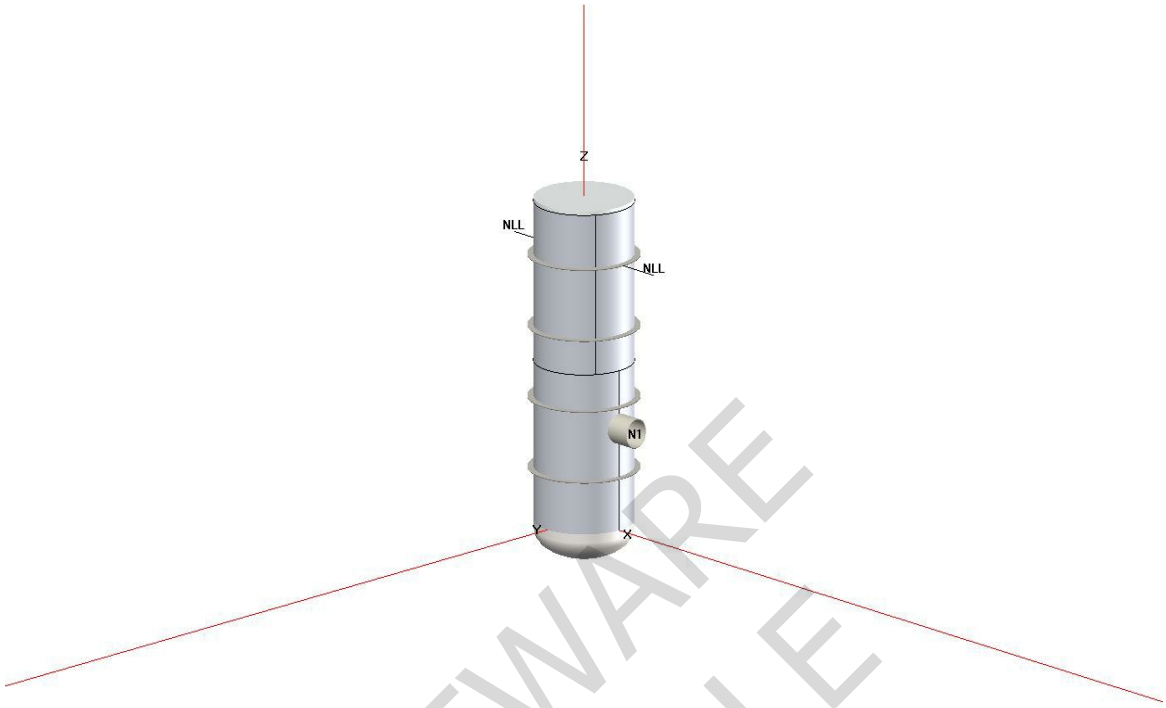
Demo Example

Your Company Address



COMPRESS Pressure Vessel Design Calculations

Vessel No: Demo Vessel
Designer: CD
Date: Wednesday, January 05, 2022

Table of Contents

Deficiencies Summary

Deficiencies for Nozzle #1 (N1)
Nozzle is located on top of the parent component's longitudinal seam. Move the longitudinal seam or activate the option switch "Through a Category A Joint" in the nozzle dialog.

Warnings Summary

Warnings for Vessel
Supports have not been added to this vessel; combined loads are not being considered. (warning)
Changes to steelmaking practices have increased the risk of brittle fracture at temperatures higher than the ASME impact test exemption temperatures. It is highly recommended that the following supplemental requirements be applied for SA-105, SA-106 B, SA-53 seamless, and SA-234: material composition should have a minimum Mn:C ratio of 5, and SA-105 flanges should require a grain size of 7 or finer. (warning)

Warnings for Welded Cover #1
Internal design pressure varies across this chamber. (warning)
Check the following component(s): (warning)
Cylinder #2 (warning)

Nozzle Schedule

Specifications									
Nozzle mark	Identifier	Size	Materials		Impact Tested	Normalized	Fine Grain	Flange	Blind
N1	Nozzle #1	6.625 OD x 0.28	Nozzle	SA-105	No	No	No	N/A	No

Nozzle Summary

Dimensions												
Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
N1	6.625	0.28	0.116	Yes	Yes	0.1875	0.116		N/A	N/A	0	100.0

Definitions	
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

Pressure Summary

Component Summary									
Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T_e external (°F)	MDMT (°F)	MDMT Exemption	Impact Tested
Welded Cover #1	100	250	132.92	132.92	80.56	250	-20	Note 1	No
Cylinder #2	100	250	308.73	309.6	139.63	250	-55	Note 2	No
Cylinder #1	100	250	307.43	309.6	139.63	250	-55	Note 3	No
Straight Flange on Ellipsoidal Head #2	150	250	307.36	309.6	139.63	250	-55	Note 5	No
Ellipsoidal Head #2	150	250	150.1	152.55	32.5	250	-55	Note 4	No
Rings #1 (Ring #3 in Group)	N/A	N/A	N/A	N/A	139.63	250	-55	Note 6	No
Rings #1 (Ring #4 in Group)	N/A	N/A	N/A	N/A	139.63	250	-55	Note 6	No
Rings #1 (Ring #2 in Group)	N/A	N/A	N/A	N/A	139.63	250	-55	Note 7	No
Rings #1	N/A	N/A	N/A	N/A	139.63	250	-55	Note 7	No
Nozzle #1 (N1)	100	250	190.81	192.25	104.69	250	-55	Note 8	No

Chamber Summary	
Design MDMT	-20 °F
Rated MDMT	-20 °F @ 132.92 psi
MAWP hot & corroded	132.92 psi @ 250 °F
MAP cold & new	132.92 psi @ 70 °F
MAEP	32.5 psi @ 250 °F

Notes for MDMT Rating		
Note #	Exemption	Details
1.	Head is impact test exempt per UG-20(f)	UCS-66 governing thickness = 0.2188 in
2.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 77.4°F, (coincident ratio = 0.4298) Rated MDMT of -97.4°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.1875 in
3.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 75.7°F, (coincident ratio = 0.434) Rated MDMT of -95.7°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.1875 in
4.	Straight Flange governs MDMT	
5.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 75.6°F, (coincident ratio = 0.4343) Rated MDMT of -95.6°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.1875 in
6.	Ring impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 77.4°F, (coincident ratio = 0.4298) Rated MDMT of -97.4°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.25 in
7.	Ring impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 75.7°F, (coincident ratio = 0.434) Rated MDMT of -95.7°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.25 in
8.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 76.6°F, (coincident ratio = 0.4317) Rated MDMT of -96.6°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.1875 in.

Revision History

Revisions			
No.	Date	Operator	Notes
0	1/ 5/2022	christian.dionisio	New vessel created ASME Section VIII Division 1 [COMPRESS 2022 Build 8200]

Settings Summary

COMPRESS 2022 Build 8200	
ASME Section VIII Division 1, 2021 Edition	
Units	U.S. Customary
Datum Line Location	0.00" from bottom seam
Vessel Design Mode	Design Mode
Minimum thickness	0.0625" per UG-16(b)
Design for cold shut down only	No
Design for lethal service (full radiography required)	No
Design nozzles for	Design P only
Corrosion weight loss	100% of theoretical loss
UG-23 Stress Increase	1.00
Skirt/legs stress increase	1.0
Minimum nozzle projection	6"
Juncture calculations for α > 30 only	Yes
Preheat P-No 1 Materials > 1.25" and <= 1.50" thick	No
UG-37(a) shell tr calculation considers longitudinal stress	No
Cylindrical shells made from pipe are entered as minimum thickness	No
Nozzles made from pipe are entered as minimum thickness	No
ASME B16.9 fittings are entered as minimum thickness	No
Butt welds	Tapered per Figure UCS-66.3(a)
Disallow Appendix 1-5, 1-8 calculations under 15 psi	No
Hydro/Pneumatic Test	
Shop Hydrotest Pressure	1.3 times vessel MAWP [UG-99(b)]
Test liquid specific gravity	1.00
Maximum stress during test	90% of yield
Required Marking - UG-116	
UG-116(e) Radiography	RT1
UG-116(f) Postweld heat treatment	None
Code Cases\Interpretations	
Use Appendix 46	No
Use UG-44(b)	No
Apply interpretation VIII-1-83-66	Yes
Apply interpretation VIII-1-86-175	Yes
Apply interpretation VIII-1-01-37	Yes
Apply interpretation VIII-1-01-150	Yes
Apply interpretation VIII-1-07-50	Yes
Apply interpretation VIII-1-16-85	No
No UCS-66.1 MDMT reduction	No
No UCS-68(c) MDMT reduction	No
Disallow UG-20(f) exemptions	No
UG-22 Loadings	
UG-22(a) Internal or External Design Pressure	Yes
UG-22(b) Weight of the vessel and normal contents under operating or test conditions	No
UG-22(c) Superimposed static reactions from weight of attached equipment (external loads)	No
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs	No
UG-22(f) Wind reactions	No
UG-22(f) Seismic reactions	No
UG-22(j) Test pressure and coincident static head acting during the test:	No
Note: UG-22(b),(c) and (f) loads only considered when supports are present.	

Note 2: UG-22(d)(1),(e),(f)-snow,(g),(h),(i) are not considered. If these loads are present, additional calculations must be performed.

License Information	
Company Name	Codeware, Inc.
License	Commercial
License Key ID	23740
Support Expires	July 03, 2022

Radiography Summary

UG-116 Radiography							
Component	Longitudinal Seam		Top Circumferential Seam		Bottom Circumferential Seam		Mark
	Category (Fig UW-3)	Radiography / Joint Type	Category (Fig UW-3)	Radiography / Joint Type	Category (Fig UW-3)	Radiography / Joint Type	
Welded Cover #1	N/A	Seamless No RT	N/A	N/A	N/A	N/A	N/A
Cylinder #2	A	Full UW-11(a) / Type 1	N/A	N/A	B	Full UW-11(a) / Type 1	RT1
Cylinder #1	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
Ellipsoidal Head #2	N/A	Seamless No RT	B	Full UW-11(a) / Type 1	N/A	N/A	RT1
Nozzle	Longitudinal Seam		Nozzle to Vessel Circumferential Seam		Nozzle free end Circumferential Seam		
Nozzle #1 (N1)	N/A	Seamless No RT	D	N/A / Type 7	B	UW-11(a)(4) exempt	N/A
UG-116(e) Required Marking: **RT1**							

Thickness Summary

Component Data								
Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
Welded Cover #1	SA-516 70	24 ID	0.875	0.875	0.7589	0	1.00	Internal
Cylinder #2	SA-516 70	24 ID	36	0.1875	0.0651	0	1.00	External
Cylinder #1	SA-516 70	24 ID	36	0.1875	0.0651	0	1.00	External
Straight Flange on Ellipsoidal Head #2	SA-516 70	24 ID	2	0.1875	0.0918	0	1.00	Internal
Ellipsoidal Head #2	SA-516 70	24 ID	6.0916	0.0916*	0.0916	0	1.00	Internal
*Head minimum thickness after forming								

Definitions	
Nominal t	Vessel wall nominal thickness
Design t	Required vessel thickness due to governing loading + corrosion
Joint E	Longitudinal seam joint efficiency
Load	
Internal	Circumferential stress due to internal pressure governs
External	External pressure governs
Wind	Combined longitudinal stress of pressure + weight + wind governs
Seismic	Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Weight (lb) Contributed by Vessel Elements											
Component	Metal New*	Metal Corroded	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid		Surface Area ft^2
							New	Corroded	New	Corroded	
Welded Cover #1	115.6	115.6	0	0	0	0	0	0	0	0	4
Cylinder #2	145.2	145.2	0	0	0	0	391.9	391.9	587.9	587.9	19
Cylinder #1	143.3	143.3	0	0	0	0	594.1	594.1	594.1	594.1	19
Ellipsoidal Head #2	25.4	25.4	0	0	0	0	98	98	98	98	6
TOTAL:	**429.5**	**429.5**	**0**	**0**	**0**	**0**	**1,084**	**1,084**	**1,280**	**1,280**	**48**
*Shells with attached nozzles have weight reduced by material cut out for opening.											

Weight (lb) Contributed by Attachments											
Component	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays	Tray Supports	Rings & Clips	Vertical Loads	Surface Area ft^2
	New	Corroded	New	Corroded							
Welded Cover #1	0	0	0	0	0	0	0	0	0	0	0
Cylinder #2	0	0	0	0	0	0	0	0	17.3	0	4
Cylinder #1	0	0	10.5	10.5	0	0	0	0	17.3	0	5
Ellipsoidal Head #2	0	0	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**10.5**	**10.5**	**0**	**0**	**0**	**0**	**34.5**	**0**	**9**

Vessel Totals		
	New	Corroded
Operating Weight (lb)	1,559	1,559
Empty Weight (lb)	474	474
Test Weight (lb)	1,754	1,754
Surface Area (ft^2)	56	-
Capacity** (US gal)	153	153
**The vessel capacity does not include volume of nozzle, piping or other attachments.		

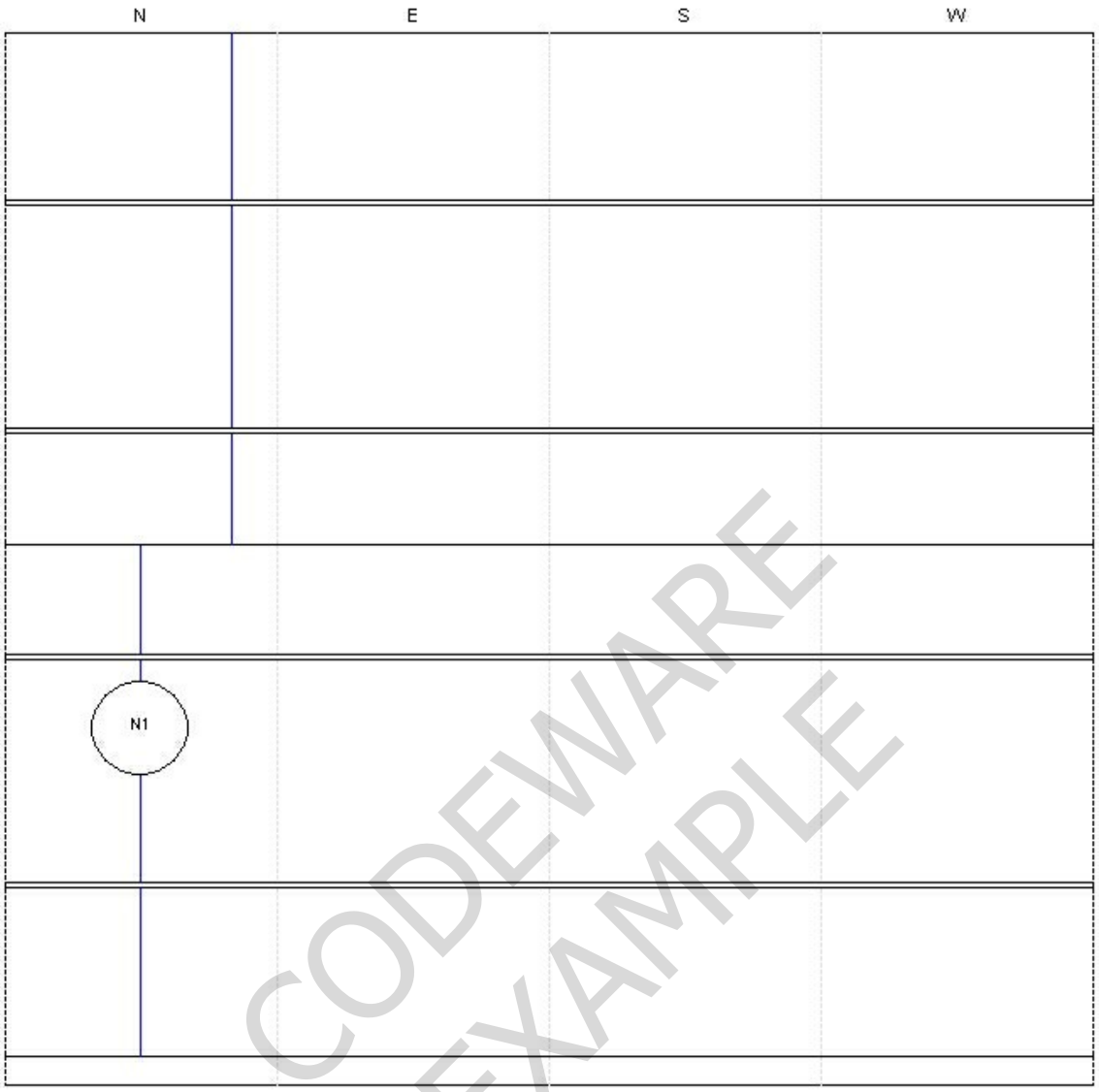
Vessel Lift Condition	
Vessel Lift Weight, New (lb)	474
Center of Gravity from Datum (in)	42.4612

Long Seam Summary

Shell Long Seam Angles	
Component	**Seam 1**
Cylinder #2	30°
Cylinder #1	0°

Shell Plate Lengths		
Component	**Starting Angle**	**Plate 1**
Cylinder #2	30°	75.9873"
Cylinder #1	0°	75.9873"

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



Shell Rollout

Hydrostatic Test

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

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

$= 1.3 \cdot 132.92 \cdot 1$

$= 172.8$ psi

Horizontal shop hydrostatic test				
Identifier	**Local test pressure (psi)**	**Test liquid static head (psi)**	**UG-99(b) stress ratio**	**UG-99(b) pressure factor**
Cylinder #2 (1)	173.887	1.09	1	1.30
Cylinder #1	173.887	1.09	1	1.30
Straight Flange on Ellipsoidal Head #2	173.887	1.09	1	1.30
Ellipsoidal Head #2	173.887	1.09	1	1.30
Welded Cover #1	173.887	1.09	1	1.30
Nozzle #1 (N1)	173.014	0.217	1	1.30
(1) Cylinder #2 limits the UG-99(b) stress ratio. (2) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange. (3) UG-99(i): Custom flange assemblies shall be tested with gaskets having identical geometries and gasket factors, and bolting having identical allowable stress at room temperature as used in the design calculations.				

The field test condition has not been investigated.

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

Vacuum Summary

Largest Unsupported Length Le			
Component	**Line of Support**	**Elevation above Datum (in)**	**Length Le (in)**
Welded Cover #1	-	72.875	N/A
-	Welded Cover #1	72	N/A
Cylinder #2 Top	-	72	16
-	Rings #1 (Ring #4 in Group)	60	14
-	Rings #1 (Ring #3 in Group)	44	16
Cylinder #2 Bottom	-	36	16
Cylinder #1 Top	-	36	16
-	Rings #1 (Ring #2 in Group)	28	16
-	Rings #1	12	16
Cylinder #1 Bottom	-	0	16
Straight Flange on Ellipsoidal Head #2 Top	-	0	16
Straight Flange on Ellipsoidal Head #2 Bottom	-	-2	16
-	1/3 depth of Ellipsoidal Head #2	-4	N/A
Ellipsoidal Head #2	-	-8.0916	N/A
For Rings, the listed value of length Le is Ls per UG-29.			

Bill of Materials

Heads / Covers						
Item #	**Type**	**Material**	**Thk [in]**	**Dia. [in]**	**Wt. [lb] (ea.)**	**Qty**
H1	Ellipsoidal Head	SA-516 70	0.0916 (min.)	24 ID	25.4	1
H2	Welded Cover	SA-516 70	0.875	24 ID	115.6	1

Shells							
Item #	**Type**	**Material**	**Thk [in]**	**Dia. [in]**	**Length [in]**	**Wt. [lb] (ea.)**	**Qty**
S1	Cylinder	SA-516 70	0.1875	24 ID	36	145.2	2

Rings						
Item #	**Type**	**Material**	**Thk [in]**	**Length [in]**	**Wt. [lb]**	**Qty**
R1	1/4x1.5 Flat Bar	SA-516 70	0.25	81.3	8.6	4

Nozzles							
Item #	**Type**	**Material**	**NPS**	**Thk [in]**	**Dia. [in]**	**Length [in]**	**Wt. [lb]**
Noz1	Nozzle	SA-105	-	0.28	6.625 OD	6.7	10.5

Welded Cover #1

ASME Section VIII Division 1, 2021 Edition				
Component		Welded Cover		
Configuration		Figure UG-34 Sketch (i)		
Weld Detail		Figure UW-13.2 Sketch (a)		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Attached To		Cylinder #2		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		100	250	-20
External		15	250	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Test horizontal		1.09	30.1875	1
Dimensions				
Inner Diameter		24"		
Nominal Thickness		0.875"		
Weld Bevel Depth (a)		0.375"		
Weld Bevel Depth (t_w)		0.1875"		
Inner Fillet Weld Leg		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		115.55		0
Corroded		115.55		0
Radiography				
Category A joints		Seamless No RT		

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.7589"
Design thickness due to external pressure (t_e)	0.3776"
Maximum allowable working pressure (MAWP)	132.92 psi
Maximum allowable pressure (MAP)	132.92 psi
Maximum allowable external pressure (MAEP)	80.56 psi
Rated MDMT	-20°F

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.2188"
MDMT =	-20°F
Material is exempt from impact testing per UG-20(f) at the Design MDMT of -20°F.	

Figure UW-13.2 Weld Sizing					
$t_{leg} \geq t_s + \frac{C_i}{0.7}$					
$a \geq 2t_s + \frac{C_{i,shell}}{0.7} + C_{o,shell}$					
Results					
$t_{leg} =$	0.1875"	$\geq$	$0.1875 + \frac{0}{0.7} =$	0.1875"	✔
$a =$	0.375"	$\geq$	$2 \cdot 0.1875 + \frac{0}{0.7} + 0 =$	0.375"	✔

Factor C from Figure UG-34 Sketch (i)

$$C = \max\left(\frac{0.33 \cdot t_r}{t_s}, 0.2\right) = \max\left(\frac{0.33 \cdot 0.0602}{0.1875}, 0.2\right) = 0.2$$

Design thickness, (at 250 °F) UG-34(c)(2)

$$t = d \cdot \sqrt{\frac{C \cdot P}{S \cdot E}} + \text{Corrosion} = 24 \cdot \sqrt{\frac{0.2 \cdot 100}{20{,}000 \cdot 1}} + 0 = 0.7589"$$

Maximum allowable working pressure, (at 250 °F)

$$C = \max\left(\frac{0.33 \cdot t_r}{t_s}, 0.2\right) = \max\left(\frac{0.33 \cdot 0.0801}{0.1875}, 0.2\right) = 0.2$$

$$MAWP = \left(\frac{S \cdot E}{C}\right) \cdot \left(\frac{t}{d}\right)^2 - P_s = \left(\frac{20{,}000 \cdot 1}{0.2}\right) \cdot \left(\frac{0.875}{24}\right)^2 - 0 = 132.92 \text{ psi}$$

Maximum allowable pressure, (At 70 °F)

$$C = \max\left(\frac{0.33 \cdot t_r}{t_s}, 0.2\right) = \max\left(\frac{0.33 \cdot 0.0801}{0.1875}, 0.2\right) = 0.2$$

$$MAP = \left(\frac{S \cdot E}{C}\right) \cdot \left(\frac{t}{d}\right)^2 = \left(\frac{20{,}000 \cdot 1}{0.2}\right) \cdot \left(\frac{0.875}{24}\right)^2 = 132.92 \text{ psi}$$

Design thickness for external pressure, (at 250 °F) UG-34(c)(2)

$$t = d \cdot \sqrt{\frac{C \cdot P_e}{S \cdot E}} + \text{Corrosion} = 24 \cdot \sqrt{\frac{0.33 \cdot 15}{20{,}000 \cdot 1}} + 0 = 0.3776"$$

Maximum allowable external pressure, (At 250 °F)

$$\text{MAEP} = \left(\frac{S \cdot E}{C}\right) \cdot \left(\frac{t}{d}\right)^2 = \left(\frac{20{,}000 \cdot 1}{0.33}\right) \cdot \left(\frac{0.875}{24}\right)^2 = 80.56 \text{ psi}$$

Cylinder #2

ASME Section VIII Division 1, 2021 Edition				
Component		Cylinder		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		100	250	-20
External		15	250	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		0.87	24	1
Test horizontal		1.09	30.1875	1
Dimensions				
Inner Diameter		24"		
Length		36"		
Nominal Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		145.15		70.5
Corroded		145.15		70.5
Radiography				
Longitudinal seam		Full UW-11(a) Type 1		
Bottom Circumferential seam		Full UW-11(a) Type 1		

Results Summary	
Governing condition	External pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0608"
Design thickness due to external pressure (t_e)	0.0651"
Maximum allowable working pressure (MAWP)	308.73 psi
Maximum allowable pressure (MAP)	309.6 psi
Maximum allowable external pressure (MAEP)	139.63 psi
Rated MDMT	-55 °F

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.1875"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{133.79 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 133.79} =$	0.0806"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0806 \cdot 1}{0.1875 - 0} =$	0.4298
Reduction in MDMT, T_R from Fig UCS-66.1 =	77.4°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 77.4, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 250 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{100.87 \cdot 12}{20{,}000 \cdot 1.00 - 0.60 \cdot 100.87} + 0 = 0.0608"$$

Maximum allowable working pressure, (at 250 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{20{,}000 \cdot 1.00 \cdot 0.1875}{12 + 0.60 \cdot 0.1875} - 0.87 = 308.73 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 0.1875}{12 + 0.60 \cdot 0.1875} = 309.6 \text{ psi}$$

External Pressure, (Corroded & at 250 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.0651} = 374.4084$$

From table G: $A = 0.000291$

From table CS-2: $B = 4{,}212.0919 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 4{,}212.09}{3 \cdot (24.375 / 0.0651)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.0651 + 0 = 0.0651"$$

Maximum Allowable External Pressure, (Corroded & at 250 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.1875} = 130.0000$$

From table G: $A = 0.001425$

From table CS-2: $B = 13{,}613.5745 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 13{,}613.57}{3 \cdot (24.375 / 0.1875)} = 139.63 \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.1875}{12.0938}\right) \cdot \left(1 - \frac{12.0938}{\infty}\right) = 0.7752\,\%$$

The extreme fiber elongation does not exceed 5%.

Rings #1 (Ring #3 in Group)

ASME Section VIII Division 1, 2021 Edition				
Component		Stiffening Ring		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Attached To		Cylinder #2		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	
No	No	No	No	
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		100	250	-20
External		15	250	
Ring Properties				
Ring type		Flat bar		
Description		1/4x1.5 Flat Bar		
Corrosion allowance		0"		
Distance from ring neutral axis to datum		44"		
Distance to previous support		16"		
Distance to next support		16"		
Internal ring		No		
Max depth to thickness ratio		12		
Ring distance to centroid		0.75"		
Ring area		0.375 in^2		
Ring inertia		0.0703 in^4		
Welds				
Weld configuration		Staggered intermittent		
Fillet weld leg size		0.25"		
Length of individual weld segments		3"		
Spacing between toes of weld segments		1.5"		
Vessel thickness at weld location, new		0.1875"		
Vessel corrosion allowance at weld location		0"		
Stiffener thickness at weld location		0.25"		

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.25"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{133.79 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 133.79} =$	0.0806"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0806 \cdot 1}{0.1875 - 0} =$	0.4298
Reduction in MDMT, T_R from Fig UCS-66.1 =	77.4°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 77.4, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

External Pressure, (Corroded & at 250°F) UG-29(a)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.0651} = 374.194$$

From Table G: $A = 2.908\text{E-}04$

From Table CS-2: $B = 4{,}216.38 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o \ / \ t)} = \frac{4 \cdot 4{,}216.38}{3 \cdot (24.375 \ / \ 0.06514)} = 15.02 \text{ psi}$$

$$B = \frac{3}{4} \cdot \left(\frac{P \cdot D_o}{t + A_s \ / \ L_s} \right) = \frac{3}{4} \cdot \left(\frac{15 \cdot 24.375}{0.0651 + 0.375 \ / \ 16} \right) = 3{,}097 \text{ psi}$$

From Table CS-2: $A = 0.00021330$ (ring, 250°F)

$$I_s' = \frac{D_o^2 \cdot L_s \cdot (t + A_s \ / \ L_s) \cdot A}{10.9}$$

$$= \frac{24.375^{\,2} \cdot 16 \cdot (0.0651 + 0.375 \ / \ 16) \cdot 0.00021330}{10.9}$$

$$= 0.0165 \text{ in}^4$$

I' for the composite corroded shell-ring cross section is 0.2159 in^4

As I' >= I_s' a 1/4x1.5 Flat Bar stiffener is adequate for an external pressure of 15 psi.

Check the stiffener ring attachment welds per UG-30

UG-30(f) minimum weld size $= \min [0.25, 0.1875 - 0 - 0, 0.25] + 0 = 0.1875 \text{ in}$

The fillet weld size of 0.25 in is adequate per UG-30(f).

Radial pressure load, $P \cdot L_s = 15 \cdot 16 = 240 \text{ lb}_f/\text{in}$

Radial shear load, $V = 0.01 \cdot P \cdot L_s \cdot D_o = 0.01 \cdot 15 \cdot 16 \cdot 24.375 = 58.5 \text{ lb}_f$

First moment of area, $Q = 0.44 \cdot 0.3878 = 0.171 \text{ in}^3$

Weld shear flow, $q = \frac{V \cdot Q}{I'} = 46.3385 \text{ lb}_f/\text{in}$

Combined weld load, $f_w = \sqrt{240^{\,2} + 46.3385^{\,2}} = 244.43 \text{ lb}_f/\text{in}$

Allowable weld stress per UW-18(d) $S_w = 0.55 \cdot S = 0.55 \cdot 20{,}000 = 11{,}000 \text{ psi}$

Fillet weld size required to resist radial pressure and shear

$$t_w = \frac{f_w \cdot (d_{\text{weld segment}} + d_{\text{toe}})}{S_w \cdot d_{\text{weld total}}} + \text{corrosion} = \frac{244.43 \cdot (3 + 1.5)}{11{,}000 \cdot 6} + 0 = 0.0167 \text{ in}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

Maximum Allowable External Pressure, (Corroded & at 250°F) UG-29(a)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.1875} = 130$$

From Table G: $A = 0.0014$

From Table CS-2: $B = 13{,}613.57 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o \ / \ t)} = \frac{4 \cdot 13{,}613.57}{3 \cdot (24.375 \ / \ 0.1875)} = 139.63 \text{ psi}$$

$$B = \frac{3}{4} \cdot \left(\frac{P \cdot D_o}{t + A_s \ / \ L_s} \right) = \frac{3}{4} \cdot \left(\frac{139.63 \cdot 24.375}{0.1875 + 0.375 \ / \ 16} \right) = 12{,}101 \text{ psi}$$

From Table CS-2: $A = 0.00095942$ (ring, 250°F)

$$I_s' = \frac{D_o^2 \cdot L_s \cdot (t + A_s \ / \ L_s) \cdot A}{10.9}$$

$$= \frac{24.375^{\ 2} \cdot 16 \cdot (0.1875 + 0.375 \ / \ 16) \cdot 0.00095942}{10.9}$$

$$= 0.1765 \text{ in}^4$$

I' for the composite corroded shell-ring cross section is 0.2159 in^4

As I' >= I_s' a 1/4x1.5 Flat Bar stiffener is adequate for an external pressure of 139.63 psi.

Check the stiffener ring attachment welds per UG-30

UG-30(f) minimum weld size $= \min [0.25, 0.1875 - 0 - 0, 0.25] + 0 = 0.1875 \text{ in}$

The fillet weld size of 0.25 in is adequate per UG-30(f).

Radial pressure load, $P \cdot L_s = 139.63 \cdot 16 = 2{,}234.02 \text{ lb}_f/\text{in}$

Radial shear load, $V = 0.01 \cdot P \cdot L_s \cdot D_o = 0.01 \cdot 139.63 \cdot 16 \cdot 24.375 = 544.54 \text{ lb}_f$

First moment of area, $Q = 0.44 \cdot 0.3878 = 0.171 \text{ in}^3$

Weld shear flow, $q = \frac{V \cdot Q}{I'} = 431.3382 \text{ lb}_f/\text{in}$

Combined weld load, $f_w = \sqrt{2{,}234.0214^{\ 2} + 431.3382^{\ 2}} = 2{,}275.28 \text{ lb}_f/\text{in}$

Allowable weld stress per UW-18(d) $S_w = 0.55 \cdot S = 0.55 \cdot 20{,}000 = 11{,}000 \text{ psi}$

Fillet weld size required to resist radial pressure and shear

$$t_w = \frac{f_w \cdot (d_{\text{weld segment}} + d_{\text{toe}})}{S_w \cdot d_{\text{weld total}}} + \text{corrosion} = \frac{2{,}275.28 \cdot (3 + 1.5)}{11{,}000 \cdot 6} + 0 = 0.1551 \text{ in}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

Rings #1 (Ring #4 in Group)

ASME Section VIII Division 1, 2021 Edition				
Component		Stiffening Ring		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Attached To		Cylinder #2		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	
No	No	No	No	
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		100	250	-20
External		15	250	
Ring Properties				
Ring type		Flat bar		
Description		1/4x1.5 Flat Bar		
Corrosion allowance		0"		
Distance from ring neutral axis to datum		60"		
Distance to previous support		12"		
Distance to next support		16"		
Internal ring		No		
Max depth to thickness ratio		12		
Ring distance to centroid		0.75"		
Ring area		0.375 in^2		
Ring inertia		0.0703 in^4		
Welds				
Weld configuration		Staggered intermittent		
Fillet weld leg size		0.25"		
Length of individual weld segments		3"		
Spacing between toes of weld segments		1.5"		
Vessel thickness at weld location, new		0.1875"		
Vessel corrosion allowance at weld location		0"		
Stiffener thickness at weld location		0.25"		

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.25"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{133.79 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 133.79} =$	0.0806"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0806 \cdot 1}{0.1875 - 0} =$	0.4298
Reduction in MDMT, T_R from Fig UCS-66.1 =	77.4°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 77.4, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

External Pressure, (Corroded & at 250°F) UG-29(a)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.0651} = 374.194$$

From Table G: $A = 2.908\text{E-}04$

From Table CS-2: $B = 4{,}216.38 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o \ / \ t)} = \frac{4 \cdot 4{,}216.38}{3 \cdot (24.375 \ / \ 0.06514)} = 15.02 \text{ psi}$$

$$B = \frac{3}{4} \cdot \left(\frac{P \cdot D_o}{t + A_s \ / \ L_s} \right) = \frac{3}{4} \cdot \left(\frac{15 \cdot 24.375}{0.0651 + 0.375 \ / \ 14} \right) = 2{,}984 \text{ psi}$$

From Table CS-2: $A = 0.00020549$ (ring, 250°F)

$$I_s' = \frac{D_o^2 \cdot L_s \cdot (t + A_s \ / \ L_s) \cdot A}{10.9}$$

$$= \frac{24.375^{\,2} \cdot 14 \cdot (0.0651 + 0.375 \ / \ 14) \cdot 0.00020549}{10.9}$$

$$= 0.0144 \text{ in}^4$$

I' for the composite corroded shell-ring cross section is 0.2159 in^4

As $I' >= I_s'$ a 1/4x1.5 Flat Bar stiffener is adequate for an external pressure of 15 psi.

Check the stiffener ring attachment welds per UG-30

UG-30(f) minimum weld size $= \min [0.25, 0.1875 - 0 - 0, 0.25] + 0 = 0.1875 \text{ in}$

The fillet weld size of 0.25 in is adequate per UG-30(f).

Radial pressure load, $P \cdot L_s = 15 \cdot 14 = 210 \text{ lb}_f/\text{in}$

Radial shear load, $V = 0.01 \cdot P \cdot L_s \cdot D_o = 0.01 \cdot 15 \cdot 14 \cdot 24.375 = 51.19 \text{ lb}_f$

First moment of area, $Q = 0.44 \cdot 0.3878 = 0.171 \text{ in}^3$

Weld shear flow, $q = \frac{V \cdot Q}{I'} = 40.5462 \text{ lb}_f/\text{in}$

Combined weld load, $f_w = \sqrt{210^{\,2} + 40.5462^{\,2}} = 213.88 \text{ lb}_f/\text{in}$

Allowable weld stress per UW-18(d) $S_w = 0.55 \cdot S = 0.55 \cdot 20{,}000 = 11{,}000 \text{ psi}$

Fillet weld size required to resist radial pressure and shear

$$t_w = \frac{f_w \cdot (d_{\text{weld segment}} + d_{\text{toe}})}{S_w \cdot d_{\text{weld total}}} + \text{corrosion} = \frac{213.88 \cdot (3 + 1.5)}{11{,}000 \cdot 6} + 0 = 0.0146 \text{ in}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

Maximum Allowable External Pressure, (Corroded & at 250°F) UG-29(a)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.1875} = 130$$

From Table G: $A = 0.0014$

From Table CS-2: $B = 13{,}613.57 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o \ / \ t)} = \frac{4 \cdot 13{,}613.57}{3 \cdot (24.375 \ / \ 0.1875)} = 139.63 \text{ psi}$$

$$B = \frac{3}{4} \cdot \left(\frac{P \cdot D_o}{t + A_s \ / \ L_s} \right) = \frac{3}{4} \cdot \left(\frac{139.63 \cdot 24.375}{0.1875 + 0.375 \ / \ 14} \right) = 11{,}912 \text{ psi}$$

From Table CS-2: $A = 0.00092182$ (ring, 250°F)

$$I_s' = \frac{D_o^2 \cdot L_s \cdot (t + A_s \ / \ L_s) \cdot A}{10.9}$$

$$= \frac{24.375^{\ 2} \cdot 14 \cdot (0.1875 + 0.375 \ / \ 14) \cdot 0.00092182}{10.9}$$

$$= 0.1507 \text{ in}^4$$

I' for the composite corroded shell-ring cross section is 0.2159 in^4

As I' >= I_s' a 1/4x1.5 Flat Bar stiffener is adequate for an external pressure of 139.63 psi.

Check the stiffener ring attachment welds per UG-30

UG-30(f) minimum weld size $= \min [0.25, 0.1875 - 0 - 0, 0.25] + 0 = 0.1875 \text{ in}$

The fillet weld size of 0.25 in is adequate per UG-30(f).

Radial pressure load, $P \cdot L_s = 139.63 \cdot 14 = 1{,}954.77 \text{ lb}_f/\text{in}$

Radial shear load, $V = 0.01 \cdot P \cdot L_s \cdot D_o = 0.01 \cdot 139.63 \cdot 14 \cdot 24.375 = 476.47 \text{ lb}_f$

First moment of area, $Q = 0.44 \cdot 0.3878 = 0.171 \text{ in}^3$

Weld shear flow, $q = \frac{V \cdot Q}{I'} = 377.4209 \text{ lb}_f/\text{in}$

Combined weld load, $f_w = \sqrt{1{,}954.7687^{\ 2} + 377.4209^{\ 2}} = 1{,}990.87 \text{ lb}_f/\text{in}$

Allowable weld stress per UW-18(d) $S_w = 0.55 \cdot S = 0.55 \cdot 20{,}000 = 11{,}000 \text{ psi}$

Fillet weld size required to resist radial pressure and shear

$$t_w = \frac{f_w \cdot (d_{\text{weld segment}} + d_{\text{toe}})}{S_w \cdot d_{\text{weld total}}} + \text{corrosion} = \frac{1{,}990.87 \cdot (3 + 1.5)}{11{,}000 \cdot 6} + 0 = 0.1357 \text{ in}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

Cylinder #1

ASME Section VIII Division 1, 2021 Edition				
Component		Cylinder		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		100	250	-20
External		15	250	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		2.17	60	1
Test horizontal		1.09	30.1875	1
Dimensions				
Inner Diameter		24"		
Length		36"		
Nominal Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		143.33		70.5
Corroded		143.33		70.5
Radiography				
Longitudinal seam		Full UW-11(a) Type 1		
Top Circumferential seam		Full UW-11(a) Type 1		
Bottom Circumferential seam		Full UW-11(a) Type 1		

Results Summary	
Governing condition	External pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0615"
Design thickness due to external pressure (t_e)	0.0651"
Maximum allowable working pressure (MAWP)	307.43 psi
Maximum allowable pressure (MAP)	309.6 psi
Maximum allowable external pressure (MAEP)	139.63 psi
Rated MDMT	-55 °F

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.1875"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{135.09 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 135.09} =$	0.0814"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0814 \cdot 1}{0.1875 - 0} =$	0.434
Reduction in MDMT, T_R from Fig UCS-66.1 =	75.7°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 75.7, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 250 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{102.17 \cdot 12}{20{,}000 \cdot 1.00 - 0.60 \cdot 102.17} + 0 = 0.0615"$$

Maximum allowable working pressure, (at 250 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{20{,}000 \cdot 1.00 \cdot 0.1875}{12 + 0.60 \cdot 0.1875} - 2.17 = 307.43 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 0.1875}{12 + 0.60 \cdot 0.1875} = 309.6 \text{ psi}$$

External Pressure, (Corroded & at 250 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.0651} = 374.4084$$

From table G: $A = 0.000291$

From table CS-2: $B = 4{,}212.0919 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 4{,}212.09}{3 \cdot (24.375 / 0.0651)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.0651 + 0 = 0.0651"$$

Maximum Allowable External Pressure, (Corroded & at 250 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.1875} = 130.0000$$

From table G: $A = 0.001425$

From table CS-2: $B = 13{,}613.5745 \text{ psi}$

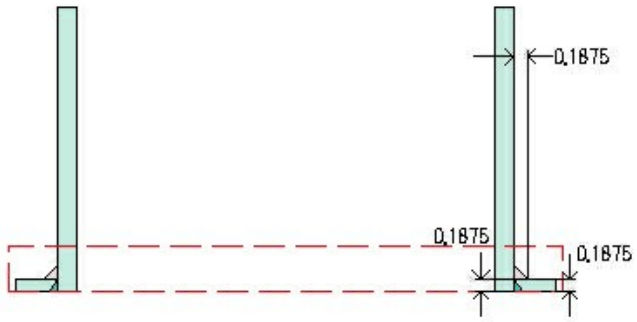
$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 13,613.57}{3 \cdot (24.375 / 0.1875)} = 139.63 \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f} \right) \cdot \left(1 - \frac{R_f}{R_o} \right) = \left(\frac{50 \cdot 0.1875}{12.0938} \right) \cdot \left(1 - \frac{12.0938}{\infty} \right) = 0.7752 \%$$

The extreme fiber elongation does not exceed 5%.

Nozzle #1 (N1)

ASME Section VIII Division 1, 2021 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Cylinder #1
Orientation	0°
Nozzle center line offset to datum line	23"
End of nozzle to shell center	18.1875"
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-105 (II-D p. 20, ln. 31)
Inside diameter, new	6.065"
Nominal wall thickness	0.28"
Corrosion allowance	0"
Projection available outside vessel, Lpr	6"
Local vessel minimum thickness	0.1875"
Liquid static head included	1.45 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Nozzle to vessel groove weld	0.1875"
Radiography	
Longitudinal seam	Seamless No RT
Circumferential seam	Spot UW-11(a)(5)(b) only Type 1

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, t_g =	0.1875"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{134.37 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 134.37} =$	0.081"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.081 \cdot 1}{0.1875 - 0} =$	0.4317
Reduction in MDMT, T_R from Fig UCS-66.1 =	76.6°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 76.6, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = \frac{134.37 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 134.37} =$	0.0205"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0205 \cdot 1}{0.28 - 0} =$	0.0731
Stress ratio ≤ 0.35, MDMT per UCS-66(b)(3) =	-155°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 101.45 psi @ 250 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.3703	1.0502	0.7669	0.2481	--	--	0.0352	0.0625	0.28

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

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

Calculations for internal pressure 101.45 psi @ 250 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.1875 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0\right]$$

$$= 0.4688 \text{ in}$$

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

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

$$= \frac{101.4451 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 101.4451}$$

$$= 0.0154 \text{ in}$$

Required thickness t_r from UG-37(a)

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

$$= \frac{101.4451 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 101.4451}$$

$$= 0.0611 \text{ in}$$

Area required per UG-37(c)

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

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

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

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

= $6.065 \cdot 0.0611 \cdot 1 + 2 \cdot 0.28 \cdot 0.0611 \cdot 1 \cdot (1 - 1)$

= 0.3703 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.7669 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0611) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0611) \cdot (1 - 1)$

= $0.7669 \ in^2$

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.0611) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0611) \cdot (1 - 1)$

= $0.1182 \ in^2$

A_2 = smaller of the following= 0.2481 in^2

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

= $5 \cdot (0.28 - 0.0154) \cdot 1 \cdot 0.1875$

= $0.2481 \ in^2$

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

= $5 \cdot (0.28 - 0.0154) \cdot 1 \cdot 0.28$

= $0.3704 \ in^2$

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

= $0.1875^{\ 2} \cdot 1$

= 0.0352 in^2

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

= $0.7669 + 0.2481 + 0.0352$

= 1.0502 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min[0.75,\ t_n,\ t] =$ 0.1875 in

$t_{c(\min)} = \min[0.25,\ 0.7 \cdot t_{\min}] =$ 0.1313 in

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

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$= \frac{101.4451 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 101.4451} + 0$$

$$= 0.0154 \text{ in}$$

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

$$= \max\left[0.0154,\ 0\right]$$

$$= 0.0154 \text{ in}$$

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

$$= \frac{101.4451 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 101.4451} + 0$$

$$= 0.0611 \text{ in}$$

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

$$= \max\left[0.0611,\ 0.0625\right]$$

$$= 0.0625 \text{ in}$$

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

$$= \min\left[0.245,\ 0.0625\right]$$

$$= 0.0625 \text{ in}$$

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

$$= \max\left[0.0154,\ 0.0625\right]$$

$$= 0.0625 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAWP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 192.25 psi @ 250 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.7037	0.7037	0.4335	0.235	--	--	0.0352	0.116	0.28

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

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

Calculations for internal pressure 192.25 psi @ 250 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.1875 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0\right]$$

$$= 0.4688 \text{ in}$$

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

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

$$= \frac{192.2523 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 192.2523}$$

$$= 0.0293 \text{ in}$$

Required thickness t_r from UG-37(a)

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

$$= \frac{192.2523 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 192.2523}$$

$$= 0.116 \text{ in}$$

Area required per UG-37(c)

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

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

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

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

= $6.065 \cdot 0.116 \cdot 1 + 2 \cdot 0.28 \cdot 0.116 \cdot 1 \cdot (1 - 1)$

= 0.7037 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.4335 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.116) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.116) \cdot (1 - 1)$

= $0.4335 \ \text{in}^2$

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.116) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.116) \cdot (1 - 1)$

= $0.0668 \ \text{in}^2$

A_2 = smaller of the following= 0.235 in^2

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

= $5 \cdot (0.28 - 0.0293) \cdot 1 \cdot 0.1875$

= $0.235 \ \text{in}^2$

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

= $5 \cdot (0.28 - 0.0293) \cdot 1 \cdot 0.28$

= $0.351 \ \text{in}^2$

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

= $0.1875^{\ 2} \cdot 1$

= 0.0352 in^2

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

= $0.4335 + 0.235 + 0.0352$

= 0.7037 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min[0.75,\ t_n,\ t] =$ 0.1875 in

$t_{c(\min)} = \min[0.25,\ 0.7 \cdot t_{\min}] =$ 0.1313 in

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

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$= \frac{192.2523 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 192.2523} + 0$$

$$= 0.0293 \text{ in}$$

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

$$= \max\left[0.0293,\ 0\right]$$

$$= 0.0293 \text{ in}$$

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

$$= \frac{192.2523 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 192.2523} + 0$$

$$= 0.116 \text{ in}$$

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

$$= \max\left[0.116,\ 0.0625\right]$$

$$= 0.116 \text{ in}$$

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

$$= \min\left[0.245,\ 0.116\right]$$

$$= 0.116 \text{ in}$$

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

$$= \max\left[0.0293,\ 0.116\right]$$

$$= 0.116 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for MAP

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

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 192.25 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.7037	0.7037	0.4335	0.235	--	--	0.0352	0.116	0.28

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

Calculations for internal pressure 192.25 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.1875 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0\right]$$

$$= 0.4688 \text{ in}$$

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

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

$$= \frac{192.2517 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 192.2517}$$

$$= 0.0293 \text{ in}$$

Required thickness t_r from UG-37(a)

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

$$= \frac{192.2517 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 192.2517}$$

$$= 0.116 \text{ in}$$

Area required per UG-37(c)

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

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

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

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

$$= 6.065 \cdot 0.116 \cdot 1 + 2 \cdot 0.28 \cdot 0.116 \cdot 1 \cdot (1 - 1)$$

$$= 0.7037 \text{ in}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.4335 in^2

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

$$= 6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.116) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.116) \cdot (1 - 1)$$

$$= 0.4335 \text{ in}^2$$

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

$$= 2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.116) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.116) \cdot (1 - 1)$$

$$= 0.0668 \text{ in}^2$$

A_2 = smaller of the following= 0.235 in^2

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

$$= 5 \cdot (0.28 - 0.0293) \cdot 1 \cdot 0.1875$$

$$= 0.235 \text{ in}^2$$

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

$$= 5 \cdot (0.28 - 0.0293) \cdot 1 \cdot 0.28$$

$$= 0.351 \text{ in}^2$$

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

$$= 0.1875^2 \cdot 1$$

$$= 0.0352 \text{ in}^2$$

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

$$= 0.4335 + 0.235 + 0.0352$$

$$= 0.7037 \text{ in}^2$$

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$= \frac{192.2517 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 192.2517} + 0$$

$$= 0.0293 \text{ in}$$

$$t_a = \max\left[t_{a\text{UG-27}},\ t_{a\text{UG-22}}\right]$$
$$= \max\left[0.0293,\ 0\right]$$
$$= 0.0293 \text{ in}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$$
$$= \frac{192.2517 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 192.2517} + 0$$
$$= 0.116 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{b\text{UG16}}\right]$$
$$= \max\left[0.116,\ 0.0625\right]$$
$$= 0.116 \text{ in}$$

$$t_b = \min\left[t_{b3},\ t_{b1}\right]$$
$$= \min\left[0.245,\ 0.116\right]$$
$$= 0.116 \text{ in}$$

$$t_{\text{UG-45}} = \max\left[t_a,\ t_b\right]$$
$$= \max\left[0.0293,\ 0.116\right]$$
$$= 0.116 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 15 psi @ 250 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.1974	1.0205	0.7424	0.2429	--	--	0.0352	0.0625	0.28

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

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

Calculations for external pressure 15 psi @ 250 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.1875 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0\right]$$

$$= 0.4688 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0209 in

From UG-37(d)(1) required thickness t_r = 0.0651 in

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

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

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

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

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

$$= 0.5 \cdot (6.065 \cdot 0.0651 \cdot 1 + 2 \cdot 0.28 \cdot 0.0651 \cdot 1 \cdot (1 - 1))$$

$$= 0.1974 \text{ in}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.7424 in^2

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

$= \quad 6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0651) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0651) \cdot (1 - 1)$

$= \quad 0.7424 \ \text{in}^2$

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

$= \quad 2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.0651) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0651) \cdot (1 - 1)$

$= \quad 0.1144 \ \text{in}^2$

A_2 = smaller of the following= 0.2429 in^2

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

$= \quad 5 \cdot (0.28 - 0.0209) \cdot 1 \cdot 0.1875$

$= \quad 0.2429 \ \text{in}^2$

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

$= \quad 5 \cdot (0.28 - 0.0209) \cdot 1 \cdot 0.28$

$= \quad 0.3627 \ \text{in}^2$

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

$= \quad 0.1875^{\,2} \cdot 1$

$= \quad 0.0352 \ \text{in}^2$

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

$= \quad 0.7424 + 0.2429 + 0.0352$

$= \quad 1.0205 \ \text{in}^2$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min [0.75, \ t_n, \ t] = 0.1875$ in

$t_{c(\min)} = \min [0.25, \ 0.7 \cdot t_{\min}] =$ 0.1313 in

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

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}} \quad = \quad 0.0209 \ \text{in}$

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

$= \quad \max [0.0209, \ 0]$

$= \quad 0.0209 \ \text{in}$

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

$= \frac{15 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 15} + 0$

$= 0.009 \text{ in}$

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

$= \max\left[0.009,\ 0.0625\right]$

$= 0.0625 \text{ in}$

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

$= \min\left[0.245,\ 0.0625\right]$

$= 0.0625 \text{ in}$

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

$= \max\left[0.0209,\ 0.0625\right]$

$= 0.0625 \text{ in}$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 250 °F) UG-28(c)

$\frac{L}{D_o} = \frac{6.4588}{6.625} = 0.9749$

$\frac{D_o}{t} = \frac{6.625}{0.0209} = 316.7207$

From table G: $A = 0.000246$

From table CS-2: $B = 3{,}563.1367 \text{ psi}$

$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 3{,}563.14}{3 \cdot (6.625 / 0.0209)} = 15 \text{ psi}$

Design thickness for external pressure P_a = 15 psi

$t_a = t + \text{Corrosion} = 0.0209 + 0 = 0.0209"$

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 104.69 psi @ 250 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.464	0.464	0.2092	0.2196	--	--	0.0352	0.063	0.28

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

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

Calculations for external pressure 104.69 psi @ 250 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.1875 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0\right]$$

$$= 0.4688 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0458 in

From UG-37(d)(1) required thickness t_r = 0.153 in

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

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

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

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

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

$$= 0.5 \cdot (6.065 \cdot 0.153 \cdot 1 + 2 \cdot 0.28 \cdot 0.153 \cdot 1 \cdot (1 - 1))$$

$$= 0.464 \text{ in}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2092 in^2

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

$= \quad 6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.153) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.153) \cdot (1 - 1)$

$= \quad 0.2092 \ \text{in}^2$

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

$= \quad 2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.153) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.153) \cdot (1 - 1)$

$= \quad 0.0323 \ \text{in}^2$

A_2 = smaller of the following= 0.2196 in^2

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

$= \quad 5 \cdot (0.28 - 0.0458) \cdot 1 \cdot 0.1875$

$= \quad 0.2196 \ \text{in}^2$

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

$= \quad 5 \cdot (0.28 - 0.0458) \cdot 1 \cdot 0.28$

$= \quad 0.3279 \ \text{in}^2$

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

$= \quad 0.1875^{\,2} \cdot 1$

$= \quad 0.0352 \ \text{in}^2$

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

$= \quad 0.2092 + 0.2196 + 0.0352$

$= \quad 0.464 \ \text{in}^2$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min [0.75, \ t_n, \ t] = 0.1875$ in

$t_{c(\min)} = \min [0.25, \ 0.7 \cdot t_{\min}] = 0.1313$ in

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

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}} = \quad 0.0458 \ \text{in}$

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

$= \quad \max [0.0458, \ 0]$

$= \quad 0.0458 \ \text{in}$

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

$$= \frac{104.6932 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 104.6932} + 0$$

$$= 0.063 \text{ in}$$

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

$$= \max\left[0.063,\ 0.0625\right]$$

$$= 0.063 \text{ in}$$

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

$$= \min\left[0.245,\ 0.063\right]$$

$$= 0.063 \text{ in}$$

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

$$= \max\left[0.0458,\ 0.063\right]$$

$$= \underline{0.063} \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 250 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{6.4588}{6.625} = 0.9749$$

$$\frac{D_o}{t} = \frac{6.625}{0.0458} = 144.7997$$

From table G: $A = 0.000795$

From table CS-2: $B = 11{,}369.6111$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 11{,}369.61}{3 \cdot (6.625 / 0.0458)} = 104.69 \text{ psi}$$

Design thickness for external pressure P_a = 104.69 psi

$$t_a = t + \text{Corrosion} = 0.0458 + 0 = 0.0458"$$

Rings #1 (Ring #2 in Group)

ASME Section VIII Division 1, 2021 Edition				
Component		Stiffening Ring		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Attached To		Cylinder #1		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	
No	No	No	No	
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		100	250	-20
External		15	250	
Ring Properties				
Ring type		Flat bar		
Description		1/4x1.5 Flat Bar		
Corrosion allowance		0"		
Distance from ring neutral axis to datum		28"		
Distance to previous support		16"		
Distance to next support		16"		
Internal ring		No		
Max depth to thickness ratio		12		
Ring distance to centroid		0.75"		
Ring area		0.375 in^2		
Ring inertia		0.0703 in^4		
Welds				
Weld configuration		Staggered intermittent		
Fillet weld leg size		0.25"		
Length of individual weld segments		3"		
Spacing between toes of weld segments		1.5"		
Vessel thickness at weld location, new		0.1875"		
Vessel corrosion allowance at weld location		0"		
Stiffener thickness at weld location		0.25"		

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.25"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{135.09 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 135.09} =$	0.0814"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0814 \cdot 1}{0.1875 - 0} =$	0.434
Reduction in MDMT, T_R from Fig UCS-66.1 =	75.7°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 75.7, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

External Pressure, (Corroded & at 250°F) UG-29(a)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.0651} = 374.194$$

From Table G: $A = 2.908\text{E-}04$

From Table CS-2: $B = 4{,}216.38 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o \ / \ t)} = \frac{4 \cdot 4{,}216.38}{3 \cdot (24.375 \ / \ 0.06514)} = 15.02 \text{ psi}$$

$$B = \frac{3}{4} \cdot \left(\frac{P \cdot D_o}{t + A_s \ / \ L_s} \right) = \frac{3}{4} \cdot \left(\frac{15 \cdot 24.375}{0.0651 + 0.375 \ / \ 16} \right) = 3{,}097 \text{ psi}$$

From Table CS-2: $A = 0.00021330$ (ring, 250°F)

$$I_s' = \frac{D_o^2 \cdot L_s \cdot (t + A_s \ / \ L_s) \cdot A}{10.9}$$

$$= \frac{24.375^{\,2} \cdot 16 \cdot (0.0651 + 0.375 \ / \ 16) \cdot 0.00021330}{10.9}$$

$$= 0.0165 \text{ in}^4$$

I' for the composite corroded shell-ring cross section is 0.2159 in^4

As $I' >= I_s'$ a 1/4x1.5 Flat Bar stiffener is adequate for an external pressure of 15 psi.

Check the stiffener ring attachment welds per UG-30

UG-30(f) minimum weld size $= \min [0.25, 0.1875 - 0 - 0, 0.25] + 0 = 0.1875 \text{ in}$

The fillet weld size of 0.25 in is adequate per UG-30(f).

Radial pressure load, $P \cdot L_s = 15 \cdot 16 = 240 \text{ lb}_f/\text{in}$

Radial shear load, $V = 0.01 \cdot P \cdot L_s \cdot D_o = 0.01 \cdot 15 \cdot 16 \cdot 24.375 = 58.5 \text{ lb}_f$

First moment of area, $Q = 0.44 \cdot 0.3878 = 0.171 \text{ in}^3$

Weld shear flow, $q = \frac{V \cdot Q}{I'} = 46.3385 \text{ lb}_f/\text{in}$

Combined weld load, $f_w = \sqrt{240^{\,2} + 46.3385^{\,2}} = 244.43 \text{ lb}_f/\text{in}$

Allowable weld stress per UW-18(d) $S_w = 0.55 \cdot S = 0.55 \cdot 20{,}000 = 11{,}000 \text{ psi}$

Fillet weld size required to resist radial pressure and shear

$$t_w = \frac{f_w \cdot (d_{\text{weld segment}} + d_{\text{toe}})}{S_w \cdot d_{\text{weld total}}} + \text{corrosion} = \frac{244.43 \cdot (3 + 1.5)}{11{,}000 \cdot 6} + 0 = 0.0167 \text{ in}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

Maximum Allowable External Pressure, (Corroded & at 250°F) UG-29(a)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.1875} = 130$$

From Table G: $A = 0.0014$

From Table CS-2: $B = 13{,}613.57 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o \ / \ t)} = \frac{4 \cdot 13{,}613.57}{3 \cdot (24.375 \ / \ 0.1875)} = 139.63 \text{ psi}$$

$$B = \frac{3}{4} \cdot \left(\frac{P \cdot D_o}{t + A_s \ / \ L_s} \right) = \frac{3}{4} \cdot \left(\frac{139.63 \cdot 24.375}{0.1875 + 0.375 \ / \ 16} \right) = 12{,}101 \text{ psi}$$

From Table CS-2: $A = 0.00095942$ (ring, 250°F)

$$I_s' = \frac{D_o^2 \cdot L_s \cdot (t + A_s \ / \ L_s) \cdot A}{10.9}$$

$$= \frac{24.375^{\ 2} \cdot 16 \cdot (0.1875 + 0.375 \ / \ 16) \cdot 0.00095942}{10.9}$$

$$= 0.1765 \text{ in}^4$$

I' for the composite corroded shell-ring cross section is 0.2159 in^4

As I' >= I_s' a 1/4x1.5 Flat Bar stiffener is adequate for an external pressure of 139.63 psi.

Check the stiffener ring attachment welds per UG-30

UG-30(f) minimum weld size $= \min [0.25, 0.1875 - 0 - 0, 0.25] + 0 = 0.1875 \text{ in}$

The fillet weld size of 0.25 in is adequate per UG-30(f).

Radial pressure load, $P \cdot L_s = 139.63 \cdot 16 = 2{,}234.02 \text{ lb}_f/\text{in}$

Radial shear load, $V = 0.01 \cdot P \cdot L_s \cdot D_o = 0.01 \cdot 139.63 \cdot 16 \cdot 24.375 = 544.54 \text{ lb}_f$

First moment of area, $Q = 0.44 \cdot 0.3878 = 0.171 \text{ in}^3$

Weld shear flow, $q = \frac{V \cdot Q}{I'} = 431.3382 \text{ lb}_f/\text{in}$

Combined weld load, $f_w = \sqrt{2{,}234.0214^{\ 2} + 431.3382^{\ 2}} = 2{,}275.28 \text{ lb}_f/\text{in}$

Allowable weld stress per UW-18(d) $S_w = 0.55 \cdot S = 0.55 \cdot 20{,}000 = 11{,}000 \text{ psi}$

Fillet weld size required to resist radial pressure and shear

$$t_w = \frac{f_w \cdot (d_{\text{weld segment}} + d_{\text{toe}})}{S_w \cdot d_{\text{weld total}}} + \text{corrosion} = \frac{2{,}275.28 \cdot (3 + 1.5)}{11{,}000 \cdot 6} + 0 = 0.1551 \text{ in}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

Rings #1

ASME Section VIII Division 1, 2021 Edition				
Component		Stiffening Ring		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Attached To		Cylinder #1		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	
No	No	No	No	
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		100	250	-20
External		15	250	

Ring Properties	
Ring type	Flat bar
Description	1/4x1.5 Flat Bar
Corrosion allowance	0"
Distance from ring neutral axis to datum	12"
Distance to previous support	16"
Distance to next support	16"
Internal ring	No
Max depth to thickness ratio	12
Ring distance to centroid	0.75"
Ring area	0.375 in^2
Ring inertia	0.0703 in^4

Welds	
Weld configuration	Staggered intermittent
Fillet weld leg size	0.25"
Length of individual weld segments	3"
Spacing between toes of weld segments	1.5"
Vessel thickness at weld location, new	0.1875"
Vessel corrosion allowance at weld location	0"
Stiffener thickness at weld location	0.25"

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.25"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{135.09 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 135.09} =$	0.0814"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0814 \cdot 1}{0.1875 - 0} =$	0.434
Reduction in MDMT, T_R from Fig UCS-66.1 =	75.7°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 75.7, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

External Pressure, (Corroded & at 250°F) UG-29(a)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.0651} = 374.194$$

From Table G: $A = 2.908\text{E-}04$

From Table CS-2: $B = 4{,}216.38 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o \ / \ t)} = \frac{4 \cdot 4{,}216.38}{3 \cdot (24.375 \ / \ 0.06514)} = 15.02 \text{ psi}$$

$$B = \frac{3}{4} \cdot \left(\frac{P \cdot D_o}{t + A_s \ / \ L_s} \right) = \frac{3}{4} \cdot \left(\frac{15 \cdot 24.375}{0.0651 + 0.375 \ / \ 16} \right) = 3{,}097 \text{ psi}$$

From Table CS-2: $A = 0.00021330$ (ring, 250°F)

$$I_s' = \frac{D_o^2 \cdot L_s \cdot (t + A_s \ / \ L_s) \cdot A}{10.9}$$

$$= \frac{24.375^{\,2} \cdot 16 \cdot (0.0651 + 0.375 \ / \ 16) \cdot 0.00021330}{10.9}$$

$$= 0.0165 \text{ in}^4$$

I' for the composite corroded shell-ring cross section is 0.2159 in^4

As I' >= I_s' a 1/4x1.5 Flat Bar stiffener is adequate for an external pressure of 15 psi.

Check the stiffener ring attachment welds per UG-30

UG-30(f) minimum weld size $= \min [0.25, 0.1875 - 0 - 0, 0.25] + 0 = 0.1875 \text{ in}$

The fillet weld size of 0.25 in is adequate per UG-30(f).

Radial pressure load, $P \cdot L_s = 15 \cdot 16 = 240 \text{ lb}_f/\text{in}$

Radial shear load, $V = 0.01 \cdot P \cdot L_s \cdot D_o = 0.01 \cdot 15 \cdot 16 \cdot 24.375 = 58.5 \text{ lb}_f$

First moment of area, $Q = 0.44 \cdot 0.3878 = 0.171 \text{ in}^3$

Weld shear flow, $q = \frac{V \cdot Q}{I'} = 46.3385 \text{ lb}_f/\text{in}$

Combined weld load, $f_w = \sqrt{240^{\,2} + 46.3385^{\,2}} = 244.43 \text{ lb}_f/\text{in}$

Allowable weld stress per UW-18(d) $S_w = 0.55 \cdot S = 0.55 \cdot 20{,}000 = 11{,}000 \text{ psi}$

Fillet weld size required to resist radial pressure and shear

$$t_w = \frac{f_w \cdot (d_{\text{weld segment}} + d_{\text{toe}})}{S_w \cdot d_{\text{weld total}}} + \text{corrosion} = \frac{244.43 \cdot (3 + 1.5)}{11{,}000 \cdot 6} + 0 = 0.0167 \text{ in}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

Maximum Allowable External Pressure, (Corroded & at 250°F) UG-29(a)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.1875} = 130$$

From Table G: $A = 0.0014$

From Table CS-2: $B = 13{,}613.57 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o \ / \ t)} = \frac{4 \cdot 13{,}613.57}{3 \cdot (24.375 \ / \ 0.1875)} = 139.63 \text{ psi}$$

$$B = \frac{3}{4} \cdot \left(\frac{P \cdot D_o}{t + A_s \ / \ L_s} \right) = \frac{3}{4} \cdot \left(\frac{139.63 \cdot 24.375}{0.1875 + 0.375 \ / \ 16} \right) = 12{,}101 \text{ psi}$$

From Table CS-2: $A = 0.00095942$ (ring, 250°F)

$$I_s' = \frac{D_o^2 \cdot L_s \cdot (t + A_s \ / \ L_s) \cdot A}{10.9}$$

$$= \frac{24.375^{\ 2} \cdot 16 \cdot (0.1875 + 0.375 \ / \ 16) \cdot 0.00095942}{10.9}$$

$$= 0.1765 \text{ in}^4$$

I' for the composite corroded shell-ring cross section is 0.2159 in^4

As I' >= I_s' a 1/4x1.5 Flat Bar stiffener is adequate for an external pressure of 139.63 psi.

Check the stiffener ring attachment welds per UG-30

UG-30(f) minimum weld size $= \min [0.25, 0.1875 - 0 - 0, 0.25] + 0 = 0.1875 \text{ in}$

The fillet weld size of 0.25 in is adequate per UG-30(f).

Radial pressure load, $P \cdot L_s = 139.63 \cdot 16 = 2{,}234.02 \text{ lb}_f/\text{in}$

Radial shear load, $V = 0.01 \cdot P \cdot L_s \cdot D_o = 0.01 \cdot 139.63 \cdot 16 \cdot 24.375 = 544.54 \text{ lb}_f$

First moment of area, $Q = 0.44 \cdot 0.3878 = 0.171 \text{ in}^3$

Weld shear flow, $q = \frac{V \cdot Q}{I'} = 431.3382 \text{ lb}_f/\text{in}$

Combined weld load, $f_w = \sqrt{2{,}234.0214^{\ 2} + 431.3382^{\ 2}} = 2{,}275.28 \text{ lb}_f/\text{in}$

Allowable weld stress per UW-18(d) $S_w = 0.55 \cdot S = 0.55 \cdot 20{,}000 = 11{,}000 \text{ psi}$

Fillet weld size required to resist radial pressure and shear

$$t_w = \frac{f_w \cdot (d_{\text{weld segment}} + d_{\text{toe}})}{S_w \cdot d_{\text{weld total}}} + \text{corrosion} = \frac{2{,}275.28 \cdot (3 + 1.5)}{11{,}000 \cdot 6} + 0 = 0.1551 \text{ in}$$

The fillet weld size of 0.25 in is adequate to resist radial pressure and shear.

Straight Flange on Ellipsoidal Head #2

ASME Section VIII Division 1, 2021 Edition				
Component		Cylinder		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (°F)**	**Design MDMT (°F)**
Internal		150	250	-20
External		15	250	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		2.24	62	1
Test horizontal		1.09	30.1875	1
Dimensions				
Inner Diameter		24"		
Length		2"		
Nominal Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)	**Capacity (US gal)**	
New		8.06	3.92	
Corroded		8.06	3.92	
Radiography				
Longitudinal seam		Seamless No RT		
Top Circumferential seam		Full UW-11(a) Type 1		

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0918"
Design thickness due to external pressure (t_e)	0.0651"
Maximum allowable working pressure (MAWP)	307.36 psi
Maximum allowable pressure (MAP)	309.6 psi
Maximum allowable external pressure (MAEP)	139.63 psi
Rated MDMT	-55 °F

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.1875"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{135.16 \cdot 12}{20{,}000 \cdot 1 - 0.6 \cdot 135.16} =$	0.0814"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0814 \cdot 1}{0.1875 - 0} =$	0.4343
Reduction in MDMT, T_R from Fig UCS-66.1 =	75.6°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 75.6, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 250 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{152.24 \cdot 12}{20{,}000 \cdot 1.00 - 0.60 \cdot 152.24} + 0 = 0.0918"$$

Maximum allowable working pressure, (at 250 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{20{,}000 \cdot 1.00 \cdot 0.1875}{12 + 0.60 \cdot 0.1875} - 2.24 = 307.36 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 0.1875}{12 + 0.60 \cdot 0.1875} = 309.6 \text{ psi}$$

External Pressure, (Corroded & at 250 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.0651} = 374.4084$$

From table G: $A = 0.000291$

From table CS-2: $B = 4{,}212.0919 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 4{,}212.09}{3 \cdot (24.375 / 0.0651)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.0651 + 0 = 0.0651"$$

Maximum Allowable External Pressure, (Corroded & at 250 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{16}{24.375} = 0.6564$$

$$\frac{D_o}{t} = \frac{24.375}{0.1875} = 130.0000$$

From table G: $A = 0.001425$

From table CS-2: $B = 13{,}613.5745 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 13{,}613.57}{3 \cdot (24.375 / 0.1875)} = 139.63 \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.1875}{12.0938}\right) \cdot \left(1 - \frac{12.0938}{\infty}\right) = 0.7752\,\%$$

The extreme fiber elongation does not exceed 5%.

Ellipsoidal Head #2

ASME Section VIII Division 1, 2021 Edition				
Component		Ellipsoidal Head		
Material		SA-516 70 (II-D p. 20, ln. 45)		
Attached To		Cylinder #1		
Impact Tested	Normalized	Fine Grain Practice	PWHT	Maximize MDMT/ No MAWP
No	No	No	No	No
		Design Pressure (psi)	Design Temperature (°F)	Design MDMT (°F)
Internal		150	250	-20
External		15	250	
Static Liquid Head				
Condition		P_s (psi)	H_s (in)	SG
Operating		2.45	68	1
Test horizontal		1.09	30.1875	1
Dimensions				
Inner Diameter		24"		
Head Ratio		2		
Minimum Thickness		0.0916"		
Corrosion	Inner	0"		
	Outer	0"		
Length L_{sf}		2"		
Nominal Thickness t_{sf}		0.1875"		
Weight and Capacity				
		Weight (lb)[1]	Capacity (US gal)[1]	
New		25.43	11.75	
Corroded		25.43	11.75	
Radiography				
Category A joints		Seamless No RT		
Head to shell seam		Full UW-11(a) Type 1		

[1] includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0916"
Design thickness due to external pressure (t_e)	0.0622"
Maximum allowable working pressure (MAWP)	150.1 psi
Maximum allowable pressure (MAP)	152.55 psi
Maximum allowable external pressure (MAEP)	32.5 psi
Straight Flange governs MDMT	-55°F

Design thickness for internal pressure, (Corroded at 250 °F) UG-32(c)(1)

$$t = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{152.45 \cdot 24}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 152.45} + 0 = 0.0915"$$

Maximum allowable working pressure, (Corroded at 250 °F) UG-32(c)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 0.0916}{24 + 0.2 \cdot 0.0916} - 2.45 = 150.1 \text{ psi}$$

Maximum allowable pressure, (New at 70 °F) UG-32(c)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 0.0916}{24 + 0.2 \cdot 0.0916} - 0 = 152.55 \text{ psi}$$

Design thickness for external pressure, (Corroded at 250 °F) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0.8932 \cdot 24.1832 = 21.6012 \text{ in}$

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{21.6012 \ / \ 0.062175} = 0.00036$$

From Table CS-2: B = 5,211.3824 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{5{,}211.3824}{21.6012 \ / \ 0.0622} = 15 \text{ psi}$$

$$t = 0.0622\text{”} + \text{Corrosion} = 0.0622\text{”} + 0\text{”} = 0.0622\text{”}$$

The head external pressure design thickness (t_e) is 0.0622".

Maximum Allowable External Pressure, (Corroded at 250 °F) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0.8932 \cdot 24.1832 = 21.6012 \text{ in}$

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{21.6012 \ / \ 0.0916} = 0.00053$$

From Table CS-2: B = 7,663.7289 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{7{,}663.7289}{21.6012 \ / \ 0.0916} = 32.498 \text{ psi}$$

The maximum allowable external pressure (MAEP) is 32.5 psi.

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 0.1875}{4.1738}\right) \cdot \left(1 - \frac{4.1738}{\infty}\right) = 3.3693\,\%$$

The extreme fiber elongation does not exceed 5%.

Liquid Level bounded by Ellipsoidal Head #2

ASME Section VIII Division 1, 2021 Edition	
Location from Datum (in)	60
Operating Liquid Specific Gravity	1