7500^2*20000*1.0000*1.00)$
= 0.0016"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $122862/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0169"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001577 - (0.016930)
= 0.5536"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001577 + (0.016930) - (0.568974)|
= 0.5505"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001577+(0.016930)) / (57.1250 - 0.40*(1.2500-0.001577+(0.016930)))
= 893.94 psi

Hot Shut Down, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $330523/(\pi*57.7500^2*13878*1.0000)$
= 0.0023"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $122862/(2*\pi*57.7500*13878*1.0000)$
= 0.0244"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002273 - (0.024399)|
= 0.0221"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002273 + (0.024399) - (0.000000)
= 0.0267"

Hot Shut Down, New, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $330523/(\pi*57.7500^2*13878*1.0000)$
= 0.0023"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $122862/(2*\pi*57.7500*13878*1.0000)$
= 0.0244"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002273 - (0.024399)|
= 0.0221"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002273 + (0.024399) - (0.000000)

= 0.0267"

Empty, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)

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

= $330523/(\pi*57.7500^2*15853*1.0000)$

= 0.0020"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $122862/(2*\pi*57.7500*15853*1.0000)$

= 0.0214"

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

= |0.000000 + 0.001990 - (0.021359)|

= 0.0194"

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

= 0.001990 + (0.021359) - (0.000000)

= 0.0233"

Empty, New, Bottom Seam

t_p = 0.0000" (Pressure)

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

= $330523/(\pi*57.7500^2*15853*1.0000)$

= 0.0020"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $122862/(2*\pi*57.7500*15853*1.0000)$

= 0.0214"

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

= |0.000000 + 0.001990 - (0.021359)|

= 0.0194"

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

= 0.001990 + (0.021359) - (0.000000)

= 0.0233"

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

t_p = 0.0000" (Pressure)

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

= $330523/(\pi*57.7500^2*13878*1.0000)$

= 0.0023"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $122862/(2*\pi*57.7500*13878*1.0000)$

= 0.0244"

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

= |0.000000 + 0.002273 - (0.024399)|

= 0.0221"

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

$= 0.002273 + (0.024399) - (0.000000)$

$=$ 0.0267"

Cylinder #5

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component: Cylinder
Material specification: SA-516 70 (II-D p. 14, ln. 20)
Material is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.9599779).

Internal design pressure: P = 400 psi @ 400°F

Static liquid head:

P_{th} =4.4279 psi (SG=1.0000, H_s=122.6653", Horizontal test head)
P_{tv} =21.9900 psi (SG=1.0000, H_s=609.1900", Vertical test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F
Rated MDMT = -24.00°F

Impact test performed
Material is normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography:	Longitudinal joint -	Full UW-11(a) Type 1
	Top circumferential joint -	Full UW-11(a) Type 1
	Bottom circumferential joint -	Full UW-11(a) Type 1

Estimated weight:	New = 14544.7461 lb	corr = 14544.7461 lb
Capacity:	New = 5006.8598 gal	corr = 5006.8598 gal

ID = 114.2500"
Length L_c = 113.3125"
t = 1.2500"

Insulation thk:	2.0000"	density:	15.0000 lb/ft³	Weight:	733.9034 lb
Insulation Support Spacing:	96.0000"	Individual Support Weight:	150.0000 lb	Total Support Weight:	150.0000 lb
Lining/Refractory thickness:	0.1250"	density:	501.1200 lb/ft³	Weight:	1472.7075 lb

Design thickness, (at 400.00°F) UG-27(c)(1)

t = P*R/(S*E - 0.60*P) + Corrosion
= 400.00*57.1250/(20000*1.00 - 0.60*400.00) + 0.0000
= 1.1564"

Maximum allowable working pressure, (at 400.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t) - P_s
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500) - 0.0000
= 431.9655 psi

Maximum allowable pressure, (at 68.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t)
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500)
= 431.9655 psi

% Extreme fiber elongation - UCS-79(d)

$= (50 * t / R_f) * (1 - R_f / R_o)$
$= (50 * 1.2500 / 57.7500) * (1 - 57.7500 / \infty)$
= 1.0823 %

Design thickness = 1.1564"

The governing condition is due to internal pressure.

The cylinder thickness of 1.2500" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5509	0.5477
Operating, Hot & New	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5509	0.5477
Hot Shut Down, Corroded	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0260	0.0307
Hot Shut Down, New	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0260	0.0307
Empty, Corroded	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0228	0.0269
Empty, New	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0228	0.0269
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0260	0.0307

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

A	=	$0.125 / (R_o / t)$
	=	0.125 / (58.3750 / 1.2500)
	=	0.002677
B	=	13877.5869 psi
S	=	20000.0000 / 1.0000
	=	20000.0000 psi
S_{cHC}	=	13877.5869 psi

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

S_{cHN}	=	S_{cHC}
	=	13877.5869 psi

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

A	=	$0.125 / (R_o / t)$
	=	0.125 / (58.3750 / 1.2500)
	=	0.002677
B	=	15853.0967 psi
S	=	20000.0000 / 1.0000
	=	20000.0000 psi
S_{cCN}	=	15853.0967 psi

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

S_{cCC} = S_{cCN}
= 15853.0967 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.3750 / 1.2500)
= 0.002677
B = 15853.0967 psi
S = 20000.0000 / 1.0000
= 20000.0000 psi
S_{cVC} = 15853.0967 psi

Operating, Hot & Corroded, Bottom Seam

t_p = P*R/(2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = M/(π*R_m^2*S_t*K_s*E_c) (bending)
= 338350/(π*57.7500²*20000*1.0000*1.00)
= 0.0016"

t_w = W/(2*π*R_m*S_t*K_s*E_c) (Weight)
= 142781/(2*π*57.7500*20000*1.0000*1.00)
= 0.0197"

t_t = t_p + t_m - t_w (total required, tensile)
= 0.568974 + 0.001615 - (0.019675)
= 0.5509"

t_c = |t_{mc} + t_{wc} - t_{pc}| (total, net tensile)
= |0.001615 + (0.019675) - (0.568974)|
= 0.5477"

Maximum allowable working pressure, Longitudinal Stress

P = 2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))
= 2*20000*1.0000*1.00*(1.2500-0.001615+(0.019675)) / (57.1250 - 0.40*(1.2500-0.001615+(0.019675)))
= 895.87 psi

Operating, Hot & New, Bottom Seam

t_p = P*R/(2*S_t*K_s*E_c + 0.40*|P|) (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = M/(π*R_m^2*S_t*K_s*E_c) (bending)
= 338350/(π*57.7500²*20000*1.0000*1.00)
= 0.0016"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $142781/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0197"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001615 - (0.019675)
= 0.5509"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001615 + (0.019675) - (0.568974)|
= 0.5477"

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001615+(0.019675)) / (57.1250 - 0.40*(1.2500-0.001615+(0.019675)))
= 895.87 psi

Hot Shut Down, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $338350/(\pi*57.7500^2*13878*1.0000)$
= 0.0023"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $142781/(2*\pi*57.7500*13878*1.0000)$
= 0.0284"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002327 - (0.028355)|
= 0.0260"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002327 + (0.028355) - (0.000000)
= 0.0307"

Hot Shut Down, New, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $338350/(\pi*57.7500^2*13878*1.0000)$
= 0.0023"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $142781/(2*\pi*57.7500*13878*1.0000)$
= 0.0284"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002327 - (0.028355)|
= 0.0260"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002327 + (0.028355) - (0.000000)

$= \underline{0.0307"}$

Empty, Corroded, Bottom Seam

$t_p = 0.0000"$ (Pressure)
$t_m = M/(\pi*R_m{}^2*S_c*K_s)$ (bending)
$= 338350/(\pi*57.7500^2*15853*1.0000)$
$= 0.0020"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)
$= 142781/(2*\pi*57.7500*15853*1.0000)$
$= 0.0248"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0.000000 + 0.002037 - (0.024821)|$
$= \underline{0.0228"}$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.002037 + (0.024821) - (0.000000)$
$= \underline{0.0269"}$

Empty, New, Bottom Seam

$t_p = 0.0000"$ (Pressure)
$t_m = M/(\pi*R_m{}^2*S_c*K_s)$ (bending)
$= 338350/(\pi*57.7500^2*15853*1.0000)$
$= 0.0020"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)
$= 142781/(2*\pi*57.7500*15853*1.0000)$
$= 0.0248"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0.000000 + 0.002037 - (0.024821)|$
$= \underline{0.0228"}$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.002037 + (0.024821) - (0.000000)$
$= \underline{0.0269"}$

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

$t_p = 0.0000"$ (Pressure)
$t_m = M/(\pi*R_m{}^2*S_c*K_s)$ (bending)
$= 338350/(\pi*57.7500^2*13878*1.0000)$
$= 0.0023"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)
$= 142781/(2*\pi*57.7500*13878*1.0000)$
$= 0.0284"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0.000000 + 0.002327 - (0.028355)|$
$= \underline{0.0260"}$

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002327 + (0.028355) - (0.000000)
= 0.0307"

Cylinder #6

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component:	Cylinder
Material specification:	SA-516 70 (II-D p. 14, ln. 20)

Material is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.9599779).

Internal design pressure: P = 400 psi @ 400°F

Static liquid head:

P_{th} =4.4279 psi (SG=1.0000, H_s=122.6653", Horizontal test head)
P_{tv} =26.0802 psi (SG=1.0000, H_s=722.5025", Vertical test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F	Impact test performed
Rated MDMT = -24.00°F	Material is normalized
	Material is not produced to Fine Grain Practice
	PWHT is not performed

Radiography:	Longitudinal joint -	Full UW-11(a) Type 1
	Top circumferential joint -	Full UW-11(a) Type 1
	Bottom circumferential joint -	Full UW-11(a) Type 1

Estimated weight:	New = 14544.7461 lb	corr = 14544.7461 lb
Capacity:	New = 5006.8598 gal	corr = 5006.8598 gal

ID = 114.2500"
Length L_c = 113.3125"
t = 1.2500"

Insulation thk:	2.0000"	density:	15.0000 lb/ft³	Weight:	733.9034 lb
Insulation Support Spacing:	96.0000"	Individual Support Weight:	150.0000 lb	Total Support Weight:	150.0000 lb
Lining/Refractory thickness:	0.1250"	density:	501.1200 lb/ft³	Weight:	1472.7075 lb

Design thickness, (at 400.00°F) UG-27(c)(1)

t = P*R/(S*E - 0.60*P) + Corrosion
= 400.00*57.1250/(20000*1.00 - 0.60*400.00) + 0.0000
= 1.1564"

Maximum allowable working pressure, (at 400.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t) - P_s
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500) - 0.0000
= 431.9655 psi

Maximum allowable pressure, (at 68.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t)
= 20000*1.00*1.2500 / (57.1250 + 0.60*1.2500)
= 431.9655 psi

% Extreme fiber elongation - UCS-79(d)

= $(50 * t / R_f) * (1 - R_f / R_o)$
= (50 * 1.2500 / 57.7500) * (1 - 57.7500 / ∞)
= 1.0823 %

Design thickness = 1.1564"

The governing condition is due to internal pressure.

The cylinder thickness of 1.2500" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5477	0.5448
Operating, Hot & New	400.00	20000.00	13877.59	400.00	0.0000	Weight	0.5477	0.5448
Hot Shut Down, Corroded	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0307	0.0348
Hot Shut Down, New	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0307	0.0348
Empty, Corroded	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0268	0.0305
Empty, New	0.00	20000.00	15853.10	0.00	0.0000	Weight	0.0268	0.0305
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	20000.00	13877.59	400.00	0.0000	Weight	0.0307	0.0348

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

A = $0.125 / (R_o / t)$
= 0.125 / (58.3750 / 1.2500)
= 0.002677
B = 13877.5869 psi
S = 20000.0000 / 1.0000
= 20000.0000 psi
S_{cHC} = 13877.5869 psi

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

S_{cHN} = S_{cHC}
= 13877.5869 psi

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

A = $0.125 / (R_o / t)$
= 0.125 / (58.3750 / 1.2500)
= 0.002677
B = 15853.0967 psi
S = 20000.0000 / 1.0000
= 20000.0000 psi
S_{cCN} = 15853.0967 psi

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

S_{cCC} = S_{cCN}
= 15853.0967 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.3750 / 1.2500)
= 0.002677
B = 15853.0967 psi
S = 20000.0000 / 1.0000
= 20000.0000 psi
S_{cVC} = 15853.0967 psi

Operating, Hot & Corroded, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 300502/(π*57.7500²*20000*1.0000*1.00)
= 0.0014"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= 164755/(2*π*57.7500*20000*1.0000*1.00)
= 0.0227"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001434 - (0.022703)
= 0.5477"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001434 + (0.022703) - (0.568974)|
= 0.5448"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001434+(0.022703)) / (57.1250 - 0.40*(1.2500-0.001434+(0.022703)))
= 898.16 psi

Operating, Hot & New, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m^2*S_t*K_s*E_c)$ (bending)
= 300502/(π*57.7500²*20000*1.0000*1.00)
= 0.0014"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $164755/(2*\pi*57.7500*20000*1.0000*1.00)$
= 0.0227"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001434 - (0.022703)
= 0.5477"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001434 + (0.022703) - (0.568974)|
= 0.5448"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.2500-0.001434+(0.022703)) / (57.1250 - 0.40*(1.2500-0.001434+(0.022703)))
= 898.16 psi

Hot Shut Down, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $300502/(\pi*57.7500^2*13878*1.0000)$
= 0.0021"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $164755/(2*\pi*57.7500*13878*1.0000)$
= 0.0327"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002067 - (0.032718)|
= 0.0307"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002067 + (0.032718) - (0.000000)
= 0.0348"

Hot Shut Down, New, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $300502/(\pi*57.7500^2*13878*1.0000)$
= 0.0021"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $164755/(2*\pi*57.7500*13878*1.0000)$
= 0.0327"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.002067 - (0.032718)|
= 0.0307"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.002067 + (0.032718) - (0.000000)

= 0.0348"

Empty, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)

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

= $300502/(\pi*57.7500^2*15853*1.0000)$

= 0.0018"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $164755/(2*\pi*57.7500*15853*1.0000)$

= 0.0286"

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

= |0.000000 + 0.001809 - (0.028641)|

= 0.0268"

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

= 0.001809 + (0.028641) - (0.000000)

= 0.0305"

Empty, New, Bottom Seam

t_p = 0.0000" (Pressure)

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

= $300502/(\pi*57.7500^2*15853*1.0000)$

= 0.0018"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $164755/(2*\pi*57.7500*15853*1.0000)$

= 0.0286"

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

= |0.000000 + 0.001809 - (0.028641)|

= 0.0268"

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

= 0.001809 + (0.028641) - (0.000000)

= 0.0305"

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

t_p = 0.0000" (Pressure)

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

= $300502/(\pi*57.7500^2*13878*1.0000)$

= 0.0021"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)

= $164755/(2*\pi*57.7500*13878*1.0000)$

= 0.0327"

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

= |0.000000 + 0.002067 - (0.032718)|

= 0.0307"

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

$= 0.002067 + (0.032718) - (0.000000)$

$=$ 0.0348"

Top Ellipsoidal Head #1

ASME Section VIII, Division 1, 2004 Edition, A06 Addenda

Component:	Ellipsoidal Head
Material Specification:	SA-516 70 (II-D p.14, ln. 20)

Straight Flange governs MDMT

Internal design pressure: P = 400 psi @ 400 °F

Static liquid head:

P_s= 0 psi (SG=1, H_s=0" Operating head)
P_{th}= 4.4279 psi (SG=1, H_s=122.6653" Horizontal test head)
P_{tv}= 1.4619 psi (SG=1, H_s=40.5" Vertical test head)

Corrosion allowance: Inner C = 0" Outer C = 0"

Design MDMT = -20°F
Rated MDMT = -40°F

Impact test performed
Material is normalized
Material is not produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

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

Estimated weight*:	new = 5,439.70 lb	corr = 5,439.70 lb
Capacity*:	new = 926.1 US gal	corr = 926.1 US gal

* includes straight flange

Inner diameter	=	114.25"
Minimum head thickness	=	1.1875"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	1.5"

Insulation thk*:	2"	density: 15 lb/ft^3	weight: 273.5283 lb
Insulation support ring spacing:	96"	individual weight: 150 lb	total weight: 150 lb
Lining/ref thk*:	0.125"	density: 501.12 lb/ft^3	weight: 520.1467 lb

* includes straight flange if applicable

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	=	1.1448"
Maximum allowable working pressure (MAWP)	=	414.8925 psi
Maximum allowable pressure (MAP)	=	414.8925 psi

Design thickness for internal pressure, (Corroded at 400 °F) UG-32(d)(1)

t = P*D/(2*S*E - 0.20*P) + Corrosion
= 400*114.25/(2*20000*1 - 0.20*400) + 0

= 1.1448"

The head internal pressure design thickness is 1.1448".

Maximum allowable working pressure, (Corroded at 400 °F) UG-32(d)(1)

P = $2*S*E*t/(D + 0.20*t) - P_s$
= 2*20000*1*1.1875/(114.25 +0.20*1.1875) - 0
= 414.8925 psi

The maximum allowable working pressure (MAWP) is 414.8925 psi.

Maximum allowable pressure, (New at 68 °F) UG-32(d)(1)

P = $2*S*E*t/(D + 0.20*t) - P_s$
= 2*20000*1*1.1875/(114.25 +0.20*1.1875) - 0
= 414.8925 psi

The maximum allowable pressure (MAP) is 414.8925 psi.

% Extreme fiber elongation - UCS-79(d)

= $(75*t / R_f)*(1 - R_f / R_o)$
= (75*1.5 / 20.1725)*(1 - 20.1725 / ∞)
= 5.5769%

The extreme fiber elongation exceeds 5 percent and the thickness exceeds 5/8 inch;. Heat treatment per UCS-56 is required if fabricated by cold forming.

Straight Flange on Top Ellipsoidal Head #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component:	Straight Flange
Material specification:	SA-516 70 (II-D p. 14, ln. 20)

Material is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 20 °F applied (ratio = 0.7999816).

Internal design pressure: P = 400 psi @ 400°F

Static liquid head:

P_{th} = 4.4279 psi (SG=1.0000, H_s=122.6653", Horizontal test head)
P_{tv} = 1.5341 psi (SG=1.0000, H_s=42.5000", Vertical test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F	Impact test performed
Rated MDMT = -40.00°F	Material is normalized
	Material is not produced to Fine Grain Practice
	PWHT is not performed

Radiography:	Longitudinal joint -	Seamless No RT
	Circumferential joint -	Full UW-11(a) Type 1

Estimated weight:	New = 308.7298 lb	corr = 308.7298 lb
Capacity:	New = 88.3726 gal	corr = 88.3726 gal

ID = 114.2500"
Length L_c = 2.0000"
t = 1.5000"

Insulation thk:	2.0000"	density:	15.0000 lb/ft³	Weight:	0.0000 lb
Lining/Refractory thickness:	0.1250"	density:	501.1200 lb/ft³	Weight:	0.0000 lb

Design thickness, (at 400.00°F) UG-27(c)(1)

t = P*R/(S*E - 0.60*P) + Corrosion
= 400.00*57.1250/(20000*1.00 - 0.60*400.00) + 0.0000
= 1.1564"

Maximum allowable working pressure, (at 400.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t) - P_s
= 20000*1.00*1.5000 / (57.1250 + 0.60*1.5000) - 0.0000
= 517.0186 psi

Maximum allowable pressure, (at 68.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t)
= 20000*1.00*1.5000 / (57.1250 + 0.60*1.5000)
= 517.0186 psi

% Extreme fiber elongation - UCS-79(d)

= (50 * t / R_f) * (1 - R_f / R_o)
= (50 * 1.5000 / 57.8750) * (1 - 57.8750 / ∞)

= 1.2959 %

Design thickness = 1.1564"

The governing condition is due to internal pressure.

The cylinder thickness of 1.5000" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	400.00	20000.00	14293.75	400.00	0.0000	Weight	0.5678	0.5678
Operating, Hot & New	400.00	20000.00	14293.75	400.00	0.0000	Weight	0.5678	0.5678
Hot Shut Down, Corroded	0.00	20000.00	14293.75	400.00	0.0000	Weight	0.0016	0.0017
Hot Shut Down, New	0.00	20000.00	14293.75	400.00	0.0000	Weight	0.0016	0.0017
Empty, Corroded	0.00	20000.00	16331.61	0.00	0.0000	Weight	0.0014	0.0015
Empty, New	0.00	20000.00	16331.61	0.00	0.0000	Weight	0.0014	0.0015
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	20000.00	14293.75	400.00	0.0000	Weight	0.0016	0.0017

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

A	=	$0.125 / (R_o / t)$
	=	0.125 / (58.6250 / 1.5000)
	=	0.003198
B	=	14293.7480 psi
S	=	20000.0000 / 1.0000
	=	20000.0000 psi
S_{cHC}	=	14293.7480 psi

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

S_{cHN}	=	S_{cHC}
	=	14293.7480 psi

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

A	=	$0.125 / (R_o / t)$
	=	0.125 / (58.6250 / 1.5000)
	=	0.003198
B	=	16331.6104 psi
S	=	20000.0000 / 1.0000
	=	20000.0000 psi
S_{cCN}	=	16331.6104 psi

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

S_{cCC} = S_{cCN}

= 16331.6104 psi

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

A = 0.125 / (R_o / t)

= 0.125 / (58.6250 / 1.5000)

= 0.003198

B = 16331.6104 psi

S = 20000.0000 / 1.0000

= 20000.0000 psi

S_{cVC} = 16331.6104 psi

Operating, Hot & Corroded, Bottom Seam

t_p = P*R/(2*S_t*K_s*E_c + 0.40*|P|) (Pressure)

= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)

= 0.5690"

t_m = M/(π*R_m^2*S_t*K_s*E_c) (bending)

= 3268/(π*57.8750^2*20000*1.0000*1.00)

= 0.0000"

t_w = W/(2*π*R_m*S_t*K_s*E_c) (Weight)

= 8684/(2*π*57.8750*20000*1.0000*1.00)

= 0.0012"

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

= 0.568974 + 0.000016 - (0.001194)

= 0.5678"

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

= |0.000016 + (0.001194) - (0.568974)|

= 0.5678"

Maximum allowable working pressure, Longitudinal Stress

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

= 2*20000*1.0000*1.00*(1.5000-0.000016+(0.001194)) / (57.1250 - 0.40*(1.5000-0.000016+(0.001194)))

= 1062.32 psi

Operating, Hot & New, Bottom Seam

t_p = P*R/(2*S_t*K_s*E_c + 0.40*|P|) (Pressure)

= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)

= 0.5690"

t_m = M/(π*R_m^2*S_t*K_s*E_c) (bending)

= 3268/(π*57.8750^2*20000*1.0000*1.00)

= 0.0000"

t_w = W/(2*π*R_m*S_t*K_s*E_c) (Weight)

$= 8684/(2*\pi*57.8750*20000*1.0000*1.00)$
$= 0.0012"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.568974 + 0.000016 - (0.001194)$
$= 0.5678"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.000016 + (0.001194) - (0.568974)|$
$= 0.5678"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
$= 2*20000*1.0000*1.00*(1.5000-0.000016+(0.001194)) / (57.1250 - 0.40*(1.5000-0.000016+(0.001194)))$
$= 1062.32$ psi

Hot Shut Down, Corroded, Bottom Seam

$t_p = 0.0000"$ (Pressure)
$t_m = M/(\pi*R_m^2*S_c*K_s)$ (bending)
$= 3268/(\pi*57.8750^2*14294*1.0000)$
$= 0.0000"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)
$= 8684/(2*\pi*57.8750*14294*1.0000)$
$= 0.0017"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0.000000 + 0.000022 - (0.001671)|$
$= 0.0016"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.000022 + (0.001671) - (0.000000)$
$= 0.0017"$

Hot Shut Down, New, Bottom Seam

$t_p = 0.0000"$ (Pressure)
$t_m = M/(\pi*R_m^2*S_c*K_s)$ (bending)
$= 3268/(\pi*57.8750^2*14294*1.0000)$
$= 0.0000"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)
$= 8684/(2*\pi*57.8750*14294*1.0000)$
$= 0.0017"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0.000000 + 0.000022 - (0.001671)|$
$= 0.0016"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.000022 + (0.001671) - (0.000000)$
$= 0.0017"$

Empty, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)

t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $3268/(\pi*57.8750^2*16332*1.0000)$
= 0.0000"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $8684/(2*\pi*57.8750*16332*1.0000)$
= 0.0015"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.000019 - (0.001462)|
= 0.0014"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.000019 + (0.001462) - (0.000000)
= 0.0015"

Empty, New, Bottom Seam

t_p = 0.0000" (Pressure)

t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $3268/(\pi*57.8750^2*16332*1.0000)$
= 0.0000"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $8684/(2*\pi*57.8750*16332*1.0000)$
= 0.0015"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.000019 - (0.001462)|
= 0.0014"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.000019 + (0.001462) - (0.000000)
= 0.0015"

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

t_p = 0.0000" (Pressure)

t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $3268/(\pi*57.8750^2*14294*1.0000)$
= 0.0000"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $8684/(2*\pi*57.8750*14294*1.0000)$
= 0.0017"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.000022 - (0.001671)|
= 0.0016"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.000022 + (0.001671) - (0.000000)

= 0.0017"

Straight Flange on Bottom Ellipsoidal Head #2

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Component: Straight Flange
Material specification: SA-516 70 (II-D p. 14, ln. 20)
Material is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 20 °F applied (ratio = 0.7999816).

Internal design pressure: P = 400 psi @ 400°F

Static liquid head:

P_{th} =4.4279 psi (SG=1.0000, H_s=122.6653", Horizontal test head)
P_{tv} =26.1524 psi (SG=1.0000, H_s=724.5025", Vertical test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F
Rated MDMT = -40.00°F

Impact test performed
Material is normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography:	Longitudinal joint -	Seamless No RT
	Circumferential joint -	Full UW-11(a) Type 1

Estimated weight: New = 308.7298 lb corr = 308.7298 lb
Capacity: New = 88.3726 gal corr = 88.3726 gal
ID = 114.2500"
Length L_c = 2.0000"
t = 1.5000"

Insulation thk:	2.0000"	density:	15.0000 lb/ft³	Weight:	0.0000 lb
Lining/Refractory thickness:	0.1250"	density:	501.1200 lb/ft³	Weight:	0.0000 lb

Design thickness, (at 400.00°F) UG-27(c)(1)

t = P*R/(S*E - 0.60*P) + Corrosion
= 400.00*57.1250/(20000*1.00 - 0.60*400.00) + 0.0000
= 1.1564"

Maximum allowable working pressure, (at 400.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t) - P_s
= 20000*1.00*1.5000 / (57.1250 + 0.60*1.5000) - 0.0000
= 517.0186 psi

Maximum allowable pressure, (at 68.00°F) UG-27(c)(1)

P = S*E*t/(R + 0.60*t)
= 20000*1.00*1.5000 / (57.1250 + 0.60*1.5000)
= 517.0186 psi

% Extreme fiber elongation - UCS-79(d)

= (50 * t / R_f) * (1 - R_f / R_o)
= (50 * 1.5000 / 57.8750) * (1 - 57.8750 / ∞)

= 1.2959 %

Design thickness = 1.1564"

The governing condition is due to internal pressure.

The cylinder thickness of 1.5000" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c					
Operating, Hot & Corroded	400.00	20000.00	14293.75	400.00	0.0000	Weight	0.5477	0.5449
Operating, Hot & New	400.00	20000.00	14293.75	400.00	0.0000	Weight	0.5477	0.5449
Hot Shut Down, Corroded	0.00	20000.00	14293.75	400.00	0.0000	Weight	0.0297	0.0337
Hot Shut Down, New	0.00	20000.00	14293.75	400.00	0.0000	Weight	0.0297	0.0337
Empty, Corroded	0.00	20000.00	16331.61	0.00	0.0000	Weight	0.0260	0.0295
Empty, New	0.00	20000.00	16331.61	0.00	0.0000	Weight	0.0260	0.0295
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	20000.00	14293.75	400.00	0.0000	Weight	0.0297	0.0337

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

A = 0.125 / (R_o / t)
= 0.125 / (58.6250 / 1.5000)
= 0.003198

B = 14293.7480 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cHC} = 14293.7480 psi

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

S_{cHN} = S_{cHC}
= 14293.7480 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.6250 / 1.5000)
= 0.003198

B = 16331.6104 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cCN} = 16331.6104 psi

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

S_{cCC} = S_{cCN}
= 16331.6104 psi

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

A = 0.125 / (R_o / t)
= 0.125 / (58.6250 / 1.5000)
= 0.003198

B = 16331.6104 psi

S = 20000.0000 / 1.0000
= 20000.0000 psi

S_{cVC} = 16331.6104 psi

Operating, Hot & Corroded, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $300502/(\pi*57.8750^2*20000*1.0000*1.00)$
= 0.0014"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)
= $164755/(2*\pi*57.8750*20000*1.0000*1.00)$
= 0.0227"

t_t = $t_p + t_m - t_w$ (total required, tensile)
= 0.568974 + 0.001428 - (0.022654)
= 0.5477"

t_c = $|t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
= |0.001428 + (0.022654) - (0.568974)|
= 0.5449"

Maximum allowable working pressure, Longitudinal Stress

P = $2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
= 2*20000*1.0000*1.00*(1.5000-0.001428+(0.022654)) / (57.1250 - 0.40*(1.5000-0.001428+(0.022654)))
= 1076.66 psi

Operating, Hot & New, Bottom Seam

t_p = $P*R/(2*S_t*K_s*E_c + 0.40*|P|)$ (Pressure)
= 400.00*57.1250/(2*20000*1.0000*1.00 + 0.40*|400.0000|)
= 0.5690"

t_m = $M/(\pi*R_m{}^2*S_t*K_s*E_c)$ (bending)
= $300502/(\pi*57.8750^2*20000*1.0000*1.00)$
= 0.0014"

t_w = $W/(2*\pi*R_m*S_t*K_s*E_c)$ (Weight)

$= 164755/(2*\pi*57.8750*20000*1.0000*1.00)$
$= 0.0227"$

$t_t = t_p + t_m - t_w$ (total required, tensile)
$= 0.568974 + 0.001428 - (0.022654)$
$= 0.5477"$

$t_c = |t_{mc} + t_{wc} - t_{pc}|$ (total, net tensile)
$= |0.001428 + (0.022654) - (0.568974)|$
$= 0.5449"$

Maximum allowable working pressure, Longitudinal Stress

$P = 2*S_t*K_s*E_c*(t-t_m+t_w) / (R - 0.40*(t-t_m+t_w))$
$= 2*20000*1.0000*1.00*(1.5000-0.001428+(0.022654)) / (57.1250 - 0.40*(1.5000-0.001428+(0.022654)))$
$= 1076.66$ psi

Hot Shut Down, Corroded, Bottom Seam

$t_p = 0.0000"$ (Pressure)
$t_m = M/(\pi*R_m^2*S_c*K_s)$ (bending)
$= 300502/(\pi*57.8750^2*14294*1.0000)$
$= 0.0020"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)
$= 164755/(2*\pi*57.8750*14294*1.0000)$
$= 0.0317"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0.000000 + 0.001998 - (0.031697)|$
$= 0.0297"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.001998 + (0.031697) - (0.000000)$
$= 0.0337"$

Hot Shut Down, New, Bottom Seam

$t_p = 0.0000"$ (Pressure)
$t_m = M/(\pi*R_m^2*S_c*K_s)$ (bending)
$= 300502/(\pi*57.8750^2*14294*1.0000)$
$= 0.0020"$

$t_w = W/(2*\pi*R_m*S_c*K_s)$ (Weight)
$= 164755/(2*\pi*57.8750*14294*1.0000)$
$= 0.0317"$

$t_t = |t_p + t_m - t_w|$ (total, net compressive)
$= |0.000000 + 0.001998 - (0.031697)|$
$= 0.0297"$

$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
$= 0.001998 + (0.031697) - (0.000000)$
$= 0.0337"$

Empty, Corroded, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $300502/(\pi*57.8750^2*16332*1.0000)$
= 0.0017"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $164755/(2*\pi*57.8750*16332*1.0000)$
= 0.0277"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.001749 - (0.027742)|
= 0.0260"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.001749 + (0.027742) - (0.000000)
= 0.0295"

Empty, New, Bottom Seam

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $300502/(\pi*57.8750^2*16332*1.0000)$
= 0.0017"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $164755/(2*\pi*57.8750*16332*1.0000)$
= 0.0277"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.001749 - (0.027742)|
= 0.0260"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.001749 + (0.027742) - (0.000000)
= 0.0295"

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

t_p = 0.0000" (Pressure)
t_m = $M/(\pi*R_m^2*S_c*K_s)$ (bending)
= $300502/(\pi*57.8750^2*14294*1.0000)$
= 0.0020"

t_w = $W/(2*\pi*R_m*S_c*K_s)$ (Weight)
= $164755/(2*\pi*57.8750*14294*1.0000)$
= 0.0317"

t_t = $|t_p + t_m - t_w|$ (total, net compressive)
= |0.000000 + 0.001998 - (0.031697)|
= 0.0297"

t_c = $t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)
= 0.001998 + (0.031697) - (0.000000)

= 0.0337"

Bottom Ellipsoidal Head #2

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Component:	Ellipsoidal Head
Material Specification:	SA-516 70 (II-D p.14, ln. 20)

Straight Flange governs MDMT

Internal design pressure: P = 400 psi @ 400 °F

Static liquid head:

P_s= 0 psi (SG=1, H_s=0" Operating head)
P_{th}= 4.4279 psi (SG=1, H_s=122.6653" Horizontal test head)
P_{tv}= 27.1835 psi (SG=1, H_s=753.065" Vertical test head)

Corrosion allowance: Inner C = 0" Outer C = 0"

Design MDMT = -20°F	Impact test performed
Rated MDMT = -40°F	Material is normalized
	Material is not produced to fine grain practice
	PWHT is not performed
	Do not Optimize MDMT / Find MAWP

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

Estimated weight*:	new = 5,474.50 lb	corr = 5,474.50 lb
Capacity*:	new = 926.1 US gal	corr = 926.1 US gal

* includes straight flange

Inner diameter	=	114.25"
Minimum head thickness	=	1.1875"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	1.5"

Insulation thk*:	2"	density: 15 lb/ft^3	weight: 273.5283 lb
Insulation support ring spacing:	96"	individual weight: 150 lb	total weight: 150 lb
Lining/ref thk*:	0.125"	density: 501.12 lb/ft^3	weight: 520.1467 lb

* includes straight flange if applicable

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	=	1.1448"
Maximum allowable working pressure (MAWP)	=	414.8925 psi
Maximum allowable pressure (MAP)	=	414.8925 psi

Design thickness for internal pressure, (Corroded at 400 °F) UG-32(d)(1)

t = P*D/(2*S*E - 0.20*P) + Corrosion
= 400*114.25/(2*20000*1 - 0.20*400) + 0

= 1.1448"

The head internal pressure design thickness is 1.1448".

Maximum allowable working pressure, (Corroded at 400 °F) UG-32(d)(1)

$P = 2*S*E*t/(D + 0.20*t) - P_s$
$= 2*20000*1*1.1875/(114.25 +0.20*1.1875) - 0$
$= 414.8925$ psi

The maximum allowable working pressure (MAWP) is 414.8925 psi.

Maximum allowable pressure, (New at 68 °F) UG-32(d)(1)

$P = 2*S*E*t/(D + 0.20*t) - P_s$
$= 2*20000*1*1.1875/(114.25 +0.20*1.1875) - 0$
$= 414.8925$ psi

The maximum allowable pressure (MAP) is 414.8925 psi.

% Extreme fiber elongation - UCS-79(d)

$= (75*t / R_f)*(1 - R_f / R_o)$
$= (75*1.5 / 20.1725)*(1 - 20.1725 / \infty)$
$= 5.5769\%$

The extreme fiber elongation exceeds 5 percent and the thickness exceeds 5/8 inch;. Heat treatment per UCS-56 is required if fabricated by cold forming.

M1A NPS 24 RFWN (1.25"wt. 23.25"ID) Manway (M1A)

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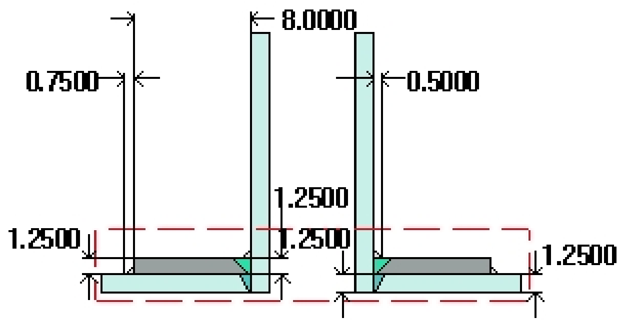


$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.5000 in
$t_{w(upper)}$ = 1.2500 in
Leg_{42} = 0.7500 in
D_p = 41.7500 in
t_e = 1.2500 in

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

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Nozzle longitudinal joint efficiency:	1.00
Pad material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Pad diameter:	41.75 in
Flange description:	24 inch Class 300 WN A105
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT: (UCS-66(b)(1)(b))	-55°F
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	57°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	657 in
End of nozzle to shell center:	70.375 in
Nozzle inside diameter, new:	23.25 in
Nozzle nominal wall thickness:	1.25 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	12 in
Pad is split:	no

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 417.43 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
28.0723	28.0796	0.9902	6.2769	--	20.0000	0.8125	0.2457	1.2500

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
543,771.19	541,788.00	1,155,497.50	193,038.00	1,694,771.50	604,288.00	1,230,306.63

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.5250	1.2500	weld size is adequate

Calculations for internal pressure 417.43 psi @ 400 °F

Nozzle is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.95998)..

Pad is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.95998)..

Nozzle rated MDMT: -24 °F
Pad rated MDMT: -24 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 23.25 in
Normal to the vessel wall outside: 2.5*(t - C) = 3.125 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 417.4316*11.625/(20000*1 - 0.6*417.4316)
= 0.2457 in

Required thickness t_r from UG-37(a)

t_r = $P*R/(S*E - 0.6*P)$
= $417.4316*57.125/(20000*1 - 0.6*417.4316)$
= 1.2074 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1
f_{r3} = lesser of f_{r2} or S_p/S_v = 1
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= $23.25*1.2074*1 + 2*1.25*1.2074*1*(1 - 1)$
= 28.0723 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.9902 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $23.25*(1*1.25 - 1*1.2074) - 2*1.25*(1*1.25 - 1*1.2074)*(1 - 1)$
= 0.9902 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $2*(1.25 + 1.25)*(1*1.25 - 1*1.2074) - 2*1.25*(1*1.25 - 1*1.2074)*(1 - 1)$
= 0.213 in^2

A_2 = smaller of the following= 6.2769 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= $5*(1.25 - 0.2457)*1*1.25$
= 6.2769 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $2*(1.25 - 0.2457)*(2.5*1.25 + 1.25)*1$
= 8.7876 in^2

A_{41} = Leg^2*f_{r3}
= 0.5^2*1
= 0.25 in^2

A_{42} = Leg^2*f_{r4}
= 0.75^2*1
= 0.5625 in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= (41.75 - 23.25 - 2*1.25)*1.25*1
= 20 in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 0.9902 + 6.2769 + 0.25 + 0.5625 + 20
= 28.0796 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check (Access Opening)

Wall thickness req'd per UG-45(a): t_{r1} = 0.2457 in (E =1)
Wall thickness per UG-16(b): t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 1.25 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*20000 =	14000 psi
Inner fillet weld in shear:	0.49*20000 =	9800 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*25.75*0.5*9800 = 198195.2 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*41.75*0.75*9800 = 482018.5 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*24.5*1.25*14000 = 673478.9 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*25.75*1.25*14800 = 748288.1 lb_f

(6) Upper groove weld in tension

$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*25.75*1.25*14800 = 748288.1 lb_f

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

$$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$$
$$= (28.0723 - 0.9902 + 2*1.25*1*(1*1.25 - 1*1.2074))*20000$$
$$= 543771.2\ lb_f$$

$$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (6.2769 + 20 + 0.25 + 0.5625)*20000$$
$$= 541788\ lb_f$$

$$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (6.2769 + 0 + 0.25 + 0 + 2*1.25*1.25*1)*20000$$
$$= 193038\ lb_f$$

$$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (6.2769 + 0 + 20 + 0.25 + 0.5625 + 0 + 2*1.25*1.25*1)*20000$$
$$= 604288\ lb_f$$

Load for path 1-1 lesser of W or W_{1-1} = 541788 lb_f
Path 1-1 through (2) & (3) = 482018.5 + 673478.9 = 1155498 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 193038 lb_f
Path 2-2 through (1), (4), (6) = 198195.2 + 748288.1 + 748288.1 = 1694772 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} = 543771.2 lb_f
Path 3-3 through (2), (4) = 482018.5 + 748288.1 = 1230307 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

% Extreme fiber elongation - UCS-79(d)

$$= (50*t / R_f)*(1 - R_f / R_o)$$
$$= (50*1.25 / 12.25)*(1 - 12.25 / \infty)$$
$$= 5.102\%$$

The extreme fiber elongation exceeds 5 percent and the thickness exceeds 5/8 inch;. Heat treatment per UCS-56 is required if fabricated by cold forming.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2) For P = 417.43 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
28.0723	28.0796	0.9902	6.2769	--	20.0000	0.8125	0.2457	1.2500

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
543,771.19	541,788.00	1,155,497.50	193,038.00	1,694,771.50	604,288.00	1,230,306.63

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.5250	1.2500	weld size is adequate

Calculations for internal pressure 417.43 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 23.25 in
Normal to the vessel wall outside:	2.5*(t - C) = 3.125 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 417.4316*11.625/(20000*1 - 0.6*417.4316)
= 0.2457 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 417.4316*57.125/(20000*1 - 0.6*417.4316)

$= \quad 1.2074$ in

Area required per UG-37(c)

Allowable stresses: $S_n = 20000$, $S_v = 20000$, $S_p = 20000$ psi

f_{r1} = lesser of 1 or $S_n/S_v = 1$
f_{r2} = lesser of 1 or $S_n/S_v = 1$
f_{r3} = lesser of f_{r2} or $S_p/S_v = 1$
f_{r4} = lesser of 1 or $S_p/S_v = 1$

$A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
$= 23.25*1.2074*1 + 2*1.25*1.2074*1*(1 - 1)$
$=$ 28.0723 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.9902 in^2

$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 23.25*(1*1.25 - 1*1.2074) - 2*1.25*(1*1.25 - 1*1.2074)*(1 - 1)$
$= 0.9902$ in^2

$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
$= 2*(1.25 + 1.25)*(1*1.25 - 1*1.2074) - 2*1.25*(1*1.25 - 1*1.2074)*(1 - 1)$
$= 0.213$ in^2

A_2 = smaller of the following= 6.2769 in^2

$= 5*(t_n - t_{rn})*f_{r2}*t$
$= 5*(1.25 - 0.2457)*1*1.25$
$= 6.2769$ in^2

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= 2*(1.25 - 0.2457)*(2.5*1.25 + 1.25)*1$
$= 8.7876$ in^2

$A_{41} = Leg^2*f_{r3}$
$= 0.5^2*1$
$=$ 0.25 in^2

$A_{42} = Leg^2*f_{r4}$
$= 0.75^2*1$
$=$ 0.5625 in^2

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (41.75 - 23.25 - 2*1.25)*1.25*1$
$=$ 20 in^2

Area	=	$A_1 + A_2 + A_{41} + A_{42} + A_5$
	=	0.9902 + 6.2769 + 0.25 + 0.5625 + 20
	=	28.0796 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = 0.5*t_{min} = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check (Access Opening)

Wall thickness req'd per UG-45(a): t_{r1} = 0.2457 in (E =1)
Wall thickness per UG-16(b): t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 1.25 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*20000 =	14000 psi
Inner fillet weld in shear:	0.49*20000 =	9800 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(π/2)*Nozzle OD*Leg*S_i = (π/2)*25.75*0.5*9800 = 198195.2 lb_f

(2) Outer fillet weld in shear
(π/2)*Pad OD*Leg*S_o = (π/2)*41.75*0.75*9800 = 482018.5 lb_f

(3) Nozzle wall in shear
(π/2)*Mean nozzle dia*t_n*S_n = (π/2)*24.5*1.25*14000 = 673478.9 lb_f

(4) Groove weld in tension
(π/2)*Nozzle OD*t_w*S_g = (π/2)*25.75*1.25*14800 = 748288.1 lb_f

(6) Upper groove weld in tension
(π/2)*Nozzle OD*t_w*S_g = (π/2)*25.75*1.25*14800 = 748288.1 lb_f

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (28.0723 - 0.9902 + 2*1.25*1*(1*1.25 - 1*1.2074))*20000$
$=$ 543771.2 lb_f

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$
$= (6.2769 + 20 + 0.25 + 0.5625)*20000$
$=$ 541788 lb_f

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (6.2769 + 0 + 0.25 + 0 + 2*1.25*1.25*1)*20000$
$=$ 193038 lb_f

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (6.2769 + 0 + 20 + 0.25 + 0.5625 + 0 + 2*1.25*1.25*1)*20000$
$=$ 604288 lb_f

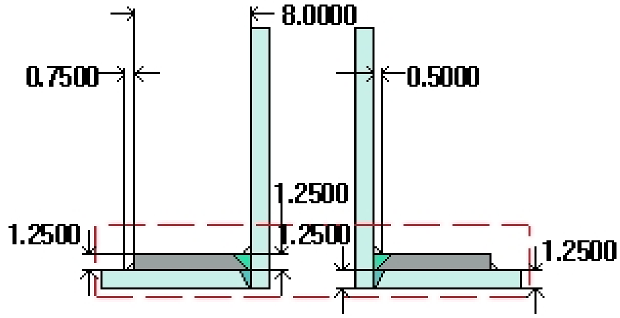
Load for path 1-1 lesser of W or W_{1-1} = 541788 lb_f
Path 1-1 through (2) & (3) = 482018.5 + 673478.9 = 1155498 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 193038 lb_f
Path 2-2 through (1), (4), (6) = 198195.2 + 748288.1 + 748288.1 = 1694772 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} = 543771.2 lb_f
Path 3-3 through (2), (4) = 482018.5 + 748288.1 = 1230307 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

M1B NPS 24 RFWN (1.25"wt. 23.25"ID) Manway (M1B)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda



$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.5000 in
$t_{w(upper)}$ = 1.2500 in
Leg_{42} = 0.7500 in
D_p = 41.7500 in
t_e = 1.2500 in

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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Nozzle longitudinal joint efficiency:	1.00
Pad material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Pad diameter:	41.75 in
Flange description:	24 inch Class 300 WN A105
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UCS-66(b)(1)(b))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	120°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	37 in
End of nozzle to shell center:	70.375 in
Nozzle inside diameter, new:	23.25 in
Nozzle nominal wall thickness:	1.25 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	12 in
Pad is split:	no

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 417.43 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
28.0723	28.0796	0.9902	6.2769	--	20.0000	0.8125	0.2457	1.2500

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
543,771.19	541,788.00	1,155,497.50	193,038.00	1,694,771.50	604,288.00	1,230,306.63

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.5250	1.2500	weld size is adequate

Calculations for internal pressure 417.43 psi @ 400 °F

Nozzle is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.95998)..

Pad is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.95998)..

Nozzle rated MDMT: -24 °F
Pad rated MDMT: -24 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 23.25 in
Normal to the vessel wall outside: 2.5*(t - C) = 3.125 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 417.4316*11.625/(20000*1 - 0.6*417.4316)
= 0.2457 in

Required thickness t_r from UG-37(a)

t_r	=	P*R/(S*E - 0.6*P)
	=	417.4316*57.125/(20000*1 - 0.6*417.4316)
	=	1.2074 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1
f_{r3} = lesser of f_{r2} or S_p/S_v = 1
f_{r4} = lesser of 1 or S_p/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	23.25*1.2074*1 + 2*1.25*1.2074*1*(1 - 1)
	=	28.0723 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.9902 in^2

=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	23.25*(1*1.25 - 1*1.2074) - 2*1.25*(1*1.25 - 1*1.2074)*(1 - 1)
=	0.9902 in^2

=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	2*(1.25 + 1.25)*(1*1.25 - 1*1.2074) - 2*1.25*(1*1.25 - 1*1.2074)*(1 - 1)
=	0.213 in^2

A_2 = smaller of the following= 6.2769 in^2

=	$5*(t_n - t_{rn})*f_{r2}*t$
=	5*(1.25 - 0.2457)*1*1.25
=	6.2769 in^2

=	$2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
=	2*(1.25 - 0.2457)*(2.5*1.25 + 1.25)*1
=	8.7876 in^2

A_{41}	=	Leg^2*f_{r3}
	=	0.5^2*1
	=	0.25 in^2

A_{42}	=	Leg^2*f_{r4}
	=	0.75^2*1
	=	0.5625 in^2

A_5 = $(D_p - d - 2^*t_n)^*t_e^*f_{r4}$
= (41.75 - 23.25 - 2*1.25)*1.25*1
= 20 in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 0.9902 + 6.2769 + 0.25 + 0.5625 + 20
= 28.0796 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = 0.5*t_{min} = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check (Access Opening)

Wall thickness req'd per UG-45(a): t_{r1} = 0.2457 in (E =1)
Wall thickness per UG-16(b): t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 1.25 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*20000 =	14000 psi
Inner fillet weld in shear:	0.49*20000 =	9800 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*25.75*0.5*9800 = 198195.2 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*41.75*0.75*9800 = 482018.5 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*24.5*1.25*14000 = 673478.9 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*25.75*1.25*14800 = 748288.1 lb_f

(6) Upper groove weld in tension

$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*25.75*1.25*14800 = 748288.1 lb_f

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

W = $(A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
= (28.0723 - 0.9902 + 2*1.25*1*(1*1.25 - 1*1.2074))*20000
= 543771.2 lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42})*S_v$
= (6.2769 + 20 + 0.25 + 0.5625)*20000
= 541788 lb_f

W_{2-2} = $(A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= (6.2769 + 0 + 0.25 + 0 + 2*1.25*1.25*1)*20000
= 193038 lb_f

W_{3-3} = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= (6.2769 + 0 + 20 + 0.25 + 0.5625 + 0 + 2*1.25*1.25*1)*20000
= 604288 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 541788 lb_f
Path 1-1 through (2) & (3) = 482018.5 + 673478.9 = 1155498 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 193038 lb_f
Path 2-2 through (1), (4), (6) = 198195.2 + 748288.1 + 748288.1 = 1694772 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} = 543771.2 lb_f
Path 3-3 through (2), (4) = 482018.5 + 748288.1 = 1230307 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

% Extreme fiber elongation - UCS-79(d)

= $(50*t / R_f)*(1 - R_f / R_o)$
= $(50*1.25 / 12.25)*(1 - 12.25 / \infty)$
= 5.102%

The extreme fiber elongation exceeds 5 percent and the thickness exceeds 5/8 inch;. Heat treatment per UCS-56 is required if fabricated by cold forming.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2) For P = 417.43 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
28.0723	28.0796	0.9902	6.2769	--	20.0000	0.8125	0.2457	1.2500

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
543,771.19	541,788.00	1,155,497.50	193,038.00	1,694,771.50	604,288.00	1,230,306.63

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.5250	1.2500	weld size is adequate

Calculations for internal pressure 417.43 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 23.25 in
Normal to the vessel wall outside:	2.5*(t - C) = 3.125 in

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

$$t_{rn} = P*R_n/(S_n*E - 0.6*P)$$
$$= 417.4316*11.625/(20000*1 - 0.6*417.4316)$$
$$= 0.2457 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = P*R/(S*E - 0.6*P)$$
$$= 417.4316*57.125/(20000*1 - 0.6*417.4316)$$

$= \quad 1.2074$ in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1
f_{r3} = lesser of f_{r2} or S_p/S_v = 1
f_{r4} = lesser of 1 or S_p/S_v = 1

$$A = d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$$
$$= 23.25*1.2074*1 + 2*1.25*1.2074*1*(1 - 1)$$
$$= 28.0723 \text{ in}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.9902 in^2

$$= d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$$
$$= 23.25*(1*1.25 - 1*1.2074) - 2*1.25*(1*1.25 - 1*1.2074)*(1 - 1)$$
$$= 0.9902 \text{ in}^2$$

$$= 2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$$
$$= 2*(1.25 + 1.25)*(1*1.25 - 1*1.2074) - 2*1.25*(1*1.25 - 1*1.2074)*(1 - 1)$$
$$= 0.213 \text{ in}^2$$

A_2 = smaller of the following= 6.2769 in^2

$$= 5*(t_n - t_{rn})*f_{r2}*t$$
$$= 5*(1.25 - 0.2457)*1*1.25$$
$$= 6.2769 \text{ in}^2$$

$$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$$
$$= 2*(1.25 - 0.2457)*(2.5*1.25 + 1.25)*1$$
$$= 8.7876 \text{ in}^2$$

$$A_{41} = Leg^2*f_{r3}$$
$$= 0.5^2*1$$
$$= 0.25 \text{ in}^2$$

$$A_{42} = Leg^2*f_{r4}$$
$$= 0.75^2*1$$
$$= 0.5625 \text{ in}^2$$

$$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$$
$$= (41.75 - 23.25 - 2*1.25)*1.25*1$$
$$= 20 \text{ in}^2$$

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 0.9902 + 6.2769 + 0.25 + 0.5625 + 20
= 28.0796 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = 0.5*t_{min} = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check (Access Opening)

Wall thickness req'd per UG-45(a): t_{r1} = 0.2457 in (E =1)
Wall thickness per UG-16(b): t_{r3} = 0.0625 in

Available nozzle wall thickness new, t_n = 1.25 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*20000 =	14000 psi
Inner fillet weld in shear:	0.49*20000 =	9800 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(π/2)*Nozzle OD*Leg*S_i = (π/2)*25.75*0.5*9800 = 198195.2 lb_f

(2) Outer fillet weld in shear
(π/2)*Pad OD*Leg*S_o = (π/2)*41.75*0.75*9800 = 482018.5 lb_f

(3) Nozzle wall in shear
(π/2)*Mean nozzle dia*t_n*S_n = (π/2)*24.5*1.25*14000 = 673478.9 lb_f

(4) Groove weld in tension
(π/2)*Nozzle OD*t_w*S_g = (π/2)*25.75*1.25*14800 = 748288.1 lb_f

(6) Upper groove weld in tension
(π/2)*Nozzle OD*t_w*S_g = (π/2)*25.75*1.25*14800 = 748288.1 lb_f

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

$$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$$
$$= (28.0723 - 0.9902 + 2*1.25*1*(1*1.25 - 1*1.2074))*20000$$
$$= 543771.2\ lb_f$$

$$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$$
$$= (6.2769 + 20 + 0.25 + 0.5625)*20000$$
$$= 541788\ lb_f$$

$$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (6.2769 + 0 + 0.25 + 0 + 2*1.25*1.25*1)*20000$$
$$= 193038\ lb_f$$

$$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$$
$$= (6.2769 + 0 + 20 + 0.25 + 0.5625 + 0 + 2*1.25*1.25*1)*20000$$
$$= 604288\ lb_f$$

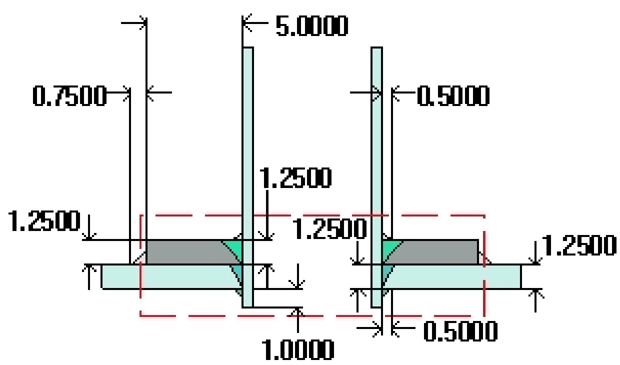
Load for path 1-1 lesser of W or W_{1-1} = 541788 lb_f
Path 1-1 through (2) & (3) = 482018.5 + 673478.9 = 1155498 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 193038 lb_f
Path 2-2 through (1), (4), (6) = 198195.2 + 748288.1 + 748288.1 = 1694772 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} = 543771.2 lb_f
Path 3-3 through (2), (4) = 482018.5 + 748288.1 = 1230307 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

N11 NPS 12 RFWN S/XH(0.5"wt) Vapor Feed Nozzle (N11)

ASME Section VIII Division 1, 2004 Edition, A06 Addenda



$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.5000 in
$t_{w(upper)}$ = 1.2500 in
Leg_{42} = 0.7500 in
Leg_{43} = 0.5000 in
h_{new} = 1.0000 in
D_p = 22.7500 in
t_e = 1.2500 in

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

Located on:	Cylinder #5
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 5)
Nozzle longitudinal joint efficiency:	1.00
Nozzle description:	12" X Heavy
Pad material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Pad diameter:	22.75 in
Flange description:	12 inch Class 300 WN A105
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UCS-66(b)(1)(b))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	90°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	136 in
End of nozzle to shell center:	67 in
Nozzle inside diameter, new:	11.75 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8.625 in
Pad is split:	no

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
14.8677	15.6988	0.0010	1.4933	0.8550	12.5000	0.8495	0.3281	0.4375

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
297,335.13	292,580.00	377,821.69	76,893.00	908,835.00	335,331.00	717,074.25

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.3500	1.2500	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -13 °F
Fig UCS-66.1 MDMT reduction = 44.3 °F, (coincident ratio = 0.57102)
Rated MDMT is governed by UCS-66(b)(2).
External nozzle loadings per UG-22 govern the coincident ratio used.

Pad is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.95998)..

Nozzle UCS-66 governing thk:	0.4375	in
Nozzle rated MDMT:	-55	°F
Pad rated MDMT:	-24	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 11.75 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 2.5$ in
Normal to the vessel wall inside:	$2.5*(t_n - C_n - C) = 1.25$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*5.875/(17100*1 - 0.6*431.9336)
= 0.1507 in

Required thickness t_r from UG-37(a)

t_r = $P*R/(S*E - 0.6*P)$
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

Area required per UG-37(c)

Allowable stresses: S_n = 17100, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 11.75*1.2499*1 + 2*0.5*1.2499*1*(1 - 0.855)
= 14.8677 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.001 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 11.75*(1*1.25 - 1*1.2499) - 2*0.5*(1*1.25 - 1*1.2499)*(1 - 0.855)
= 0.001 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.25 + 0.5)*(1*1.25 - 1*1.2499) - 2*0.5*(1*1.25 - 1*1.2499)*(1 - 0.855)
= 0.0003 in^2

A_2 = smaller of the following= 1.4933 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5 - 0.1507)*0.855*1.25
= 1.8666 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.5 - 0.1507)*(2.5*0.5 + 1.25)*0.855
= 1.4933 in^2

A_3 = smaller of the following= 0.855 in^2

= $5*t*t_i*f_{r2}$
= 5*1.25*0.5*0.855

$= \underline{2.6719}\ in^2$

$= 5*t_i*t_i*f_{r2}$
$= 5*0.5*0.5*0.855$
$= \underline{1.0688}\ in^2$

$= 2*h*t_i*f_{r2}$
$= 2*1*0.5*0.855$
$= \underline{0.855}\ in^2$

$A_{41} = Leg^2*f_{r3}$
$= 0.5^2*0.855$
$= \underline{0.2138}\ in^2$

$A_{42} = Leg^2*f_{r4}$
$= 0.6495^2*1$
$= \underline{0.4219}\ in^2$

(Part of the weld is outside of the limits)
$A_{43} = Leg^2*f_{r2}$
$= 0.5^2*0.855$
$= \underline{0.2138}\ in^2$

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (22.75 - 11.75 - 2*0.5)*1.25*1$
$= \underline{12.5}\ in^2$

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
$= 0.001 + 1.4933 + 0.855 + 0.2138 + 0.4219 + 0.2138 + 12.5$
$= \underline{15.6988}\ in^2$

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.5 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = 0.5*t_{min} = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a): t_{r1} = 0.253 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1): t_{r2} = 1.2499 in

Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.3281 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.3281 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.3281 in

Available nozzle wall thickness new, t_n = 0.8750*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi
Lower fillet weld in shear:	0.49*17100 =	8379 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*12.75*0.5*8379 = 83905.86 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*22.75*0.75*9800 = 262656.8 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*12.25*0.5*11970 = 115164.9 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*12.75*1.25*14800 = 370511.6 lb_f

(5) Lower fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_l = $(\pi/2)$*12.75*0.5*8379 = 83905.86 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*12.75*1.25*14800 = 370511.6 lb_f

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (14.8677 - 0.001 + 2*0.5*0.855*(1*1.25 - 1*1.2499))*20000$
$=$ 297335.1 lb_f

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$
$= (1.4933 + 12.5 + 0.2138 + 0.4219)*20000$
$=$ 292580 lb_f

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$

$= (1.4933 + 0.855 + 0.2138 + 0.2138 + 2*0.5*1.25*0.855)*20000$

$= \underline{76893}\ lb_f$

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

$= (1.4933 + 0.855 + 12.5 + 0.2138 + 0.4219 + 0.2138 + 2*0.5*1.25*0.855)*20000$

$= \underline{335331}\ lb_f$

Load for path 1-1 lesser of W or W_{1-1} = 292580 lb_f
Path 1-1 through (2) & (3) = 262656.8 + 115164.9 = 377821.7 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 76893 lb_f
Path 2-2 through (1), (4), (5), (6) = 83905.86 + 370511.6 + 83905.86 + 370511.6 = 908835 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} = 297335.1 lb_f
Path 3-3 through (2), (4), (5) = 262656.8 + 370511.6 + 83905.86 = 717074.3 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	7,500.00	lb_f
Circumferential moment:	M_c =	306,360.00	lb_f-in
Circumferential shear:	V_c =	8,010.00	lb_f
Longitudinal moment:	M_L =	306,360.00	lb_f-in
Longitudinal shear:	V_L =	8,010.00	lb_f
Torsion moment:	M_t =	919,080.00	lb_f-in
Internal pressure:	P =	431.934	psi
Mean shell radius:	R_m =	57.7500	in
Local shell thickness:	t =	1.2500	in
Shell yield stress:	S_y =	32,500.00	psi

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

R_m/t =46.2

Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = $I*P*R_i/t$ = 19,739.00 psi

Local longitudinal pressure stress = $I*P*R_i/2t$ = 9,870.00 psi

Maximum combined stress (P_L+P_b+Q) = 29,941.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 21,147.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the pad edge per WRC Bulletin 107										
Figure	**value**	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	4.7547	0.1723	0	0	0	0	-494	-494	-494	-494
4C*	6.7893	0.1723	-705	-705	-705	-705	0	0	0	0
1C	0.0755	0.1723	0	0	0	0	-2,174	2,174	-2,174	2,174
2C-1	0.0419	0.1723	-1,207	1,207	-1,207	1,207	0	0	0	0
3A*	1.8755	0.1723	0	0	0	0	-800	-800	800	800
1A	0.0786	0.1723	0	0	0	0	-9,290	9,290	9,290	-9,290
3B*	4.9555	0.1723	-2,113	-2,113	2,113	2,113	0	0	0	0
1B-1	0.0286	0.1723	-3,380	3,380	3,380	-3,380	0	0	0	0
Pressure stress*			19,739	19,739	19,739	19,739	19,739	19,739	19,739	19,739
Total circumferential stress			12,334	21,508	23,320	18,974	6,981	29,909	27,161	12,929
Primary membrane circumferential stress*			16,921	16,921	21,147	21,147	18,445	18,445	20,045	20,045
3C*	4.7547	0.1723	-494	-494	-494	-494	0	0	0	0
4C*	6.7893	0.1723	0	0	0	0	-705	-705	-705	-705
1C-1	0.0761	0.1723	-2,192	2,192	-2,192	2,192	0	0	0	0
2C	0.0442	0.1723	0	0	0	0	-1,273	1,273	-1,273	1,273
4A*	3.4540	0.1723	0	0	0	0	-1,473	-1,473	1,473	1,473
2A	0.0401	0.1723	0	0	0	0	-4,740	4,740	4,740	-4,740
4B*	1.8711	0.1723	-798	-798	798	798	0	0	0	0
2B-1	0.0428	0.1723	-5,059	5,059	5,059	-5,059	0	0	0	0
Pressure stress*			9,870	9,870	9,870	9,870	9,870	9,870	9,870	9,870
Total longitudinal stress			1,327	15,829	13,041	7,307	1,679	13,705	14,105	7,171
Primary membrane longitudinal stress*			8,578	8,578	10,174	10,174	7,692	7,692	10,638	10,638
Shear from M_t			904	904	904	904	904	904	904	904
Circ shear from V_c			179	179	-179	-179	0	0	0	0

Long shear from V_L	0	0	0	0	-179	-179	179	179
Total Shear stress	1,083	1,083	725	725	725	725	1,083	1,083
Combined stress (P_L+P_b+Q)	12,440	21,708	23,371	19,019	7,078	29,941	27,250	13,126

Note: * denotes primary stress.

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

R_m/t =23.1

Pressure stress intensity factor, I = 0.92054 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = $I*P*R_i/t$ = 18,171.00 psi

Local longitudinal pressure stress = $I*P*R_i/2t$ = 9,086.00 psi

Maximum combined stress (P_L+P_b+Q) = 25,938.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 19,744.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the nozzle OD per WRC Bulletin 107										
Figure	**value**	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	3.9258	0.0966	0	0	0	0	-204	-204	-204	-204
4C*	4.2402	0.0966	-220	-220	-220	-220	0	0	0	0
1C	0.1567	0.0966	0	0	0	0	-1,128	1,128	-1,128	1,128
2C-1	0.1177	0.0966	-847	847	-847	847	0	0	0	0
3A*	0.5482	0.0966	0	0	0	0	-209	-209	209	209
1A	0.1017	0.0966	0	0	0	0	-5,362	5,362	5,362	-5,362
3B*	1.9399	0.0966	-738	-738	738	738	0	0	0	0
1B-1	0.0533	0.0966	-2,810	2,810	2,810	-2,810	0	0	0	0
Pressure stress*			18,171	18,171	18,171	18,171	19,739	19,739	19,739	19,739
Total circumferential stress			13,556	20,870	20,652	16,726	12,836	25,816	23,978	15,510
Primary membrane circumferential stress*			17,213	17,213	18,689	18,689	19,326	19,326	19,744	19,744
3C*	3.9258	0.0966	-204	-204	-204	-204	0	0	0	0
4C*	4.2402	0.0966	0	0	0	0	-220	-220	-220	-220
1C-1	0.1595	0.0966	-1,148	1,148	-1,148	1,148	0	0	0	0
2C	0.1173	0.0966	0	0	0	0	-845	845	-845	845
4A*	0.7190	0.0966	0	0	0	0	-274	-274	274	274
2A	0.0584	0.0966	0	0	0	0	-3,079	3,079	3,079	-3,079
4B*	0.5249	0.0966	-200	-200	200	200	0	0	0	0
2B-1	0.0850	0.0966	-4,482	4,482	4,482	-4,482	0	0	0	0
Pressure stress*			9,870	9,870	9,870	9,870	9,086	9,086	9,086	9,086
Total longitudinal stress			3,836	15,096	13,200	6,532	4,668	12,516	11,374	6,906
Primary membrane longitudinal stress*			9,466	9,466	9,866	9,866	8,592	8,592	9,140	9,140
Shear from M_t			1,440	1,440	1,440	1,440	1,440	1,440	1,440	1,440

Circ shear from V_c	160	160	-160	-160	0	0	0	0
Long shear from V_L	0	0	0	0	-160	-160	160	160
Total Shear stress	1,600	1,600	1,280	1,280	1,280	1,280	1,600	1,600
Combined stress (P_L+P_b+Q)	13,813	21,284	20,866	16,884	13,032	25,938	24,178	15,798

Note: * denotes primary stress.

Stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\ (Pm)} = P*R_i/(2*t_n) - P_r/(\pi*(R_o^2 - R_i^2)) + M*R_o/I$
$= 431.9336*5.875/(2*0.4375) - 7{,}500.00/(\pi*(6.375^2 - 5.875^2)) + 433{,}258.5*6.375/361.5439$
$= 10{,}149.88$ psi

The average primary stress P_m (see Division 2 Appendix 4-138(b)) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 17,100.00psi)

Shear in the nozzle due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (8010^2 + 8010^2)^{0.5} / (\pi*5.875*0.5)$
$= 1228$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 919080 / (2*\pi*5.875^2*0.5)$
$= 8476$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 1228 + 8476$
$= 9703$ psi

UG-45(c): The total combined shear stress (9703 psi) is below than the allowable ($0.7*S_n = 0.7*17100 = 11970$ psi)

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
14.8677	15.6988	0.0010	1.4933	0.8550	12.5000	0.8495	0.3281	0.4375

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
297,335.13	292,580.00	377,821.69	76,893.00	908,835.00	335,331.00	717,074.25

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate

Nozzle to pad groove (Upper)	0.3500	1.2500	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 11.75 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 2.5$ in
Normal to the vessel wall inside:	$2.5*(t_n - C_n - C) = 1.25$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*5.875/(17100*1 - 0.6*431.9336)
= 0.1507 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

Area required per UG-37(c)

Allowable stresses: S_n = 17100, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 11.75*1.2499*1 + 2*0.5*1.2499*1*(1 - 0.855)
= 14.8677 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.001 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 11.75*(1*1.25 - 1*1.2499) - 2*0.5*(1*1.25 - 1*1.2499)*(1 - 0.855)
= 0.001 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.25 + 0.5)*(1*1.25 - 1*1.2499) - 2*0.5*(1*1.25 - 1*1.2499)*(1 - 0.855)
= 0.0003 in^2

A_2 = smaller of the following= 1.4933 in^2

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

= $5*(0.5 - 0.1507)*0.855*1.25$
= $1.8666\ in^2$

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $2*(0.5 - 0.1507)*(2.5*0.5 + 1.25)*0.855$
= $1.4933\ in^2$

A_3 = smaller of the following= 0.855 in^2

= $5*t*t_i*f_{r2}$
= $5*1.25*0.5*0.855$
= 2.6719 in^2

= $5*t_i*t_i*f_{r2}$
= $5*0.5*0.5*0.855$
= 1.0688 in^2

= $2*h*t_i*f_{r2}$
= $2*1*0.5*0.855$
= 0.855 in^2

A_{41} = Leg^2*f_{r3}
= $0.5^2*0.855$
= 0.2138 in^2

A_{42} = Leg^2*f_{r4}
= 0.6495^2*1
= 0.4219 in^2

(Part of the weld is outside of the limits)
A_{43} = Leg^2*f_{r2}
= $0.5^2*0.855$
= 0.2138 in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(22.75 - 11.75 - 2*0.5)*1.25*1$
= 12.5 in^2

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
= $0.001 + 1.4933 + 0.855 + 0.2138 + 0.4219 + 0.2138 + 12.5$
= 15.6988 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.5 in

$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = 0.5*t_{min} = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.253 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.3281 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.3281 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.3281 in

Available nozzle wall thickness new, t_n = 0.8750*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi
Lower fillet weld in shear:	0.49*17100 =	8379 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*12.75*0.5*8379 = 83905.86 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*22.75*0.75*9800 = 262656.8 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*12.25*0.5*11970 = 115164.9 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*12.75*1.25*14800 = 370511.6 lb_f

(5) Lower fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_l = $(\pi/2)$*12.75*0.5*8379 = 83905.86 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*12.75*1.25*14800 = 370511.6 lb_f

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (14.8677 - 0.001 + 2*0.5*0.855*(1*1.25 - 1*1.2499))*20000$
$= 297335.1\ lb_f$

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$
$= (1.4933 + 12.5 + 0.2138 + 0.4219)*20000$
$= 292580\ lb_f$

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (1.4933 + 0.855 + 0.2138 + 0.2138 + 2*0.5*1.25*0.855)*20000$
$= 76893\ lb_f$

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (1.4933 + 0.855 + 12.5 + 0.2138 + 0.4219 + 0.2138 + 2*0.5*1.25*0.855)*20000$
$= 335331\ lb_f$

Load for path 1-1 lesser of W or W_{1-1} = 292580 lb_f
Path 1-1 through (2) & (3) = 262656.8 + 115164.9 = 377821.7 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 76893 lb_f
Path 2-2 through (1), (4), (5), (6) = 83905.86 + 370511.6 + 83905.86 + 370511.6 = 908835 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} = 297335.1 lb_f
Path 3-3 through (2), (4), (5) = 262656.8 + 370511.6 + 83905.86 = 717074.3 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

N12 NPS 8 RFWN S/XH(0.5"wt) Amine Feed Nozzle (N12)

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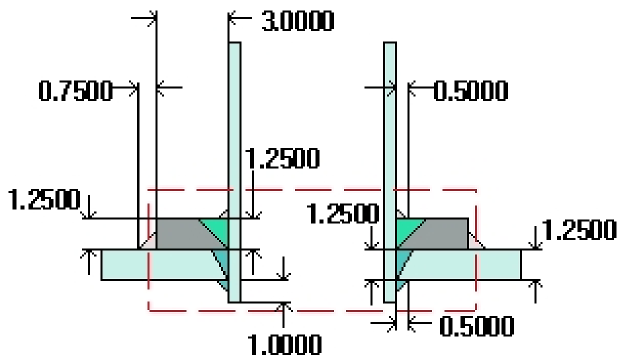

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.5000 in
$t_{w(upper)}$ = 1.2500 in
Leg_{42} = 0.7500 in
Leg_{43} = 0.5000 in
h_{new} = 1.0000 in
D_p = 14.6250 in
t_e = 1.2500 in

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

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 5)
Nozzle longitudinal joint efficiency:	1.00
Nozzle description:	8" Sch 80 (XS)
Pad material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Pad diameter:	14.625 in
Flange description:	8 inch Class 300 WN A105
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UCS-66(b)(1)(b))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	90°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	666 in
End of nozzle to shell center:	67 in
Nozzle inside diameter, new:	7.625 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8.625 in
Pad is split:	no

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
9.7118	10.8738	0.0007	1.7194	0.8550	7.5000	0.7987	0.2875	0.4375

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
194,223.55	196,086.00	245,235.69	81,415.00	614,800.06	238,837.00	476,250.81

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.3500	1.2500	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -13 °F
Fig UCS-66.1 MDMT reduction = 34.8 °F, (coincident ratio = 0.65227).
External nozzle loadings per UG-22 govern the coincident ratio used.

Pad is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 4 °F applied (ratio = 0.95998)..

Nozzle UCS-66 governing thk:	0.4375	in
Nozzle rated MDMT:	-47.8	°F
Pad rated MDMT:	-24	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 7.625 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 2.5$ in
Normal to the vessel wall inside:	$2.5*(t_n - C_n - C) = 1.25$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*3.8125/(17100*1 - 0.6*431.9336)
= 0.0978 in

Required thickness t_r from UG-37(a)

t_r = $P*R/(S*E - 0.6*P)$
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

Area required per UG-37(c)

Allowable stresses: S_n = 17100, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 7.625*1.2499*1 + 2*0.5*1.2499*1*(1 - 0.855)
= 9.7118 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0007 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 7.625*(1*1.25 - 1*1.2499) - 2*0.5*(1*1.25 - 1*1.2499)*(1 - 0.855)
= 0.0007 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.25 + 0.5)*(1*1.25 - 1*1.2499) - 2*0.5*(1*1.25 - 1*1.2499)*(1 - 0.855)
= 0.0003 in^2

A_2 = smaller of the following= 1.7194 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5 - 0.0978)*0.855*1.25
= 2.1493 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.5 - 0.0978)*(2.5*0.5 + 1.25)*0.855
= 1.7194 in^2

A_3 = smaller of the following= 0.855 in^2

= $5*t*t_i*f_{r2}$
= 5*1.25*0.5*0.855
= 2.6719 in^2

$= 5*t_i*t_i*f_{r2}$
$= 5*0.5*0.5*0.855$
$=$ 1.0688 in^2

$= 2*h*t_i*f_{r2}$
$= 2*1*0.5*0.855$
$=$ 0.855 in^2

$A_{41} = Leg^2*f_{r3}$
$= 0.5^2*0.855$
$=$ 0.2138 in^2

$A_{42} = Leg^2*f_{r4}$
$= 0.6092^2*1$
$=$ 0.3711 in^2

(Part of the weld is outside of the limits)
$A_{43} = Leg^2*f_{r2}$
$= 0.5^2*0.855$
$=$ 0.2138 in^2

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (14.625 - 7.625 - 2*0.5)*1.25*1$
$=$ 7.5 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
$= 0.0007 + 1.7194 + 0.855 + 0.2138 + 0.3711 + 0.2138 + 7.5$
$=$ 10.8738 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.5 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.2875 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2818 in

The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2818 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2875 in

Available nozzle wall thickness new, t_n = 0.8750*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi
Lower fillet weld in shear:	0.49*17100 =	8379 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*8.625*0.5*8379 = 56759.84 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*14.625*0.75*9800 = 168850.8 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*8.125*0.5*11970 = 76384.88 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*8.625*1.25*14800 = 250640.2 lb_f

(5) Lower fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_l = $(\pi/2)$*8.625*0.5*8379 = 56759.84 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*8.625*1.25*14800 = 250640.2 lb_f

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (9.7118 - 0.0007 + 2*0.5*0.855*(1*1.25 - 1*1.2499))*20000$
$=$ 194223.5 lb_f

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$
$= (1.7194 + 7.5 + 0.2138 + 0.3711)*20000$
$=$ 196086 lb_f

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (1.7194 + 0.855 + 0.2138 + 0.2138 + 2*0.5*1.25*0.855)*20000$
$=$ 81415 lb_f

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

= (1.7194 + 0.855 + 7.5 + 0.2138 + 0.3711 + 0.2138 + 2*0.5*1.25*0.855)*20000

= 238837 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 194223.5 lb_f
Path 1-1 through (2) & (3) = 168850.8 + 76384.88 = 245235.7 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} = 81415 lb_f
Path 2-2 through (1), (4), (5), (6) = 56759.84 + 250640.2 + 56759.84 + 250640.2 = 614800.1 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} = 194223.5 lb_f
Path 3-3 through (2), (4), (5) = 168850.8 + 250640.2 + 56759.84 = 476250.8 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	4,100.00	lb_f
Circumferential moment:	M_c =	176,520.00	lb_f-in
Circumferential shear:	V_c =	4,400.00	lb_f
Longitudinal moment:	M_L =	176,520.00	lb_f-in
Longitudinal shear:	V_L =	4,400.00	lb_f
Torsion moment:	M_t =	529,560.00	lb_f-in
Internal pressure:	P =	431.934	psi
Mean shell radius:	R_m =	57.7500	in
Local shell thickness:	t =	1.2500	in
Shell yield stress:	S_y =	32,500.00	psi

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

R_m/t =46.2

Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = $I*P*R_i/t$ = 19,739.00 psi

Local longitudinal pressure stress = $I*P*R_i/2t$ = 9,870.00 psi

Maximum combined stress (P_L+P_b+Q) = 30,433.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 21,274.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the pad edge per WRC Bulletin 107										
Figure	**value**	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	6.6438	0.1108	0	0	0	0	-377	-377	-377	-377
4C*	7.8032	0.1108	-443	-443	-443	-443	0	0	0	0
1C	0.1105	0.1108	0	0	0	0	-1,740	1,740	-1,740	1,740
2C-1	0.0758	0.1108	-1,193	1,193	-1,193	1,193	0	0	0	0
3A*	1.6010	0.1108	0	0	0	0	-612	-612	612	612
1A	0.0931	0.1108	0	0	0	0	-9,863	9,863	9,863	-9,863
3B*	5.1748	0.1108	-1,978	-1,978	1,978	1,978	0	0	0	0
1B-1	0.0418	0.1108	-4,428	4,428	4,428	-4,428	0	0	0	0
Pressure stress*			19,739	19,739	19,739	19,739	19,739	19,739	19,739	19,739
Total circumferential stress			11,697	22,939	24,509	18,039	7,147	30,353	28,097	11,851
Primary membrane circumferential stress*			17,318	17,318	21,274	21,274	18,750	18,750	19,974	19,974
3C*	6.6438	0.1108	-377	-377	-377	-377	0	0	0	0
4C*	7.8032	0.1108	0	0	0	0	-443	-443	-443	-443
1C-1	0.1132	0.1108	-1,782	1,782	-1,782	1,782	0	0	0	0
2C	0.0759	0.1108	0	0	0	0	-1,195	1,195	-1,195	1,195
4A*	2.3794	0.1108	0	0	0	0	-909	-909	909	909
2A	0.0502	0.1108	0	0	0	0	-5,318	5,318	5,318	-5,318
4B*	1.5303	0.1108	-585	-585	585	585	0	0	0	0
2B-1	0.0647	0.1108	-6,854	6,854	6,854	-6,854	0	0	0	0
Pressure stress*			9,870	9,870	9,870	9,870	9,870	9,870	9,870	9,870
Total longitudinal stress			272	17,544	15,150	5,006	2,005	15,031	14,459	6,213
Primary membrane longitudinal stress*			8,908	8,908	10,078	10,078	8,518	8,518	10,336	10,336
Shear from M_t			1,261	1,261	1,261	1,261	1,261	1,261	1,261	1,261
Circ shear from V_c			153	153	-153	-153	0	0	0	0

Long shear from V_L	0	0	0	0	-153	-153	153	153
Total Shear stress	1,414	1,414	1,108	1,108	1,108	1,108	1,414	1,414
Combined stress (P_L+P_b+Q)	11,869	23,287	24,638	18,133	7,376	30,433	28,242	12,186

Note: * denotes primary stress.

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

R_m/t =23.1

Pressure stress intensity factor, I = 0.90241 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = $I*P*R_i/t$ = 17,813.00 psi

Local longitudinal pressure stress = $I*P*R_i/2t$ = 8,907.00 psi

Maximum combined stress (P_L+P_b+Q) = 25,248.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 19,724.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the nozzle OD per WRC Bulletin 107										
Figure	**value**	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	4.2794	0.0653	0	0	0	0	-122	-122	-122	-122
4C*	4.4274	0.0653	-126	-126	-126	-126	0	0	0	0
1C	0.1919	0.0653	0	0	0	0	-755	755	-755	755
2C-1	0.1544	0.0653	-608	608	-608	608	0	0	0	0
3A*	0.3314	0.0653	0	0	0	0	-107	-107	107	107
1A	0.1062	0.0653	0	0	0	0	-4,769	4,769	4,769	-4,769
3B*	1.2426	0.0653	-403	-403	403	403	0	0	0	0
1B-1	0.0581	0.0653	-2,609	2,609	2,609	-2,609	0	0	0	0
Pressure stress*			17,813	17,813	17,813	17,813	19,739	19,739	19,739	19,739
Total circumferential stress			14,067	20,501	20,091	16,089	13,986	25,034	23,738	15,710
Primary membrane circumferential stress*			17,284	17,284	18,090	18,090	19,510	19,510	19,724	19,724
3C*	4.2794	0.0653	-122	-122	-122	-122	0	0	0	0
4C*	4.4274	0.0653	0	0	0	0	-126	-126	-126	-126
1C-1	0.1970	0.0653	-775	775	-775	775	0	0	0	0
2C	0.1519	0.0653	0	0	0	0	-598	598	-598	598
4A*	0.4169	0.0653	0	0	0	0	-135	-135	135	135
2A	0.0622	0.0653	0	0	0	0	-2,793	2,793	2,793	-2,793
4B*	0.3242	0.0653	-105	-105	105	105	0	0	0	0
2B-1	0.0966	0.0653	-4,338	4,338	4,338	-4,338	0	0	0	0
Pressure stress*			9,870	9,870	9,870	9,870	8,907	8,907	8,907	8,907
Total longitudinal stress			4,530	14,756	13,416	6,290	5,255	12,037	11,111	6,721
Primary membrane longitudinal stress*			9,643	9,643	9,853	9,853	8,646	8,646	8,916	8,916
Shear from M_t			1,813	1,813	1,813	1,813	1,813	1,813	1,813	1,813

Circ shear from V_c	130	130	-130	-130	0	0	0	0
Long shear from V_L	0	0	0	0	-130	-130	130	130
Total Shear stress	1,943	1,943	1,683	1,683	1,683	1,683	1,943	1,943
Combined stress (P_L+P_b+Q)	14,448	21,096	20,491	16,370	14,299	25,248	24,030	16,112

Note: * denotes primary stress.

Stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\ (Pm)} = P*R_i/(2*t_n) - P_r/(\pi*(R_o^2 - R_i^2)) + M*R_o/I$
$= 431.9336*3.8125/(2*0.4375) - 4{,}100.00/(\pi*(4.3125^2 - 3.8125^2)) + 249{,}637.0*4.3125/105.7162$
$= 11{,}744.23$ psi

The average primary stress P_m (see Division 2 Appendix 4-138(b)) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 17,100.00psi)

Shear in the nozzle due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (4400^2 + 4400^2)^{0.5} / (\pi*3.8125*0.5)$
$= 1039$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 529560 / (2*\pi*3.8125^2*0.5)$
$= 11597$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 1039 + 11597$
$= 12636$ psi

UG-45(c): The total combined shear stress (12636psi) is greater than the allowable (0.7*S_n = 0.7*17100 = 11970 psi)

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) **For P = 431.93 psi @ 68 °F** **The opening is adequately reinforced**							**UG-45 Nozzle Wall Thickness Summary (in)** **The nozzle passes UG-45**	
A required	**A available**	**A_1**	**A_2**	**A_3**	**A_5**	**A welds**	**t_{req}**	**t_{min}**
9.7118	10.8738	0.0007	1.7194	0.8550	7.5000	0.7987	0.2875	0.4375

Weld Failure Path Analysis Summary (lb_f) **All failure paths are stronger than the applicable weld loads**						
Weld load W	**Weld load W_{1-1}**	**Path 1-1 strength**	**Weld load W_{2-2}**	**Path 2-2 strength**	**Weld load W_{3-3}**	**Path 3-3 strength**
194,223.55	196,086.00	245,235.69	81,415.00	614,800.06	238,837.00	476,250.81

UW-16 Weld Sizing Summary			
Weld description	**Required weld size (in)**	**Actual weld size (in)**	**Status**
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.3500	1.2500	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 7.625 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 2.5 in
Normal to the vessel wall inside:	$2.5*(t_n - C_n - C)$ = 1.25 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*3.8125/(17100*1 - 0.6*431.9336)
= 0.0978 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

Area required per UG-37(c)

Allowable stresses: S_n = 17100, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 7.625*1.2499*1 + 2*0.5*1.2499*1*(1 - 0.855)
= 9.7118 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0007 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 7.625*(1*1.25 - 1*1.2499) - 2*0.5*(1*1.25 - 1*1.2499)*(1 - 0.855)
= 0.0007 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.25 + 0.5)*(1*1.25 - 1*1.2499) - 2*0.5*(1*1.25 - 1*1.2499)*(1 - 0.855)
= 0.0003 in^2

A_2 = smaller of the following= 1.7194 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5 - 0.0978)*0.855*1.25
= 2.1493 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.5 - 0.0978)*(2.5*0.5 + 1.25)*0.855
= 1.7194 in^2

A_3 = smaller of the following= 0.855 in^2

= $5*t*t_i*f_{r2}$
= 5*1.25*0.5*0.855
= 2.6719 in^2

= $5*t_i*t_i*f_{r2}$
= 5*0.5*0.5*0.855
= 1.0688 in^2

= $2*h*t_i*f_{r2}$
= 2*1*0.5*0.855
= 0.855 in^2

A_{41} = Leg^2*f_{r3}
= $0.5^2*0.855$
= 0.2138 in^2

A_{42} = Leg^2*f_{r4}
= 0.6092^2*1
= 0.3711 in^2

(Part of the weld is outside of the limits)
A_{43} = Leg^2*f_{r2}
= $0.5^2*0.855$
= 0.2138 in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= (14.625 - 7.625 - 2*0.5)*1.25*1
= 7.5 in^2

Area = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
= 0.0007 + 1.7194 + 0.855 + 0.2138 + 0.3711 + 0.2138 + 7.5
= 10.8738 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.5 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = 0.5*t_{min} = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	t_{r1} = 0.2875 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2818 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2818 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2875 in

Available nozzle wall thickness new, t_n = 0.8750*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi
Lower fillet weld in shear:	0.49*17100 =	8379 psi

Strength of welded joints:

(1) Inner fillet weld in shear
(π/2)*Nozzle OD*Leg*S_i = (π/2)*8.625*0.5*8379 = 56759.84 lb_f

(2) Outer fillet weld in shear
(π/2)*Pad OD*Leg*S_o = (π/2)*14.625*0.75*9800 = 168850.8 lb_f

(3) Nozzle wall in shear
(π/2)*Mean nozzle dia*t_n*S_n = (π/2)*8.125*0.5*11970 = 76384.88 lb_f

(4) Groove weld in tension
(π/2)*Nozzle OD*t_w*S_g = (π/2)*8.625*1.25*14800 = 250640.2 lb_f

(5) Lower fillet weld in shear
(π/2)*Nozzle OD*Leg*S_l = (π/2)*8.625*0.5*8379 = 56759.84 lb_f

(6) Upper groove weld in tension
(π/2)*Nozzle OD*t_w*S_g = (π/2)*8.625*1.25*14800 = 250640.2 lb_f

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (9.7118 - 0.0007 + 2*0.5*0.855*(1*1.25 - 1*1.2499))*20000$
$=$ 194223.5 lb_f

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$
$= (1.7194 + 7.5 + 0.2138 + 0.3711)*20000$
$=$ 196086 lb_f

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (1.7194 + 0.855 + 0.2138 + 0.2138 + 2*0.5*1.25*0.855)*20000$
$=$ 81415 lb_f

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (1.7194 + 0.855 + 7.5 + 0.2138 + 0.3711 + 0.2138 + 2*0.5*1.25*0.855)*20000$
$=$ 238837 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 194223.5 lb_f
Path 1-1 through (2) & (3) = 168850.8 + 76384.88 = 245235.7 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} = 81415 lb_f
Path 2-2 through (1), (4), (5), (6) = 56759.84 + 250640.2 + 56759.84 + 250640.2 = 614800.1 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} = 194223.5 lb_f
Path 3-3 through (2), (4), (5) = 168850.8 + 250640.2 + 56759.84 = 476250.8 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

N17 NPS 8 RFWN S/XH(0.5"wt) Amine Outlet Nozzle (N17)

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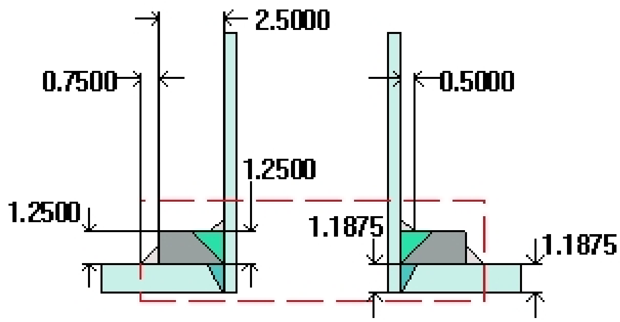

$t_{w(lower)}$ = 1.1875 in
Leg_{41} = 0.5000 in
$t_{w(upper)}$ = 1.2500 in
Leg_{42} = 0.7500 in
D_p = 13.6250 in
t_e = 1.2500 in

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

Located on:	Bottom Ellipsoidal Head #2
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 5)
Nozzle longitudinal joint efficiency:	1.00
Nozzle description:	8" Sch 80 (XS)
Pad material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Pad diameter:	13.625 in
Flange description:	8 inch Class 300 WN A105
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UCS-66(b)(1)(b))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	225°
Calculated as hillside:	no
Local vessel minimum thickness:	1.1875 in
End of nozzle to datum line:	-50 in
Nozzle inside diameter, new:	7.625 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	18.3315 in
Distance to head center, R:	0 in
Pad is split:	no

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 448.27 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
8.9737	8.9737	0.2438	1.7036	--	6.2500	0.7763	0.2896	0.4375

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
175,154.30	174,598.00	233,690.31	58,654.25	545,508.25	194,904.25	395,413.63

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.3500	1.2500	weld size is adequate

Calculations for internal pressure 448.27 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -13 °F
Fig UCS-66.1 MDMT reduction = 34.8 °F, (coincident ratio = 0.65227).
External nozzle loadings per UG-22 govern the coincident ratio used.

Pad is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 10 °F applied (ratio = 0.9)..

Nozzle UCS-66 governing thk:	0.4375	in
Nozzle rated MDMT:	-47.8	°F
Pad rated MDMT:	-30	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 7.625 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 2.5 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 448.2669*3.8125/(17100*1 - 0.6*448.2669)
= 0.1015 in

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

t_r = $P*K_1*D/(2*S*E - 0.2*P)$
= 448.2669*0.9*114.25/(2*20000*1 - 0.2*448.2669)
= 1.1549 in

Area required per UG-37(c)

Allowable stresses: S_n = 17100, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 7.625*1.1549*1 + 2*0.5*1.1549*1*(1 - 0.855)
= 8.9737 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2438 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 7.625*(1*1.1875 - 1*1.1549) - 2*0.5*(1*1.1875 - 1*1.1549)*(1 - 0.855)
= 0.2438 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.1875 + 0.5)*(1*1.1875 - 1*1.1549) - 2*0.5*(1*1.1875 - 1*1.1549)*(1 - 0.855)
= 0.1053 in^2

A_2 = smaller of the following= 1.7036 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5 - 0.1015)*0.855*1.1875
= 2.023 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.5 - 0.1015)*(2.5*0.5 + 1.25)*0.855
= 1.7036 in^2

A_{41} = Leg^2*f_{r3}
= $0.5^2*0.855$
= 0.2138 in^2

A_{42} = Leg^2*f_{r4}

= 0.75^2*1
= 0.5625 in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= (13.625 - 7.625 - 2*0.5)*1.25*1
= 6.25 in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 0.2438 + 1.7036 + 0.2138 + 0.5625 + 6.25
= 8.9737 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.5 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	t_{r1} = 0.2896 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2832 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2818 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2832 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2818 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2896 in

Available nozzle wall thickness new, t_n = 0.8750*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*8.625*0.5*8379 = 56759.84 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*13.625*0.75*9800 = 157305.4 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*8.125*0.5*11970 = 76384.88 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*8.625*1.1875*14800 = 238108.2 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*8.625*1.25*14800 = 250640.2 lb_f

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

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$
= (8.9737 - 0.2438 + 2*0.5*0.855*(1*1.1875 - 1*1.1549))*20000
= 175154.3 lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$
= (1.7036 + 6.25 + 0.2138 + 0.5625)*20000
= 174598 lb_f

W_{2-2} = $(A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$
= (1.7036 + 0 + 0.2138 + 0 + 2*0.5*1.1875*0.855)*20000
= 58654.25 lb_f

W_{3-3} = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$
= (1.7036 + 0 + 6.25 + 0.2138 + 0.5625 + 0 + 2*0.5*1.1875*0.855)*20000
= 194904.3 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 174598 lb_f
Path 1-1 through (2) & (3) = 157305.4 + 76384.88 = 233690.3 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 58654.25 lb_f
Path 2-2 through (1), (4), (6) = 56759.84 + 238108.2 + 250640.2 = 545508.3 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} = 175154.3 lb_f
Path 3-3 through (2), (4) = 157305.4 + 238108.2 = 395413.6 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	4,100.00	lb_f
Circumferential moment:	M_1 =	176,520.00	lb_f-in
Circumferential shear:	V_2 =	4,400.00	lb_f
Longitudinal moment:	M_2 =	176,520.00	lb_f-in
Longitudinal shear:	V_1 =	4,400.00	lb_f
Torsion moment:	M_t =	529,560.00	lb_f-in
Internal pressure:	P =	448.267	psi
Head yield stress:	S_y =	32,500.00	psi

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

Mean dish radius R_m = 103.9329 in

U = r_o/Sqr(R_m*t) = 0.613
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i/2*t = 19,505.00 psi

Maximum combined stress (P_L+P_b+Q) = 31,818.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 20,621.00 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the pad edge per WRC Bulletin 107									
Figure	**value**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
SR-2*	0.1132	-329	-329	-329	-329	-329	-329	-329	-329
SR-2	0.0668	-1,165	1,165	-1,165	1,165	-1,165	1,165	-1,165	1,165
SR-3*	0.1282	0	0	0	0	-1,445	-1,445	1,445	1,445
SR-3	0.1779	0	0	0	0	-12,027	12,027	12,027	-12,027
SR-3*	0.1282	-1,445	-1,445	1,445	1,445	0	0	0	0
SR-3	0.1779	-12,027	12,027	12,027	-12,027	0	0	0	0
Pressure stress*		19,505	19,505	19,505	19,505	19,505	19,505	19,505	19,505
Total O_x stress		4,539	30,923	31,483	9,759	4,539	30,923	31,483	9,759
Membrane O_x stress*		17,731	17,731	20,621	20,621	17,731	17,731	20,621	20,621
SR-2*	0.0335	-97	-97	-97	-97	-97	-97	-97	-97
SR-2	0.0206	-359	359	-359	359	-359	359	-359	359
SR-3*	0.0385	0	0	0	0	-434	-434	434	434
SR-3	0.0547	0	0	0	0	-3,698	3,698	3,698	-3,698
SR-3*	0.0385	-434	-434	434	434	0	0	0	0
SR-3	0.0547	-3,698	3,698	3,698	-3,698	0	0	0	0
Pressure stress*		19,505	19,505	19,505	19,505	19,505	19,505	19,505	19,505
Total O_y stress		14,917	23,031	23,181	16,503	14,917	23,031	23,181	16,503
Membrane O_y stress*		18,974	18,974	19,842	19,842	18,974	18,974	19,842	19,842
Shear from M_t		1,529	1,529	1,529	1,529	1,529	1,529	1,529	1,529
Shear from V_1		0	0	0	0	-173	-173	173	173
Shear from V_2		173	173	-173	-173	0	0	0	0
Total Shear stress		1,702	1,702	1,356	1,356	1,356	1,356	1,702	1,702
Combined stress (P_L+P_b+Q)		15,189	31,274	31,699	16,765	15,091	31,149	31,818	16,908

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

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

Mean dish radius R_m = 103.9329 in

U = r_o/Sqr(R_m*t) = 0.271
Pressure stress intensity factor, I = 0.4965 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i/2*t = 9,684.00 psi

Maximum combined stress (P_L+P_b+Q) = 16,661.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 9,855.00 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the nozzle OD per WRC Bulletin 107									
Figure	**value**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
SR-2*	0.1987	-137	-137	-137	-137	-137	-137	-137	-137
SR-2	0.1516	-628	628	-628	628	-628	628	-628	628
SR-3*	0.1648	0	0	0	0	-308	-308	308	308
SR-3	0.5380	0	0	0	0	-6,025	6,025	6,025	-6,025
SR-3*	0.1648	-308	-308	308	308	0	0	0	0
SR-3	0.5380	-6,025	6,025	6,025	-6,025	0	0	0	0
Pressure stress*		9,684	9,684	9,684	9,684	9,684	9,684	9,684	9,684
Total O_x stress		2,586	15,892	15,252	4,458	2,586	15,892	15,252	4,458
Membrane O_x stress*		9,239	9,239	9,855	9,855	9,239	9,239	9,855	9,855
SR-2*	0.0603	-42	-42	-42	-42	-42	-42	-42	-42
SR-2	0.0455	-188	188	-188	188	-188	188	-188	188
SR-3*	0.0502	0	0	0	0	-94	-94	94	94
SR-3	0.1574	0	0	0	0	-1,763	1,763	1,763	-1,763
SR-3*	0.0502	-94	-94	94	94	0	0	0	0
SR-3	0.1574	-1,763	1,763	1,763	-1,763	0	0	0	0
Pressure stress*		9,684	9,684	9,684	9,684	9,684	9,684	9,684	9,684
Total O_y stress		7,597	11,499	11,311	8,161	7,597	11,499	11,311	8,161
Membrane O_y stress*		9,548	9,548	9,736	9,736	9,548	9,548	9,736	9,736
Shear from M_t		1,859	1,859	1,859	1,859	1,859	1,859	1,859	1,859
Shear from V_1		0	0	0	0	-133	-133	133	133
Shear from V_2		133	133	-133	-133	0	0	0	0
Total Shear stress		1,992	1,992	1,726	1,726	1,726	1,726	1,992	1,992
Combined stress (P_L+P_b+Q)		8,292	16,661	15,901	8,841	8,134	16,489	16,083	9,029

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\ (Pm)} = P*R_i/(2*t_n) - P_r/(\pi*(R_o^2 - R_i^2)) + M*R_o/I$
$= 448.2669*3.8125/(2*0.4375) - 4,100.00/(\pi*(4.3125^2 - 3.8125^2)) + 249,637.0*4.3125/105.7162$
= 11,815.40 psi

The average primary stress P_m (see Division 2 Appendix 4-138(b)) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 17,100.00psi)

Shear in the nozzle due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (4400^2 + 4400^2)^{0.5} / (\pi*3.8125*0.5)$
= 1039 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 529560 / (2*\pi*3.8125^2*0.5)$
= 11597 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 1039 + 11597
= 12636 psi

UG-45(c): The total combined shear stress (12636psi) is greater than the allowable (0.7*S_n = 0.7*17100 = 11970 psi)

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2) For P = 448.27 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
8.9737	8.9737	0.2438	1.7036	--	6.2500	0.7763	0.2896	0.4375

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
175,154.30	174,598.00	233,690.31	58,654.25	545,508.25	194,904.25	395,413.63

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate

Nozzle to pad groove (Upper)	0.3500	1.2500	weld size is adequate

Calculations for internal pressure 448.27 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: d = 7.625 in

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

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 448.2669*3.8125/(17100*1 - 0.6*448.2669)
= 0.1015 in

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

t_r = $P*K_1*D/(2*S*E - 0.2*P)$
= 448.2669*0.9*114.25/(2*20000*1 - 0.2*448.2669)
= 1.1549 in

Area required per UG-37(c)

Allowable stresses: S_n = 17100, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 7.625*1.1549*1 + 2*0.5*1.1549*1*(1 - 0.855)
= 8.9737 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2438 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 7.625*(1*1.1875 - 1*1.1549) - 2*0.5*(1*1.1875 - 1*1.1549)*(1 - 0.855)
= 0.2438 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.1875 + 0.5)*(1*1.1875 - 1*1.1549) - 2*0.5*(1*1.1875 - 1*1.1549)*(1 - 0.855)
= 0.1053 in^2

A_2 = smaller of the following= 1.7036 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5 - 0.1015)*0.855*1.1875

= 2.023 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.5 - 0.1015)*(2.5*0.5 + 1.25)*0.855
= 1.7036 in^2

A_{41} = Leg^2*f_{r3}
= $0.5^2*0.855$
= 0.2138 in^2

A_{42} = Leg^2*f_{r4}
= 0.75^2*1
= 0.5625 in^2

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= (13.625 - 7.625 - 2*0.5)*1.25*1
= 6.25 in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 0.2438 + 1.7036 + 0.2138 + 0.5625 + 6.25
= 8.9737 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.5 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	t_{r1} = 0.2896 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2832 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2818 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2832 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2818 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2896 in

Available nozzle wall thickness new, t_n = 0.8750*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*8.625*0.5*8379 = 56759.84 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*13.625*0.75*9800 = 157305.4 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*8.125*0.5*11970 = 76384.88 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*8.625*1.1875*14800 = 238108.2 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*8.625*1.25*14800 = 250640.2 lb_f

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

$W = (A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
$= (8.9737 - 0.2438 + 2*0.5*0.855*(1*1.1875 - 1*1.1549))*20000$
$=$ 175154.3 lb_f

$W_{1\text{-}1} = (A_2 + A_5 + A_{41} + A_{42})*S_v$
$= (1.7036 + 6.25 + 0.2138 + 0.5625)*20000$
$=$ 174598 lb_f

$W_{2\text{-}2} = (A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (1.7036 + 0 + 0.2138 + 0 + 2*0.5*1.1875*0.855)*20000$
$=$ 58654.25 lb_f

$W_{3\text{-}3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
$= (1.7036 + 0 + 6.25 + 0.2138 + 0.5625 + 0 + 2*0.5*1.1875*0.855)*20000$
$=$ 194904.3 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 174598 lb_f
Path 1-1 through (2) & (3) = 157305.4 + 76384.88 = 233690.3 lb_f
Path 1-1 is stronger than $W_{1\text{-}1}$ so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 58654.25 lb_f
Path 2-2 through (1), (4), (6) = 56759.84 + 238108.2 + 250640.2 = 545508.3 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} = 175154.3 lb_f
Path 3-3 through (2), (4) = 157305.4 + 238108.2 = 395413.6 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

N18 NPS 2 RFLWN(0.655"wt) HC liquid Outlet Nozzle (N18)

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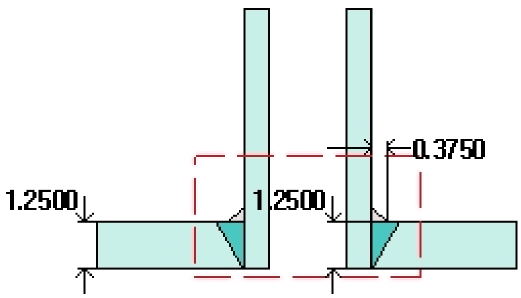

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	335°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	4 in
End of nozzle to shell center:	65 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	6.625 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk: 0.655 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N35 NPS 2 RFLWN(0.655"wt) Steam Out Nozzle (N35)

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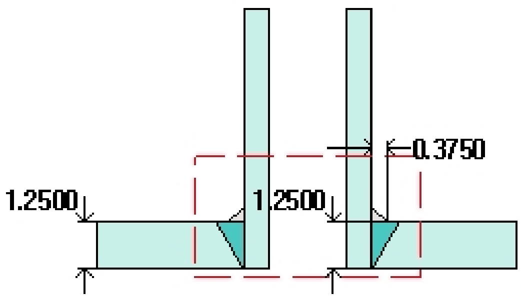

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	310°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	5 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk: 0.655 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

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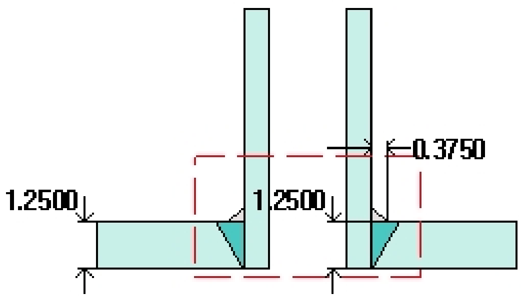
$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in



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

Located on:	Cylinder #5
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	350°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	124 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.5786	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact tested to -55 °F (UCS-66(g)).
External nozzle loadings per UG-22 govern the coincident ratio used.

Nozzle UCS-66 governing thk:	0.655	in
Nozzle rated MDMT:	-55	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.5786 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.5786 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Applied Loads

Radial load:	P_r =	700.00	lb_f
Circumferential moment:	M_c =	40,800.00	lb_f-in
Circumferential shear:	V_c =	900.00	lb_f
Longitudinal moment:	M_L =	40,800.00	lb_f-in
Longitudinal shear:	V_L =	900.00	lb_f
Torsion moment:	M_t =	122,400.00	lb_f-in
Internal pressure:	P =	431.934	psi
Mean shell radius:	R_m =	57.7500	in
Local shell thickness:	t =	1.2500	in
Shell yield stress:	S_y =	32,500.00	psi

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

R_m/t =46.2

Pressure stress intensity factor, I = 1.09498 (derived from PVP-Vol. 399, pages 77-82)

Local circumferential pressure stress = $I*P*R_i/t$ = 21,614.00 psi

Local longitudinal pressure stress = $I*P*R_i/2t$ = 10,807.00 psi

Maximum combined stress (P_L+P_b+Q) = 33,624.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 21,981.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the nozzle OD per WRC Bulletin 107

Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	9.1976	0.0251	0	0	0	0	-89	-89	-89	-89
4C*	9.1067	0.0251	-88	-88	-88	-88	0	0	0	0
1C	0.2603	0.0251	0	0	0	0	-700	700	-700	700
2C-1	0.2180	0.0251	-586	586	-586	586	0	0	0	0
3A*	0.2878	0.0251	0	0	0	0	-112	-112	112	112
1A	0.1054	0.0251	0	0	0	0	-11,403	11,403	11,403	-11,403
3B*	1.1669	0.0251	-455	-455	455	455	0	0	0	0
1B-1	0.0635	0.0251	-6,870	6,870	6,870	-6,870	0	0	0	0
Pressure stress*			21,614	21,614	21,614	21,614	19,739	19,739	19,739	19,739
Total circumferential stress			13,615	28,527	28,265	15,697	7,435	31,641	30,465	9,059
Primary membrane circumferential stress*			21,071	21,071	21,981	21,981	19,538	19,538	19,762	19,762
3C*	9.1976	0.0251	-89	-89	-89	-89	0	0	0	0
4C*	9.1067	0.0251	0	0	0	0	-88	-88	-88	-88
1C-1	0.2636	0.0251	-709	709	-709	709	0	0	0	0
2C	0.2103	0.0251	0	0	0	0	-565	565	-565	565
4A*	0.3543	0.0251	0	0	0	0	-138	-138	138	138
2A	0.0641	0.0251	0	0	0	0	-6,935	6,935	6,935	-6,935
4B*	0.3036	0.0251	-118	-118	118	118	0	0	0	0
2B-1	0.1073	0.0251	-11,609	11,609	11,609	-11,609	0	0	0	0
Pressure stress*			9,870	9,870	9,870	9,870	10,807	10,807	10,807	10,807
Total longitudinal stress			-2,655	21,981	20,799	-1,001	3,081	18,081	17,227	4,487
Primary membrane longitudinal stress*			9,663	9,663	9,899	9,899	10,581	10,581	10,857	10,857
Shear from M_t			5,690	5,690	5,690	5,690	5,690	5,690	5,690	5,690
Circ shear from V_c			138	138	-138	-138	0	0	0	0

Long shear from V_L	0	0	0	0	-138	-138	138	138
Total Shear stress	5,828	5,828	5,552	5,552	5,552	5,552	5,828	5,828
Combined stress (P_L+P_b+Q)	20,014	31,938	31,222	20,053	11,927	33,624	32,665	13,033

Note: * denotes primary stress.

Stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\ (Pm)} = P*R_i/(2*t_n) - P_r/(\pi*(R_o^2 - R_i^2)) + M*R_o/I$
$= 431.9336*1/(2*0.655) - 700/(\pi*(1.655^2 - 1^2)) + 57{,}699.91*1.655/5.106861$
= 18,900.63 psi

The average primary stress P_m (see Division 2 Appendix 4-138(b)) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 20,000.00psi)

Shear in the nozzle due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (900^2 + 900^2)^{0.5} / (\pi*1*0.655)$
= 619 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 122400 / (2*\pi*1^2*0.655)$
= 29741 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 619 + 29741
= 30360 psi

UG-45(c): The total combined shear stress (30360psi) is greater than the allowable ($0.7*S_n$ = 0.7*20000 = 14000 psi)

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							**UG-45 Nozzle Wall Thickness Summary (in)** The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.5786	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = $P*R/(S*E - 0.6*P)$
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.5786 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.5786 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N45B NPS 2 RFLWN(0.655"wt) LG-1012 Nozzle (N45B)

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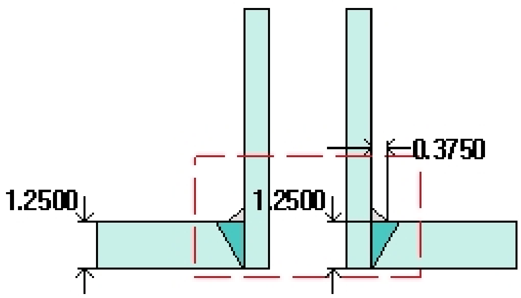

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	350°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	10 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk:	0.655	in
Nozzle rated MDMT:	-155	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t)$= 2.905 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t)$= 2.905 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N46A NPS 3 RFLWN(0.810"wt) LT-17 Nozzle (N46A)

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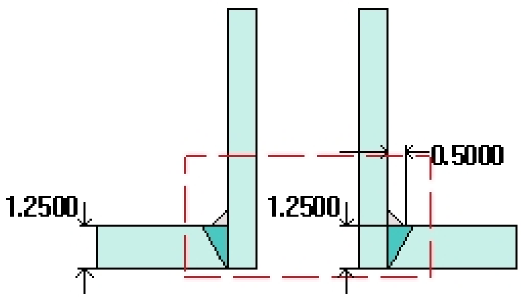

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.5000 in

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

Located on:	Cylinder #5
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	3 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	325°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	118 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	3 in
Nozzle nominal wall thickness:	0.81 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 415.31 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6036	3.6040	0.2011	3.1529	--	--	0.2500	0.2258	0.8100

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Calculations for internal pressure 415.31 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.0389).

Nozzle UCS-66 governing thk:	0.81 in
Nozzle rated MDMT:	-155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 3.56$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 2.025$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 415.3076*1.5/(20000*1 - 0.6*415.3076)
= 0.0315 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 415.3076*57.125/(20000*1 - 0.6*415.3076)
= 1.2012 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	3*1.2012*1 + 2*0.81*1.2012*1*(1 - 1)
	=	3.6036 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2011 in^2

=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	3*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
=	0.1464 in^2
=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	2*(1.25 + 0.81)*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
=	0.2011 in^2

A_2 = smaller of the following= 3.1529 in^2

=	$5*(t_n - t_{rn})*f_{r2}*t$
=	5*(0.81 - 0.0315)*1*1.25
=	4.8656 in^2
=	$5*(t_n - t_{rn})*f_{r2}*t_n$
=	5*(0.81 - 0.0315)*1*0.81
=	3.1529 in^2

A_{41}	=	Leg^2*f_{r2}
	=	0.5^2*1
	=	0.25 in^2

Area	=	$A_1 + A_2 + A_{41}$
	=	0.2011 + 3.1529 + 0.25
	=	3.604 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 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} = 0.0315 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2012 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2258 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2012 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2258 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2258 in

Available nozzle wall thickness new, t_n = 0.81 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2) For P = 415.31 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6036	3.6040	0.2011	3.1529	--	--	0.2500	0.2258	0.8100

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Calculations for internal pressure 415.31 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 3.56 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 2.025 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 415.3076*1.5/(20000*1 - 0.6*415.3076)

= 0.0315 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 415.3076*57.125/(20000*1 - 0.6*415.3076)

= 1.2012 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	3*1.2012*1 + 2*0.81*1.2012*1*(1 - 1)
	=	3.6036 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2011 in^2

	=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	3*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.1464 in^2
	=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	2*(1.25 + 0.81)*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.2011 in^2

A_2 = smaller of the following= 3.1529 in^2

	=	$5*(t_n - t_{rn})*f_{r2}*t$
	=	5*(0.81 - 0.0315)*1*1.25
	=	4.8656 in^2
	=	$5*(t_n - t_{rn})*f_{r2}*t_n$
	=	5*(0.81 - 0.0315)*1*0.81
	=	3.1529 in^2

A_{41}	=	Leg^2*f_{r2}
	=	0.5^2*1
	=	0.25 in^2

Area	=	$A_1 + A_2 + A_{41}$
	=	0.2011 + 3.1529 + 0.25
	=	3.604 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 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} = 0.0315 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2012 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2258 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2012 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2258 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2258 in

Available nozzle wall thickness new, t_n = 0.81 in

The nozzle neck thickness is adequate.

N46B NPS 3 RFLWN(0.810"wt) LT-17 Nozzle (N46B)

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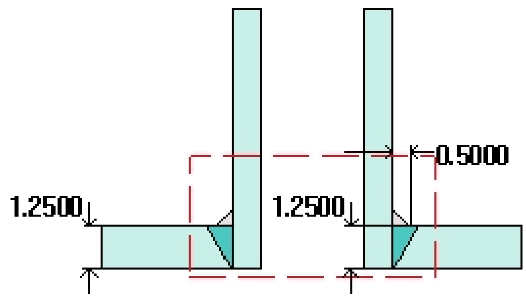

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.5000 in

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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	3 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	325°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	13 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	3 in
Nozzle nominal wall thickness:	0.81 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 415.31 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6036	3.6040	0.2011	3.1529	--	--	0.2500	0.2258	0.8100

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Calculations for internal pressure 415.31 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.0389).

Nozzle UCS-66 governing thk:	0.81 in
Nozzle rated MDMT:	-155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 3.56$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 2.025$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 415.3076*1.5/(20000*1 - 0.6*415.3076)
= 0.0315 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 415.3076*57.125/(20000*1 - 0.6*415.3076)
= 1.2012 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	3*1.2012*1 + 2*0.81*1.2012*1*(1 - 1)
	=	3.6036 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2011 in^2

	=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	3*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.1464 in^2
	=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	2*(1.25 + 0.81)*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.2011 in^2

A_2 = smaller of the following= 3.1529 in^2

	=	$5*(t_n - t_{rn})*f_{r2}*t$
	=	5*(0.81 - 0.0315)*1*1.25
	=	4.8656 in^2
	=	$5*(t_n - t_{rn})*f_{r2}*t_n$
	=	5*(0.81 - 0.0315)*1*0.81
	=	3.1529 in^2

A_{41}	=	Leg^2*f_{r2}
	=	0.5^2*1
	=	0.25 in^2

Area	=	$A_1 + A_2 + A_{41}$
	=	0.2011 + 3.1529 + 0.25
	=	3.604 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 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} = 0.0315 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2012 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2258 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2012 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2258 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2258 in

Available nozzle wall thickness new, t_n = 0.81 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2) For P = 415.31 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6036	3.6040	0.2011	3.1529	--	--	0.2500	0.2258	0.8100

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Calculations for internal pressure 415.31 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 3.56 in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 2.025 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 415.3076*1.5/(20000*1 - 0.6*415.3076)
= 0.0315 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 415.3076*57.125/(20000*1 - 0.6*415.3076)
= 1.2012 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	3*1.2012*1 + 2*0.81*1.2012*1*(1 - 1)
	=	3.6036 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2011 in^2

	=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	3*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.1464 in^2
	=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	2*(1.25 + 0.81)*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.2011 in^2

A_2 = smaller of the following= 3.1529 in^2

	=	$5*(t_n - t_{rn})*f_{r2}*t$
	=	5*(0.81 - 0.0315)*1*1.25
	=	4.8656 in^2
	=	$5*(t_n - t_{rn})*f_{r2}*t_n$
	=	5*(0.81 - 0.0315)*1*0.81
	=	3.1529 in^2

A_{41}	=	Leg^2*f_{r2}
	=	0.5^2*1
	=	0.25 in^2

Area	=	$A_1 + A_2 + A_{41}$
	=	0.2011 + 3.1529 + 0.25
	=	3.604 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 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} = 0.0315 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2012 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2258 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2012 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2258 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2258 in

Available nozzle wall thickness new, t_n = 0.81 in

The nozzle neck thickness is adequate.

N47A NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle (N47A)

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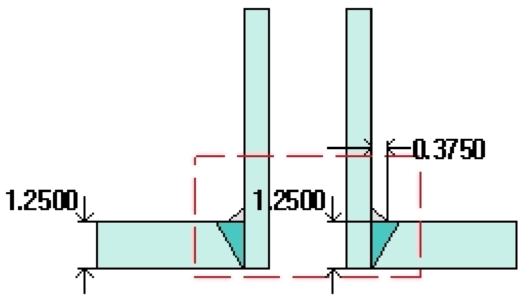

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #5
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	300°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	117.375 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk:	0.655	in
Nozzle rated MDMT:	-155	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N47B NPS 2 RFLWN(0.655"wt) LSH-48 Nozzle (N47B)

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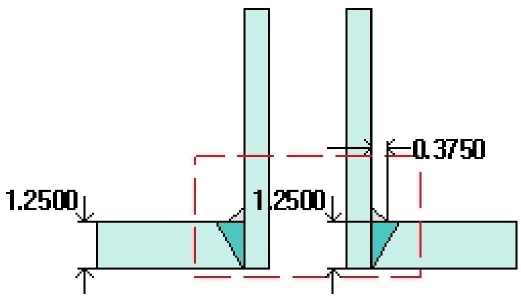

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	300°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	101.375 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk:	0.655 in
Nozzle rated MDMT:	-155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t)$= 2.905 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N48A NPS 2 RFLWN(0.655"wt) LG-105 Nozzle (N48A)

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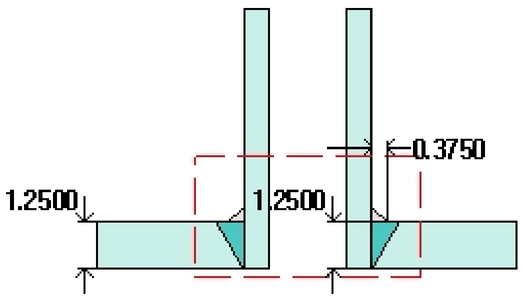

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #5
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	220°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	124 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk:	0.655	in
Nozzle rated MDMT:	-155	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = $P*R/(S*E - 0.6*P)$
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N48B NPS 2 RFLWN(0.655"wt) LG-105 Nozzle (N48B)

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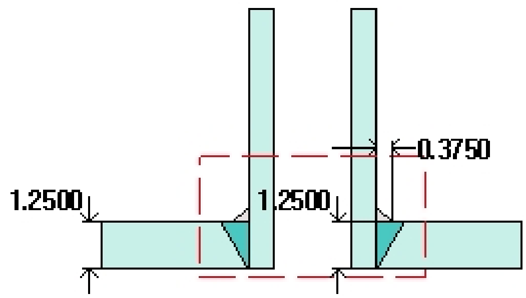

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11) (normalized)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	220°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	3 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk:	0.655	in
Nozzle rated MDMT:	-155	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = $P*R/(S*E - 0.6*P)$
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N49A NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle (N49A)

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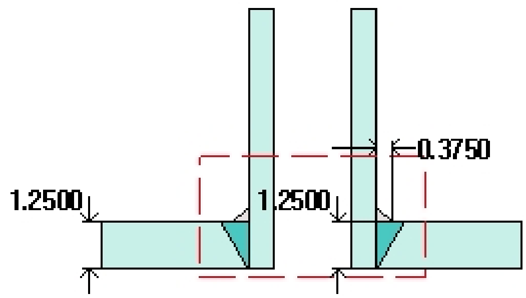

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #5
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	180°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	139 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk:	0.655	in
Nozzle rated MDMT:	-155	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N49B NPS 2 RFLWN(0.655"wt) LI-1011 Nozzle (N49B)

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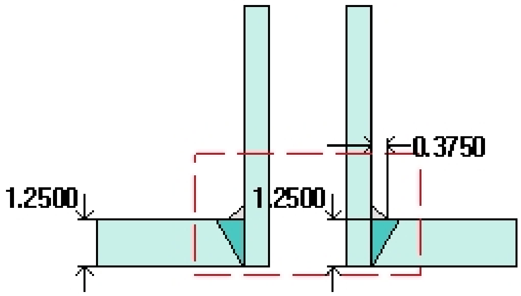
$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in



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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	180°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	3 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk:	0.655	in
Nozzle rated MDMT:	-155	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = $P*R/(S*E - 0.6*P)$
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N50A NPS 3 RFLWN(0.81"wt) LT-16 Nozzle (N50A)

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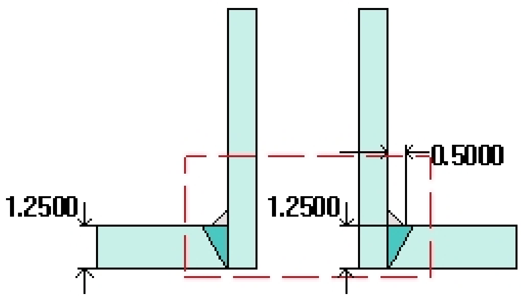

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.5000 in

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

Located on:	Cylinder #5
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	3 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	285°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	124 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	3 in
Nozzle nominal wall thickness:	0.81 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 415.31 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6036	3.6040	0.2011	3.1529	--	--	0.2500	0.2258	0.8100

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Calculations for internal pressure 415.31 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.0389).

Nozzle UCS-66 governing thk: 0.81 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 3.56$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 2.025$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 415.3076*1.5/(20000*1 - 0.6*415.3076)
= 0.0315 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 415.3076*57.125/(20000*1 - 0.6*415.3076)
= 1.2012 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	3*1.2012*1 + 2*0.81*1.2012*1*(1 - 1)
	=	3.6036 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2011 in^2

	=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	3*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.1464 in^2
	=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	2*(1.25 + 0.81)*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.2011 in^2

A_2 = smaller of the following= 3.1529 in^2

	=	$5*(t_n - t_{rn})*f_{r2}*t$
	=	5*(0.81 - 0.0315)*1*1.25
	=	4.8656 in^2
	=	$5*(t_n - t_{rn})*f_{r2}*t_n$
	=	5*(0.81 - 0.0315)*1*0.81
	=	3.1529 in^2

A_{41}	=	Leg^2*f_{r2}
	=	0.5^2*1
	=	0.25 in^2

Area	=	$A_1 + A_2 + A_{41}$
	=	0.2011 + 3.1529 + 0.25
	=	3.604 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 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} = 0.0315 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2012 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2258 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2012 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2258 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2258 in

Available nozzle wall thickness new, t_n = 0.81 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2) For P = 415.31 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6036	3.6040	0.2011	3.1529	--	--	0.2500	0.2258	0.8100

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Calculations for internal pressure 415.31 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t)$= 3.56 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 2.025 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 415.3076*1.5/(20000*1 - 0.6*415.3076)
= 0.0315 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 415.3076*57.125/(20000*1 - 0.6*415.3076)
= 1.2012 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	3*1.2012*1 + 2*0.81*1.2012*1*(1 - 1)
	=	3.6036 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2011 in^2

=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	3*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
=	0.1464 in^2
=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	2*(1.25 + 0.81)*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
=	0.2011 in^2

A_2 = smaller of the following= 3.1529 in^2

=	$5*(t_n - t_{rn})*f_{r2}*t$
=	5*(0.81 - 0.0315)*1*1.25
=	4.8656 in^2
=	$5*(t_n - t_{rn})*f_{r2}*t_n$
=	5*(0.81 - 0.0315)*1*0.81
=	3.1529 in^2

A_{41}	=	Leg^2*f_{r2}
	=	0.5^2*1
	=	0.25 in^2

Area	=	$A_1 + A_2 + A_{41}$
	=	0.2011 + 3.1529 + 0.25
	=	3.604 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 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} = 0.0315 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2012 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2258 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2012 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2258 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2258 in

Available nozzle wall thickness new, t_n = 0.81 in

The nozzle neck thickness is adequate.

N50B NPS 3 RFLWN(0.81"wt) LT-16 Nozzle (N50B)

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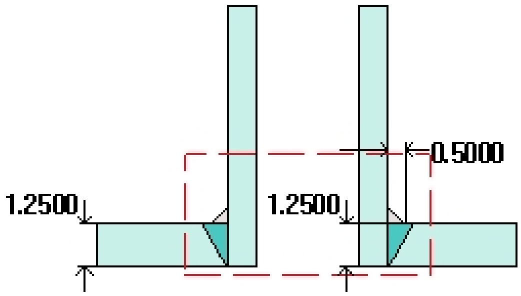

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.5000 in

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

Located on:	Cylinder #6
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	3 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	285°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	5 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	3 in
Nozzle nominal wall thickness:	0.81 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 415.31 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6036	3.6040	0.2011	3.1529	--	--	0.2500	0.2258	0.8100

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Calculations for internal pressure 415.31 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.0389).

Nozzle UCS-66 governing thk:	0.81 in
Nozzle rated MDMT:	-155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 3.56$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 2.025$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 415.3076*1.5/(20000*1 - 0.6*415.3076)
= 0.0315 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 415.3076*57.125/(20000*1 - 0.6*415.3076)
= 1.2012 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	3*1.2012*1 + 2*0.81*1.2012*1*(1 - 1)
	=	3.6036 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2011 in^2

=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	3*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
=	0.1464 in^2

=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
=	2*(1.25 + 0.81)*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
=	0.2011 in^2

A_2 = smaller of the following= 3.1529 in^2

=	$5*(t_n - t_{rn})*f_{r2}*t$
=	5*(0.81 - 0.0315)*1*1.25
=	4.8656 in^2

=	$5*(t_n - t_{rn})*f_{r2}*t_n$
=	5*(0.81 - 0.0315)*1*0.81
=	3.1529 in^2

A_{41}	=	Leg^2*f_{r2}
	=	0.5^2*1
	=	0.25 in^2

Area	=	$A_1 + A_2 + A_{41}$
	=	0.2011 + 3.1529 + 0.25
	=	3.604 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 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} = 0.0315 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2012 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2258 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2012 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2258 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2258 in

Available nozzle wall thickness new, t_n = 0.81 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2) For P = 415.31 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
3.6036	3.6040	0.2011	3.1529	--	--	0.2500	0.2258	0.8100

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Calculations for internal pressure 415.31 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 3.56 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 2.025 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 415.3076*1.5/(20000*1 - 0.6*415.3076)

= 0.0315 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 415.3076*57.125/(20000*1 - 0.6*415.3076)

= 1.2012 in

Area required per UG-37(c)

Allowable stresses: S_n = 20000, S_v = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 1
f_{r2} = lesser of 1 or S_n/S_v = 1

A	=	$d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
	=	3*1.2012*1 + 2*0.81*1.2012*1*(1 - 1)
	=	3.6036 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2011 in^2

	=	$d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	3*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.1464 in^2
	=	$2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
	=	2*(1.25 + 0.81)*(1*1.25 - 1*1.2012) - 2*0.81*(1*1.25 - 1*1.2012)*(1 - 1)
	=	0.2011 in^2

A_2 = smaller of the following= 3.1529 in^2

	=	$5*(t_n - t_{rn})*f_{r2}*t$
	=	5*(0.81 - 0.0315)*1*1.25
	=	4.8656 in^2
	=	$5*(t_n - t_{rn})*f_{r2}*t_n$
	=	5*(0.81 - 0.0315)*1*0.81
	=	3.1529 in^2

A_{41}	=	Leg^2*f_{r2}
	=	0.5^2*1
	=	0.25 in^2

Area	=	$A_1 + A_2 + A_{41}$
	=	0.2011 + 3.1529 + 0.25
	=	3.604 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.75 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 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} = 0.0315 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2012 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.2258 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2012 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.2258 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.2258 in

Available nozzle wall thickness new, t_n = 0.81 in

The nozzle neck thickness is adequate.

N51A NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle (N51A)

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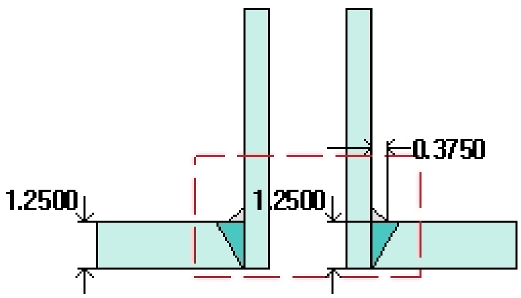

$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in

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

Located on:	Cylinder #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	30°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	652 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk:	0.655	in
Nozzle rated MDMT:	-155	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	$(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N51B NPS 2 RFLWN(0.655"wt) PDT-118 Nozzle (N51B)

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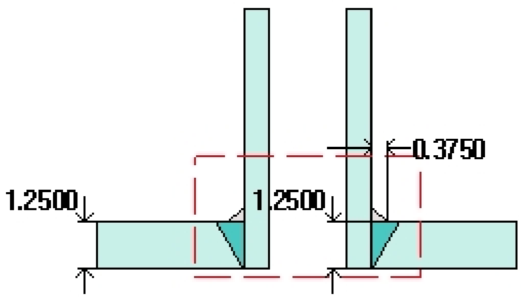
$t_{w(lower)}$ = 1.2500 in
Leg_{41} = 0.3750 in



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

Located on:	Cylinder #5
Liquid static head included:	0 psi
Nozzle material specification:	SA-350 LF2 Cl 1 (II-D p. 14, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Flange description:	2 inch Class 300 LWN A350 LF2 Cl.1
Bolt Material:	SA-193 B7M Bolt <= 2 1/2 (II-D p. 382, ln. 30)
Flange rated MDMT:	-55°F
(UG-84 provisions apply)	
(Flange impact tested to -55.00°F (UCS-66(g)))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	135°
Local vessel minimum thickness:	1.25 in
Nozzle center line offset to datum line:	172 in
End of nozzle to shell center:	66.375 in
Nozzle inside diameter, new:	2 in
Nozzle nominal wall thickness:	0.655 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	8 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 400 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 400 °F

Nozzle is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.03207).

Nozzle UCS-66 governing thk: 0.655 in
Nozzle rated MDMT: -155 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t) = 2.905$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 1.6375$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 431.9336*1/(20000*1 - 0.6*431.9336)
= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)
= 431.9336*57.125/(20000*1 - 0.6*431.9336)
= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

The vessel wall thickness governs the MAP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 431.93 psi @ 68 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.1890	0.6550

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.2625	weld size is adequate

Calculations for internal pressure 431.93 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $(R_n + t_n + t)$= 2.905 in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e$ = 1.6375 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$

= 431.9336*1/(20000*1 - 0.6*431.9336)

= 0.0219 in

Required thickness t_r from UG-37(a)

t_r = P*R/(S*E - 0.6*P)

= 431.9336*57.125/(20000*1 - 0.6*431.9336)

= 1.2499 in

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

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t = 0.655 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 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} = 0.0219 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2499 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.189 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2499 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.189 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.189 in

Available nozzle wall thickness new, t_n = 0.655 in

The nozzle neck thickness is adequate.

N6 NPS 6 RFWN(0.432"wt) S/80 Purge Nozzle (N6)

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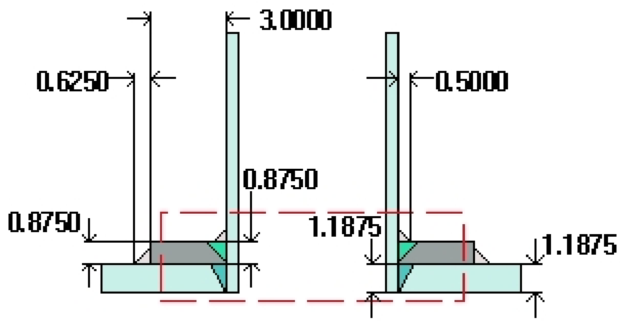

$t_{w(lower)}$ = 1.1875 in
Leg_{41} = 0.5000 in
$t_{w(upper)}$ = 0.8750 in
Leg_{42} = 0.6250 in
D_p = 13.0069 in
t_e = 0.8750 in

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

Located on:	Top Ellipsoidal Head #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 5)
Nozzle longitudinal joint efficiency:	1.00
Nozzle description:	6" Sch 80 (XS)
Pad material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Pad diameter:	13.0069 in
Flange description:	6 inch Class 300 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Flange rated MDMT:	-55°F
(UCS-66(b)(1)(b))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	90°
Calculated as hillside:	yes
Local vessel minimum thickness:	1.1875 in
End of nozzle to datum line:	722.5025 in
Nozzle inside diameter, new:	5.761 in
Nozzle nominal wall thickness:	0.432 in
Nozzle corrosion allowance:	0 in
Opening chord length:	6.1068 in
Projection available outside vessel, Lpr:	14.8941 in
Distance to head center, R:	33 in
Pad is split:	no

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 415.67 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
6.6731	6.6744	0.6982	1.2065	--	4.5559	0.2138	0.3445	0.3780

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
121,223.10	119,523.26	175,444.63	45,950.60	361,257.31	137,067.86	308,035.75

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.4375	weld size is adequate
Nozzle to pad groove (Upper)	0.3024	0.8750	weld size is adequate

Calculations for internal pressure 415.67 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -19.66 °F
Fig UCS-66.1 MDMT reduction = 8.9 °F, (coincident ratio = 0.9112).
External nozzle loadings per UG-22 govern the coincident ratio used.

Pad is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 10 °F applied (ratio = 0.9)..

Nozzle UCS-66 governing thk:	0.378	in
Nozzle rated MDMT:	-28.56	°F
Pad rated MDMT:	-30	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 6.1068 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 1.955 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 415.6738*2.8805/(17100*1 - 0.6*415.6738)
= 0.0711 in

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

t_r = $P*K_1*D/(2*S*E - 0.2*P)$
= 415.6738*0.9*114.25/(2*20000*1 - 0.2*415.6738)
= 1.0708 in

Area required per UG-37(c)

Allowable stresses: S_n = 17100, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 6.1068*1.0708*1 + 2*0.432*1.0708*1*(1 - 0.855)
= 6.6731 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.6982 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 6.1068*(1*1.1875 - 1*1.0708) - 2*0.432*(1*1.1875 - 1*1.0708)*(1 - 0.855)
= 0.6982 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.1875 + 0.432)*(1*1.1875 - 1*1.0708) - 2*0.432*(1*1.1875 - 1*1.0708)*(1 - 0.855)
= 0.3635 in^2

A_2 = smaller of the following= 1.2065 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.432 - 0.0711)*0.855*1.1875
= 1.8321 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.432 - 0.0711)*(2.5*0.432 + 0.875)*0.855
= 1.2065 in^2

A_{41} = Leg^2*f_{r3}
= $0.5^2*0.855$
= 0.2138 in^2

A_{42} = Leg^2*f_{r4}

= 0^2*1

= [0] in^2

(Part of the weld is outside of the limits)

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

= (12.2136 - 7.0069)*0.875*1

= 4.5559 in^2

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

= 0.6982 + 1.2065 + 0.2138 + 0 + 4.5559

= 6.6744 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.432 in

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

$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in

$t_{w(min)}$ = $0.5*t_{min}$ = 0.375 in

$t_{w(actual)}$ = 0.7*Leg = 0.7*0.625 = 0.4375 in

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	t_{r1} = 0.3445 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.1897 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.245 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.1897 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.245 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.3445 in

Available nozzle wall thickness new, t_n = 0.8750*0.432 = 0.378 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*6.625*0.5*8379 = 43598.14 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*13.0069*0.625*9800 = 125141 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*6.193*0.432*11970 = 50303.58 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*6.625*1.1875*14800 = 182894.7 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*6.625*0.875*14800 = 134764.5 lb_f

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

$W = (A - A_1 + 2 t_n f_{r1} (E_1 t - F t_r)) S_v$
= (6.6731 - 0.6982 + 2*0.432*0.855*(1*1.1875 - 1*1.0708))*20000
= 121223.1 lb_f

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42}) S_v$
= (1.2065 + 4.5559 + 0.2138 + 0)*20000
= 119523.3 lb_f

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2 t_n t f_{r1}) S_v$
= (1.2065 + 0 + 0.2138 + 0 + 2*0.432*1.1875*0.855)*20000
= 45950.6 lb_f

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 t_n t f_{r1}) S_v$
= (1.2065 + 0 + 4.5559 + 0.2138 + 0 + 0 + 2*0.432*1.1875*0.855)*20000
= 137067.9 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 119523.3 lb_f
Path 1-1 through (2) & (3) = 125141 + 50303.58 = 175444.6 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 45950.6 lb_f
Path 2-2 through (1), (4), (6) = 43598.14 + 182894.7 + 134764.5 = 361257.3 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} = 121223.1 lb_f
Path 3-3 through (2), (4) = 125141 + 182894.7 = 308035.8 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	2,900.00	lb_f
Circumferential moment:	M_1 =	126,000.00	lb_f-in
Circumferential shear:	V_2 =	3,200.00	lb_f
Longitudinal moment:	M_2 =	126,000.00	lb_f-in
Longitudinal shear:	V_1 =	3,200.00	lb_f
Torsion moment:	M_t =	378,000.00	lb_f-in
Internal pressure:	P =	415.674	psi
Head yield stress:	S_y =	32,500.00	psi

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

Mean dish radius R_m = 103.9329 in

U = r_o/Sqr(R_m*t) = 0.568
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i/2*t = 18,086.00 psi

Maximum combined stress (P_L+P_b+Q) = 28,136.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 18,920.00 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the pad edge per WRC Bulletin 107									
Figure	**value**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
SR-2*	0.1214	-250	-250	-250	-250	-250	-250	-250	-250
SR-2	0.0728	-898	898	-898	898	-898	898	-898	898
SR-3*	0.1348	0	0	0	0	-1,084	-1,084	1,084	1,084
SR-3	0.2038	0	0	0	0	-9,835	9,835	9,835	-9,835
SR-3*	0.1348	-1,084	-1,084	1,084	1,084	0	0	0	0
SR-3	0.2038	-9,835	9,835	9,835	-9,835	0	0	0	0
Pressure stress*		18,086	18,086	18,086	18,086	18,086	18,086	18,086	18,086
Total O_x stress		6,019	27,485	27,857	9,983	6,019	27,485	27,857	9,983
Membrane O_x stress*		16,752	16,752	18,920	18,920	16,752	16,752	18,920	18,920
SR-2*	0.0359	-74	-74	-74	-74	-74	-74	-74	-74
SR-2	0.0223	-275	275	-275	275	-275	275	-275	275
SR-3*	0.0406	0	0	0	0	-327	-327	327	327
SR-3	0.0618	0	0	0	0	-2,982	2,982	2,982	-2,982
SR-3*	0.0406	-327	-327	327	327	0	0	0	0
SR-3	0.0618	-2,982	2,982	2,982	-2,982	0	0	0	0
Pressure stress*		18,086	18,086	18,086	18,086	18,086	18,086	18,086	18,086
Total O_y stress		14,428	20,942	21,046	15,632	14,428	20,942	21,046	15,632
Membrane O_y stress*		17,685	17,685	18,339	18,339	17,685	17,685	18,339	18,339
Shear from M_t		1,271	1,271	1,271	1,271	1,271	1,271	1,271	1,271
Shear from V_1		0	0	0	0	-136	-136	136	136
Shear from V_2		136	136	-136	-136	0	0	0	0
Total Shear stress		1,407	1,407	1,135	1,135	1,135	1,135	1,407	1,407
Combined stress (P_L+P_b+Q)		14,657	27,775	28,041	15,852	14,579	27,676	28,136	15,963

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

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

Mean dish radius R_m = 103.9329 in

U = r_o/Sqr(R_m*t) = 0.226
Pressure stress intensity factor, I = 0.49736 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i/2*t = 8,995.00 psi

Maximum combined stress (P_L+P_b+Q) = 18,454.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 9,177.00 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the nozzle OD per WRC Bulletin 107									
Figure	**value**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
SR-2*	0.2146	-146	-146	-146	-146	-146	-146	-146	-146
SR-2	0.1768	-723	723	-723	723	-723	723	-723	723
SR-3*	0.1621	0	0	0	0	-328	-328	328	328
SR-3	0.6664	0	0	0	0	-8,089	8,089	8,089	-8,089
SR-3*	0.1621	-328	-328	328	328	0	0	0	0
SR-3	0.6664	-8,089	8,089	8,089	-8,089	0	0	0	0
Pressure stress*		8,995	8,995	8,995	8,995	8,995	8,995	8,995	8,995
Total O_x stress		-291	17,333	16,543	1,811	-291	17,333	16,543	1,811
Membrane O_x stress*		8,521	8,521	9,177	9,177	8,521	8,521	9,177	9,177
SR-2*	0.0664	-45	-45	-45	-45	-45	-45	-45	-45
SR-2	0.0528	-216	216	-216	216	-216	216	-216	216
SR-3*	0.0490	0	0	0	0	-99	-99	99	99
SR-3	0.1940	0	0	0	0	-2,355	2,355	2,355	-2,355
SR-3*	0.0490	-99	-99	99	99	0	0	0	0
SR-3	0.1940	-2,355	2,355	2,355	-2,355	0	0	0	0
Pressure stress*		8,995	8,995	8,995	8,995	8,995	8,995	8,995	8,995
Total O_y stress		6,280	11,422	11,188	6,910	6,280	11,422	11,188	6,910
Membrane O_y stress*		8,851	8,851	9,049	9,049	8,851	8,851	9,049	9,049
Shear from M_t		2,658	2,658	2,658	2,658	2,658	2,658	2,658	2,658
Shear from V_1		0	0	0	0	-149	-149	149	149
Shear from V_2		149	149	-149	-149	0	0	0	0
Total Shear stress		2,807	2,807	2,509	2,509	2,509	2,509	2,807	2,807
Combined stress (P_L+P_b+Q)		8,643	18,454	17,535	7,938	8,268	18,254	17,745	8,152

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\ (Pm)} = P*R_i/(2*t_n) - P_r/(\pi*(R_o^2 - R_i^2)) + M*R_o/I$
$= 415.6738*2.8805/(2*0.378) - 2,900.00/(\pi*(3.3125^2 - 2.8805^2)) + 178,190.9*3.3125/40.49067$
= 15,816.37 psi

The average primary stress P_m (see Division 2 Appendix 4-138(b)) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 17,100.00psi)

Shear in the nozzle due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (3200^2 + 3200^2)^{0.5} / (\pi*2.8805*0.432)$
= 1158 psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 378000 / (2*\pi*2.8805^2*0.432)$
= 16784 psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
= 1158 + 16784
= 17941 psi

UG-45(c): The total combined shear stress (17941psi) is greater than the allowable ($0.7*S_n$ = 0.7*17100 = 11970 psi)

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2) **For P = 415.67 psi @ 68 °F** **The opening is adequately reinforced**							**UG-45 Nozzle Wall Thickness Summary (in)** **The nozzle passes UG-45**	
A required	**A available**	**A_1**	**A_2**	**A_3**	**A_5**	**A welds**	**t_{req}**	**t_{min}**
6.6731	6.6744	0.6982	1.2065	--	4.5559	0.2138	0.3445	0.3780

Weld Failure Path Analysis Summary (lb_f) **All failure paths are stronger than the applicable weld loads**						
Weld load W	**Weld load W_{1-1}**	**Path 1-1 strength**	**Weld load W_{2-2}**	**Path 2-2 strength**	**Weld load W_{3-3}**	**Path 3-3 strength**
121,223.10	119,523.26	175,444.63	45,950.60	361,257.31	137,067.86	308,035.75

UW-16 Weld Sizing Summary			
Weld description	**Required weld size (in)**	**Actual weld size (in)**	**Status**
Nozzle to pad fillet (Leg_{41})	0.2500	0.3500	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.4375	weld size is adequate

Nozzle to pad groove (Upper)	0.3024	0.8750	weld size is adequate

Calculations for internal pressure 415.67 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 6.1068$ in

Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 1.955$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 415.6738*2.8805/(17100*1 - 0.6*415.6738)
= 0.0711 in

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

t_r = $P*K_1*D/(2*S*E - 0.2*P)$
= 415.6738*0.9*114.25/(2*20000*1 - 0.2*415.6738)
= 1.0708 in

Area required per UG-37(c)

Allowable stresses: $S_n = 17100$, $S_v = 20000$, $S_p = 20000$ psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 6.1068*1.0708*1 + 2*0.432*1.0708*1*(1 - 0.855)
= 6.6731 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.6982 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 6.1068*(1*1.1875 - 1*1.0708) - 2*0.432*(1*1.1875 - 1*1.0708)*(1 - 0.855)
= 0.6982 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.1875 + 0.432)*(1*1.1875 - 1*1.0708) - 2*0.432*(1*1.1875 - 1*1.0708)*(1 - 0.855)
= 0.3635 in^2

A_2 = smaller of the following= 1.2065 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.432 - 0.0711)*0.855*1.1875

= $1.8321\ in^2$

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= $2*(0.432 - 0.0711)*(2.5*0.432 + 0.875)*0.855$
= $1.2065\ in^2$

A_{41} = Leg^2*f_{r3}
= $0.5^2*0.855$
= 0.2138 in^2

A_{42} = Leg^2*f_{r4}
= 0^2*1
= 0 in^2

(Part of the weld is outside of the limits)
A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= $(12.2136 - 7.0069)*0.875*1$
= 4.5559 in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= $0.6982 + 1.2065 + 0.2138 + 0 + 4.5559$
= 6.6744 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.432 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.5 = 0.35 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.625 = 0.4375 in

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	t_{r1} = 0.3445 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.1897 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.245 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.1897 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.245 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.3445 in

Available nozzle wall thickness new, t_n = 0.8750*0.432 = 0.378 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*6.625*0.5*8379 = 43598.14 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*13.0069*0.625*9800 = 125141 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*6.193*0.432*11970 = 50303.58 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*6.625*1.1875*14800 = 182894.7 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*6.625*0.875*14800 = 134764.5 lb_f

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

W = $(A - A_1 + 2*t_n*f_{r1}*(E_1*t - F*t_r))*S_v$
= (6.6731 - 0.6982 + 2*0.432*0.855*(1*1.1875 - 1*1.0708))*20000
= 121223.1 lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42})*S_v$
= (1.2065 + 4.5559 + 0.2138 + 0)*20000
= 119523.3 lb_f

W_{2-2} = $(A_2 + A_3 + A_{41} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= (1.2065 + 0 + 0.2138 + 0 + 2*0.432*1.1875*0.855)*20000
= 45950.6 lb_f

W_{3-3} = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2*t_n*t*f_{r1})*S_v$
= (1.2065 + 0 + 4.5559 + 0.2138 + 0 + 0 + 2*0.432*1.1875*0.855)*20000
= 137067.9 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 119523.3 lb_f
Path 1-1 through (2) & (3) = 125141 + 50303.58 = 175444.6 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 45950.6 lb_f
Path 2-2 through (1), (4), (6) = 43598.14 + 182894.7 + 134764.5 = 361257.3 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} = 121223.1 lb_f
Path 3-3 through (2), (4) = 125141 + 182894.7 = 308035.8 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

N7 NPS 12 RFWN(0.500"wt) S/XH Vapor Outlet Nozzle (N7)

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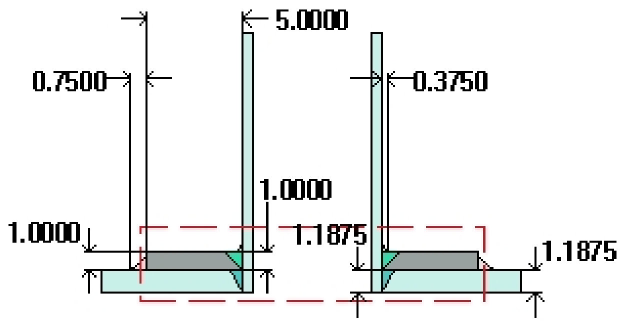


$t_{w(lower)}$ = 1.1875 in
Leg_{41} = 0.3750 in
$t_{w(upper)}$ = 1.0000 in
Leg_{42} = 0.7500 in
D_p = 22.7500 in
t_e = 1.0000 in

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

Located on:	Top Ellipsoidal Head #1
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 5)
Nozzle longitudinal joint efficiency:	1.00
Nozzle description:	12" X Heavy
Pad material specification:	SA-516 70 (II-D p. 14, ln. 20) (normalized)
Pad diameter:	22.75 in
Flange description:	12 inch Class 300 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 382, ln. 33)
Flange rated MDMT:	-55°F
(UCS-66(b)(1)(b))	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	635 psi @ 400°F
ASME B16.5 flange rating MAP:	740 psi @ 68°F
ASME B16.5 flange hydro test:	1125 psi @ 68°F
Nozzle orientation:	0°
Calculated as hillside:	no
Local vessel minimum thickness:	1.1875 in
End of nozzle to datum line:	722.5025 in
Nozzle inside diameter, new:	11.75 in
Nozzle nominal wall thickness:	0.5 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	10.9283 in
Distance to head center, R:	0 in
Pad is split:	no

Reinforcement Calculations for Internal Pressure

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

UG-37 Area Calculation Summary (in^2) For P = 424.1 psi @ 400 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
12.9954	12.9992	1.1024	1.3547	--	10.0000	0.5421	0.3281	0.4375

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
239,484.45	237,936.00	377,821.69	49,804.25	711,324.69	258,242.25	614,642.81

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.3500	1.0000	weld size is adequate

Calculations for internal pressure 424.1 psi @ 400 °F

Fig UCS-66.2 general note (1) applies.

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -13 °F
Fig UCS-66.1 MDMT reduction = 44.3 °F, (coincident ratio = 0.57102)
Rated MDMT is governed by UCS-66(b)(2).
External nozzle loadings per UG-22 govern the coincident ratio used.

Pad is impact tested per UG-84 to -20 °F
UCS-66(i) reduction of 10 °F applied (ratio = 0.9)..

Nozzle UCS-66 governing thk:	0.4375	in
Nozzle rated MDMT:	-55	°F
Pad rated MDMT:	-30	°F

Limits of reinforcement per UG-40

Parallel to the vessel wall:	d = 11.75 in
Normal to the vessel wall outside:	$2.5*(t_n - C_n) + t_e$ = 2.25 in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 424.0967*5.875/(17100*1 - 0.6*424.0967)
= 0.1479 in

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

t_r = $P*K_1*D/(2*S*E - 0.2*P)$
= 424.0967*0.9*114.25/(2*20000*1 - 0.2*424.0967)
= 1.0925 in

Area required per UG-37(c)

Allowable stresses: S_n = 17100, S_v = 20000, S_p = 20000 psi

f_{r1} = lesser of 1 or S_n/S_v = 0.855
f_{r2} = lesser of 1 or S_n/S_v = 0.855
f_{r3} = lesser of f_{r2} or S_p/S_v = 0.855
f_{r4} = lesser of 1 or S_p/S_v = 1

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 11.75*1.0925*1 + 2*0.5*1.0925*1*(1 - 0.855)
= 12.9954 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.1024 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 11.75*(1*1.1875 - 1*1.0925) - 2*0.5*(1*1.1875 - 1*1.0925)*(1 - 0.855)
= 1.1024 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.1875 + 0.5)*(1*1.1875 - 1*1.0925) - 2*0.5*(1*1.1875 - 1*1.0925)*(1 - 0.855)
= 0.3068 in^2

A_2 = smaller of the following= 1.3547 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5 - 0.1479)*0.855*1.1875
= 1.7875 in^2

= $2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
= 2*(0.5 - 0.1479)*(2.5*0.5 + 1)*0.855
= 1.3547 in^2

A_{41} = Leg^2*f_{r3}
= $0.375^2*0.855$
= 0.1202 in^2

A_{42} = $Leg^2 * f_{r4}$
= $0.6495^2 * 1$
= 0.4219 in^2

(Part of the weld is outside of the limits)

A_5 = $(D_p - d - 2*t_n)*t_e*f_{r4}$
= (22.75 - 11.75 - 2*0.5)*1*1
= 10 in^2

Area = $A_1 + A_2 + A_{41} + A_{42} + A_5$
= 1.1024 + 1.3547 + 0.1202 + 0.4219 + 10
= 12.9992 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.5 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	t_{r1} = 0.2515 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2139 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.3281 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2139 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.3281 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.3281 in

Available nozzle wall thickness new, t_n = 0.8750*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*12.75*0.375*8379 = 62929.39 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*22.75*0.75*9800 = 262656.8 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*12.25*0.5*11970 = 115164.9 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*12.75*1.1875*14800 = 351986 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*12.75*1*14800 = 296409.3 lb_f

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

$W = (A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$
= (12.9954 - 1.1024 + 2*0.5*0.855*(1*1.1875 - 1*1.0925))*20000
= 239484.5 lb_f

$W_{1-1} = (A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$
= (1.3547 + 10 + 0.1202 + 0.4219)*20000
= 237936 lb_f

$W_{2-2} = (A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$
= (1.3547 + 0 + 0.1202 + 0 + 2*0.5*1.1875*0.855)*20000
= 49804.25 lb_f

$W_{3-3} = (A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$
= (1.3547 + 0 + 10 + 0.1202 + 0.4219 + 0 + 2*0.5*1.1875*0.855)*20000
= 258242.3 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 237936 lb_f
Path 1-1 through (2) & (3) = 262656.8 + 115164.9 = 377821.7 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 49804.25 lb_f
Path 2-2 through (1), (4), (6) = 62929.39 + 351986 + 296409.3 = 711324.7 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} = 239484.5 lb_f
Path 3-3 through (2), (4) = 262656.8 + 351986 = 614642.8 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Applied Loads

Radial load:	P_r =	7,500.00	lb_f
Circumferential moment:	M_1 =	306,360.00	lb_f-in
Circumferential shear:	V_2 =	8,010.00	lb_f
Longitudinal moment:	M_2 =	306,360.00	lb_f-in
Longitudinal shear:	V_1 =	8,010.00	lb_f
Torsion moment:	M_t =	919,080.00	lb_f-in
Internal pressure:	P =	424.097	psi
Head yield stress:	S_y =	32,500.00	psi

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

Mean dish radius R_m = 103.9329 in

U = r_o/Sqr(R_m*t) = 1.024
Pressure stress intensity factor, I = 1 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i/2*t = 18,453.00 psi

Maximum combined stress (P_L+P_b+Q) = 27,136.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 19,586.00 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the pad edge per WRC Bulletin 107									
Figure	**value**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
SR-2*	0.0649	-345	-345	-345	-345	-345	-345	-345	-345
SR-2	0.0344	-1,098	1,098	-1,098	1,098	-1,098	1,098	-1,098	1,098
SR-3*	0.0756	0	0	0	0	-1,478	-1,478	1,478	1,478
SR-3	0.0719	0	0	0	0	-8,436	8,436	8,436	-8,436
SR-3*	0.0756	-1,478	-1,478	1,478	1,478	0	0	0	0
SR-3	0.0719	-8,436	8,436	8,436	-8,436	0	0	0	0
Pressure stress*		18,453	18,453	18,453	18,453	18,453	18,453	18,453	18,453
Total O_x stress		7,096	26,164	26,924	12,248	7,096	26,164	26,924	12,248
Membrane O_x stress*		16,630	16,630	19,586	19,586	16,630	16,630	19,586	19,586
SR-2*	0.0201	-107	-107	-107	-107	-107	-107	-107	-107
SR-2	0.0103	-329	329	-329	329	-329	329	-329	329
SR-3*	0.0228	0	0	0	0	-446	-446	446	446
SR-3	0.0217	0	0	0	0	-2,546	2,546	2,546	-2,546
SR-3*	0.0228	-446	-446	446	446	0	0	0	0
SR-3	0.0217	-2,546	2,546	2,546	-2,546	0	0	0	0
Pressure stress*		18,453	18,453	18,453	18,453	18,453	18,453	18,453	18,453
Total O_y stress		15,025	20,775	21,009	16,575	15,025	20,775	21,009	16,575
Membrane O_y stress*		17,900	17,900	18,792	18,792	17,900	17,900	18,792	18,792
Shear from M_t		952	952	952	952	952	952	952	952
Shear from V_1		0	0	0	0	-189	-189	189	189
Shear from V_2		189	189	-189	-189	0	0	0	0
Total Shear stress		1,141	1,141	763	763	763	763	1,141	1,141
Combined stress (P_L+P_b+Q)		15,186	26,396	27,021	16,706	15,098	26,270	27,136	16,857

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

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

Mean dish radius R_m = 103.9329 in

U = r_o/Sqr(R_m*t) = 0.423
Pressure stress intensity factor, I = 0.53442 (derived from PVP-Vol. 399, pages 77-82)

Local pressure stress = I*P*R_i/2*t = 9,862.00 psi

Maximum combined stress (P_L+P_b+Q) = 18,268.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = 10,281.00 psi
Allowable local primary membrane stress (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the nozzle OD per WRC Bulletin 107									
Figure	**value**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
SR-2*	0.1531	-240	-240	-240	-240	-240	-240	-240	-240
SR-2	0.0990	-931	931	-931	931	-931	931	-931	931
SR-3*	0.1553	0	0	0	0	-659	-659	659	659
SR-3	0.3070	0	0	0	0	-7,821	7,821	7,821	-7,821
SR-3*	0.1553	-659	-659	659	659	0	0	0	0
SR-3	0.3070	-7,821	7,821	7,821	-7,821	0	0	0	0
Pressure stress*		9,862	9,862	9,862	9,862	9,862	9,862	9,862	9,862
Total O_x stress		211	17,715	17,171	3,391	211	17,715	17,171	3,391
Membrane O_x stress*		8,963	8,963	10,281	10,281	8,963	8,963	10,281	10,281
SR-2*	0.0459	-72	-72	-72	-72	-72	-72	-72	-72
SR-2	0.0302	-284	284	-284	284	-284	284	-284	284
SR-3*	0.0476	0	0	0	0	-202	-202	202	202
SR-3	0.0925	0	0	0	0	-2,357	2,357	2,357	-2,357
SR-3*	0.0476	-202	-202	202	202	0	0	0	0
SR-3	0.0925	-2,357	2,357	2,357	-2,357	0	0	0	0
Pressure stress*		9,862	9,862	9,862	9,862	9,862	9,862	9,862	9,862
Total O_y stress		6,947	12,229	12,065	7,919	6,947	12,229	12,065	7,919
Membrane O_y stress*		9,588	9,588	9,992	9,992	9,588	9,588	9,992	9,992
Shear from M_t		1,645	1,645	1,645	1,645	1,645	1,645	1,645	1,645
Shear from V_1		0	0	0	0	-183	-183	183	183
Shear from V_2		183	183	-183	-183	0	0	0	0
Total Shear stress		1,828	1,828	1,462	1,462	1,462	1,462	1,828	1,828
Combined stress (P_L+P_b+Q)		7,664	18,268	17,560	8,350	7,343	18,080	17,758	8,565

Notes: (1) * denotes primary stress.

(2) The nozzle is assumed to be a rigid (solid) attachment.

Stress in the nozzle wall due to internal pressure + external loads

$\sigma_{n\ (Pm)} = P*R_i/(2*t_n) - P_r/(\pi*(R_o^2 - R_i^2)) + M*R_o/I$
$= 424.0967*5.875/(2*0.4375) - 7{,}500.00/(\pi*(6.375^2 - 5.875^2)) + 433{,}258.5*6.375/361.5439$
$= 10{,}097.26$ psi

The average primary stress P_m (see Division 2 Appendix 4-138(b)) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 17,100.00psi)

Shear in the nozzle due to external loads

$\sigma_{shear} = (V_L^2 + V_c^2)^{0.5} / (\pi*R_i*t_n)$
$= (8010^2 + 8010^2)^{0.5} / (\pi*5.875*0.5)$
$= 1228$ psi

$\sigma_{torsion} = M_t / (2*\pi*R_i^2*t_n)$
$= 919080 / (2*\pi*5.875^2*0.5)$
$= 8476$ psi

$\sigma_{total} = \sigma_{shear} + \sigma_{torsion}$
$= 1228 + 8476$
$= 9703$ psi

UG-45(c): The total combined shear stress (9703 psi) is below than the allowable ($0.7*S_n = 0.7*17100 = 11970$ psi)

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in²) For P = 424.1 psi @ 68 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
12.9954	12.9992	1.1024	1.3547	--	10.0000	0.5421	0.3281	0.4375

Weld Failure Path Analysis Summary (lb_f) All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
239,484.45	237,936.00	377,821.69	49,804.25	711,324.69	258,242.25	614,642.81

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.2500	0.2625	weld size is adequate
Pad to shell fillet (Leg_{42})	0.3750	0.5250	weld size is adequate
Nozzle to pad groove (Upper)	0.3500	1.0000	weld size is adequate

Calculations for internal pressure 424.1 psi @ 68 °F

Limits of reinforcement per UG-40

Parallel to the vessel wall: $d = 11.75$ in
Normal to the vessel wall outside: $2.5*(t_n - C_n) + t_e = 2.25$ in

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

t_{rn} = $P*R_n/(S_n*E - 0.6*P)$
= 424.0967*5.875/(17100*1 - 0.6*424.0967)
= 0.1479 in

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

t_r = $P*K_1*D/(2*S*E - 0.2*P)$
= 424.0967*0.9*114.25/(2*20000*1 - 0.2*424.0967)
= 1.0925 in

Area required per UG-37(c)

Allowable stresses: $S_n = 17100$, $S_v = 20000$, $S_p = 20000$ psi

f_{r1} = lesser of 1 or $S_n/S_v = 0.855$
f_{r2} = lesser of 1 or $S_n/S_v = 0.855$
f_{r3} = lesser of f_{r2} or $S_p/S_v = 0.855$
f_{r4} = lesser of 1 or $S_p/S_v = 1$

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= 11.75*1.0925*1 + 2*0.5*1.0925*1*(1 - 0.855)
= 12.9954 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 1.1024 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 11.75*(1*1.1875 - 1*1.0925) - 2*0.5*(1*1.1875 - 1*1.0925)*(1 - 0.855)
= 1.1024 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= 2*(1.1875 + 0.5)*(1*1.1875 - 1*1.0925) - 2*0.5*(1*1.1875 - 1*1.0925)*(1 - 0.855)
= 0.3068 in^2

A_2 = smaller of the following= 1.3547 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= 5*(0.5 - 0.1479)*0.855*1.1875
= 1.7875 in^2

$= 2*(t_n - t_{rn})*(2.5*t_n + t_e)*f_{r2}$
$= 2*(0.5 - 0.1479)*(2.5*0.5 + 1)*0.855$
$= 1.3547$ in^2

$A_{41} = Leg^2*f_{r3}$
$= 0.375^2*0.855$
$= 0.1202$ in^2

$A_{42} = Leg^2*f_{r4}$
$= 0.6495^2*1$
$= 0.4219$ in^2

(Part of the weld is outside of the limits)

$A_5 = (D_p - d - 2*t_n)*t_e*f_{r4}$
$= (22.75 - 11.75 - 2*0.5)*1*1$
$= 10$ in^2

Area $= A_1 + A_2 + A_{41} + A_{42} + A_5$
$= 1.1024 + 1.3547 + 0.1202 + 0.4219 + 10$
$= 12.9992$ in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: t_{min} = lesser of 0.75 or t_n or t_e = 0.5 in
$t_{c(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.25 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.375 = 0.2625 in

Outer fillet: t_{min} = lesser of 0.75 or t_e or t = 0.75 in
$t_{w(min)}$ = $0.5*t_{min}$ = 0.375 in
$t_{w(actual)}$ = 0.7*Leg = 0.7*0.75 = 0.525 in

UG-45 Nozzle Neck Thickness Check

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

Wall thickness per UG-45(a):	t_{r1} = 0.2515 in (E =1) (pressure plus external loads govern in longitudinal direction)
Wall thickness per UG-45(b)(1):	t_{r2} = 1.2139 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.3281 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 1.2139 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.3281 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.3281 in

Available nozzle wall thickness new, t_n = 0.8750*0.5 = 0.4375 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	0.74*20000 =	14800 psi
Nozzle wall in shear:	0.7*17100 =	11970 psi
Inner fillet weld in shear:	0.49*17100 =	8379 psi
Outer fillet weld in shear:	0.49*20000 =	9800 psi
Upper groove weld in tension:	0.74*20000 =	14800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$(\pi/2)$*Nozzle OD*Leg*S_i = $(\pi/2)$*12.75*0.375*8379 = 62929.39 lb_f

(2) Outer fillet weld in shear
$(\pi/2)$*Pad OD*Leg*S_o = $(\pi/2)$*22.75*0.75*9800 = 262656.8 lb_f

(3) Nozzle wall in shear
$(\pi/2)$*Mean nozzle dia*t_n*S_n = $(\pi/2)$*12.25*0.5*11970 = 115164.9 lb_f

(4) Groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*12.75*1.1875*14800 = 351986 lb_f

(6) Upper groove weld in tension
$(\pi/2)$*Nozzle OD*t_w*S_g = $(\pi/2)$*12.75*1*14800 = 296409.3 lb_f

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

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$
= (12.9954 - 1.1024 + 2*0.5*0.855*(1*1.1875 - 1*1.0925))*20000
= 239484.5 lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$
= (1.3547 + 10 + 0.1202 + 0.4219)*20000
= 237936 lb_f

W_{2-2} = $(A_2 + A_3 + A_{41} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$
= (1.3547 + 0 + 0.1202 + 0 + 2*0.5*1.1875*0.855)*20000
= 49804.25 lb_f

W_{3-3} = $(A_2 + A_3 + A_5 + A_{41} + A_{42} + A_{43} + 2 \cdot t_n \cdot t \cdot f_{r1}) \cdot S_v$
= (1.3547 + 0 + 10 + 0.1202 + 0.4219 + 0 + 2*0.5*1.1875*0.855)*20000
= 258242.3 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 237936 lb_f
Path 1-1 through (2) & (3) = 262656.8 + 115164.9 = 377821.7 lb_f
Path 1-1 is stronger than W_{1-1} so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or W_{2-2} = 49804.25 lb_f

Path 2-2 through (1), (4), (6) = 62929.39 + 351986 + 296409.3 = 711324.7 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} = 239484.5 lb_f
Path 3-3 through (2), (4) = 262656.8 + 351986 = 614642.8 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

Platform #2 /Ladder

Distance from platform base to datum:	604.00"
Platform attached to :	Cylinder #1
Platform start angle:	0.00 degrees
Platform end angle:	110.00 degrees
Platform shell clearance:	L_c = 6.00"
Platform width:	W = 54.00" (4.50 ft)
Platform projected length:	L = 60.00" (5.00 ft)
Platform wind force coefficient:	C_f = 1.30
Floor grating weight:	25.00 psf
Railing height:	h = 42.01" (3.50 ft)
Railing weight:	12.00 lb/ft
Estimated platform & railing weight:	1979.90 lb
Distance from ladder start to datum:	406.00"
Ladder angle:	0.00 degrees
Ladder weight:	25.00 lb/ft
Included in vessel lift weight:	Yes
Present when vessel is empty:	Yes
Present during hydrotest:	Yes

Platform Wind Shear Calculation

Local wind pressure: P_w = 0.00 psf

Wind shear: $V_p = P_w * C_f * A_e$ = 0.00 lbf

Platform #3 / Ladder

Distance from platform base to datum:	406.00"
Platform attached to :	Cylinder #3
Platform start angle:	255.00 degrees
Platform end angle:	27.00 degrees
Platform shell clearance:	L_c = 6.00"
Platform width:	W = 48.00" (4.00 ft)
Platform projected length:	L = 108.00" (9.00 ft)
Platform wind force coefficient:	C_f = 1.30
Floor grating weight:	25.00 psf
Railing height:	h = 42.01" (3.50 ft)
Railing weight:	12.00 lb/ft
Estimated platform & railing weight:	2051.57 lb
Distance from ladder start to datum:	85.00"
Ladder angle:	0.00 degrees
Ladder weight:	25.00 lb/ft
Included in vessel lift weight:	Yes
Present when vessel is empty:	Yes
Present during hydrotest:	Yes

Platform Wind Shear Calculation

Local wind pressure: P_w = 0.00 psf

Wind shear: $V_p = P_w * C_f * A_e$ = 0.00 lbf

Platform #4 / Ladder

Distance from platform base to datum:	85.00"
Platform attached to :	Cylinder #6
Platform start angle:	225.00 degrees
Platform end angle:	342.00 degrees
Platform shell clearance:	L_c = 6.00"
Platform width:	W = 48.00" (4.00 ft)
Platform projected length:	L = 54.00" (4.50 ft)
Platform wind force coefficient:	C_f = 1.30
Floor grating weight:	25.00 psf
Railing height:	h = 42.01" (3.50 ft)
Railing weight:	12.00 lb/ft
Estimated platform & railing weight:	1829.35 lb
Distance from ladder start to datum:	10.00"
Ladder angle:	225.00 degrees
Ladder weight:	25.00 lb/ft
Included in vessel lift weight:	Yes
Present when vessel is empty:	Yes
Present during hydrotest:	Yes

Platform Wind Shear Calculation

Local wind pressure: P_w = 0.00 psf

Wind shear: $V_p = P_w * C_f * A_e$ = 0.00 lbf

Platform #5 / Ladder

Distance from platform base to datum:	10.00"
Platform attached to :	Cylinder #6
Platform start angle:	100.00 degrees
Platform end angle:	155.00 degrees
Platform shell clearance:	L_c = 6.00"
Platform width:	W = 42.00" (3.50 ft)
Platform projected length:	L = 48.00" (4.00 ft)
Platform wind force coefficient:	C_f = 1.30
Floor grating weight:	25.00 psf
Railing height:	h = 42.01" (3.50 ft)
Railing weight:	12.00 lb/ft
Estimated platform & railing weight:	783.69 lb
Distance from ladder start to datum:	-98.00"
Ladder angle:	155.00 degrees
Ladder weight:	25.00 lb/ft
Included in vessel lift weight:	Yes
Present when vessel is empty:	Yes
Present during hydrotest:	Yes

Platform Wind Shear Calculation

Local wind pressure: P_w = 0.00 psf

Wind shear: $V_p = P_w * C_f * A_e$ = 0.00 lbf

Platform #6 / Ladder

Distance from platform base to datum:	-11.00"
Platform attached to :	Support Skirt
Platform start angle:	225.00 degrees
Platform end angle:	342.00 degrees
Platform shell clearance:	L_c = 6.00"
Platform width:	W = 42.00" (3.50 ft)
Platform projected length:	L = 48.00" (4.00 ft)
Platform wind force coefficient:	C_f = 1.30
Floor grating weight:	25.00 psf
Railing height:	h = 42.01" (3.50 ft)
Railing weight:	12.00 lb/ft
Estimated platform & railing weight:	1559.74 lb
Distance from ladder start to datum:	-98.00"
Ladder angle:	225.00 degrees
Ladder weight:	25.00 lb/ft
Included in vessel lift weight:	Yes
Present when vessel is empty:	Yes
Present during hydrotest:	Yes

Platform Wind Shear Calculation

Local wind pressure: P_w = 0.00 psf

Wind shear: V_p = P_w * C_f * A_e = 0.00 lbf

Top Platform #1 /Ladder

Distance from platform base to datum:	724.00"
Platform attached to :	Top Ellipsoidal Head #1
Platform orientation:	0.00 degrees
Platform offset:	48.00"
Platform width:	W = 96.00" (8.00 ft)
Platform length:	L = 96.00" (8.00 ft)
Platform wind force coefficient:	C_f = 1.30
Floor grating weight:	22.00 psf
Railing height:	h = 42.00" (3.50 ft)
Railing weight:	12.00 lb/ft
Estimated platform & railing weight:	1792.00 lb
Distance from ladder start to datum:	605.00"
Ladder angle:	0.00 degrees
Ladder weight:	25.00 lb/ft
Included in vessel lift weight:	Yes
Present when vessel is empty:	Yes
Present during hydrotest:	Yes

Platform Wind Shear Calculation

Local wind pressure: P_w = 0.00 psf

Wind shear: $V_p = P_w * C_f * A_e$ = 0.00 lbf

Skirt Base Ring #1

Base configuration:	external bolt chairs
Foundation compressive strength:	750 psi
Concrete ultimate 28-day strength:	3,000.00 psi
Anchor bolt material:	SA-320
Anchor bolt allowable stress, S_b:	20,000.00 psi
Bolt circle, BC:	121.375 in
Anchor bolt corrosion allowance:	0.125 in
Anchor bolt clearance:	0.5 in
Base plate material:	SA-516-70
Base plate allowable stress, S_p:	20,000.00 psi
Base plate inner diameter, D_i:	104.875 in
Base plate outer diameter, D_o:	127.875 in
Base plate thickness, t_b:	1.5 in
Gusset separation, w:	6 in
Gusset height, h:	6.75 in
Gusset thickness, t_g:	0.5 in
Compression plate width:	6.0625 in
Compression plate length:	8 in
Compression plate thickness, t_c:	1.25 in
Initial bolt preload:	10 % (2,000.00 psi)
Number of bolts, N:	20
Bolt size and type:	1.5 inch series 8 threaded
Bolt root area (corroded), A_b:	0.9289 in^2
Diameter of anchor bolt holes, d_b:	2 in

Load	Vessel condition	Base M (lb-ft)	W (lb)	Required bolt area (in^2)	t_r Base (in)	Foundation bearing stress (psi)	$t_r$comp plate (in)	t_r gusset (in)
Weight	operating, corroded	21,641.8	182,003.5	0.0000	0.4680	59.83	0.3899	0.1318
Weight	operating, new	21,641.8	182,003.5	0.0000	0.4680	59.83	0.3899	0.1318
Weight	empty, corroded	21,641.8	182,003.5	0.0000	0.4680	59.83	0.3899	0.1318
Weight	empty, new	21,641.8	182,003.5	0.0000	0.4680	59.83	0.3899	0.1318
Weight	test, new	21,641.8	448,248.9	0.0000	0.6740	124.11	0.3899	0.1318

Anchor bolt load (operating, corroded + Weight)

P = -W / N + 48 * M /(N*BC)
= -182,003.5 / 20 + 48 * 21,641.82 /(20*121.375)
= -8,672.241 lb

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, corroded + Weight)

$A_c = pi*(D_o^2 - D_i^2)/4 - N*pi*d_b^2/4$
$= \pi*(127.875^2 - 104.875^2)/4 - 20*\pi*2^2/4$
$= 4,141.6011\ in^2$

$I_c = \pi*(D_o^4 - D_i^4)/64$
$= \pi*(127.875^4 - 104.875^4)/64$
$= 7,187,157.5000\ in^4$

$f_c = N*A_b*Preload/A_c + W/A_c + 6*M*D_o/I_c$
= 20*1.405*2,000.00/4,141.601 + 182,003.5/4,141.601 + 6*21,641.82*127.875/7,187,158
= 59.83 psi

As f_c <= 750 psi the base plate width is satisfactory.

Base plate required thickness (operating, corroded + Weight)

From Brownell & Young, Table 10.3:, l/b = 0.5231842

$M_x = 0.03299*59.82516*12.06554^2 = 287.316$

$M_y = -0.3062*59.82516*6.3125^2 = -729.9478$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*729.9478 / 20,000.00)^{0.5}$
= 0.4679576 in

The base plate thickness is satisfactory.

Check the compression plate for bolt load (Jawad & Farr equation 12.13)

$t_{cr} = (3.91*F/(S_y*(2*b/w+w/(2*l)-d_b*(2/w+1/(2*l)))))^{0.5}$
$= (3.91*2,810.00/(36,000.00*(2*6.0625/6+6/(2*3.062)-2*(2/6+1/(2*3.062)))))^{0.5}$
= 0.3899244 in

The compression plate thickness is satisfactory.

Check gusset plate thickness (Bednar chapter 4.3)

Radius of gyration of gusset

$r = 0.289*t_g$
= 0.289*0.5
= 0.1445 in

Cross sectional area of one gusset

$A_g = t_g*(b - 0.25)$
= 0.5*(6.3125 - 0.25)
= 3.03125 in^2

Gusset allowable stress

$S_a = 17000 - 0.485*(h / r)^2$
$= 17000 - 0.485*(6.75 / 0.1445)^2$
= 15,941.69 psi

Gusset axial stress due to bolt load

$S_g = F / (2 * A_g)$
= 2,810.00 / (2 * 3.03125)
= 463.51 psi

The gusset plate thickness is satisfactory.

Check skirt thickness for bolt load reaction (Brownell & Young eq. 10.59)

$t = 1.76*(F*l/(M_b*h_c*S_s))^{2/3}*(OD_s/2)^{1/3}$
$= 1.76*(0*3.0625/(18.10343*9.5*30{,}000.00))^{2/3}*(115.25/2)^{1/3}$
= 0 in

The skirt thickness is satisfactory.

Note: No local skirt reaction is present because the foundation resists the initial bolt preload.

Anchor bolt load (operating, new + Weight)

P = -W / N + 48 * M /(N*BC)
= -182,003.5 / 20 + 48 * 21,641.82 /(20*121.375)
= -8,672.241 lb

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, new + Weight)

$A_c = pi*(D_o^2 - D_i^2)/4 - N*pi*d_b^2/4$
$= \pi*(127.875^2 - 104.875^2)/4 - 20*\pi*2^2/4$
$= 4{,}141.6011\ in^2$

$I_c = \pi*(D_o^4 - D_i^4)/64$
$= \pi*(127.875^4 - 104.875^4)/64$
$= 7{,}187{,}157.5000\ in^4$

$f_c = N*A_b*Preload/A_c + W/A_c + 6*M*D_o/I_c$
= 20*1.405*2,000.00/4,141.601 + 182,003.5/4,141.601 + 6*21,641.82*127.875/7,187,158
= 59.83 psi

As f_c <= 750 psi the base plate width is satisfactory.

Base plate required thickness (operating, new + Weight)

From Brownell & Young, Table 10.3:, l/b = 0.5231842

$M_x = 0.03299*59.82516*12.06554^2 = 287.316$

$M_y = -0.3062*59.82516*6.3125^2 = -729.9478$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*729.9478 / 20{,}000.00)^{0.5}$
= 0.4679576 in

The base plate thickness is satisfactory.

Check the compression plate for bolt load (Jawad & Farr equation 12.13)

$t_{cr} = (3.91*F/(S_y*(2*b/w+w/(2*l)-d_b*(2/w+1/(2*l)))))^{0.5}$
$= (3.91*2{,}810.00/(36{,}000.00*(2*6.0625/6+6/(2*3.062)-2*(2/6+1/(2*3.062)))))^{0.5}$
= 0.3899244 in

The compression plate thickness is satisfactory.

Check gusset plate thickness (Bednar chapter 4.3)

Radius of gyration of gusset

$r = 0.289*t_g$
$= 0.289*0.5$
$= 0.1445$ in

Cross sectional area of one gusset

$A_g = t_g*(b - 0.25)$
$= 0.5*(6.3125 - 0.25)$
$= 3.03125$ in^2

Gusset allowable stress

$S_a = 17000 - 0.485*(h / r)^2$
$= 17000 - 0.485*(6.75 / 0.1445)^2$
$= 15,941.69$ psi

Gusset axial stress due to bolt load

$S_g = F / (2 * A_g)$
$= 2,810.00 / (2 * 3.03125)$
$= 463.51$ psi

The gusset plate thickness is satisfactory.

Check skirt thickness for bolt load reaction (Brownell & Young eq. 10.59)

$t = 1.76*(F*l/(M_b*h_c*S_s))^{2/3}*(OD_s/2)^{1/3}$
$= 1.76*(0*3.0625/(18.10343*9.5*30,000.00))^{2/3}*(115.25/2)^{1/3}$
$= 0$ in

The skirt thickness is satisfactory.

Note: No local skirt reaction is present because the foundation resists the initial bolt preload.

Anchor bolt load (empty, corroded + Weight)

$P = -W / N + 48 * M /(N*BC)$
$= -182,003.5 / 20 + 48 * 21,641.82 /(20*121.375)$
$= -8,672.241$ lb

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (empty, corroded + Weight)

$A_c = pi*(D_o^2 - D_i^2)/4 - N*pi*d_b^2/4$
$= \pi*(127.875^2 - 104.875^2)/4 - 20*\pi*2^2/4$
$= 4,141.6011$ in^2

$I_c = \pi*(D_o^4 - D_i^4)/64$
$= \pi*(127.875^4 - 104.875^4)/64$
$= 7,187,157.5000$ in^4

$f_c = N*A_b*Preload/A_c + W/A_c + 6*M*D_o/I_c$
$= 20*1.405*2,000.00/4,141.601 + 182,003.5/4,141.601 + 6*21,641.82*127.875/7,187,158$
= 59.83 psi

As f_c <= 750 psi the base plate width is satisfactory.

Base plate required thickness (empty, corroded + Weight)

From Brownell & Young, Table 10.3:, l/b = 0.5231842

M_x = 0.03299*59.82516*12.06554^2 = 287.316

M_y = -0.3062*59.82516*6.3125^2 = -729.9478

$t_r = (6*M_{max} / S_p)^{0.5}$
= (6*729.9478 / 20,000.00)$^{0.5}$
= 0.4679576 in

The base plate thickness is satisfactory.

Check the compression plate for bolt load (Jawad & Farr equation 12.13)

$t_{cr} = (3.91*F/(S_y*(2*b/w+w/(2*l)-d_b*(2/w+1/(2*l)))))^{0.5}$
= (3.91*2,810.00/(36,000.00*(2*6.0625/6+6/(2*3.062)-2*(2/6+1/(2*3.062)))))$^{0.5}$
= 0.3899244 in

The compression plate thickness is satisfactory.

Check gusset plate thickness (Bednar chapter 4.3)

Radius of gyration of gusset

$r = 0.289*t_g$
= 0.289*0.5
= 0.1445 in

Cross sectional area of one gusset

$A_g = t_g*(b - 0.25)$
= 0.5*(6.3125 - 0.25)
= 3.03125 in^2

Gusset allowable stress

$S_a = 17000 - 0.485*(h / r)^2$
= 17000 - 0.485*(6.75 / 0.1445)^2
= 15,941.69 psi

Gusset axial stress due to bolt load

$S_g = F / (2 * A_g)$
= 2,810.00 / (2 * 3.03125)
= 463.51 psi

The gusset plate thickness is satisfactory.

Check skirt thickness for bolt load reaction (Brownell & Young eq. 10.59)

$t = 1.76*(F*l/(M_b*h_c*S_s))^{2/3}*(OD_s/2)^{1/3}$
= 1.76*(0*3.0625/(18.10343*9.5*30,000.00))$^{2/3}$*(115.25/2)$^{1/3}$
= 0 in

The skirt thickness is satisfactory.

Note: No local skirt reaction is present because the foundation resists the initial bolt preload.

Anchor bolt load (empty, new + Weight)

P = -W / N + 48 * M /(N*BC)
= -182,003.5 / 20 + 48 * 21,641.82 /(20*121.375)
= -8,672.241 lb

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (empty, new + Weight)

$A_c = pi*(D_o^2 - D_i^2)/4 - N*pi*d_b^2/4$
$= \pi*(127.875^2 - 104.875^2)/4 - 20*\pi*2^2/4$
$= 4{,}141.6011\ in^2$

$I_c = \pi*(D_o^4 - D_i^4)/64$
$= \pi*(127.875^4 - 104.875^4)/64$
$= 7{,}187{,}157.5000\ in^4$

$f_c = N*A_b*Preload/A_c + W/A_c + 6*M*D_o/I_c$
= 20*1.405*2,000.00/4,141.601 + 182,003.5/4,141.601 + 6*21,641.82*127.875/7,187,158
= 59.83 psi

As f_c <= 750 psi the base plate width is satisfactory.

Base plate required thickness (empty, new + Weight)

From Brownell & Young, Table 10.3:, l/b = 0.5231842

$M_x = 0.03299*59.82516*12.06554^2 = 287.316$

$M_y = -0.3062*59.82516*6.3125^2 = -729.9478$

$t_r = (6*M_{max} / S_p)^{0.5}$
$= (6*729.9478 / 20{,}000.00)^{0.5}$
= 0.4679576 in

The base plate thickness is satisfactory.

Check the compression plate for bolt load (Jawad & Farr equation 12.13)

$t_{cr} = (3.91*F/(S_y*(2*b/w+w/(2*l)-d_b*(2/w+1/(2*l)))))^{0.5}$
$= (3.91*2{,}810.00/(36{,}000.00*(2*6.0625/6+6/(2*3.062)-2*(2/6+1/(2*3.062)))))^{0.5}$
= 0.3899244 in

The compression plate thickness is satisfactory.

Check gusset plate thickness (Bednar chapter 4.3)

Radius of gyration of gusset

$r = 0.289*t_g$
= 0.289*0.5
= 0.1445 in

Cross sectional area of one gusset

$A_g = t_g*(b - 0.25)$
$= 0.5*(6.3125 - 0.25)$
$= 3.03125\ in^2$

Gusset allowable stress

$S_a = 17000 - 0.485*(h / r)^2$
$= 17000 - 0.485*(6.75 / 0.1445)^2$
$= 15,941.69$ psi

Gusset axial stress due to bolt load

$S_g = F / (2 * A_g)$
$= 2,810.00 / (2 * 3.03125)$
$= 463.51$ psi

The gusset plate thickness is satisfactory.

Check skirt thickness for bolt load reaction (Brownell & Young eq. 10.59)

$t = 1.76*(F*l/(M_b*h_c*S_s))^{2/3}*(OD_s/2)^{1/3}$
$= 1.76*(0*3.0625/(18.10343*9.5*30,000.00))^{2/3}*(115.25/2)^{1/3}$
$= 0$ in

The skirt thickness is satisfactory.

Note: No local skirt reaction is present because the foundation resists the initial bolt preload.

Anchor bolt load (test, new + Weight)

$P = -W / N + 48 * M /(N*BC)$
$= -448,248.9 / 20 + 48 * 21,641.82 /(20*121.375)$
$= -21,984.51$ lb

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (test, new + Weight)

$A_c = pi*(D_o^2 - D_i^2)/4 - N*pi*d_b^2/4$
$= \pi*(127.875^2 - 104.875^2)/4 - 20*\pi*2^2/4$
$= 4,141.6011\ in^2$

$I_c = \pi*(D_o^4 - D_i^4)/64$
$= \pi*(127.875^4 - 104.875^4)/64$
$= 7,187,157.5000\ in^4$

$f_c = N*A_b*Preload/A_c + W/A_c + 6*M*D_o/I_c$
$= 20*1.405*2,000.00/4,141.601 + 448,248.9/4,141.601 + 6*21,641.82*127.875/7,187,158$
= 124.11 psi

As $f_c <= 750$ psi the base plate width is satisfactory.

Base plate required thickness (test, new + Weight)

From Brownell & Young, Table 10.3:, l/b = 0.5231842

$M_x = 0.03299*124.1108*12.06554^2 = 596.0538$

M_y = -0.3062*124.1108*6.3125^2 = -1,514.319

$t_r = (6*M_{max} / S_p)^{0.5}$
= $(6*1,514.319 / 20,000.00)^{0.5}$
= 0.6740147 in

The base plate thickness is satisfactory.

Check the compression plate for bolt load (Jawad & Farr equation 12.13)

$t_{cr} = (3.91*F/(S_y*(2*b/w+w/(2*l)-d_b*(2/w+1/(2*l)))))^{0.5}$
= $(3.91*2,810.00/(36,000.00*(2*6.0625/6+6/(2*3.062)-2*(2/6+1/(2*3.062)))))^{0.5}$
= 0.3899244 in

The compression plate thickness is satisfactory.

Check gusset plate thickness (Bednar chapter 4.3)

Radius of gyration of gusset

$r = 0.289*t_g$
= 0.289*0.5
= 0.1445 in

Cross sectional area of one gusset

$A_g = t_g*(b - 0.25)$
= 0.5*(6.3125 - 0.25)
= 3.03125 in^2

Gusset allowable stress

$S_a = 17000 - 0.485*(h / r)^2$
= 17000 - 0.485*(6.75 / 0.1445)^2
= 15,941.69 psi

Gusset axial stress due to bolt load

$S_g = F / (2 * A_g)$
= 2,810.00 / (2 * 3.03125)
= 463.51 psi

The gusset plate thickness is satisfactory.

Check skirt thickness for bolt load reaction (Brownell & Young eq. 10.59)

$t = 1.76*(F*l/(M_b*h_c*S_s))^{2/3}*(OD_s/2)^{1/3}$
= $1.76*(0*3.0625/(18.10343*9.5*30,000.00))^{2/3}*(115.25/2)^{1/3}$
= 0 in

The skirt thickness is satisfactory.

Note: No local skirt reaction is present because the foundation resists the initial bolt preload.

Support Skirt

Material:		SA-516 70 (II-D p. 14, ln. 20)
Design temperature, operating:	401	°F
Inner diameter at top, new:	114	in
Inner diameter at bottom, new:	114	in
Overall length:	89.71	in
Corrosion allowance inside:	0	in
Corrosion allowance outside:	0	in
Weld joint efficiency top:	0.55	
Weld joint efficiency bottom:	0.8	
Nominal thickness, new:	0.625	in
Skirt is attached to:		Bottom Ellipsoidal Head #2
Skirt attachment offset:	8.2864	in down from the top seam

Skirt design thickness, largest of the following + corrosion = 0.0941 in

The governing condition is due to weight, compressive stress at the base, test & new.

The skirt thickness of 0.6250 in is adequate.

Loading	Vessel Condition (Stress)	Governing Skirt Location	Temperature (°F)	Allowable Stress (psi)	Calculated Stress/E (psi)	Required thickness (in)
Weight	operating, corroded (+)	bottom	401.00	11,926.63	-757.48	0.0397
Weight	operating, corroded (-)	bottom	401.00	11,926.63	838.01	0.0439
Weight	empty, corroded (+)	bottom	68.00	13,419.88	-757.48	0.0353
Weight	empty, corroded (-)	bottom	68.00	13,419.88	838.01	0.0390
Weight	test, new (+)	bottom	68.00	13,419.88	-1,940.45	0.0904
Weight	test, new (-)	bottom	68.00	13,419.88	2,020.98	0.0941

Loading due to weight, operating & corroded

Windward side (tensile)

Required thickness, tensile stress at base:
$t = -W/(\pi*D*S_t*E) + 48*M/(\pi*D^2*S_t*E)$
$= -179{,}545.5/(\pi*114.625*11{,}926.63*1) + 48*21{,}641.82/(\pi*114.625^2*11{,}926.63*1)$
= 0.0397 in

Required thickness, tensile stress at the top:
$t = -W_t/(\pi*D_t*S_t*E) + 48*M_t/(\pi*D_t^2*S_t*E)$
$= -173{,}831.6/(\pi*114.625*11{,}926.63*1) + 48*21{,}641.82/(\pi*114.625^2*11{,}926.63*1)$
= 0.0384 in

Leeward side (compressive)

Required thickness, compressive stress at base:
$t = W/(\pi*D*S_c*E_c) + 48*M/(\pi*D^2*S_c*E_c)$
$= 179{,}545.5/(\pi*114.625*11{,}926.63*1) + 48*21{,}641.82/(\pi*114.625^2*11{,}926.63*1)$
= 0.0439 in

Required thickness, compressive stress at the top:

$t = W_t/(\pi^*D_t^*S_c^*E_c) + 48^*M_t/(\pi^*D_t^{2*}S_c^*E_c)$
$= 173{,}831.6/(\pi^*114.625^*11{,}926.63^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}11{,}926.63^*1)$
= 0.0426 in

Loading due to weight, empty & corroded

Windward side (tensile)

Required thickness, tensile stress at base:
$t = -W/(\pi^*D^*S_t^*E) + 48^*M/(\pi^*D^{2*}S_t^*E)$
$= -179{,}545.5/(\pi^*114.625^*13{,}419.88^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}13{,}419.88^*1)$
= 0.0353 in

Required thickness, tensile stress at the top:
$t = -W_t/(\pi^*D_t^*S_t^*E) + 48^*M_t/(\pi^*D_t^{2*}S_t^*E)$
$= -173{,}831.6/(\pi^*114.625^*13{,}419.88^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}13{,}419.88^*1)$
= 0.0341 in

Leeward side (compressive)

Required thickness, compressive stress at base:
$t = W/(\pi^*D^*S_c^*E_c) + 48^*M/(\pi^*D^{2*}S_c^*E_c)$
$= 179{,}545.5/(\pi^*114.625^*13{,}419.88^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}13{,}419.88^*1)$
= 0.0390 in

Required thickness, compressive stress at the top:
$t = W_t/(\pi^*D_t^*S_c^*E_c) + 48^*M_t/(\pi^*D_t^{2*}S_c^*E_c)$
$= 173{,}831.6/(\pi^*114.625^*13{,}419.88^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}13{,}419.88^*1)$
= 0.0378 in

Loading due to weight, test & new

Windward side (tensile)

Required thickness, tensile stress at base:
$t = -W/(\pi^*D^*S_t^*E) + 48^*M/(\pi^*D^{2*}S_t^*E)$
$= -445{,}791.0/(\pi^*114.625^*13{,}419.88^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}13{,}419.88^*1)$
= 0.0904 in

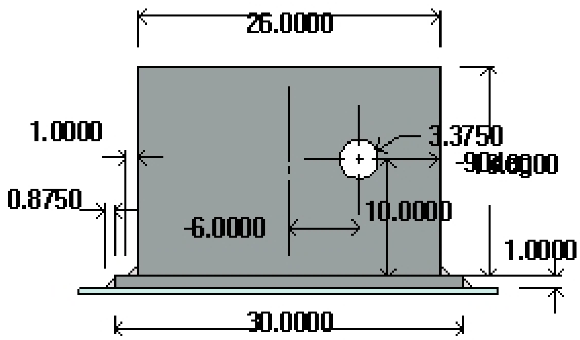
Required thickness, tensile stress at the top:
$t = -W_t/(\pi^*D_t^*S_t^*E) + 48^*M_t/(\pi^*D_t^{2*}S_t^*E)$
$= -440{,}077.1/(\pi^*114.625^*13{,}419.88^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}13{,}419.88^*1)$
= 0.0892 in

Leeward side (compressive)

Required thickness, compressive stress at base:
$t = W/(\pi^*D^*S_c^*E_c) + 48^*M/(\pi^*D^{2*}S_c^*E_c)$
$= 445{,}791.0/(\pi^*114.625^*13{,}419.88^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}13{,}419.88^*1)$
= 0.0941 in

Required thickness, compressive stress at the top:
$t = W_t/(\pi^*D_t^*S_c^*E_c) + 48^*M_t/(\pi^*D_t^{2*}S_c^*E_c)$
$= 440{,}077.1/(\pi^*114.625^*13{,}419.88^*1) + 48^*21{,}641.82/(\pi^*114.625^{2*}13{,}419.88^*1)$
= 0.0929 in

Tailing Lug



Geometry Inputs

Attached To	Support Skirt
Material	A36
Orientation	Longitudinal
Distance from datum	-97.9964"
Angular Position	216.00°
Length of Lug, L	26.0000"
Height of Lug, B	18.0000"
Thickness of Lug, t	2.5401"
Hole Diameter, d	3.3750"
Load eccentricity, a_1	-6.0000"
Distance from Load to shell or pad, a_2	10.0000"
Weld size, t_w	1.0000"
Width of Pad, B_p	6.0000"
Length of Pad, L_p	30.0000"
Pad Thickness, t_p	1.0000"
Pad weld size, t_{wp}	0.8750"
Load angle normal to vessel, β	-90.0000 °
Load angle from vertical, ϕ	-180.0000 °

Intermediate Values

Load factor	2.0000
Vessel Weight (new, incl. Load Factor), W	364007 lb
Lug Weight (new), W_{lug}	397 lb
Distance from center of gravity to top lug, l_1	374.4596"

Distance from center of gravity to tail lug, l_2	420.5393"
Distance from vessel center line to tail lug, l_3	68.6250"
Allowable stress, tensile, σ_t	20000 psi
Allowable stress, shear, σ_s	14000 psi
Allowable stress, bearing, σ_p	20000 psi
Allowable stress, bending, σ_b	22000 psi
Allowable stress, weld shear, $\tau_{allowable}$	14000 psi

Summary Values

Required Lift pin diameter, d_{reqd}	2.7922"
Required Lug thickness, t_{reqd}	2.5401"

Lug Stress Ratio, σ_{ratio}	0.37
Weld Shear Stress Ratio, τ_{ratio}	0.85
Lug design	Acceptable
Base ring requires a stiffener beam. $Abeam_s$ = 6.9772 in²	

Lift Forces

Lift force on lugs during rotational lift (0° ≤ α ≤ 90°):

$N*F_{top} = W*(l_2*\cos(\alpha) + l_3*\sin(\alpha)) / (l_1*\cos(\alpha) + l_2*\cos(\alpha) + l_3*\sin(\alpha))$

$F_{tail} = W - (N * F)$

α [°]	F_{top}[lbf]	F_{tail}[lbf]
0	96276	171454
15	98214	167578
30	100346	163315
45	103088	157830
60	107426	149154
75	117165	129676
90	182004	0
36[1]	101336	161335
38[2]	101693	160621
38[3]	101693	160621
[1]Lift angle at maximum lug stress.		
[2]Lift angle at maximum weld stress.		
[3]Lift angle at maximum pad weld stress.		

Lug Pin Diameter - Shear stress

d_{reqd} = $(2 * F_r / (\pi * \sigma_s))^{0.5}$
= $(2 * 171454.2344 / (\pi * 14000.0))^{0.5}$ = 2.7922"

d_{reqd} / d = 2.7922 / 3.3750 = 0.83 Acceptable

σ = F_r / A
= $F_r / (2*(0.25*\pi*d^2))$
= $171454.2344 / (2 * (0.25 * \pi * 3.3750^2))$ = 9582.5430 psi

σ / σ_s = 9582.54 / 14000.00 = 0.68 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_r / ((L - d) * \sigma_t)$
= 171454.2344 / ((26.0000 - 3.3750)*20000.0) = 0.3789"

t_{reqd} / t = 0.3789 / 2.5401 = 0.15 Acceptable

σ = F_r / A
= $F_r / ((L - d) * t)$
= 171454.2344 / ((26.0000 - 3.3750)*2.5401) = 2983.4255 psi

σ / σ_t = 2983.43 / 20000.00 = 0.15 Acceptable

Lug Thickness - Bearing stress

t_{reqd} = $F_v / (d * \sigma_p)$
= 171454.2344 / (3.3750 * 20000.0)
= 2.5401"

t_{reqd} / t = 2.5401 / 2.5401 = 1.00 Acceptable

σ = $F_v / A_{bearing}$
= $F_v / (d * (t))$
= 171454.2344 / (3.3750 *(2.5401)) = 20000.0000 psi

σ / σ_p = 20000.00 / 20000.00 = 1.00 Acceptable

Lug Plate Stress

Lug stress tensile + bending during lift:

σ_{ratio} = $F_{ten} / (A_{ten}*\sigma_t) + M_{bend} / (Z_{bend}*\sigma_b) \leq 1.0$
= $(F_{tail}(\alpha) * \cos(\alpha)) / (t * L * \sigma_t) + (6 * abs(F_{tail}(\alpha) * \sin(\alpha) * Hght - F_{tail}(\alpha) * \cos(\alpha) * a_1)) / (t * L^2 * \sigma_b) \leq 1.0$
=

161335*cos(36.0) / (2.5401*26.0000*20000.0) + 6*abs(161335*sin(36.0)*10.0000 - 161335*cos(36.0)*-6.0000) / (2.5401*26.0000²*22000.0)

= 0.37 Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Maximum shear stress occurs at lift angle 38.00°; lift force = 160620.9219 lbf

A_{weld} = (0.707)*h*2*(L + t)

= (0.707)*1.0000*2*(26.0000 + 2.5401) = 40.3556 in²

τ_t = F_{tail} * cos(α) / A_{weld}

= 160621 * cos(38.0) / 40.3556 = 3136.3887 psi

τ_b = M * c / I

= 3 * (F_{tail} * sin(α) * Hght - F_{tail} * cos(α) * a_1) / (0.707 * h * L * (3*t + L))

= 3 * abs(160621 * sin(38.0) * 10.0000 - 160621 * cos(38.0) * -6.0000) / (618.0063) = 8486.8418 psi

τ_s = F_{tail} * sin(α) / A_{weld}

= 160621 * sin(38.0) / 40.3556 = 2450.4160 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable} \leq 1.0$

= sqr ($(3136.3887 + 8486.8418)^2 + (2450.4160)^2$) / 14000.00 = 0.85 Acceptable

Pad Weld Stress, tensile, bending and shear during lift:

Maximum shear stress occurs at lift angle 38.00°; lift force = 160620.9219 lbf

A_{weld} = (0.707)*h_p*2*(L_p + B_p)

= (0.707)*0.8750*2*(30.0000 + 6.0000) = 44.5410 in²

τ_t = F_{tail} * cos(α) / A_{weld}

= 160621 * cos(38.0) / 44.5410 = 2841.6738 psi

τ_b = M * c / I

= 3 * (F_{tail} * sin(α) * Hght - F_{tail} * cos(α) * a_1) / (0.707 * h * L_p * (3*W_p + L_p))

= 3 * abs(160621 * sin(38.0) * 11.0000 - 160621 * cos(38.0) * -6.0000) / (890.8200) = 6220.7695 psi

τ_s = F_{tail} * sin(α) / A_{weld}

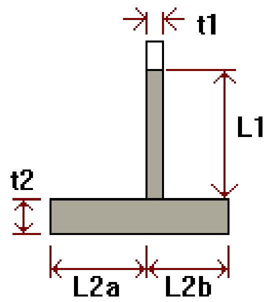
= 160621 * sin(38.0) / 44.5410 = 2220.1594 psi

τ_{ratio} = sqr($(\tau_t + \tau_b)^2 + \tau_s^2$) / $\tau_{allowable} \leq 1.0$

= sqr ($(2841.6738 + 6220.7695)^2 + (2220.1594)^2$) / 14000.00 = 0.67 Acceptable

Base Ring Sectional Properties

t_1	0.6250"	L_1	4.6683"
t_2	1.5000"	L_{2a}	6.3125"
		L_{2b}	5.1875"
Base Ring Geometry			



Effective skirt length:

$R_m = (D_i + t_1)*0.5$
$= (114.0000 + 0.6250) * 0.5 = 57.3125"$
$L_1 = 0.78*sqr(R_m * t_1)$
$= 0.78*sqr(57.3125 * 0.6250) = 4.6683"$

Section Area:

$A_1 = t_1 * L_1 = 0.6250 * 4.6683 = 2.9177\ in^2$
$A_2 = t_2 * L_2 = 1.5000 * (6.3125 + 5.1875) = 17.2500\ in^2$
$A_{total} = A_1 + A_2 = 2.9177 + 17.2500 = 20.1677\ in^2$

Centroid, C:

$h_1 = L_{2a} + 0.5*t_1 = 6.3125 + 0.5*0.6250 = 6.6250"$
$h_2 = 0.5*(L_{2a} + L_{2b}) = 0.5*(6.3125 + 5.1875) = 5.7500"$
$C = ((A_1*h_1) + (A_2*h_2)) / A_{total}$
$= ((2.9177*6.6250) + (17.2500*5.7500)) / 20.1677 = 5.8766"$

Moment of Inertia, I:

$I_1 = (L_1 * t_1^3)/12 + A_1*(h_1 - C)^2 = (4.6683 * 0.6250^3)/12 + 2.9177*(6.6250 - 5.8766)^2 = 1.7in^4$
$I_2 = t_2 * (L_{2a} + L_{2b})^3/12 + A_2 * (h_2 - C)^2 = 1.5000 * (6.3125 + 5.1875)^3/12 + 17.2500 * (5.7500 - 5.8766)^2 = 190.4in^4$
$I_{ring} = I_1 + I_2 = 1.7292 + 190.3858 = 192.1in^4$

Section Modulus, Z:

$Z = I_{ring} / C = 192.1150 / 5.8766 = 32.692in^3$

Base Ring Loads without stiffener beam

Base Ring Load

$W_r = W = F_{tail} = 171454.2344$ lbf

Base Ring Loading

Reference: Roark's Formulas for stress & Strain - 6th Edition. Table 17, case 20

For thin ring sections $k_1 = k_2 = 1.0$

Change in vertical diameter, $D_V = (-W) * R^3 * (\pi * k_1 / 8 - k_2^2 / \pi) / (E * I)$
Internal Moment, $M_A = W * R * (k_2 - 0.5) / (2 * \pi)$
Internal Force, $N_A = 0.75 * W / \pi$

Internal Shear Force, V_A = 0

Ring loading, W_r = 171454.2344 lbf

D_{Vr} = -171454.2344 * 58.0609^3 * (π * 1 / 8 - 1^2 / π) / (29410588.0000 * 192.1150) = -0.4418"

M_{Ar} = 171454.2344 * 58.0609 * (1.0 - 0.5) / (2 * π) = 792176.9375 lbf-in

N_{Ar} = 0.75 * 171454.2344 / π = 40931.6836 lbf

Load Equations

LT_M = W * R * (1 - cos(x) - 0.5 * x * sin(x)) / π

LT_N = -W * (x * sin(x)) / (2 * π)

LT_V = W * (sin(x) - x * cos(x)) / (2 * π)

M = M_A - N_A * R * (1 - cos(x)) + V_A * R * sin(x) + LT_M

N = N_A * cos(x) + V_A * sin(x) + LT_N

V = -N_A * sin(x) + V_A * cos(x) + LT_V

Load Table for Load W_r

x [°]	LT_M [in-lbf]	LT_N [lbf]	LT_V [lbf]	M [in-lbf]	N [lbf]	V [lbf]
0.00	0.00	0.00	0.00	792176.94	40931.68	0.00
30.00	9743.50	-7143.93	1270.25	483525.63	28303.95	-19195.59
60.00	147503.73	-24747.29	9344.07	-248584.80	-4281.45	-26103.81
90.00	680010.44	-42863.56	27287.79	-904343.56	-42863.56	-13643.89
120.00	1879361.50	-49494.57	52207.63	-893258.00	-69960.42	16759.75
150.00	3838974.75	-35719.64	75512.11	196484.50	-71167.52	55046.27
180.00	6337416.00	0.01	85727.12	2376531.00	-40931.68	85727.12

Maximum Stress in Base Ring Section

Allowable Base Ring Stresses

F_a = 0.6 * F_y = 21600.0000 psi

F_b = 0.66 * F_y = 23760.0000 psi

F_s = 0.4 * F_y = 14400.0000 psi

Base Ring Stresses

Maximum combined stress occurs at 0.00 degrees

f_a = N / A = -40931.6758 / 20.1677 = -2029.5669 psi

f_b = M / Z = 2376531.0000 / 32.6916 = 72695.4688 psi

f_a / F_a + f_b / F_b = 3.15 **Unacceptable**

Maximum shear stress occurs at 0.00 degrees

f_s = V / A = 85727.1172 / 20.1677 = 4250.7158 psi

f_s / F_s = 0.30 Acceptable

Base Ring Loads - with stiffener beam

Stiffener Beam Load

W_s = $(0.0372 * F_{tail} * R^2) / ((I_{ring} / Abeam_s) + 0.0744 * R^2)$
= $(0.0372 * 171454.2344 * 58.0609^2) / ((192.1150 / 6.9772) + 0.0744 * 58.0609^2)$
= 77246.6875 lbf

Stiffener Beam - tensile stress

S_{beam} = $W_s / Abeam_s$
= 77246.6875 / 6.9772
= 11071.2627 psi

S_{beam} / F_y = 11071.2627 / 36000.0000
= 0.31

Base Ring Load

W_r = $W - W_s$ = 171454.2344 - 77246.6875 = 94207.5469 lbf

Base Ring Loading

Stiffener loading, W_s	= 77246.6875 lbf	
D_{Vs}	= $-77246.6875 * 58.0609^3 * (\pi * 1 / 8 - 1^2 / \pi) / (29410588.0000 * 192.1150)$	= -0.1991"
M_{As}	= $77246.6875 * 58.0609 * (1.0 - 0.5) / (2 * \pi)$	= 356906.0000 lbf-in
N_{As}	= $0.75 * 77246.6875 / \pi$	= 18441.2871 lbf
Ring loading, W_r	= 94207.5469 lbf	
D_{Vr}	= $-94207.5469 * 58.0609^3 * (\pi * 1 / 8 - 1^2 / \pi) / (29410588.0000 * 192.1150)$	= -0.2428"
M_{Ar}	= $94207.5469 * 58.0609 * (1.0 - 0.5) / (2 * \pi)$	= 435270.9375 lbf-in
N_{Ar}	= $0.75 * 94207.5469 / \pi$	= 22490.3945 lbf

Load Table for Load W_s

x [°]	LT_M [in-lbf]	LT_N [lbf]	LT_V [lbf]	M [in-lbf]	N [lbf]	V [lbf]
0.00	0.00	0.00	0.00	356906.00	18441.29	0.00
30.00	4389.82	-3218.61	572.30	217846.80	12752.01	-8648.35
60.00	66456.07	-11149.60	4209.86	-111996.91	-1928.96	-11760.76
90.00	306370.69	-19311.67	12294.19	-407441.25	-19311.67	-6147.09
120.00	846724.25	-22299.20	23521.53	-402446.75	-31519.84	7550.91
150.00	1729604.88	-16093.06	34021.09	88523.88	-32063.68	24800.45
180.00	2855248.25	0.00	38623.34	1070718.38	-18441.28	38623.34

Load Table for Load W_r

x [°]	LT_M [in-lbf]	LT_N [lbf]	LT_V [lbf]	M [in-lbf]	N [lbf]	V [lbf]
0.00	0.00	0.00	0.00	435270.94	22490.39	0.00

30.00	5353.68	-3925.31	697.95	265678.84	15551.94	-10547.24
60.00	81047.66	-13597.69	5134.21	-136587.81	-2352.49	-14343.05
90.00	373639.72	-23551.89	14993.60	-496902.16	-23551.89	-7496.80
120.00	1032637.31	-27195.38	28686.10	-490811.06	-38440.57	9208.84
150.00	2109369.75	-19626.57	41491.02	107960.75	-39103.83	30245.82
180.00	3482167.75	0.00	47103.77	1305813.00	-22490.39	47103.78

Load Table for Combined Loads W_s and W_r

x [°]	M [in-lbf]	N [lbf]	V [lbf]
0.00	1662719.00	-4049.10	47103.78
30.00	325807.56	-26351.82	21597.47
60.00	-602808.00	-40369.53	-2551.92
90.00	-904343.38	-42863.56	-13643.89
120.00	-539034.56	-33872.34	-6792.14
150.00	354202.72	-16511.75	14253.21
180.00	1505989.25	4049.11	38623.34

Maximum Stress in Base Ring Section

Base Ring Stresses

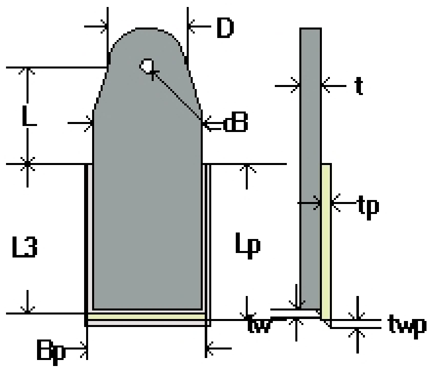
Maximum combined stress occurs at 0.00 degrees

f_a	=	N / A	=	-4049.1033 / 20.1677	=	-200.7718 psi
f_b	=	M / Z	=	1662719.0000 / 32.6916	=	50860.7461 psi
$f_a / F_a + f_b / F_b$	=	2.15			**Unacceptable**	

Maximum shear stress occurs at 0.00 degrees

f_s	=	V / A	=	47103.7773 / 20.1677	=	2335.6060 psi
f_s / F_s	=	0.16			Acceptable	

Top Lifting Lug



Geometry Inputs

Attached To	Cylinder #1
Material	SA-516-70
Orientation	Longitudinal
Distance from datum	642.0025"
Angular Position	126.00°
Length of Lug, L	24.0000"
Width of Lug, B	28.0000"
Thickness of Lug, t	2.6963"
Hole Diameter, d	3.3750"
Lug Diameter at pin, D	20.0000"
Weld size, t_w	1.0000"
Collar Thickness, t_1	0.0000"
Collar Diameter	0.0000"
Width of Pad, B_p	30.0000"
Length of Pad, L_p	40.0000"
Pad Thickness, t_p	1.2500"
Pad weld size, t_{wp}	1.0000"
Weld Length, L_3	38.0000"
Load angle from vertical, ϕ	0.0000 °

Intermediate Values

Load factor	2.0000
Vessel Weight (new, incl. Load Factor), W	364007 lb
Lug Weight (new), W_{lug}	

	1916 lb (Qty=2)
Distance from center of gravity to top lug, l_1	374.4596"
Distance from center of gravity to tail lug, l_2	420.5393"
Distance from vessel center line to tail lug, l_3	68.6250"
Allowable stress, tensile, σ_t	20000 psi
Allowable stress, shear, σ_s	14000 psi
Allowable stress, bearing, σ_p	20000 psi
Allowable stress, bending, σ_b	20000 psi
Allowable stress, weld shear, $\tau_{allowable}$	14000 psi

Summary Values

Required Lift pin diameter, d_{reqd}	2.8768"
Required Lug thickness, t_{reqd}	2.6963"
Required Lug collar thickness, t_{1reqd}	0.0000"
Lug Stress Ratio, σ_{ratio}	0.34
Weld Shear Stress Ratio, τ_{ratio}	0.47
Lug design	Acceptable
Local stresses (WRC 107)	Acceptable

COMPRESS assumes a spreader beam is used to prevent weak axis bending of the top lugs. No consideration is given for any bracing plate from the lug to the vessel.

Lift Forces

Lift force on lugs during rotational lift ($0° \le \alpha \le 90°$):

$N*F_{top} = W*(l_2*\cos(\alpha) + l_3*\sin(\alpha)) / (l_1*\cos(\alpha) + l_2*\cos(\alpha) + l_3*\sin(\alpha))$

$F_{tail} = W - (N * F)$

α [°]	F_{top}[lbf]	F_{tail}[lbf]
0	96276	171454
15	98214	167578
30	100346	163315
45	103088	157830
60	107426	149154
75	117165	129676
90	182004	0
15[1]	98214	167578
12[2]	97821	168365
12[3]	97821	168365
[1]Lift angle at maximum lug stress.		
[2]Lift angle at maximum weld stress.		

[3]Lift angle at maximum pad weld stress.	
Shell angle at lift lug	0.00°

Lug Pin Diameter - Shear stress

d_{reqd} = $(2 * F_v / (\pi * \sigma_s))^{0.5}$
= $(2 * 182003.5000 / (\pi * 14000.0))^{0.5}$ = 2.8768"

d_{reqd} / d = 2.8768 / 3.3750 = 0.85 Acceptable

σ = F_v / A
= $F_v / (2*(0.25*\pi*d^2))$
= $182003.5000 / (2 * (0.25 * \pi * 3.3750^2))$ = 10172.1396 psi

σ / σ_s = 10172.14 / 14000.00 = 0.73 Acceptable

Lug Thickness - Tensile stress

t_{reqd} = $F_v / ((D - d) * \sigma_t)$
= 182003.5000 / ((20.0000 - 3.3750)*20000.0) = 0.5474"

t_{reqd} / t = 0.5474 / 2.6963 = 0.20 Acceptable

σ = F_v / A
= $F_v / ((D - d) * t)$
= 182003.5000 / ((20.0000 - 3.3750)*2.6963) = 4060.1504 psi

σ / σ_t = 4060.15 / 20000.00 = 0.20 Acceptable

Lug Thickness - Bearing stress

t_{reqd} = $F_v / (d * \sigma_p)$
= 182003.5000 / (3.3750 * 20000.0)
= 2.6963"

t_{reqd} / t = 2.6963 / 2.6963 = 1.00 Acceptable

σ = $F_v / A_{bearing}$
= $F_v / (d * (t))$
= 182003.5000 / (3.3750 *(2.6963)) = 20000.0000 psi

σ / σ_p = 20000.00 / 20000.00 = 1.00 Acceptable

Lug Plate Stress

Lug stress, tensile + bending, during rotational lift:

σ_{ratio} = $F_{ten} / (A_{ten}*\sigma_t) + M_{bend} / (Z_{bend}*\sigma_b) \leq 1.0$

= $(F_{top}(\alpha) * \sin(\alpha)) / (t * B * \sigma_t) + (6*F_{top}(\alpha) * L * \cos(\alpha)) / (t * B^2 * \sigma_b) \leq 1.0$

= 98214 * sin(15.0) / (2.6963*28.0000*20000.0) + 6*98214*24.0000*cos(15.0) / (2.6963*28.0000^2*20000)

= 0.34 Acceptable

Weld Stress

Weld stress, direct and torsional shear, during rotational lift:

Direct shear:

Maximum weld shear stress occurs at lift angle 12.00°; lift force = 97820.9531 lbf

A_{weld} = $(0.707)*h*(2*L_3 + B)$

= (0.707)*1.0000*(2*38.0000 + 28.0000) = 73.5280 in²

τ_1 = $(F_{top}(\alpha) * / A_{weld})$

= 97821 / 73.5280 = 1330 psi

torsional shear:

x = $L_3^2 / (2*L_3 + B)$

= 38.0000^2 / (2*38.0000 + 28.0000) = 13.8846"

r = $sqr((0.5*B)^2 + (L_3-x)^2)$

= sqr((0.5*28.0000)^2 + (38.0000 - 13.8846)^2) = 27.8846"

J = $0.707*h*((8*L_3^3 + 6*L_3*B^2 + B^3) / 12 - L_3^4 / (2*L_3 + B))$

= 0.707*1.0000* ((8*38.0000^3 + 6*38.0000*28.0000^2 + 28.0000^3) / 12 - 38.0000^4 / (2*38.0000 + 28.0000)) = 23512.90 in^4

τ_2 = M * r / J

= $[F(\alpha) * \cos(\alpha) * (L + L_3 - x)] * r / J$

= (97821.0 * cos(12.0) * 48.1154) * 27.8846 / 23512.9004 = 5460 psi

τ = $sqr((\tau_{1x} + \tau_{2x})^2 + (\tau_{1y} + \tau_{2y})^2)$ = 6613 psi

$\tau / \tau_{allowable}$ = 6612.90 / 14000.00 = 0.47 ≤ 1.0 Acceptable

Pad Weld Stress

Direct shear:

Maximum weld shear stress occurs at lift angle 12.00°; lift force = 97820.9531 lbf

A_{weld} = $(0.707)*h_p*(2*L_p + B_p)$

= (0.707)*1.0000*(2*40.0000 + 30.0000) = 77.7700 in²

τ_1 = $(F_{top}(\alpha) * / A_{weld})$

$= 97821 / 77.7700$ = 1258 psi

torsional shear:

$x_p = L_p^2 / (2*L_p + B_p)$

$= 40.0000^2 / (2*40.0000 + 30.0000)$ = 14.5455"

$r_p = sqr((0.5*B_p)^2 + (L_p-x_p)^2)$

$= sqr((0.5*30.0000)^2 + (40.0000 - 14.5455)^2)$ = 29.5455"

$J_p = 0.707*h_p*((8*L_p^3 + 6*L_p*B_p^2 + B_p^3) / 12 - L_p^4 / (2*L_p + B_p))$

$= 0.707*1.0000* ((8*40.0000^3 + 6*40.0000*30.0000^2 + 30.0000^3) / 12 - 40.0000^4 / (2*40.0000 + 30.0000))$ = 28028.27 in^4

$\tau_2 = M * r_p / J_p$

$= [F(\alpha) * \cos(\alpha) * (L + L_p - x_p)] * r_p / J_p$

$= (97821.0 * \cos(12.0) * 49.4545) * 29.5455 / 28028.2656$ = 4988 psi

$\tau = sqr((\tau_{1x} + \tau_{2x})^2 + (\tau_{1y} + \tau_{2y})^2)$ = 6073 psi

$\tau / \tau_{allowable} = 6072.98 / 14000.00 = 0.43 \leq 1.0$ Acceptable

WRC 107 Analysis

Geometry

Height(radial):	2.6963"	Pad Thickness:	1.2500"
Width (circumferential):	28.0000"	Pad Width:	30.0000"
Length	38.0000"	Pad Length:	40.0000"
Fillet Weld Size:	1.0000"	Pad Weld Size:	1.0000"
Location Angle:	126.00&deg		

Applied Loads

Radial load:	P_r =	0.00	lb_f
Circumferential moment:	M_c =	127,898.22	lb_f-in
Circumferential shear:	V_c =	94,867.73	lb_f
Longitudinal moment:	M_L =	34,270.23	lb_f-in
Longitudinal shear:	V_L =	25,419.73	lb_f
Torsion moment:	M_t =	4,079,312.50	lb_f-in
Internal pressure:	P =	0.000	psi
Mean shell radius:	R_m =	57.7500	in
Shell yield stress:	S_y =	38,000.00	psi

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

R_m/t =23.1

C_1 = 15.0000, C_2 = 20.0000 in

Local circumferential pressure stress = $P*R_i/t$ = 0 psi

Local longitudinal pressure stress = $P*R_i/2t$ = 0 psi

Maximum combined stress (P_L+P_b+Q) = 2,624.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = -95.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the lug edge per WRC Bulletin 107

Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.5122	0.3479	0	0	0	0	0	0	0	0
4C*	2.8146	0.3199	0	0	0	0	0	0	0	0
1C	0.0622	0.2879	0	0	0	0	0	0	0	0
2C-1	0.0287	0.2879	0	0	0	0	0	0	0	0
3A*	1.0143	0.2859	0	0	0	0	-48	-48	48	48
1A	0.0757	0.3189	0	0	0	0	-505	505	505	-505
3B*	2.1067	0.3147	-24	-24	24	24	0	0	0	0
1B-1	0.0213	0.3095	-39	39	39	-39	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			-63	15	63	-15	-553	457	553	-457
Primary membrane circumferential stress*			-24	-24	24	24	-48	-48	48	48
3C*	1.6717	0.3199	0	0	0	0	0	0	0	0
4C*	2.6701	0.3479	0	0	0	0	0	0	0	0
1C-1	0.0511	0.3249	0	0	0	0	0	0	0	0
2C	0.0307	0.3249	0	0	0	0	0	0	0	0
4A*	1.9469	0.2859	0	0	0	0	-95	-95	95	95
2A	0.0342	0.3590	0	0	0	0	-203	203	203	-203
4B*	0.9665	0.3147	-14	-14	14	14	0	0	0	0
2B-1	0.0347	0.3431	-58	58	58	-58	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			-72	44	72	-44	-298	108	298	-108
Primary membrane longitudinal stress*			-14	-14	14	14	-95	-95	95	95
Shear from M_t			680	680	680	680	907	907	907	907
Circ shear from V_c			632	632	-632	-632	0	0	0	0

Long shear from V_L	0	0	0	0	-127	-127	127	127
Total Shear stress	1,312	1,312	48	48	780	780	1,034	1,034
Combined stress (P_L+P_b+Q)	2,624	2,624	116	100	1,581	1,599	2,084	2,097

Note: * denotes primary stress.

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

R_m/t =46.2

C_1 = 16.0000, C_2 = 21.0000 in

Local circumferential pressure stress = $P*R_i/t$ = 0 psi

Local longitudinal pressure stress = $P*R_i/2t$ = 0 psi

Maximum combined stress (P_L+P_b+Q) = 4,762.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-60,000.00 psi

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

Maximum local primary membrane stress (P_L) = -409.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-30,000.00 psi

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

Stresses at the pad edge per WRC Bulletin 107										
Figure	**value**	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.7305	0.3658	0	0	0	0	0	0	0	0
4C*	4.4522	0.3376	0	0	0	0	0	0	0	0
1C	0.0618	0.3053	0	0	0	0	0	0	0	0
2C-1	0.0144	0.3053	0	0	0	0	0	0	0	0
3A*	1.5543	0.3033	0	0	0	0	-134	-134	134	134
1A	0.0615	0.3346	0	0	0	0	-1,563	1,563	1,563	-1,563
3B*	2.8766	0.3321	-62	-62	62	62	0	0	0	0
1B-1	0.0128	0.3243	-90	90	90	-90	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			-152	28	152	-28	-1,697	1,429	1,697	-1,429
Primary membrane circumferential stress*			-62	-62	62	62	-134	-134	134	134
3C*	1.9604	0.3376	0	0	0	0	0	0	0	0
4C*	4.1217	0.3658	0	0	0	0	0	0	0	0
1C-1	0.0283	0.3426	0	0	0	0	0	0	0	0
2C	0.0300	0.3426	0	0	0	0	0	0	0	0
4A*	4.4973	0.3033	0	0	0	0	-409	-409	409	409
2A	0.0249	0.3717	0	0	0	0	-570	570	570	-570
4B*	1.5727	0.3321	-41	-41	41	41	0	0	0	0
2B-1	0.0211	0.3590	-134	134	134	-134	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			-175	93	175	-93	-979	161	979	-161
Primary membrane longitudinal stress*			-41	-41	41	41	-409	-409	409	409
Shear from M_t			1,195	1,195	1,195	1,195	1,569	1,569	1,569	1,569

Circ shear from V_c	1,186	1,186	-1,186	-1,186	0	0	0	0
Long shear from V_L	0	0	0	0	-242	-242	242	242
Total Shear stress	2,381	2,381	9	9	1,327	1,327	1,811	1,811
Combined stress (P_L+P_b+Q)	4,762	4,762	178	-94	2,749	2,941	3,692	3,838

Note: * denotes primary stress.

Trays #1

Number of trays in group:	19
Distance from bottom tray to datum:	184.00"
Space between trays:	24.00"
Tray weight:	12.00lb/ft^2
Tray diameter	114.00"
Support weight:	500.00 lb each
Operating liquid depth on tray:	0.00"
Tray liquid specific gravity:	1.00
Estimated tray weight, Empty:	1350.59 lb each
Estimated tray weight, Operating	1350.59 lb each
Included in vessel lift weight:	Yes
Present when vessel is empty:	Yes
Present during hydrotest:	Yes
Number of Passes:	1

Vertical Load #1

Load Orientation:	Vertical Load
Elevation above datum:	300.00"
Direction angle:	0.00 degrees
Distance from center of vessel:	0.00"
Magnitude of force:	15000.00 lb

Present when operating:	Yes
Included in vessel lift weight:	Yes
Present when vessel is empty:	Yes
Present during hydrotest:	Yes