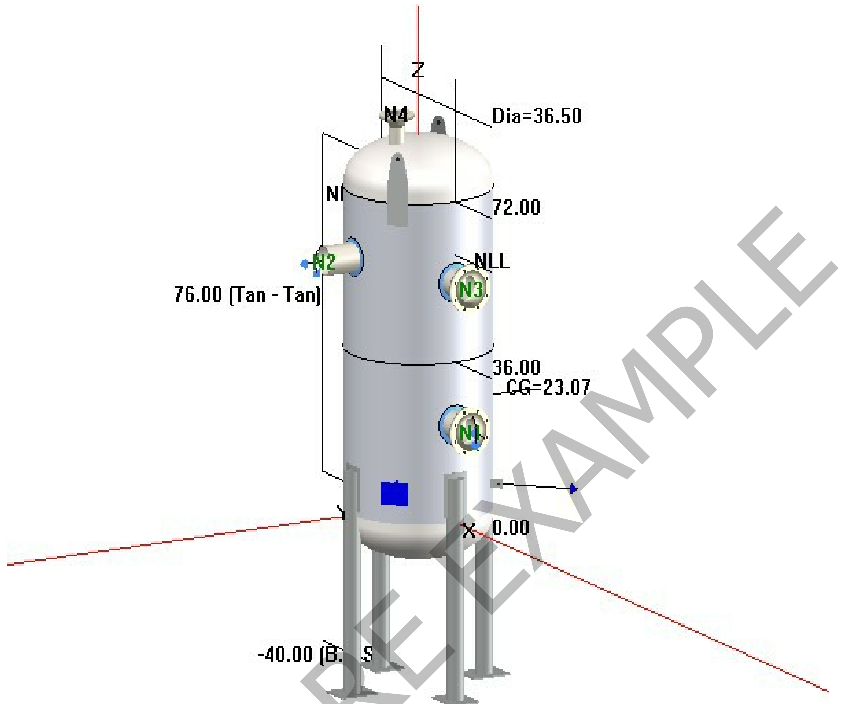
CODEWARE®

6530 Sawyer Loop Rd.

Sarasota, FL, USA 34238



COMPRESS Pressure Vessel Design Calculations

CODEWARE EXAMPLE

Vessel No:	V-123
Customer:	Under Pressure Vessel Fabricators Inc.
Designer:	CTD
Date:	Friday, February 09, 2024
Name:	Vertical Vessel Build 8500
P.O. Number:	123456
Unit Number:	2256-001

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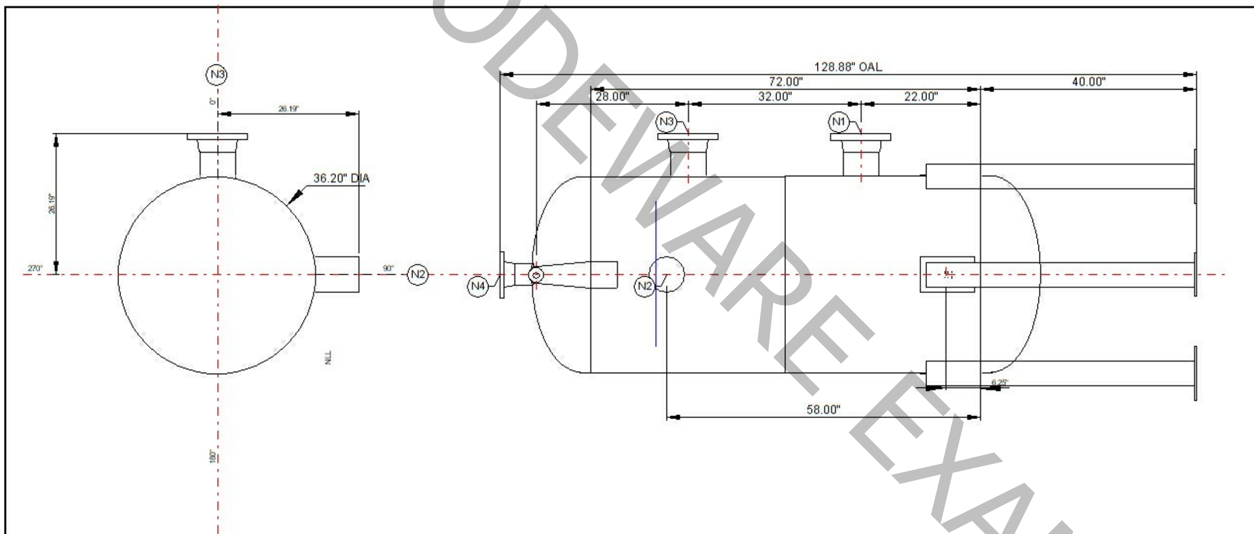

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DESIGN DATA

Design Pressure	100 psi
Vacuum Pressure	15 psi
Test Pressure (Shop)	130 psi
Design Temperature	650 °F
MDMT	-20 °F
Corrosion Allowance	0 "
Radiography	RT1
PWHT	None

Estimated Weights

Dry: 1,001 lb Wet: 3,516 lb

Materials

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

NOZZLE SCHEDULE

MARK	NOZZLE	SIZE & SCH	FLANGE	MARK	NOZZLE	SIZE & SCH	FLANGE
N1	Nozzle #1	6.625 OD x 0.28	NPS 6 WN Class 150				
N3	Nozzle #3	6.625 OD x 0.28	NPS 6 WN Class 150				
N2	Nozzle #2	6.625 OD x 0.28					
N4	Nozzle #4	NPS 3.5 Sch 40 (Std)	NPS 3.5 WN Class 150				

REVISIONS

REV	DATE	DESCRIPTION
0	01/06/2022	FOR APPROVAL

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

DWN BY:
CHK BY:
DATE:

General Arrangement

DWG NO. 145685-1 Rev 0

Vertical Vessel Build 8500.CW7

Deficiencies Summary

Deficiencies for Nozzle #1 (N1)
ASME PCC-1 Equation O-9: The gasket maximum stress is exceeded (Sb_{sel} = 42,000 psi < 17,600 psi).

Deficiencies for Nozzle #2 (N2)
Nozzle #2 (N2) is overstressed for API 660 - Design: "P_L + P_B + Q" (90,171 psi is greater than 56,400 psi).

Warnings Summary

Warnings for Legs #1
As the pad thickness (0.1875 in) is less than the vessel thickness (0.25 in), it is recommended that the attachment be welded directly to the vessel instead of on top of the pad. (warning)

Warnings for Nozzle #1 (N1)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)

Warnings for Nozzle #3 (N3)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)

Warnings for Seismic Code
ASCE 7-22 provisions require a separate design for support legs over 24 in. (610 mm) long. Additional calculations may be required for this equipment support structure. See ASCE 7-22 Commentary, Section C13.6.4. (warning)

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

ASME B16.5 / B16.47 Flange Warnings Summary

Flange	Applicable Warnings
Nozzle #4 (N4)	1, 2
Nozzle #3 (N3)	1, 2
Nozzle #1 (N1)	1, 2

No.	Warning
1	For Class 150 flanges, ASME B16.5 para. 5.4.3 recommends gaskets to be in accordance with Nonmandatory Appendix B, Table B1, Group No. I.
2	For Class 150 flanges when temperature exceeds 400 °F, care should be taken to avoid imposing severe external loads and/or thermal gradients or leakage may develop. ASME B16.5 para. 2.5.2.

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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	NPS 6 Class 150 WN A105	No
			Pad	SA-105	No	No	No		
N2	Nozzle #2	6.625 OD x 0.28	Nozzle	SA-105	No	No	No	N/A	No
			Pad	SA-105	No	No	No		
N3	Nozzle #3	6.625 OD x 0.28	Nozzle	SA-105	No	No	No	NPS 6 Class 150 WN A105	No
			Pad	SA-105	No	No	No		
N4	Nozzle #4	NPS 3.5 Sch 40 (Std)	Nozzle	SA-106 B Smls pipe	No	No	No	NPS 3 1/2 Class 150 WN A105	No

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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	0.192	Yes	Yes	0.25	0.192		1	0.125	0	100.0
N2	6.625	0.28	0.1549	Yes	Yes	0.1875	0.1511		1	0.125	0	100.0
N3	6.625	0.28	0.1549	Yes	Yes	0.1875	0.1549		1	0.125	0	100.0
N4	4	0.226	0.1101	Yes	Yes	0.1007*	0.0867		N/A	N/A	0	100.0
*Head minimum thickness after forming												

Definitions	
t_n	Nozzle thickness
Req t_n	Nozzle thickness required per UG-45/UG-16 Increased for pipe to account for 12.5% pipe thickness tolerance
Nom t	Vessel wall thickness
Design t	Required vessel wall thickness due to pressure + corrosion allowance per UG-37
User t	Local vessel wall thickness (near opening)
A_a	Area available per UG-37, governing condition
A_r	Area required per UG-37, governing condition
Corr	Corrosion allowance on nozzle wall

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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
Ellipsoidal Head #1	100	650	105.12	111.83	15.02	650	-55	Note 1		No
Straight Flange on Ellipsoidal Head #1	100	650	194.62	207.04	18.38	650	-55	Note 2		No
Cylinder #2	100	650	193.75	207.04	18.38	650	-55	Note 3		No
Cylinder #1	100	650	256.79	275.48	36.93	650	-55	Note 4		No
Straight Flange on Ellipsoidal Head #2	100	650	256.72	275.48	36.93	650	-55	Note 6		No
Ellipsoidal Head #2	100	650	193.07	208.12	44.69	650	-55	Note 5		No
Legs #1	100	650	100	N/A	N/A	N/A	N/A	N/A		N/A
Nozzle #1 (N1)	100	650	123.63	211.98	36.93	650	-55	Nozzle	Note 7	No
								Pad	Note 8	No
Nozzle #2 (N2)	100	650	156.85	171.19	18.38	650	-55	Nozzle	Note 9	No
								Pad	Note 10	No
Nozzle #3 (N3)	100	650	124.78	171.19	18.38	650	-55	Nozzle	Note 11	No
								Pad	Note 12	No
Nozzle #4 (N4)	100	650	100.57	103.8	15.02	650	-55	Note 13		No

Chamber Summary	
Design MDMT	-20 °F
Rated MDMT	-20 °F @ 100 psi
MAWP hot & corroded	100 psi @ 650 °F
MAP cold & new	103.8 psi @ 70 °F
MAEP	15.02 psi @ 650 °F

(1) The MAWP is limited due to the MAWP limit set in the Calculations tab of the Set Mode dialog.
(2) The rated MDMT is limited to the design MDMT based on the setting in the Calculations tab of the Set Mode dialog.

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Notes for MDMT Rating		
Note #	Exemption	Details
1.	Straight Flange governs MDMT	
2.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 62.2°F, (coincident ratio = 0.4814) Rated MDMT of -82.2°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 = 61.3°F, (coincident ratio = 0.4856) Rated MDMT of -81.3°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.1875 in
4.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 118.9°F, (coincident ratio = 0.3689) Rated MDMT of -138.9°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.25 in
5.	Straight Flange governs MDMT	
6.	Material impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 118.7°F, (coincident ratio = 0.3692) Rated MDMT of -138.7°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.25 in
7.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 121.5°F, (coincident ratio = 0.3664) Rated MDMT of -141.5°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.25 in.
8.	Pad impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 121.5°F, (coincident ratio = 0.3664) Rated MDMT of -141.5°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.125 in.
9.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 62°F, (coincident ratio = 0.4824) Rated MDMT of -82°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.1875 in.
10.	Pad impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 62°F, (coincident ratio = 0.4824) Rated MDMT of -82°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.125 in.
11.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 61.8°F, (coincident ratio = 0.483) Rated MDMT of -81.8°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.1875 in.
12.	Pad impact test exemption temperature from Fig UCS-66 Curve B = -20°F Fig UCS-66.1 MDMT reduction = 61.8°F, (coincident ratio = 0.483) Rated MDMT of -81.8°F is limited to -55°F by UCS-66(b)(2)	UCS-66 governing thickness = 0.125 in.
13.	Nozzle is impact test exempt per UCS-66(d) (NPS 4 or smaller pipe).	

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Revision History

Revisions			
No.	Date	Operator	Notes
0	1/ 6/2022	christian.dionisio	New vessel created ASME Section VIII Division 1 [COMPRESS 2022 Build 8200]
1	4/18/2024	christian.dionisio	Converted from ASME Section VIII Division 1, 2021 Edition to ASME Section VIII Division 1, 2023 Edition. During the conversion, changes may have been made to your vessel (some may be listed above). Please check your vessel carefully.
2	12/17/2024	christian.dionisio	Converted from ASME Section VIII Division 1, 2023 Edition to ASME Section VIII Division 2, 2023 Edition Class 1. During the conversion, changes may have been made to your vessel (some may be listed above). Please check your vessel carefully.
3	1/13/2025	christian.dionisio	Converted from ASME Section VIII Division 2, 2023 Edition Class 1 to ASME Section VIII Division 1, 2023 Edition. During the conversion, changes may have been made to your vessel (some may be listed above). Please check your vessel carefully.

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Settings Summary

COMPRESS 2025 Build 8510	
ASME Section VIII Division 1, 2023 Edition	
Units	U.S. Customary
Datum Line Location	0.00" from bottom seam
Vessel Design Mode	Rating Mode (Analysis)
Minimum thickness	0.0625" per UG-16(b)
Design for cold shut down only	No
Design for lethal service (full radiography required)	No
Design nozzles for	Design P only
Corrosion weight loss	100% of theoretical loss
UG-23 Stress Increase	1.00
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
Use Code Case 2901-1	No
Use Code Case 3035	No
Apply interpretation VIII-1-83-66	Yes
Apply interpretation VIII-1-86-175	Yes
Apply interpretation VIII-1-01-37	Yes
Apply interpretation VIII-1-01-150	Yes
Apply interpretation VIII-1-07-50	Yes
Apply interpretation VIII-1-16-85	No
No UCS-66.1 MDMT reduction	No
No UCS-68(c) MDMT reduction	No
Disallow UG-20(f) exemptions	No
UG-22 Loadings	
UG-22(a) Internal or External Design Pressure	Yes
UG-22(b) Weight of the vessel and normal contents under operating or test conditions	Yes
UG-22(c) Superimposed static reactions from weight of attached equipment (external loads)	No
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs	Yes
UG-22(f) Wind reactions	No
UG-22(f) Seismic reactions	Yes
UG-22(j) Test pressure and coincident static head acting during the test:	No

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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	81004
Support Expires	June 03, 2027
Account Number	502363524104218

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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	
Ellipsoidal Head #1	N/A	Seamless No RT	N/A	N/A	B	Full UW-11(a) / Type 1	RT1
Cylinder #2	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	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 #4 (N4)	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
Nozzle #2 (N2)	N/A	Seamless No RT	D	N/A / Type 7	B	UW-11(a)(4) exempt	N/A
Nozzle #3 (N3)	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
Nozzle #1 (N1)	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
Nozzle Flange	Longitudinal Seam		Flange Face		Nozzle to Flange Circumferential Seam		
ASME B16.5/16.47 flange attached to Nozzle #4 (N4)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
ASME B16.5/16.47 flange attached to Nozzle #3 (N3)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
ASME B16.5/16.47 flange attached to Nozzle #1 (N1)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
UG-116(e) Required Marking: **RT1**							

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Thickness Summary

Component Data								
Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
Ellipsoidal Head #1	SA-516 70	36 ID	9.1007	0.1007*	0.1007	0	1.00	External
Straight Flange on Ellipsoidal Head #1	SA-516 70	36 ID	2	0.1875	0.1729	0	1.00	External
Cylinder #2	SA-516 70	36 ID	36	0.1875	0.1729	0	1.00	External
Cylinder #1	SA-516 70	36 ID	36	0.25	0.1732	0	1.00	External
Straight Flange on Ellipsoidal Head #2	SA-516 70	36 ID	2	0.25	0.1732	0	1.00	External
Ellipsoidal Head #2	SA-516 70	36 ID	9.1875	0.1875*	0.1007	0	1.00	External
*Head minimum thickness after forming								

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

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Material Summary

Material Data					
Identifier	**Material**	**Impact Tested**	**Normalized**	**Fine Grain**	**PWHT**
Ellipsoidal Head #1	SA-516 70	No	No	No	No
Cylinder #2	SA-516 70	No	No	No	No
Cylinder #1	SA-516 70	No	No	No	No
Ellipsoidal Head #2	SA-516 70	No	No	No	No
Nozzle #1 (N1)	SA-105	No	No	No	No
Nozzle #1 (N1) Pad	SA-105	No	No	No	No
Nozzle #2 (N2)	SA-105	No	No	No	No
Nozzle #2 (N2) Pad	SA-105	No	No	No	No
Nozzle #3 (N3)	SA-105	No	No	No	No
Nozzle #3 (N3) Pad	SA-105	No	No	No	No
Nozzle #4 (N4)	SA-106 B Smls pipe	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #4 (N4)	A105	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #3 (N3)	A105	No	No	No	No
ASME B16.5/16.47 flange attached to Nozzle #1 (N1)	A105	No	No	No	No

Vessel Summary	
Components impact tested	None
Impact Test Temperature	(-50 °F)
Post weld heat treatment	None

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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	
Ellipsoidal Head #1	54.5	54.5	0	0	0	0	0	0	295.2	295.2	13
Cylinder #2	213.5	213.5	0	0	0	0	893.4	893.4	1,335.8	1,335.8	28
Cylinder #1	287.6	287.6	0	0	0	0	1,327.4	1,327.4	1,327.4	1,327.4	28
Ellipsoidal Head #2	96.4	96.4	0	0	0	0	293.9	293.9	293.9	293.9	13
Legs #1	227.2	227.2	0	0	0	0	0	0	0	0	22
TOTAL:	**879.2**	**879.2**	**0**	**0**	**0**	**0**	**2,514.7**	**2,514.7**	**3,252.2**	**3,252.2**	**104**
*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							
Ellipsoidal Head #1	0	0	15.4	15.4	0	0	0	0	0	0	1
Cylinder #2	0	0	47.8	47.8	0	0	0	0	20.9	0	4
Cylinder #1	0	0	33.1	33.1	0	0	0	0	4.6	0	2
Ellipsoidal Head #2	0	0	0	0	0	0	0	0	0	0	0
Legs #1	0	0	0	0	0	0	0	0	0	0	0
TOTAL:	**0**	**0**	**96.3**	**96.3**	**0**	**0**	**0**	**0**	**25.4**	**0**	**7**

Vessel Totals		
	New	Corroded
Operating Weight (lb)	3,516	3,516
Empty Weight (lb)	1,001	1,001
Test Weight (lb)	4,253	4,253
Surface Area (ft^2)	111	-
Capacity** (US gal)	388	388
**The vessel capacity does not include volume of nozzle, piping or other attachments.		

Vessel Lift Condition	
Vessel Lift Weight, New (lb)	1,001
Center of Gravity from Datum (in)	23.069

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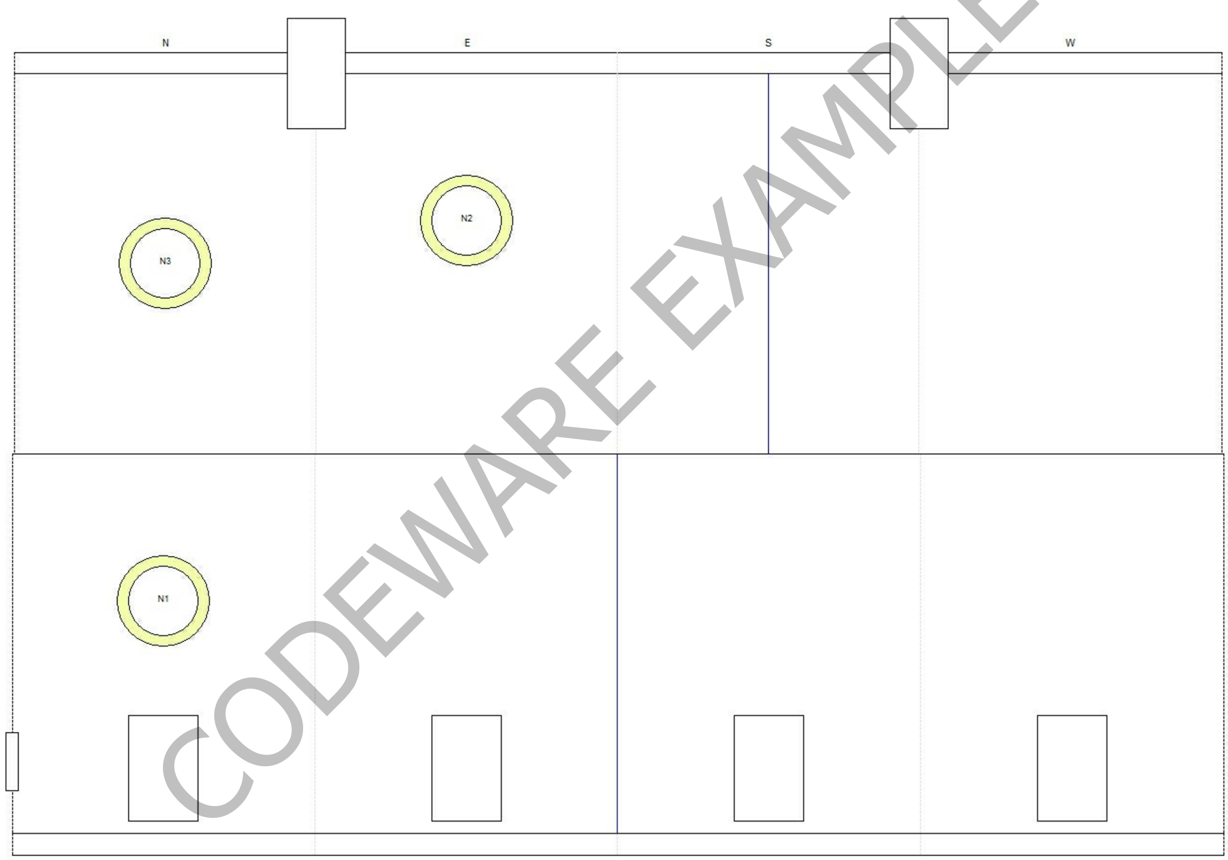
Long Seam Summary

Shell Long Seam Angles	
Component	Seam 1
Cylinder #2	180°
Cylinder #1	135°

Shell Plate Lengths		
Component	Starting Angle	Plate 1
Cylinder #2	180°	113.6864"
Cylinder #1	135°	113.8827"

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 $= 1.3 \cdot MAWP \cdot LSR$

$= 1.3 \cdot 100 \cdot 1$

$= 130 \quad \text{psi}$

Horizontal shop hydrostatic test				
Identifier	**Local test pressure (psi)**	**Test liquid static head (psi)**	**UG-99(b) stress ratio**	**UG-99(b) pressure factor**
Ellipsoidal Head #1	131.595	1.595	1.0638	1.30
Straight Flange on Ellipsoidal Head #1	131.595	1.595	1.0638	1.30
Cylinder #2	131.595	1.595	1.0638	1.30
Cylinder #1	131.595	1.595	1.0638	1.30
Straight Flange on Ellipsoidal Head #2	131.595	1.595	1.0638	1.30
Ellipsoidal Head #2	131.595	1.595	1.0638	1.30
Nozzle #1 (N1)	130.287	0.287	1.1236	1.30
Nozzle #2 (N2)	131.055	1.055	1.1236	1.30
Nozzle #3 (N3)	130.289	0.289	1.1236	1.30
Nozzle #4 (N4) (1)	131.009	1.009	1	1.30
(1) Nozzle #4 (N4) limits the UG-99(b) stress ratio. (2) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.				

The field test condition has not been investigated.

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

Horizontal shop hydrostatic test - Minimum test temperature							
Identifier	**Exempt per UG-20(f)**	**Base Rated MDMT (°F)**	**t_r (in)**	**Ratio**	**MDMT Reduction (°F)**	**Rated MDMT (°F)**	**Minimum Test Temperature (°F)**
Ellipsoidal Head #1	No	-20	0.0915	0.9085	9.2	-29.2	0.8
Straight Flange on Ellipsoidal Head #1	No	-20	0.0917	0.4891	60.5	-55	-25
Cylinder #2	No	-20	0.0917	0.4891	60.5	-55	-25
Cylinder #1	No	-20	0.0917	0.3669	121	-55	-25
Straight Flange on Ellipsoidal Head #2	No	-20	0.0917	0.3669	121	-55	-25
Ellipsoidal Head #2	No	-20	0.0915	0.4879	60.8	-55	-25
Nozzle #1 (N1)	No	-20	0.0917	0.3669	121	-55	-25
Reinforcing pad attached to Nozzle #1 (N1)	No	-20	0.0917	0.3669	121	-55	-25
Flange attached to Nozzle #1 (N1)	No	0	...	0.3519	137.4	-55	-25
Bolts for Nozzle #1 (N1)	...	-55	...	...	...	-55	-25
Nozzle #2 (N2)	No	-20	0.0917	0.4891	60.5	-55	-25
Reinforcing pad attached to Nozzle #2 (N2)	No	-20	0.0917	0.4891	60.5	-55	-25
Nozzle #3 (N3)	No	-20	0.0917	0.4891	60.5	-55	-25
Reinforcing pad attached to Nozzle #3 (N3)	No	-20	0.0917	0.4891	60.5	-55	-25
Flange attached to Nozzle #3 (N3)	No	0	...	0.3519	137.4	-55	-25
Bolts for Nozzle #3 (N3)	...	-55	...	...	...	-55	-25
Nozzle #4 (N4)	No	-55	0.0915	0.9085	9.2	-55	-25
Flange attached to Nozzle #4 (N4)	No	0	...	0.3544	134.5	-55	-25
Bolts for Nozzle #4 (N4)	...	-55	...	...	...	-55	-25
Chamber Rated MDMT	...	-20	...	...	...	-20	**10**
Limit chamber rated MDMT to Design MDMT option is active.							

CODEWARE EXAMPLE

CODEWARE EXAMPLE

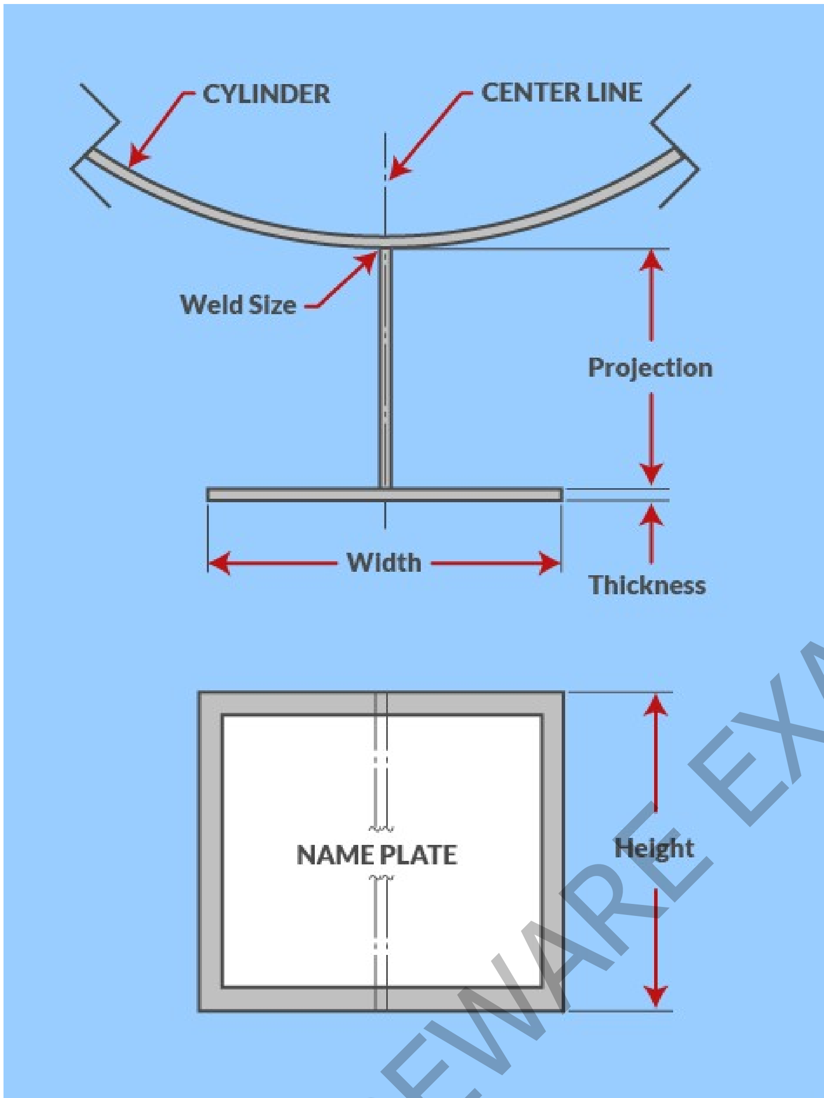
Vacuum Summary

Largest Unsupported Length Le			
Component	**Line of Support**	**Elevation above Datum (in)**	**Length Le (in)**
Ellipsoidal Head #1	-	83.1007	N/A
-	1/3 depth of Ellipsoidal Head #1	77	N/A
Straight Flange on Ellipsoidal Head #1 Top	-	74	82
Straight Flange on Ellipsoidal Head #1 Bottom	-	72	82
Cylinder #2 Top	-	72	82
Cylinder #2 Bottom	-	36	82
Cylinder #1 Top	-	36	82
Cylinder #1 Bottom	-	0	82
Straight Flange on Ellipsoidal Head #2 Top	-	0	82
Straight Flange on Ellipsoidal Head #2 Bottom	-	-2	82
-	1/3 depth of Ellipsoidal Head #2	-5	N/A
Ellipsoidal Head #2	-	-11.1875	N/A

CODEWARE EXAMPLE

Nameplate Summary

Geometry



Orientation	Longitudinal
Projection	3"
Height	5"
Width	7"
Thickness	0.25"
Weld Size	0.1875"
Material	
Attached To	Cylinder #1 (7.5" from bottom end)
Angle	45°

CODEWARE EXAMPLE

Nameplate Content	
National Board Number	NB Number
Certification Mark Designator	U
Manufacturer's Serial Number	Manf. Serial No.
Certified by	Codeware Example
Notes	Nameplate Notes
Construction Type	W
Special Service	
Non Destructive Examination	RT1
PWHT	None
MAWP	100 psi @ 650 °F
MDMT	-20 °F @ 100 psi
MAEP	15.02 psi @ 650 °F

CODEWARE EXAMPLE

Foundation Load Summary

Legs #1: Total Loading at Base				
Load	Vessel Condition	Base Shear (lb_f)	Base Moment (lb_f-ft)	Vertical Force (lb_f)
Weight Only (D)	Operating, Corroded	0	150	3,516
Weight Only (D)	Operating, New	0	150	3,516
Weight Only (D)	Empty, Corroded	0	150	1,001
Weight Only (D)	Empty, New	0	150	1,001
Weight Only (D)	Shop Hydrotest, New	0	150	4,253
Seismic Only (0.7 * E)	Operating, Corroded	656	3,959	394
Seismic Only (0.7 * E)	Operating, New	656	3,959	394
Seismic Only (0.7 * E)	Empty, Corroded	168	1,090	112
Seismic Only (0.7 * E)	Empty, New	168	1,090	112
Seismic Only (0.7 * E)	External Pressure, Corroded	656	3,959	394

All values reported are service loads for Allowable Stress Design (ASD).

Vertical Force values in the Seismic case represent the 0.7 * 0.2 * S_{DS} dead load factor (compressive) as described in the Seismic Code report. The 0.7 term is the ASD load combination factor.

Support Information	
Support Type	Legs
Number of Support Elements (Base Plates)	4
Base Plate Length	10"
Base Plate Width	8"
Base Plate Thickness	0.375"
Number of Anchor Bolts Per Base Plate	1
Bolt Circle Diameter	38.375"
Bolt Size and Type	3/8" coarse bolt
Bolt Hole Clearance	0.375"
Center of Gravity (Distance from Support Base)	63.069"

CODEWARE EXAMPLE

Bill of Materials

Heads						
Item #	Type	Material	Thk [in]	Dia. [in]	Wt. [lb] (ea.)	Qty
H1	Ellipsoidal Head	SA-516 70	0.1007 (min.)	36 ID	54.9	1
H2	Ellipsoidal Head	SA-516 70	0.1875 (min.)	36 ID	96.4	1

Shells							
Item #	Type	Material	Thk [in]	Dia. [in]	Length [in]	Wt. [lb] (ea.)	Qty
S1	Cylinder	SA-516 70	0.1875	36 ID	36	217.2	1
S2	Cylinder	SA-516 70	0.25	36 ID	36	290.1	1

Legs						
Item #	Type	Material	Thk [in]	Length [in]	Wt. [lb]	Qty
L1	4 inch sch 40 pipe	Leg material	0.237	50	56.8	4

Nozzles							
Item #	Type	Material	NPS	Thk [in]	Dia. [in]	Length [in]	Wt. [lb]
Noz1	Nozzle	SA-106 B Smls pipe	NPS 3.5 Sch 40 (Std)	0.226	4 OD	4.5	3.4
Noz2	Nozzle	SA-105	-	0.28	6.625 OD	19.2	33.5

Flanges						
Item #	Type	Material	NPS	Dia. [in]	Wt. [lb] (ea.)	Qty
AF1	ASME B16.5 Welding Neck - Class 150	A105	3 1/2	8.5 x 3.55	12	1
AF2	ASME B16.5 Welding Neck - Class 150	A105	6	11 x 6.07	24	2

Gaskets				
Item #	Type	Size [in]	Thk [in]	Qty
G1	Not specified	6.25 x 6.125	0.175	1
There are 2 flanges that do not include gasket information.				

Fasteners				
Item #	Description	Material	Length [in]	Qty
FB1	5/8" coarse bolt	SA-193 B7 Bolt <= 2 1/2	3	8
FB2	3/4" coarse bolt	SA-193 B7 Bolt <= 2 1/2	3.3	16
SB1	3/8" coarse bolt	Support Leg bolt material	-	4
All listed flange bolts require associated nuts and washers in accordance with Division 1, UCS-11.				

Plates				
Item #	Material	Thk [in]	Wt. [lb]	Qty [ft^2]
Plate1	SA-105	0.125	49.6	1.22
Plate1 - Note: Applies to nozzle pad				
Plate2	Unspecified material	0.1875	13.8	1.81
Plate2 - Note: Applies to support leg plates				
Plate3	Unspecified material	0.375	34	2.22
Plate3 - Note: Applies to support leg base plates				
Plate4	A36	0.5	10.6	0.52
Plate4 - Note: Applies to lift lug plates				
Plate5	A36	0.625	1.1	0.0417
Plate5 - Note: Applies to lift lug plates				
Plate6	Unspecified material	0.25	3.5	0.3472
Plate6 - Note: Applies to nameplate front, nameplate projection				

CODEWARE EXAMPLE

Liquid Level bounded by Ellipsoidal Head #2

ASME Section VIII Division 1, 2023 Edition	
Location from Datum (in)	60
Operating Liquid Specific Gravity	1

CODEWARE EXAMPLE

Ellipsoidal Head #1

ASME Section VIII Division 1, 2023 Edition					
Component		Ellipsoidal Head			
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	650	-20	
External		15	650		
Static Liquid Head					
Condition		P_s (psi)	H_s (in)	SG	
Test horizontal		1.6	44.1875	1	
Dimensions					
Inner Diameter		36"			
Head Ratio		2			
Minimum Thickness		0.1007"			
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		54.55		35.25	
Corroded		54.55		35.25	
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	external pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0958"
Design thickness due to external pressure (t_e)	0.1007"
Maximum allowable working pressure (MAWP)	105.12 psi
Maximum allowable pressure (MAP)	111.83 psi
Maximum allowable external pressure (MAEP)	15.02 psi
Straight Flange governs MDMT	-55°F

Design thickness for internal pressure, (Corroded at 650 °F) UG-32(c)(1)

$$t = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{100 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 100} + 0 = 0.0958"$$

Maximum allowable working pressure, (Corroded at 650 °F) UG-32(c)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 18{,}800 \cdot 1 \cdot 0.1007}{36 + 0.2 \cdot 0.1007} - 0 = 105.12 \text{ psi}$$

CODEWARE EXAMPLE

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

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 0.1007}{36 + 0.2 \cdot 0.1007} - 0 = 111.83 \text{ psi}$$

Design thickness for external pressure, (Corroded at 650 °F) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0.895 \cdot 36.2014 = 32.401$ in

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{32.401 \ / \ 0.100643} = 0.000388$$

From Table CS-2: B = 4,829.0887 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{4{,}829.0887}{32.401 \ / \ 0.1006} = 15 \text{ psi}$$

$$t = 0.1006\text{"} + \text{Corrosion} = 0.1006\text{"} + 0\text{"} = 0.1006\text{"}$$

The head external pressure design thickness (t_e) is 0.1006".

Maximum Allowable External Pressure, (Corroded at 650 °F) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0.895 \cdot 36.2014 = 32.401$ in

$$A = \frac{0.125}{R_o \ / \ t} = \frac{0.125}{32.401 \ / \ 0.1007} = 0.000388$$

From Table CS-2: B = 4,831.7742 psi

$$P_a = \frac{B}{R_o \ / \ t} = \frac{4{,}831.7742}{32.401 \ / \ 0.1007} = 15.0168 \text{ psi}$$

The maximum allowable external pressure (MAEP) is 15.02 psi.

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 0.1875}{6.2138}\right) \cdot \left(1 - \frac{6.2138}{\infty}\right) = 2.2631\,\%$$

The extreme fiber elongation does not exceed 5%.

CODEWARE EXAMPLE

Straight Flange on Ellipsoidal Head #1

ASME Section VIII Division 1, 2023 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	650	-20	
External		15	650		
Static Liquid Head					
Condition		**P_s (psi)**	**H_s (in)**	**SG**	
Test horizontal		1.6	44.1875	1	
Dimensions					
Inner Diameter		36"			
Length		2"			
Nominal Thickness		0.1875"			
Corrosion	**Inner**	0"			
	Outer	0"			
Weight and Capacity					
		Weight (lb)		**Capacity (US gal)**	
New		12.07		8.81	
Corroded		12.07		8.81	
Radiography					
Longitudinal seam		Seamless No RT			
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)	0.0961"
Design thickness due to external pressure (t_e)	0.1729"
Design thickness due to combined loadings + corrosion	0.0478"
Maximum allowable working pressure (MAWP)	194.62 psi
Maximum allowable pressure (MAP)	207.04 psi
Maximum allowable external pressure (MAEP)	18.38 psi
Rated MDMT	-55 °F

CODEWARE EXAMPLE

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.1875"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{100 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 100} =$	0.0903"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0903 \cdot 1}{0.1875 - 0} =$	0.4814
$\text{Stress ratio longitudinal} = \frac{4{,}780 \cdot 1}{20{,}000 \cdot 1} =$	0.239
Reduction in MDMT, T_R from Fig UCS-66.1 =	62.2°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 62.2, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 650 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{100 \cdot 18}{18{,}800 \cdot 1.00 - 0.60 \cdot 100} + 0 = 0.0961"$$

Maximum allowable working pressure, (at 650 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{18{,}800 \cdot 1.00 \cdot 0.1875}{18 + 0.60 \cdot 0.1875} - 0 = 194.62 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 0.1875}{18 + 0.60 \cdot 0.1875} = 207.04 \text{ psi}$$

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{82}{36.375} = 2.2543$$

$$\frac{D_o}{t} = \frac{36.375}{0.1729} = 210.4376$$

From table G: $A = 0.000189$

From table CS-2: $B = 2{,}367.4126 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}367.41}{3 \cdot (36.375/0.1729)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.1729 + 0 = 0.1729"$$

Maximum Allowable External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{82}{36.375} = 2.2543$$

$$\frac{D_o}{t} = \frac{36.375}{0.1875} = 194.0000$$

CODEWARE EXAMPLE

From table G: $A = 0.000213$

From table CS-2: $B = 2{,}674.7775$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}674.78}{3 \cdot (36.375/0.1875)} = 18.38 \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.1875}{18.0938}\right) \cdot \left(1 - \frac{18.0938}{\infty}\right) = 0.5181\,\%$$

The extreme fiber elongation does not exceed 5%.

Thickness Required Due to Pressure + External Loads								
Condition	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Pressure P (psi)	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
	S_t	S_c						
Operating, Hot & Corroded	18,800	8,919	650	0	Seismic	393.31	0.0478	0.0478
Operating, Hot & New	18,800	8,919	650	0	Seismic	393.31	0.0478	0.0478
Hot Shut Down, Corroded	18,800	8,919	650	0	Seismic	0	0	0.0001
Hot Shut Down, New	18,800	8,919	650	0	Seismic	0	0	0.0001
Empty, Corroded	20,000	13,226	70	0	Seismic	0	0	0.0001
Empty, New	20,000	13,226	70	0	Seismic	0	0	0.0001
Vacuum	18,800	8,919	650	0	Seismic	186.49	0.0151	0.0152
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	18,800	8,919	650	0	Seismic	0	0.0001	0.0001

CODEWARE EXAMPLE

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.1875/0.1875} = 0.001289$$

$$B = 8{,}919 \text{ psi}$$

$$S = \frac{18{,}800}{1.00} = 18{,}800 \text{ psi}$$

$$S_{cHC} = \min(B, S) = 8{,}919 \text{ psi}$$

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

$$S_cHN = S_cHC = 8{,}919 \text{ psi}$$

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.1875/0.1875} = 0.001289$$

$$B = 13{,}226 \text{ psi}$$

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

$$S_{cCN} = \min(B, S) = 13{,}226 \text{ psi}$$

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

$$S_c\mathbb{C} = S_cCN = 13{,}226 \text{ psi}$$

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.1875/0.1875} = 0.001289$$

$$B = 8{,}919 \text{ psi}$$

$$S = \frac{18{,}800}{1.00} = 18{,}800 \text{ psi}$$

$$S_{cVC} = \min(B, S) = 8{,}919 \text{ psi}$$

Operating, Hot & Corroded, Seismic, Bottom Seam

CODEWARE EXAMPLE

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

= $\dfrac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

= $\dfrac{277}{\pi \cdot 18.0938\ ^2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

= $\dfrac{0.49*70}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

= $0.0478 + 0 - (0)$

= 0.0478"

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

= $\dfrac{1.11*70}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

= $|0 + (0) - (0.0478)|$

= 0.0478"

Maximum allowable working pressure, Longitudinal Stress

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

= $\dfrac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.1875 - 0 + (0))}{18 - 0.40 \cdot (0.1875 - 0 + (0))}$

= 393.31 psi

Operating, Hot & New, Seismic, Bottom Seam

CODEWARE EXAMPLE

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

$= \frac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

$= \frac{277}{\pi \cdot 18.0938^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= \frac{0.49{*}70}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= 0.0478 + 0 - (0)$

= 0.0478"

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

$= \frac{1.11{*}70}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= |0 + (0) - (0.0478)|$

= 0.0478"

Maximum allowable working pressure, Longitudinal Stress

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

$= \frac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.1875 - 0 + (0))}{18 - 0.40 \cdot (0.1875 - 0 + (0))}$

= 393.31 psi

Hot Shut Down, Corroded, Seismic, Bottom Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \frac{277}{\pi \cdot 18.0938^{\ 2} \cdot 8{,}919.13 \cdot 1.00}$

= 0"

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

$= \frac{0.49*70}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0"

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

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

= 0"

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

$= \frac{1.11*70}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0.0001"

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

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

= 0.0001"

Hot Shut Down, New, Seismic, Bottom Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \frac{277}{\pi \cdot 18.0938^{\ 2} \cdot 8{,}919.13 \cdot 1.00}$

= 0"

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

$= \frac{0.49*70}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0"

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

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

= 0"

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

$= \frac{1.11*70}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0.0001"

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

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

= 0.0001"

Empty, Corroded, Seismic, Bottom Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{266}{\pi \cdot 18.0938^{\ 2} \cdot 13{,}226.29 \cdot 1.00}$

= 0"

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

$= \dfrac{0.49*70}{2 \cdot \pi \cdot 18.0938 \cdot 13{,}226.29 \cdot 1.00}$

= 0"

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

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

= 0"

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

$= \dfrac{1.11*70}{2 \cdot \pi \cdot 18.0938 \cdot 13{,}226.29 \cdot 1.00}$

= 0.0001"

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

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

= 0.0001"

Empty, New, Seismic, Bottom Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{266}{\pi \cdot 18.0938\ ^2 \cdot 13{,}226.29 \cdot 1.00}$

= 0"

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

$= \dfrac{0.49*70}{2 \cdot \pi \cdot 18.0938 \cdot 13{,}226.29 \cdot 1.00}$

= 0"

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

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

= 0"

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

$= \dfrac{1.11*70}{2 \cdot \pi \cdot 18.0938 \cdot 13{,}226.29 \cdot 1.00}$

= 0.0001"

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

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

= 0.0001"

Vacuum, Seismic, Bottom Seam

CODEWARE EXAMPLE

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

= $\frac{-15 \cdot 18}{2 \cdot 8{,}919.13 \cdot 1.00 + 0.40 \cdot |15|}$

= -0.0151

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

= $\frac{277}{\pi \cdot 18.0938\ ^2 \cdot 8{,}919.13 \cdot 1.00}$

= 0"

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

= $\frac{0.49*70}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0"

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

= $|-0.0151 + 0 - (0)|$

= 0.0151"

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

= $\frac{1.11*70}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0.0001"

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

= $0 + (0.0001) - (-0.0151)$

= 0.0152"

Maximum Allowable External Pressure, Longitudinal Stress

P = $\frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0.40 \cdot (t - t_{mc} - t_{wc})}$

= $\frac{2 \cdot 8{,}919.13 \cdot 1.00 \cdot (0.1875 - 0 - 0.0001)}{18 - 0.40 \cdot (0.1875 - 0 - 0.0001)}$

= 186.49 psi

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

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{92}{\pi \cdot 18.0938\ ^2 \cdot 8{,}919.13 \cdot 1.00}$

= 0"

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

$= \dfrac{70}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0.0001"

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

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

= 0.0001"

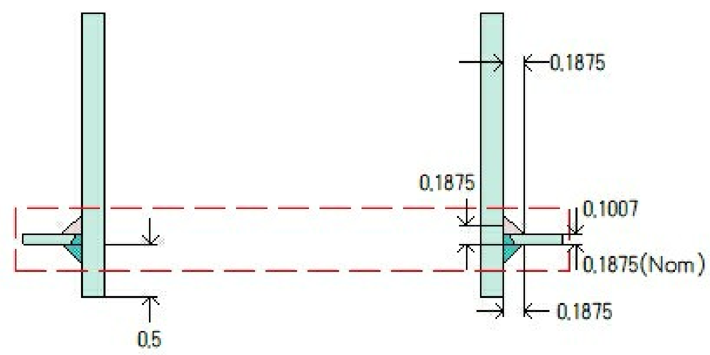
$t_c = t_{mc} + t_{wc} - t_{pc}$ (total required, compressive)

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

= 0.0001"

CODEWARE EXAMPLE

Nozzle #4 (N4)

ASME Section VIII Division 1, 2023 Edition	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Ellipsoidal Head #1
Orientation	90°
End of nozzle to datum line	88.8757"
Calculated as hillside	Yes
Distance to head center, R	6"
Passes through a Category A joint	No
Nozzle	
Description	NPS 3.5 Sch 40 (Std)
Access opening	No
Material specification	SA-106 B Smls pipe (II-D p. 16, ln. 16)
Inside diameter, new	3.548"
Pipe nominal wall thickness	0.226"
Pipe minimum wall thickness[1]	0.1978"
Corrosion allowance	0"
Opening chord length	3.6037"
Projection available outside vessel, Lpr	3.19"
Internal projection, h_{new}	0.5"
Projection available outside vessel to flange face, Lf	6"
Local vessel minimum thickness	0.1007"
Liquid static head included	0 psi
Welds	
Inner fillet, Leg_{41}	0.1875"
Lower fillet, Leg_{43}	0.1875"
Nozzle to vessel groove weld	0.1875"
Radiography	
Longitudinal seam	Seamless No RT
Circumferential seam	Full UW-11(a) Type 1

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

CODEWARE EXAMPLE

ASME B16.5-2020 Flange	
Description	NPS 3.5 Class 150 WN A105
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	125 psi @ 650°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3509) Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, t_g =	0.1007"
Impact test exempt per UCS-66(d) (NPS 4 or smaller pipe) =	-155°F
$t_r = \dfrac{100 \cdot 0.9 \cdot 36}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 100} =$	0.081"
Stress ratio $= \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0.081 \cdot 1}{0.1007 - 0} =$	0.8048
MDMT limited per UCS-68(b) =	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
Impact test exempt per UCS-66(d) (NPS 4 or smaller pipe) =	-155°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

CODEWARE EXAMPLE

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 100 psi @ 650 °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}
0.3142	0.3178	0.0516	0.0987	0.1035	--	0.064	0.0958	0.1978

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 100 psi @ 650 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[3.6037,\ 1.8019 + (0.226 - 0) + (0.1007 - 0)\right]$$
$$= 3.6037\ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0) + 0\right]$$
$$= 0.2518\ \text{in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$
$$= \min\left[0.5,\ 2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0 - 0)\right]$$
$$= 0.2518\ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{100 \cdot 1.774}{17{,}100 \cdot 1 - 0.6 \cdot 100}$$
$$= 0.0104\ \text{in}$$

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

$$t_r = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P}$$
$$= \frac{100 \cdot 0.9 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 100}$$
$$= 0.0862\ \text{in}$$

CODEWARE EXAMPLE

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

$$t_r = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{100 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 100} = 0.0958 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 17,100, S_v = 18,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9096

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9096

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

= $3.6037 \cdot 0.0862 \cdot 1 + 2 \cdot 0.226 \cdot 0.0862 \cdot 1 \cdot (1 - 0.9096)$

= 0.3142 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0516 in^2

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

= $3.6037 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0862) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0862) \cdot (1 - 0.9096)$

= 0.0516 in^2

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

= $2 \cdot (0.1007 + 0.226) \cdot (1 \cdot 0.1007 - 1 \cdot 0.0862) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0862) \cdot (1 - 0.9096)$

= 0.0089 in^2

A_2 = smaller of the following= 0.0987 in^2

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

= $5 \cdot (0.226 - 0.0104) \cdot 0.9096 \cdot 0.1007$

= 0.0987 in^2

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

= $5 \cdot (0.226 - 0.0104) \cdot 0.9096 \cdot 0.226$

= 0.2216 in^2

A_3 = smaller of the following= 0.1035 in^2

= $5 \cdot t \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.1007 \cdot 0.226 \cdot 0.9096$

= 0.1035 in^2

CODEWARE EXAMPLE

$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.226 \cdot 0.226 \cdot 0.9096$

= 0.2323 in^2

$= 2 \cdot h \cdot t_i \cdot f_{r2}$

$= 2 \cdot 0.5 \cdot 0.226 \cdot 0.9096$

= 0.2056 in^2

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

$= 0.1875\ ^2 \cdot 0.9096$

= 0.032 in^2

$A_{43} = Leg^2 \cdot f_{r2}$

$= 0.1875\ ^2 \cdot 0.9096$

= 0.032 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{43}$

$= 0.0516 + 0.0987 + 0.1035 + 0.032 + 0.032$

= 0.3178 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

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

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

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

$$= \frac{100 \cdot 1.774}{17{,}100 \cdot 1 - 0.6 \cdot 100} + 0$$

$$= 0.0104 \text{ in}$$

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

$$= \max\,[0.0104,\ 0]$$

$$= 0.0104 \text{ in}$$

CODEWARE EXAMPLE

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

$$= \frac{100 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 100} + 0$$

$$= 0.0958 \text{ in}$$

$$t_{b1} = \max\left[t_{b1},\ t_{bUG16}\right]$$

$$= \max\left[0.0958,\ 0.0625\right]$$

$$= 0.0958 \text{ in}$$

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

$$= \min\left[0.1978,\ 0.0958\right]$$

$$= 0.0958 \text{ in}$$

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

$$= \max\left[0.0104,\ 0.0958\right]$$

$$= 0.0958 \text{ in}$$

Available nozzle wall thickness new, $t_n = 0.875 \cdot 0.226 = 0.1978$ in

The nozzle neck thickness is adequate.

CODEWARE EXAMPLE

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 = 100.57 psi @ 650 °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}
0.316	0.3161	0.0499	0.0987	0.1035	–	0.064	0.0963	0.1978

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 100.57 psi @ 650 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[3.6037,\ 1.8019 + (0.226 - 0) + (0.1007 - 0)\right]$$

$$= 3.6037 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0) + 0\right]$$

$$= 0.2518 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.5,\ 2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0 - 0)\right]$$

$$= 0.2518 \text{ in}$$

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

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

$$= \frac{100.5665 \cdot 1.774}{17{,}100 \cdot 1 - 0.6 \cdot 100.5665}$$

$$= 0.0105 \text{ in}$$

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

CODEWARE EXAMPLE

$$t_r = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{100.5665 \cdot 0.9 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 100.5665}$$

$$= 0.0867 \text{ in}$$

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

$$t_r = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{100.57 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 100.57} = 0.0963 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 17,100, S_v = 18,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9096

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9096

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

$$= 3.6037 \cdot 0.0867 \cdot 1 + 2 \cdot 0.226 \cdot 0.0867 \cdot 1 \cdot (1 - 0.9096)$$

= 0.316 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0499 in^2

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

$$= 3.6037 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0867) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0867) \cdot (1 - 0.9096)$$

$$= 0.0499 \text{ in}^2$$

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

$$= 2 \cdot (0.1007 + 0.226) \cdot (1 \cdot 0.1007 - 1 \cdot 0.0867) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0867) \cdot (1 - 0.9096)$$

$$= 0.0086 \text{ in}^2$$

A_2 = smaller of the following= 0.0987 in^2

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

$$= 5 \cdot (0.226 - 0.0105) \cdot 0.9096 \cdot 0.1007$$

$$= 0.0987 \text{ in}^2$$

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

$$= 5 \cdot (0.226 - 0.0105) \cdot 0.9096 \cdot 0.226$$

$$= 0.2215 \text{ in}^2$$

A_3 = smaller of the following= 0.1035 in^2

CODEWARE EXAMPLE

$= 5 \cdot t \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.1007 \cdot 0.226 \cdot 0.9096$

$=$ 0.1035 in^2

$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.226 \cdot 0.226 \cdot 0.9096$

$=$ 0.2323 in^2

$= 2 \cdot h \cdot t_i \cdot f_{r2}$

$= 2 \cdot 0.5 \cdot 0.226 \cdot 0.9096$

$=$ 0.2056 in^2

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

$= 0.1875^{\ 2} \cdot 0.9096$

$=$ 0.032 in^2

$A_{43} = Leg^2 \cdot f_{r2}$

$= 0.1875^{\ 2} \cdot 0.9096$

$=$ 0.032 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{43}$

$= 0.0499 + 0.0987 + 0.1035 + 0.032 + 0.032$

$=$ 0.3161 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

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

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

CODEWARE EXAMPLE

UG-45 Nozzle Neck Thickness Check

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

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

$$= \frac{100.5665 \cdot 1.774}{17{,}100 \cdot 1 - 0.6 \cdot 100.5665} + 0$$

$$= 0.0105 \text{ in}$$

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

$$= \max\left[0.0105,\ 0\right]$$

$$= 0.0105 \text{ in}$$

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

$$= \frac{100.57 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 100.57} + 0$$

$$= 0.0963 \text{ in}$$

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

$$= \max\left[0.0963,\ 0.0625\right]$$

$$= 0.0963 \text{ in}$$

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

$$= \min\left[0.1978,\ 0.0963\right]$$

$$= 0.0963 \text{ in}$$

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

$$= \max\left[0.0105,\ 0.0963\right]$$

$$= \underline{0.0963} \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.226$ = 0.1978 in

The nozzle neck thickness is adequate.

CODEWARE EXAMPLE

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 = 103.8 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}
0.3087	0.3088	0.0587	0.0926	0.0973	--	0.0602	0.0935	0.1978

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

Calculations for internal pressure 103.8 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[3.6037,\ 1.8019 + (0.226 - 0) + (0.1007 - 0)\right]$$

$$= 3.6037\ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0) + 0\right]$$

$$= 0.2518\ \text{in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.5,\ 2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0 - 0)\right]$$

$$= 0.2518\ \text{in}$$

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

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

$$= \frac{103.7954 \cdot 1.774}{17{,}100 \cdot 1 - 0.6 \cdot 103.7954}$$

$$= 0.0108\ \text{in}$$

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

$$t_r = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P}$$

$$= \frac{103.7954 \cdot 0.9 \cdot 36}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 103.7954}$$

$$= 0.0841\ \text{in}$$

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

CODEWARE EXAMPLE

$t_r = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} = \frac{103.8 \cdot 36}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 103.8} = 0.0935 \text{ in}$

Area required per UG-37(c)

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

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

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

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

= $3.6037 \cdot 0.0841 \cdot 1 + 2 \cdot 0.226 \cdot 0.0841 \cdot 1 \cdot (1 - 0.855)$

= 0.3087 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0587 in^2

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

= $3.6037 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0841) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0841) \cdot (1 - 0.855)$

= 0.0587 in^2

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

= $2 \cdot (0.1007 + 0.226) \cdot (1 \cdot 0.1007 - 1 \cdot 0.0841) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.0841) \cdot (1 - 0.855)$

= 0.0097 in^2

A_2 = smaller of the following= 0.0926 in^2

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

= $5 \cdot (0.226 - 0.0108) \cdot 0.855 \cdot 0.1007$

= 0.0926 in^2

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

= $5 \cdot (0.226 - 0.0108) \cdot 0.855 \cdot 0.226$

= 0.2079 in^2

A_3 = smaller of the following= 0.0973 in^2

= $5 \cdot t \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.1007 \cdot 0.226 \cdot 0.855$

= 0.0973 in^2

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.226 \cdot 0.226 \cdot 0.855$

= 0.2184 in^2

CODEWARE EXAMPLE

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.5 \cdot 0.226 \cdot 0.855$

= 0.1932 in^2

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

= $0.1875^{\ 2} \cdot 0.855$

= 0.0301 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

= $0.1875^{\ 2} \cdot 0.855$

= 0.0301 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{43}$

$= 0.0587 + 0.0926 + 0.0973 + 0.0301 + 0.0301$

= 0.3088 in^2

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

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

$$= \frac{103.7954 \cdot 1.774}{17{,}100 \cdot 1 - 0.6 \cdot 103.7954} + 0$$

$$= 0.0108 \text{ in}$$

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

$$= \max\left[0.0108,\ 0\right]$$

$$= 0.0108 \text{ in}$$

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

$$= \frac{103.8 \cdot 36}{2 \cdot 20{,}000 \cdot 1 - 0.2 \cdot 103.8} + 0$$

$$= 0.0935 \text{ in}$$

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

$$= \max\left[0.0935,\ 0.0625\right]$$

$$= 0.0935 \text{ in}$$

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

$$= \min\left[0.1978,\ 0.0935\right]$$

$$= 0.0935 \text{ in}$$

CODEWARE EXAMPLE

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

$$= \max\left[0.0108,\ 0.0935\right]$$

$$= 0.0935 \ \text{in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.226$ = 0.1978 in

The nozzle neck thickness is adequate.

CODEWARE EXAMPLE

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 15 psi @ 650 °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}
0.1834	0.2635	0.0002	0.0958	0.1035	--	0.064	0.0625	0.1978

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 @ 650 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[3.6036,\ 1.8018 + (0.226 - 0) + (0.1007 - 0)\right]$$
$$= 3.6036 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0) + 0\right]$$
$$= 0.2518 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$
$$= \min\left[0.5,\ 2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0 - 0)\right]$$
$$= 0.2518 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0168 in

From UG-37(d)(1) required thickness t_r = 0.1006 in

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

Allowable stresses: S_n = 17,100, S_v = 18,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9096

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9096

$$A = 0.5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$$
$$= 0.5 \cdot (3.6036 \cdot 0.1006 \cdot 1 + 2 \cdot 0.226 \cdot 0.1006 \cdot 1 \cdot (1 - 0.9096))$$
$$= 0.1834 \text{ in}^2$$

CODEWARE EXAMPLE

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0002 in^2

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

$$= 3.6036 \cdot (1 \cdot 0.1007 - 1 \cdot 0.1006) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.1006) \cdot (1 - 0.9096)$$

$$= 0.0002 \ \text{in}^2$$

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

$$= 2 \cdot (0.1007 + 0.226) \cdot (1 \cdot 0.1007 - 1 \cdot 0.1006) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.1006) \cdot (1 - 0.9096)$$

$$= 0 \ \text{in}^2$$

A_2 = smaller of the following= 0.0958 in^2

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

$$= 5 \cdot (0.226 - 0.0168) \cdot 0.9096 \cdot 0.1007$$

$$= 0.0958 \ \text{in}^2$$

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

$$= 5 \cdot (0.226 - 0.0168) \cdot 0.9096 \cdot 0.226$$

$$= 0.215 \ \text{in}^2$$

A_3 = smaller of the following= 0.1035 in^2

$$= 5 \cdot t \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.1007 \cdot 0.226 \cdot 0.9096$$

= 0.1035 in^2

$$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.226 \cdot 0.226 \cdot 0.9096$$

= 0.2323 in^2

$$= 2 \cdot h \cdot t_i \cdot f_{r2}$$

$$= 2 \cdot 0.5 \cdot 0.226 \cdot 0.9096$$

= 0.2056 in^2

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

$$= 0.1875^{\,2} \cdot 0.9096$$

= 0.032 in^2

$$A_{43} = Leg^2 \cdot f_{r2}$$

$$= 0.1875^{\,2} \cdot 0.9096$$

= 0.032 in^2

CODEWARE EXAMPLE

$$Area = A_1 + A_2 + A_3 + A_{41} + A_{43}$$
$$= 0.0002 + 0.0958 + 0.1035 + 0.032 + 0.032$$
$$= 0.2635 \text{ in}^2$$

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

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

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

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

$$t_{a\text{UG-28}} = 0.0168 \text{ in}$$

$$t_a = \max[t_{a\text{UG-28}},\ t_{a\text{UG-22}}]$$
$$= \max[0.0168,\ 0]$$
$$= 0.0168 \text{ in}$$

$$t_{b2} = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion}$$
$$= \frac{15 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 15} + 0$$
$$= 0.0144 \text{ in}$$

$$t_{b2} = \max[t_{b2},\ t_{b\text{UG16}}]$$
$$= \max[0.0144,\ 0.0625]$$
$$= 0.0625 \text{ in}$$

$$t_b = \min[t_{b3},\ t_{b2}]$$
$$= \min[0.1978,\ 0.0625]$$
$$= 0.0625 \text{ in}$$

$$t_{\text{UG-45}} = \max[t_a,\ t_b]$$
$$= \max[0.0168,\ 0.0625]$$
$$= 0.0625 \text{ in}$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.226$ = 0.1978 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 650 °F) UG-28(c)

CODEWARE EXAMPLE

$$\frac{L}{D_o} = \frac{6.7121}{4} = 1.6780$$

$$\frac{D_o}{t} = \frac{4}{0.0168} = 238.3010$$

From table G: $A = 0.000214$

From table CS-2: $B = 2{,}680.8813 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}680.88}{3 \cdot (4/0.0168)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$t_a = t + \text{Corrosion} = 0.0168 + 0 =$ 0.0168"

CODEWARE EXAMPLE

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 15.02 psi @ 650 °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}
0.1835	0.2633	--	0.0958	0.1035	--	0.064	0.0625	0.1978

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 15.02 psi @ 650 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[3.6036,\ 1.8018 + (0.226 - 0) + (0.1007 - 0)\right]$$

$$= 3.6036 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0) + 0\right]$$

$$= 0.2518 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.5,\ 2.5 \cdot (0.1007 - 0),\ 2.5 \cdot (0.226 - 0 - 0)\right]$$

$$= 0.2518 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0168 in

From UG-37(d)(1) required thickness t_r = 0.1007 in

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

Allowable stresses: S_n = 17,100, S_v = 18,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9096

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9096

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

$$= 0.5 \cdot (3.6036 \cdot 0.1007 \cdot 1 + 2 \cdot 0.226 \cdot 0.1007 \cdot 1 \cdot (1 - 0.9096))$$

$$= 0.1835 \text{ in}^2$$

CODEWARE EXAMPLE

Area available from FIG. UG-37.1

A_1 = larger of the following= 0 in^2

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

= $3.6036 \cdot (1 \cdot 0.1007 - 1 \cdot 0.1007) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.1007) \cdot (1 - 0.9096)$

= $0 \ \text{in}^2$

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

= $2 \cdot (0.1007 + 0.226) \cdot (1 \cdot 0.1007 - 1 \cdot 0.1007) - 2 \cdot 0.226 \cdot (1 \cdot 0.1007 - 1 \cdot 0.1007) \cdot (1 - 0.9096)$

= $0 \ \text{in}^2$

A_2 = smaller of the following= 0.0958 in^2

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

= $5 \cdot (0.226 - 0.0168) \cdot 0.9096 \cdot 0.1007$

= $0.0958 \ \text{in}^2$

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

= $5 \cdot (0.226 - 0.0168) \cdot 0.9096 \cdot 0.226$

= $0.215 \ \text{in}^2$

A_3 = smaller of the following= 0.1035 in^2

= $5 \cdot t \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.1007 \cdot 0.226 \cdot 0.9096$

= 0.1035 in^2

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.226 \cdot 0.226 \cdot 0.9096$

= 0.2323 in^2

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.5 \cdot 0.226 \cdot 0.9096$

= 0.2056 in^2

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

= $0.1875^{\ 2} \cdot 0.9096$

= 0.032 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

= $0.1875^{\ 2} \cdot 0.9096$

= 0.032 in^2

CODEWARE EXAMPLE

$$
\begin{aligned}
Area &= A_1 + A_2 + A_3 + A_{41} + A_{43} \\
&= 0 + 0.0958 + 0.1035 + 0.032 + 0.032 \\
&= 0.2633 \text{ in}^2
\end{aligned}
$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

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

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

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

$$t_{a\text{UG-28}} = 0.0168 \text{ in}$$

$$
\begin{aligned}
t_a &= \max\left[t_{a\text{UG-28}},\ t_{a\text{UG-22}}\right] \\
&= \max\left[0.0168,\ 0\right] \\
&= 0.0168 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_{b2} &= \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} \\
&= \frac{15.02 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 15.02} + 0 \\
&= 0.0144 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_{b2} &= \max\left[t_{b2},\ t_{b\text{UG16}}\right] \\
&= \max\left[0.0144,\ 0.0625\right] \\
&= 0.0625 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_b &= \min\left[t_{b3},\ t_{b2}\right] \\
&= \min\left[0.1978,\ 0.0625\right] \\
&= 0.0625 \text{ in}
\end{aligned}
$$

$$
\begin{aligned}
t_{\text{UG-45}} &= \max\left[t_a,\ t_b\right] \\
&= \max\left[0.0168,\ 0.0625\right] \\
&= 0.0625 \text{ in}
\end{aligned}
$$

Available nozzle wall thickness new, t_n = $0.875 \cdot 0.226$ = 0.1978 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 650 °F) UG-28(c)

CODEWARE EXAMPLE

$$\frac{L}{D_o} = \frac{6.7121}{4} = 1.6780$$

$$\frac{D_o}{t} = \frac{4}{0.0168} = 238.1977$$

From table G: $A = 0.000214$

From table CS-2: $B = 2{,}682.8523 \ \text{psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}682.85}{3 \cdot (4/0.0168)} = 15.02 \ \text{psi}$$

Design thickness for external pressure P_a = 15.02 psi

$t_a = t + \text{Corrosion} = 0.0168 + 0 =$ 0.0168"

CODEWARE EXAMPLE

Cylinder #2

ASME Section VIII Division 1, 2023 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	650	-20
External		15	650	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		0.87	24	1
Test horizontal		1.6	44.1875	1
Dimensions				
Inner Diameter		36"		
Length		36"		
Nominal Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		213.51		158.63
Corroded		213.51		158.63
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)	0.0969"
Design thickness due to external pressure (t_e)	0.1729"
Design thickness due to combined loadings + corrosion	0.0481"
Maximum allowable working pressure (MAWP)	193.75 psi
Maximum allowable pressure (MAP)	207.04 psi
Maximum allowable external pressure (MAEP)	18.38 psi
Rated MDMT	-55 °F

CODEWARE EXAMPLE

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.1875"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{100.87 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 100.87} =$	0.0911"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0911 \cdot 1}{0.1875 - 0} =$	0.4856
$\text{Stress ratio longitudinal} = \frac{4{,}805 \cdot 1}{20{,}000 \cdot 1} =$	0.2403
Reduction in MDMT, T_R from Fig UCS-66.1 =	61.3°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 61.3, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 650 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{100.87 \cdot 18}{18{,}800 \cdot 1.00 - 0.60 \cdot 100.87} + 0 = 0.0969"$$

Maximum allowable working pressure, (at 650 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{18{,}800 \cdot 1.00 \cdot 0.1875}{18 + 0.60 \cdot 0.1875} - 0.87 = 193.75 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 0.1875}{18 + 0.60 \cdot 0.1875} = 207.04 \text{ psi}$$

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{82}{36.375} = 2.2543$$

$$\frac{D_o}{t} = \frac{36.375}{0.1729} = 210.4376$$

From table G: $A = 0.000189$

From table CS-2: $B = 2{,}367.4126 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}367.41}{3 \cdot (36.375/0.1729)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.1729 + 0 = 0.1729"$$

Maximum Allowable External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{82}{36.375} = 2.2543$$

$$\frac{D_o}{t} = \frac{36.375}{0.1875} = 194.0000$$

CODEWARE EXAMPLE

From table G: $A = 0.000213$

From table CS-2: $B = 2{,}674.7775$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}674.78}{3 \cdot (36.375/0.1875)} = \underline{18.38} \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.1875}{18.0938}\right) \cdot \left(1 - \frac{18.0938}{\infty}\right) = 0.5181\,\%$$

The extreme fiber elongation does not exceed 5%.

External Pressure + Weight + Seismic Loading Check (Bergman, ASME paper 54-A-104)

$$P_v = \frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m} + \frac{M}{\pi \cdot R_m^2} = \frac{1.11 \cdot 352.1}{2 \cdot \pi \cdot 18.0938} + \frac{6{,}412}{\pi \cdot 18.0938^{\ 2}} = 9.6781 \ \text{lb/in}$$

$$\alpha = \frac{P_v}{P_e \cdot D_o} = \frac{9.6781}{15 \cdot 36.375} = 0.0177$$

$$n = 4$$

$$m = \frac{1.23}{\left(\frac{L}{D_o}\right)^2} = \frac{1.23}{\left(\frac{82}{36.375}\right)^2} = 0.242$$

$$RatioP_e = \frac{n^2 - 1 + m + m \cdot \alpha}{n^2 - 1 + m} = \frac{4^2 - 1 + 0.242 + 0.242 \cdot 0.0177}{4^2 - 1 + 0.242} = 1.0003$$

$$RatioP_e \cdot P_e \le \text{MAEP}$$

$$(1.0003 \cdot 15 = 15) \le 18.38$$

Cylinder thickness is satisfactory.

CODEWARE EXAMPLE

Thickness Required Due to Pressure + External Loads								
Condition	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Pressure P (psi)	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
	S_t	S_c						
Operating, Hot & Corroded	18,800	8,919	650	0	Seismic	392.78	0.0481	0.0473
Operating, Hot & New	18,800	8,919	650	0	Seismic	392.78	0.0481	0.0473
Hot Shut Down, Corroded	18,800	8,919	650	0	Seismic	0	0.0003	0.0011
Hot Shut Down, New	18,800	8,919	650	0	Seismic	0	0.0003	0.0011
Empty, Corroded	20,000	13,226	70	0	Seismic	0	0.0001	0.0005
Empty, New	20,000	13,226	70	0	Seismic	0	0.0001	0.0005
Vacuum	18,800	8,919	650	0	Seismic	185.51	0.0146	0.0162
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	18,800	8,919	650	0	Seismic	0	0.0002	0.0005

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.1875/0.1875} = 0.001289$$

$$B = 8{,}919 \quad \text{psi}$$

$$S = \frac{18{,}800}{1.00} = 18{,}800 \quad \text{psi}$$

$S_{cHC} = \min(B, S) =$ 8,919 psi

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

$S_cHN = S_cHC =$ 8,919 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.1875/0.1875} = 0.001289$$

$$B = 13{,}226 \quad \text{psi}$$

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

$S_{cCN} = \min(B, S) =$ 13,226 psi

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

$S_c\mathbb{C} = S_cCN =$ 13,226 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.1875/0.1875} = 0.001289$$

$$B = 8{,}919 \quad \text{psi}$$

$$S = \frac{18{,}800}{1.00} = 18{,}800 \quad \text{psi}$$

$S_{cVC} = \min(B, S) =$ 8,919 psi

Operating, Hot & Corroded, Seismic, Bottom Seam

CODEWARE EXAMPLE

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

= $\frac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

= $\frac{6{,}412}{\pi \cdot 18.0938^{\;2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0003"

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

= $\frac{0.49*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0001"

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

= $0.0478{+}0.0003 - (0.0001)$

= 0.0481"

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

= $\frac{1.11*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0002"

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

= $|0.0003 + (0.0002) - (0.0478)|$

= 0.0473"

Maximum allowable working pressure, Longitudinal Stress

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

= $\frac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.1875 - 0.0003 + (0.0001))}{18 - 0.40 \cdot (0.1875 - 0.0003 + (0.0001))}$

= 392.78 psi

Operating, Hot & New, Seismic, Bottom Seam

CODEWARE EXAMPLE

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

$= \frac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

$= \frac{6{,}412}{\pi \cdot 18.0938^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0003"

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

$= \frac{0.49*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0001"

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

$= 0.0478 + 0.0003 - (0.0001)$

= 0.0481"

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

$= \frac{1.11*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0002"

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

$= |0.0003 + (0.0002) - (0.0478)|$

= 0.0473"

Maximum allowable working pressure, Longitudinal Stress

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

$= \frac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.1875 - 0.0003 + (0.0001))}{18 - 0.40 \cdot (0.1875 - 0.0003 + (0.0001))}$

= 392.78 psi

Hot Shut Down, Corroded, Seismic, Bottom Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$$= \frac{6{,}412}{\pi \cdot 18.0938^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0003"

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

$$= \frac{0.49*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0001"

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

= $0 + 0.0003 - (0.0001)$

= 0.0003"

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

$$= \frac{6{,}412}{\pi \cdot 18.0938^{\ 2} \cdot 8{,}919.13 \cdot 1.00}$$

= 0.0007"

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

$$= \frac{1.11*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$$

= 0.0004"

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

= $0.0007 + (0.0004) - (0)$

= 0.0011"

Hot Shut Down, New, Seismic, Bottom Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$$= \frac{6{,}412}{\pi \cdot 18.0938^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0003"

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

$$= \frac{0.49*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0001"

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

= $0 + 0.0003 - (0.0001)$

= 0.0003"

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

$$= \frac{6{,}412}{\pi \cdot 18.0938^{\ 2} \cdot 8{,}919.13 \cdot 1.00}$$

= 0.0007"

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

$$= \frac{1.11*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$$

= 0.0004"

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

= $0.0007 + (0.0004) - (0)$

= 0.0011"

Empty, Corroded, Seismic, Bottom Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{3{,}436}{\pi \cdot 18.0938\ ^2 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0.0002"

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

$= \dfrac{0.49*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0.0001"

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

$= 0 + 0.0002 - (0.0001)$

= 0.0001"

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

$= \dfrac{3{,}436}{\pi \cdot 18.0938\ ^2 \cdot 13{,}226.29 \cdot 1.00}$

= 0.0003"

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

$= \dfrac{1.11*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 13{,}226.29 \cdot 1.00}$

= 0.0003"

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

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

= 0.0005"

Empty, New, Seismic, Bottom Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$$= \frac{3{,}436}{\pi \cdot 18.0938^{\ 2} \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$$

= 0.0002"

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

$$= \frac{0.49 * 352.1}{2 \cdot \pi \cdot 18.0938 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$$

= 0.0001"

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

$$= 0 + 0.0002 - (0.0001)$$

= 0.0001"

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

$$= \frac{3{,}436}{\pi \cdot 18.0938^{\ 2} \cdot 13{,}226.29 \cdot 1.00}$$

= 0.0003"

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

$$= \frac{1.11 * 352.1}{2 \cdot \pi \cdot 18.0938 \cdot 13{,}226.29 \cdot 1.00}$$

= 0.0003"

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

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

= 0.0005"

Vacuum, Seismic, Bottom Seam

CODEWARE EXAMPLE

$t_p = \dfrac{P \cdot R}{2 \cdot S_c \cdot K_s + 0.40 \cdot |P|}$ (Pressure)

$= \dfrac{-15 \cdot 18}{2 \cdot 8{,}919.13 \cdot 1.00 + 0.40 \cdot |15|}$

= -0.0151

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

$= \dfrac{6{,}412}{\pi \cdot 18.0938^{\ 2} \cdot 8{,}919.13 \cdot 1.00}$

= 0.0007"

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

$= \dfrac{0.49*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0.0002"

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

$= |-0.0151 + 0.0007 - (0.0002)|$

= 0.0146"

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

$= \dfrac{1.11*352.1}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0.0004"

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

$= 0.0007 + (0.0004) - (-0.0151)$

= 0.0162"

Maximum Allowable External Pressure, Longitudinal Stress

$P = \dfrac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0.40 \cdot (t - t_{mc} - t_{wc})}$

$= \dfrac{2 \cdot 8{,}919.13 \cdot 1.00 \cdot (0.1875 - 0.0007 - 0.0004)}{18 - 0.40 \cdot (0.1875 - 0.0007 - 0.0004)}$

= 185.51 psi

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

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{990}{\pi \cdot 18.0938^{\ 2} \cdot 8{,}919.13 \cdot 1.00}$

= 0.0001"

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

$= \dfrac{352.1}{2 \cdot \pi \cdot 18.0938 \cdot 8{,}919.13 \cdot 1.00}$

= 0.0003"

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

$= |0 + 0.0001 - (0.0003)|$

= 0.0002"

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

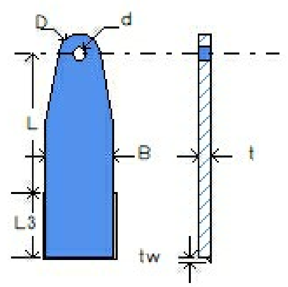
$= 0.0001 + (0.0003) - (0)$

= 0.0005"

CODEWARE EXAMPLE

Ear lug

Geometry Inputs	



Attached To	Cylinder #2
Material	A36
Distance of Lift Point From Datum	82"
Angular Position	45° and 225°
Length, L	10"
Width, B	5"
Thickness, t	0.5"
Hole Diameter, d	1"
Pin Diameter, Dp	0.875"
Diameter at Pin, D	3"
Load Angle from Vertical, ϕ	0°
Has Brace Plate	No
Welds	
Size, t_w	0.25"
Weld Length, L_3	5"

Intermediate Values	
Load Factor	1.5000
Vessel Weight (new, incl. Load Factor), W	1,501.5 lb
Lug Weight (new), W_{lug}	20.9 lb (Qty=2)
Distance from Center of Gravity to Top Lug, l_1	58.931"
Distance from Center of Gravity to Tail Lug, l_2	16.819"
Distance from Vessel Center Line to Tail Lug, l_3	20.25"
Allowable Stress, Tensile, σ_t	19,980 psi
Allowable Stress, Shear, σ_s	13,320 psi
Allowable Stress, Bearing, σ_p	29,970 psi
Allowable Stress, Bending, σ_b	22,201 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	13,320 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

CODEWARE EXAMPLE

Summary Values	
Required Lift Pin Diameter, d_{reqd}	0.1894"
Required Lug Thickness, t_{reqd}	0.0286"
Lug Stress Ratio, σ_{ratio}	0.05
Weld Shear Stress Ratio, τ_{ratio}	0.05
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable
Maximum Out of Plane Lift Angle - Weak Axis Bending	31.64°

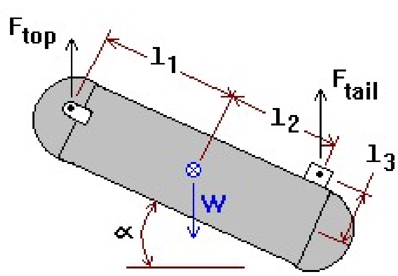
COMPRESS recommends a spreader beam be used to prevent weak axis bending of the top lugs.
No consideration is given for any bracing plate from the lug to the vessel.

Lift Forces

Lift force on lugs during rotational lift (0°≤ α ≤ 90°):

$$2 \cdot F_{\top} = W \cdot \frac{l_2 \cdot \cos(\alpha) + l_3 \cdot \sin(\alpha)}{l_1 \cdot \cos(\alpha) + l_2 \cdot \cos(\alpha) + l_3 \cdot \sin(\alpha)}$$

$$F_{tail} = W - (2 \cdot F)$$



α [°]	F_{top}[lbf]	F_{tail}[lbf]
0	167	1,168
15	206	1,090
30	245	1,012
45	290	922
60	352	798
75	458	585
90	751	0
38[1]	268	966
37[2]	265	972
[1]Lift angle at maximum lug stress.		
[2]Lift angle at maximum weld stress.		
Shell angle at lift lug	0.00°	

Lug Pin Diameter - Shear stress

CODEWARE EXAMPLE

$$d_{\text{reqd}} = \sqrt{\frac{2 \cdot F_v}{\pi \cdot \sigma_s}}$$

$$= \sqrt{\frac{2 \cdot 751}{\pi \cdot 13{,}320}} = 0.1894"$$

$$\frac{d_{reqd}}{D_p} = \frac{0.1894}{0.875} = 0.22$$ Acceptable

$$\sigma = \frac{F_v}{A}$$

$$= \frac{F_v}{2 \cdot (0.25 \cdot \pi \cdot D_p^2)}$$

$$= \frac{751}{2 \cdot (0.25 \cdot \pi \cdot 0.875\ ^2)} = 624 \text{ psi}$$

$$\frac{\sigma}{\sigma_s} = \frac{624}{13{,}320} = 0.05$$ Acceptable

Lug Thickness - Tensile stress

$$t_{\text{reqd}} = \frac{F_v}{(D - d) \cdot \sigma_t}$$

$$= \frac{751}{(3 - 1) \cdot 19{,}980} = 0.0188"$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.0188}{0.5} = 0.04$$ Acceptable

$$\sigma = \frac{F_v}{A}$$

$$= \frac{F_v}{(D - d) \cdot t}$$

$$= \frac{751}{(3 - 1) \cdot 0.5} = 751 \text{ psi}$$

$$\frac{\sigma}{\sigma_t} = \frac{751}{19{,}980} = 0.04$$ Acceptable

Lug Thickness - Bearing stress

$$t_{\text{reqd}} = \frac{F_v}{D_p \cdot \sigma_p}$$

$$= \frac{751}{0.875 \cdot 29{,}970} = 0.0286"$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.0286}{0.5} = 0.06$$ Acceptable

CODEWARE EXAMPLE

$$\sigma = \frac{F_v}{A_{\text{bearing}}}$$

$$= \frac{F_v}{D_p \cdot (t)}$$

$$= \frac{751}{0.875 \cdot (0.5)} = 1{,}716 \text{ psi}$$

$$\frac{\sigma}{\sigma_p} = \frac{1{,}716}{29{,}970} = 0.06 \quad \text{Acceptable}$$

Lug Thickness - Shear stress

$$t_{\text{reqd}} = \frac{\frac{F_v}{\sigma_s}}{2 \cdot L_{\text{shear}}}$$

$$= \frac{\frac{751}{13{,}320}}{2 \cdot 1.1097} = 0.0254''$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.0254}{0.5} = 0.05 \quad \text{Acceptable}$$

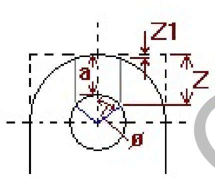
$$\tau = \frac{F_v}{A_{\text{shear}}}$$

$$= \frac{F_v}{2 \cdot t \cdot L_{\text{shear}}}$$

$$= \frac{751}{2 \cdot 0.5 \cdot 1.1097} = 677 \text{ psi}$$

$$\frac{\tau}{\sigma_s} = \frac{677}{13{,}320} = 0.05 \quad \text{Acceptable}$$

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



$$\phi = 55 \cdot \frac{D_p}{d}$$

$$= 55 \cdot \frac{0.875}{1}$$

$$= 48.125^\circ$$

$$Z = 0.5 \cdot (D - d) + 0.5 \cdot D_p \cdot (1 - \cos(\phi))$$

$$= 0.5 \cdot (3 - 1) + 0.5 \cdot 0.875 \cdot (1 - \cos(48.125))$$

$$= 1.1455''$$

$$Z1 = 0.5 \cdot D - \sqrt{0.25 \cdot D \cdot D - (0.5 \cdot D_p \cdot \sin(\phi))^2}$$

$$= 0.5 \cdot 3 - \sqrt{0.25 \cdot 3 \cdot 3 - (0.5 \cdot 0.875 \cdot \sin(48.125))^2}$$

$$= 0.0358''$$

$$L_{\text{shear}} = Z - Z1$$

$$= 1.1097''$$

CODEWARE EXAMPLE

Lug Plate Stress

Lug stress, tensile + bending, during rotational lift:

$$\sigma_{\text{ratio}} = \left[\frac{F_{\text{ten}}}{A_{\text{ten}} \cdot \sigma_t}\right] + \left[\frac{M_{\text{bend}}}{Z +_{\text{bend}} \cdot \sigma_b}\right] \leq 1$$

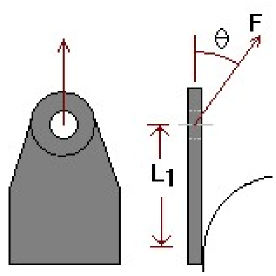
$$= \left[\frac{F_{\text{top}}(\alpha) \cdot \sin(\alpha)}{t \cdot B \cdot \sigma_t}\right] + \left[\frac{6 \cdot F_{\text{top}}(\alpha) \cdot L \cdot \cos(\alpha)}{t \cdot B_2 \cdot \sigma_b}\right] \leq 1$$

$$= 268 \cdot \frac{\sin(38.0)}{0.5 \cdot 5 \cdot 19{,}980} + 6 \cdot (268) \cdot 10 \cdot \frac{\cos(38.0)}{0.5 \cdot 5^2 \cdot 22{,}201}$$

= 0.05 Acceptable

Weak Axis Bending Stress

Maximum lift cable angle from vertical θ = 31.64°



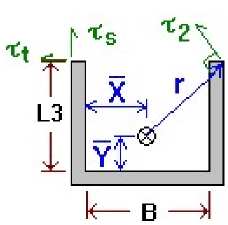
$$\sigma_b = \frac{M}{Z} = \frac{F \cdot \sin(\theta) \cdot L_1}{Z}$$

$$F \cdot \cos(\theta) = 0.5 \cdot W \quad \Rightarrow \quad F = 0.5 \cdot \frac{W}{\cos(\theta)}$$

$$\theta = \arctan\left(\frac{2 \cdot \sigma_b \cdot Z}{W \cdot L_1}\right)$$

$$\theta = \arctan\left(\frac{2 \cdot 22{,}201 \cdot \left(5 \cdot \frac{0.5^2}{6}\right)}{1{,}502 \cdot 10}\right) = 31.64\,^\circ$$

Weld Stress



Weld stress, direct and torsional shear, during rotational lift:

Direct shear:

Maximum weld shear stress occurs at lift angle 37.00°; lift force = 265 lb_f

$$A_{weld} = 0.707 \cdot t_w \cdot (2 \cdot L_3 + B)$$

$$= 0.707 \cdot 0.25 \cdot (2 \cdot 5 + 5) = 2.6512 \text{ in}^2$$

CODEWARE EXAMPLE

$$\tau_t = F_{\text{lug}} \cdot \frac{\cos(\alpha)}{A_{\text{weld}}}$$

$$= 265 \cdot \frac{\cos(37.0)}{2.6512} = 80 \text{ psi}$$

$$\tau_s = F_{\text{lug}} \cdot \frac{\sin(\alpha)}{A_{\text{weld}}}$$

$$= 265 \cdot \frac{\sin(37.0)}{2.6512} = 60 \text{ psi}$$

Torsional shear:

Weld centroid:

$$Y_{\text{bar}} = \frac{L_3^2}{2 \cdot L_3 + B}$$

$$= \frac{5^2}{2 \cdot 5 + 5} = 1.6667$$

Second polar moment of area:

$$J = 0.707 \cdot t_w \cdot \left(\frac{8 \cdot L_3^3 + 6 \cdot L_3 \cdot B^2 + B^3}{12} - \frac{L_3^4}{2 \cdot L_3 + B} \right)$$

$$= 0.707 \cdot 0.25 \cdot \left(\frac{8 \cdot 5^3 + 6 \cdot 5 \cdot 5^2 + 5^3}{12} - \frac{5^4}{2 \cdot 5 + 5} \right) = 20.25 \text{ in}^4$$

Radial distance from centroid to weld:

$$r = \sqrt{(X_{\text{bar}})^2 + (L_3 - Y_{\text{bar}})^2}$$

$$= \sqrt{(0.5 \cdot 5)^2 + (5 - 1.6667)^2} = 4.1667"$$

$$\theta_r = \arctan\left(\frac{L_3 - Y_{\text{bar}}}{X_{\text{bar}}} \right)$$

$$= \arctan\left(\frac{3.3333}{2.5} \right) = 53.13^\circ$$

CODEWARE EXAMPLE

$$\tau_2 = M \cdot \frac{r}{J}$$

$$= [F(\alpha) \cdot \cos(\alpha) \cdot (L + L_3 - Y_{\text{bar}})] \cdot \frac{r}{J}$$

$$= (265 \cdot \cos(37.0) \cdot 13.3333) \cdot \frac{4.1667}{20.2526}$$

= 580 psi

$$\tau_{ratio} = \frac{\sqrt{(\tau_t + \tau_2 \cdot \sin(\theta_r))^{\,2} + (\tau_s + \tau_2 \cdot \cos(\theta_r))^{\,2}}}{\tau_{\text{allowable}}} \leq 1$$

$$= \frac{\sqrt{(80 + 580 \cdot \sin(53.13))^{\,2} + (60 + 580 \cdot \cos(53.13))^{\,2}}}{13{,}320}$$

= 0.05 Acceptable

WRC 537 Analysis

Maximum stress ratio occurs at lift angle = 90.00° with lift force = 751 lb_f

Geometry	
Height (radial)	0.5"
Width (circumferential)	5"
Length	5"
Fillet Weld Size:	0.25"
Located On	Cylinder #2 (5" from top end)
Location Angle	45.00° and 225.00°

Applied Loads	
Radial load, P_r	0 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	187.7 lb_f-in
Longitudinal shear, V_L	750.76 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	18.0938"
Design factor	3

CODEWARE EXAMPLE

Maximum stresses due to the applied loads at the lug edge

$$\gamma = \frac{R_m}{T} = \frac{18.0938}{0.1875} = 96.5$$

$$C_1 = 2.75, C_2 = 2.75 \ \ \text{in}$$

Local circumferential pressure stress $= \dfrac{P \cdot R_i}{T} = 0 \ \ \text{psi}$

Local longitudinal pressure stress $= \dfrac{P \cdot R_i}{2 \cdot T} = 0 \ \ \text{psi}$

Maximum combined stress $(P_L + P_b + Q) = 728 \ \ \text{psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 60{,}000 \ \ \text{psi}$

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

Maximum local primary membrane stress $(P_L) = -180 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 30{,}000 \text{ psi}$

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

CODEWARE EXAMPLE

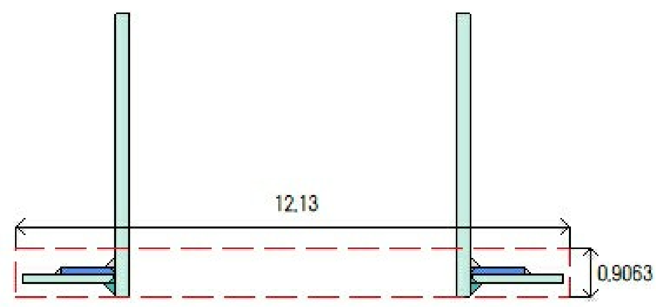
Stresses at the lug edge per WRC Bulletin 537										
Figure	Y	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	7.6636	0.152	0	0	0	0	0	0	0	0
4C*	13.2299	0.152	0	0	0	0	0	0	0	0
1C	0.0584	0.152	0	0	0	0	0	0	0	0
2C-1	0.0298	0.152	0	0	0	0	0	0	0	0
3A*	4.0076	0.152	0	0	0	0	0	0	0	0
1A	0.0682	0.152	0	0	0	0	0	0	0	0
3B*	8.9462	0.152	-180	-180	180	180	0	0	0	0
1B-1	0.0205	0.152	-238	238	238	-238	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			-418	58	418	-58	0	0	0	0
Primary membrane circumferential stress*			-180	-180	180	180	0	0	0	0
3C*	7.6636	0.152	0	0	0	0	0	0	0	0
4C*	13.2299	0.152	0	0	0	0	0	0	0	0
1C-1	0.0609	0.152	0	0	0	0	0	0	0	0
2C	0.03	0.152	0	0	0	0	0	0	0	0
4A*	8.5067	0.152	0	0	0	0	0	0	0	0
2A	0.031	0.152	0	0	0	0	0	0	0	0
4B*	3.6974	0.152	-74	-74	74	74	0	0	0	0
2B-1	0.0276	0.152	-322	322	322	-322	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			-396	248	396	-248	0	0	0	0
Primary membrane longitudinal stress*			-74	-74	74	74	0	0	0	0
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	-364	-364	364	364
Total Shear stress			0	0	0	0	-364	-364	364	364
Combined stress (P_L+P_b+Q)			-418	248	418	-248	728	728	728	728

* denotes primary stress.

CODEWARE EXAMPLE

Nozzle #2 (N2)

ASME Section VIII Division 1, 2023 Edition	



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

Location and Orientation	
Located on	Cylinder #2
Orientation	90°
Nozzle center line offset to datum line	58"
End of nozzle to shell center	26.1875"
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	8"
Internal projection, h_{new}	0.25"
Local vessel minimum thickness	0.1875"
Liquid static head included	0.18 psi
Reinforcing Pad	
Material specification	SA-105 (II-D p. 20, ln. 31)
Diameter, D_p	8.625"
Thickness, t_e	0.125"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.1875"
Outer fillet, Leg_{42}	0.125"
Lower fillet, Leg_{43}	0.25"
Nozzle to vessel groove weld	0.1875"
Pad groove weld	0.125"
Radiography	
Longitudinal seam	Seamless No RT
Circumferential seam	Spot UW-11(b) Type 1

CODEWARE EXAMPLE

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, t_g =	0.1875"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{100.18 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 100.18} =$	0.0904"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0904 \cdot 1}{0.1875 - 0} =$	0.4824
$\text{Stress ratio longitudinal} = \frac{4{,}781 \cdot 1}{20{,}000 \cdot 1} =$	0.2391
Reduction in MDMT, T_R from Fig UCS-66.1 =	62°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 62, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = \frac{100.18 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 100.18} =$	0.0152"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0152 \cdot 1}{0.28 - 0} =$	0.0544
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.	

UCS-66 Material Toughness Requirements Pad	
Governing thickness, t_g =	0.125"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{100.18 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 100.18} =$	0.0904"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0904 \cdot 1}{0.1875 - 0} =$	0.4824
$\text{Stress ratio longitudinal} = \frac{4{,}781 \cdot 1}{20{,}000 \cdot 1} =$	0.2391
Reduction in MDMT, T_R from Fig UCS-66.1 =	62°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 62, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

CODEWARE EXAMPLE

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 100.18 psi @ 650 °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}
0.5865	1.2608	0.5508	0.2334	0.1326	0.2367	0.1073	0.0962	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
1,580.97	9,742.16	49,542.67	10,487.88	83,989.77	15,216.08	64,607.69

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for internal pressure 100.18 psi @ 650 °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

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.4688\ \text{in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25\ \text{in}$$

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

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

$$= \frac{100.1817 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 100.1817}$$

$$= 0.0171\ \text{in}$$

Required thickness t_r from UG-37(a)

CODEWARE EXAMPLE

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

= $\frac{100.1817 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 100.1817}$

= 0.0962 in

Area required per UG-37(c)

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

= $6.065 \cdot 0.0962 \cdot 1 + 2 \cdot 0.28 \cdot 0.0962 \cdot 1 \cdot (1 - 0.9468)$

= 0.5865 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.5508 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0962) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0962) \cdot (1 - 0.9468)$

= 0.5508 in^2

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.0962) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0962) \cdot (1 - 0.9468)$

= 0.0826 in^2

A_2 = smaller of the following= 0.2334 in^2

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

= $5 \cdot (0.28 - 0.0171) \cdot 0.9468 \cdot 0.1875$

= 0.2334 in^2

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

= $2 \cdot (0.28 - 0.0171) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$

= 0.4107 in^2

A_3 = smaller of the following= 0.1326 in^2

CODEWARE EXAMPLE

= $5 \cdot t \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.1875 \cdot 0.28 \cdot 0.9468$

= 0.2485 in^2

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

= 0.3711 in^2

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

= 0.1326 in^2

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

= $0.1875^{\ 2} \cdot 0.9468$

= 0.0333 in^2

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

= $0.125^{\ 2} \cdot 0.9468$

= 0.0148 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

= $0.25^{\ 2} \cdot 0.9468$

= 0.0592 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

= 0.2367 in^2

$Area$ = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

= $0.5508 + 0.2334 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

= 1.2608 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\left[0.75,\ t_n,\ t_e\right] =$ 0.125 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\left[0.75,\ t_e,\ t\right] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

CODEWARE EXAMPLE

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

$$= \frac{100.1817 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 100.1817} + 0$$

$$= 0.0171 \ \text{in}$$

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

$$= \max\left[0.0171,\ 0\right]$$

$$= 0.0171 \ \text{in}$$

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

$$= \frac{100.1817 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 100.1817} + 0$$

$$= 0.0962 \ \text{in}$$

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

$$= \max\left[0.0962,\ 0.0625\right]$$

$$= 0.0962 \ \text{in}$$

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

$$= \min\left[0.245,\ 0.0962\right]$$

$$= 0.0962 \ \text{in}$$

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

$$= \max\left[0.0171,\ 0.0962\right]$$

$$= 0.0962 \ \text{in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 18{,}800$ =	13,912 psi
Nozzle wall in shear:	$0.7 \cdot 17{,}800$ =	12,460 psi
Inner fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi
Outer fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi
Upper groove weld in tension:	$0.74 \cdot 17{,}800$ =	13,172 psi
Lower fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi

Strength of welded joints:

(1) Inner fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 8{,}722$ = 17,018.57 lb_f

(2) Outer fillet weld in shear

CODEWARE EXAMPLE

$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 8{,}722$ = 14,770.84 lb_f

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 12{,}460$ = 34,771.83 lb_f

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 13{,}912$ = 27,145.42 lb_f

(5) Lower fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 8{,}722$ = 22,691.43 lb_f

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 13{,}172$ = 17,134.34 lb_f

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

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(0.5865 - 0.5508 + 2 \cdot 0.28 \cdot 0.9468 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0962)) \cdot 18{,}800$

= 1,580.97 lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.2334 + 0.2367 + 0.0333 + 0.0148) \cdot 18{,}800$

= 9,742.16 lb_f

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

= $(0.2334 + 0.1326 + 0.0333 + 0.0592 + 2 \cdot 0.28 \cdot 0.1875 \cdot 0.9468) \cdot 18{,}800$

= 10,487.88 lb_f

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

= $(0.2334 + 0.1326 + 0.2367 + 0.0333 + 0.0148 + 0.0592 + 2 \cdot 0.28 \cdot 0.1875 \cdot 0.9468) \cdot 18{,}800$

= 15,216.08 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 1,580.97 lb_f
Path 1-1 through (2) & (3) = 14,770.84 + 34,771.83 = 49,542.67 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} = 1,580.97 lb_f
Path 2-2 through (1), (4), (5), (6) = 17,018.57 + 27,145.42 + 22,691.43 + 17,134.34 = 83,989.77 lb_f
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or W_{3-3} = 1,580.97 lb_f
Path 3-3 through (2), (4), (5) = 14,770.84 + 27,145.42 + 22,691.43 = 64,607.69 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

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 = 157.03 psi @ 650 °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}
0.9209	0.921	0.2197	0.2247	0.1326	0.2367	0.1073	0.1511	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
13,545.83	9,578.6	49,542.67	10,324.32	83,989.77	15,052.52	64,607.69

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for internal pressure 157.03 psi @ 650 °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

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.4688 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

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

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

$$= \frac{157.0282 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 157.0282}$$

$$= 0.0269 \text{ in}$$

Required thickness t_r from UG-37(a)

CODEWARE EXAMPLE

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

= $\frac{157.0282 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 157.0282}$

= 0.1511 in

Area required per UG-37(c)

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

= $6.065 \cdot 0.1511 \cdot 1 + 2 \cdot 0.28 \cdot 0.1511 \cdot 1 \cdot (1 - 0.9468)$

= 0.9209 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.2197 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1511) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1511) \cdot (1 - 0.9468)$

= 0.2197 in^2

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1511) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1511) \cdot (1 - 0.9468)$

= 0.0329 in^2

A_2 = smaller of the following= 0.2247 in^2

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

= $5 \cdot (0.28 - 0.0269) \cdot 0.9468 \cdot 0.1875$

= 0.2247 in^2

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

= $2 \cdot (0.28 - 0.0269) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$

= 0.3954 in^2

A_3 = smaller of the following= 0.1326 in^2

CODEWARE EXAMPLE

$= 5 \cdot t \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.1875 \cdot 0.28 \cdot 0.9468$

$= 0.2485$ in^2

$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

$= 0.3711$ in^2

$= 2 \cdot h \cdot t_i \cdot f_{r2}$

$= 2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

$= 0.1326$ in^2

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

$= 0.1875^2 \cdot 0.9468$

$= 0.0333$ in^2

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

$= 0.125^2 \cdot 0.9468$

$= 0.0148$ in^2

$A_{43} = Leg^2 \cdot f_{r2}$

$= 0.25^2 \cdot 0.9468$

$= 0.0592$ in^2

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

$= (8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

$= 0.2367$ in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.2197 + 0.2247 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

$= 0.921$ in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\,[0.75,\ t_n,\ t_e] =$ 0.125 in

$t_{c(\min)} = \min\,[0.25,\ 0.7 \cdot t_{\min}] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\,[0.75,\ t_e,\ t] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

CODEWARE EXAMPLE

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

$$= \frac{157.0282 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 157.0282} + 0$$

$$= 0.0269 \text{ in}$$

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

$$= \max\left[0.0269,\ 0\right]$$

$$= 0.0269 \text{ in}$$

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

$$= \frac{157.0282 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 157.0282} + 0$$

$$= 0.1511 \text{ in}$$

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

$$= \max\left[0.1511,\ 0.0625\right]$$

$$= 0.1511 \text{ in}$$

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

$$= \min\left[0.245,\ 0.1511\right]$$

$$= 0.1511 \text{ in}$$

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

$$= \max\left[0.0269,\ 0.1511\right]$$

$$= 0.1511 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 18{,}800$	=	13,912 psi
Nozzle wall in shear:	$0.7 \cdot 17{,}800$	=	12,460 psi
Inner fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi
Outer fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi
Upper groove weld in tension:	$0.74 \cdot 17{,}800$	=	13,172 psi
Lower fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi

Strength of welded joints:

(1) Inner fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 8{,}722$ = 17,018.57 lb_f

(2) Outer fillet weld in shear

CODEWARE EXAMPLE

$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 8{,}722$ = 14,770.84 lb_f

(3) Nozzle wall in shear

$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 12{,}460$ = 34,771.83 lb_f

(4) Groove weld in tension

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 13{,}912$ = 27,145.42 lb_f

(5) Lower fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 8{,}722$ = 22,691.43 lb_f

(6) Upper groove weld in tension

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 13{,}172$ = 17,134.34 lb_f

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

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(0.9209 - 0.2197 + 2 \cdot 0.28 \cdot 0.9468 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1511)) \cdot 18{,}800$

= 13,545.83 lb_f

$W_{1\text{-}1}$ = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.2247 + 0.2367 + 0.0333 + 0.0148) \cdot 18{,}800$

= 9,578.6 lb_f

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

= $(0.2247 + 0.1326 + 0.0333 + 0.0592 + 2 \cdot 0.28 \cdot 0.1875 \cdot 0.9468) \cdot 18{,}800$

= 10,324.32 lb_f

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

= $(0.2247 + 0.1326 + 0.2367 + 0.0333 + 0.0148 + 0.0592 + 2 \cdot 0.28 \cdot 0.1875 \cdot 0.9468) \cdot 18{,}800$

= 15,052.52 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 9,578.6 lb_f
Path 1-1 through (2) & (3) = 14,770.84 + 34,771.83 = 49,542.67 lb_f
Path 1-1 is stronger than $W_{1\text{-}1}$ so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 10,324.32 lb_f
Path 2-2 through (1), (4), (5), (6) = 17,018.57 + 27,145.42 + 22,691.43 + 17,134.34 = 83,989.77 lb_f
Path 2-2 is stronger than $W_{2\text{-}2}$ so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 13,545.83 lb_f
Path 3-3 through (2), (4), (5) = 14,770.84 + 27,145.42 + 22,691.43 = 64,607.69 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

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 = 171.19 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}
0.9392	0.9393	0.198	0.238	0.14	0.25	0.1133	0.1549	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
15,190.09	10,776	55,665.92	11,614	92,748.16	16,926	70,970.54

Calculations for internal pressure 171.19 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

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.4688 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

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

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

$$= \frac{171.188 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 171.188}$$

$$= 0.0261 \text{ in}$$

Required thickness t_r from UG-37(a)

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

$$= \frac{171.188 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 171.188}$$

$$= 0.1549 \text{ in}$$

CODEWARE EXAMPLE

Area required per UG-37(c)

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

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

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

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 1

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

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

$$= 6.065 \cdot 0.1549 \cdot 1 + 2 \cdot 0.28 \cdot 0.1549 \cdot 1 \cdot (1 - 1)$$

= 0.9392 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.198 in^2

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

$$= 6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549) \cdot (1 - 1)$$

$$= 0.198 \ \text{in}^2$$

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

$$= 2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549) \cdot (1 - 1)$$

$$= 0.0305 \ \text{in}^2$$

A_2 = smaller of the following= 0.238 in^2

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

$$= 5 \cdot (0.28 - 0.0261) \cdot 1 \cdot 0.1875$$

$$= 0.238 \ \text{in}^2$$

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

$$= 2 \cdot (0.28 - 0.0261) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 1$$

$$= 0.4189 \ \text{in}^2$$

A_3 = smaller of the following= 0.14 in^2

$$= 5 \cdot t \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.1875 \cdot 0.28 \cdot 1$$

= 0.2625 in^2

CODEWARE EXAMPLE

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.28 \cdot 0.28 \cdot 1$

= 0.392 in^2

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.25 \cdot 0.28 \cdot 1$

= 0.14 in^2

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

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

= 0.0352 in^2

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

= $0.125^{\,2} \cdot 1$

= 0.0156 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

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

= 0.0625 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 1$

= 0.25 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.198 + 0.238 + 0.14 + 0.0352 + 0.0156 + 0.0625 + 0.25$

= 0.9393 in^2

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$= \frac{171.188 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 171.188} + 0$$

$$= 0.0261 \text{ in}$$

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

$$= \max\left[0.0261,\ 0\right]$$

$$= 0.0261 \text{ in}$$

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

$$= \frac{171.188 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 171.188} + 0$$

$$= 0.1549 \text{ in}$$

CODEWARE EXAMPLE

$t_{b1} = \max[t_{b1},\ t_{bUG16}]$

$= \max[0.1549,\ 0.0625]$

$= 0.1549$ in

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

$= \min[0.245,\ 0.1549]$

$= 0.1549$ in

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

$= \max[0.0261,\ 0.1549]$

$=$ 0.1549 in

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 20{,}000$ =	14,800 psi
Nozzle wall in shear:	$0.7 \cdot 20{,}000$ =	14,000 psi
Inner fillet weld in shear:	$0.49 \cdot 20{,}000$ =	9,800 psi
Outer fillet weld in shear:	$0.49 \cdot 20{,}000$ =	9,800 psi
Upper groove weld in tension:	$0.74 \cdot 20{,}000$ =	14,800 psi
Lower fillet weld in shear:	$0.49 \cdot 20{,}000$ =	9,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 9{,}800$ = 19,121.99 lb_f

(2) Outer fillet weld in shear
$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 9{,}800$ = 16,596.44 lb_f

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 14{,}000$ = 39,069.47 lb_f

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 14{,}800$ = 28,878.11 lb_f

(5) Lower fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 9{,}800$ = 25,495.99 lb_f

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 14{,}800$ = 19,252.07 lb_f

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

CODEWARE EXAMPLE

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(0.9392 - 0.198 + 2 \cdot 0.28 \cdot 1 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549)) \cdot 20{,}000$

= 15,190.09 lb_f

$W_{1\text{-}1}$ = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.238 + 0.25 + 0.0352 + 0.0156) \cdot 20{,}000$

= 10,776 lb_f

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

= $(0.238 + 0.14 + 0.0352 + 0.0625 + 2 \cdot 0.28 \cdot 0.1875 \cdot 1) \cdot 20{,}000$

= 11,614 lb_f

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

= $(0.238 + 0.14 + 0.25 + 0.0352 + 0.0156 + 0.0625 + 2 \cdot 0.28 \cdot 0.1875 \cdot 1) \cdot 20{,}000$

= 16,926 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 10,776 lb_f
Path 1-1 through (2) & (3) = 16,596.44 + 39,069.47 = 55,665.92 lb_f
Path 1-1 is stronger than $W_{1\text{-}1}$ so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 11,614 lb_f
Path 2-2 through (1), (4), (5), (6) = 19,121.99 + 28,878.11 + 25,495.99 + 19,252.07 = 92,748.16 lb_f
Path 2-2 is stronger than $W_{2\text{-}2}$ so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 15,190.09 lb_f
Path 3-3 through (2), (4), (5) = 16,596.44 + 28,878.11 + 25,495.99 = 70,970.54 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 15 psi @ 650 °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}
0.5267	0.7916	0.0884	0.2266	0.1326	0.2367	0.1073	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 size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for external pressure 15 psi @ 650 °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

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.4688 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0247 in

From UG-37(d)(1) required thickness t_r = 0.1729 in

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

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

CODEWARE EXAMPLE

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

= $0.5 \cdot (6.065 \cdot 0.1729 \cdot 1 + 2 \cdot 0.28 \cdot 0.1729 \cdot 1 \cdot (1 - 0.9468))$

= 0.5267 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0884 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1729) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1729) \cdot (1 - 0.9468)$

= 0.0884 in^2

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1729) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1729) \cdot (1 - 0.9468)$

= 0.0133 in^2

A_2 = smaller of the following= 0.2266 in^2

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

= $5 \cdot (0.28 - 0.0247) \cdot 0.9468 \cdot 0.1875$

= 0.2266 in^2

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

= $2 \cdot (0.28 - 0.0247) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$

= 0.3989 in^2

A_3 = smaller of the following= 0.1326 in^2

= $5 \cdot t \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.1875 \cdot 0.28 \cdot 0.9468$

= 0.2485 in^2

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

= 0.3711 in^2

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

= 0.1326 in^2

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

= $0.1875^{2} \cdot 0.9468$

= 0.0333 in^2

CODEWARE EXAMPLE

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

= $0.125^2 \cdot 0.9468$

= 0.0148 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

= $0.25^2 \cdot 0.9468$

= 0.0592 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

= 0.2367 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.0884 + 0.2266 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

= 0.7916 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\left[0.75,\ t_n,\ t_e\right] =$ 0.125 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\left[0.75,\ t_e,\ t\right] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}} = 0.0247$ in

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

$= \max\left[0.0247,\ 0\right]$

$= 0.0247$ in

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

= $\dfrac{15 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 15} + 0$

= 0.0144 in

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

$= \max\left[0.0144,\ 0.0625\right]$

$= 0.0625$ in

CODEWARE EXAMPLE

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

$= \min[0.245,\ 0.0625]$

$= 0.0625$ in

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

$= \max[0.0247,\ 0.0625]$

$= 0.0625$ in

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{8.3042}{6.625} = 1.2535$$

$$\frac{D_o}{t} = \frac{6.625}{0.0247} = 268.5437$$

From table G: $A = 0.000241$

From table CS-2: $B = 3{,}021.142$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 3{,}021.14}{3 \cdot (6.625/0.0247)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$t_a = t + \text{Corrosion} = 0.0247 + 0 =$ 0.0247"

CODEWARE EXAMPLE

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 18.38 psi @ 650 °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}
0.5714	0.7013	--	0.2247	0.1326	0.2367	0.1073	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 size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for external pressure 18.38 psi @ 650 °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

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.4688 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0269 in

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

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

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

CODEWARE EXAMPLE

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

= $0.5 \cdot (6.065 \cdot 0.1875 \cdot 1 + 2 \cdot 0.28 \cdot 0.1875 \cdot 1 \cdot (1 - 0.9468))$

= 0.5714 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1875) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1875) \cdot (1 - 0.9468)$

= $0 \ \text{in}^2$

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1875) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1875) \cdot (1 - 0.9468)$

= $0 \ \text{in}^2$

A_2 = smaller of the following= 0.2247 in^2

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

= $5 \cdot (0.28 - 0.0269) \cdot 0.9468 \cdot 0.1875$

= $0.2247 \ \text{in}^2$

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

= $2 \cdot (0.28 - 0.0269) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$

= $0.3955 \ \text{in}^2$

A_3 = smaller of the following= 0.1326 in^2

= $5 \cdot t \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.1875 \cdot 0.28 \cdot 0.9468$

= 0.2485 in^2

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

= 0.3711 in^2

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

= 0.1326 in^2

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

= $0.1875^{\,2} \cdot 0.9468$

= 0.0333 in^2

CODEWARE EXAMPLE

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

= $0.125^2 \cdot 0.9468$

= 0.0148 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

= $0.25^2 \cdot 0.9468$

= 0.0592 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

= 0.2367 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0 + 0.2247 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

= 0.7013 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\left[0.75,\ t_n,\ t_e\right] =$ 0.125 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\left[0.75,\ t_e,\ t\right] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}} = 0.0269$ in

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

$= \max\left[0.0269,\ 0\right]$

$= 0.0269$ in

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

= $\dfrac{18.3834 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 18.3834} + 0$

= 0.0176 in

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

$= \max\left[0.0176,\ 0.0625\right]$

$= 0.0625$ in

CODEWARE EXAMPLE

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

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

$= 0.0625$ in

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

$= \max\left[0.0269,\ 0.0625\right]$

$=$ 0.0625 in

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{8.3042}{6.625} = 1.2535$$

$$\frac{D_o}{t} = \frac{6.625}{0.0269} = 246.6349$$

From table G: $A = 0.000272$

From table CS-2: $B = 3{,}400.4427$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 3{,}400.44}{3 \cdot (6.625/0.0269)} = 18.38 \text{ psi}$$

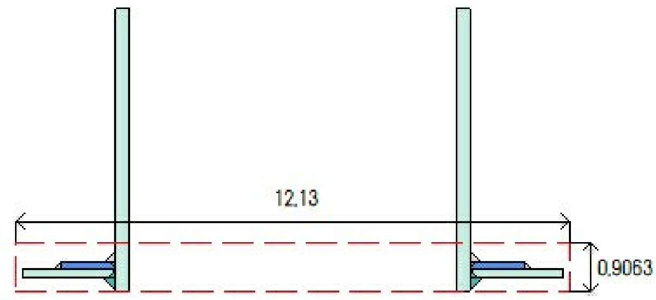
Design thickness for external pressure P_a = 18.38 psi

$t_a = t + \text{Corrosion} = 0.0269 + 0 =$ 0.0269"

CODEWARE EXAMPLE

Nozzle #3 (N3)

ASME Section VIII Division 1, 2023 Edition



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

Location and Orientation	
Located on	Cylinder #2
Orientation	0°
Nozzle center line offset to datum line	54"
End of nozzle to shell center	26.1875"
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	4.5"
Internal projection, h_{new}	0.25"
Projection available outside vessel to flange face, Lf	8"
Local vessel minimum thickness	0.1875"
Liquid static head included	0.33 psi
Reinforcing Pad	
Material specification	SA-105 (II-D p. 20, ln. 31)
Diameter, D_p	8.625"
Thickness, t_e	0.125"
Is split	No
Welds	
Inner fillet, Leg_{41}	0.1875"
Outer fillet, Leg_{42}	0.125"
Lower fillet, Leg_{43}	0.25"
Nozzle to vessel groove weld	0.1875"
Pad groove weld	0.125"
Radiography	
Longitudinal seam	Seamless No RT
Circumferential seam	Full UW-11(a) Type 1

CODEWARE EXAMPLE

ASME B16.5-2020 Flange	
Description	NPS 6 Class 150 WN A105
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0.22 psi
MAWP rating	125 psi @ 650°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3516) Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, t_g =	0.1875"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{100.33 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 100.33} =$	0.0906"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0906 \cdot 1}{0.1875 - 0} =$	0.483
$\text{Stress ratio longitudinal} = \frac{4{,}784 \cdot 1}{20{,}000 \cdot 1} =$	0.2392
Reduction in MDMT, T_R from Fig UCS-66.1 =	61.8°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 61.8, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = \frac{100.33 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 100.33} =$	0.0153"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0153 \cdot 1}{0.28 - 0} =$	0.0545
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.	

CODEWARE EXAMPLE

UCS-66 Material Toughness Requirements Pad	
Governing thickness, t_g =	0.125"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{100.33 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 100.33} =$	0.0906"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0906 \cdot 1}{0.1875 - 0} =$	0.483
$\text{Stress ratio longitudinal} = \frac{4{,}784 \cdot 1}{20{,}000 \cdot 1} =$	0.2392
Reduction in MDMT, T_R from Fig UCS-66.1 =	61.8°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 61.8, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

CODEWARE EXAMPLE

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 100.33 psi @ 650 °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}
0.5874	1.2599	0.55	0.2333	0.1326	0.2367	0.1073	0.0964	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
1,610.65	9,740.28	49,542.67	10,486	83,989.77	15,214.2	64,607.69

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for internal pressure 100.33 psi @ 650 °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

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.4688 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

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

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

$$= \frac{100.326 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 100.326}$$

$$= 0.0172 \text{ in}$$

Required thickness t_r from UG-37(a)

CODEWARE EXAMPLE

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

= $\frac{100.326 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 100.326}$

= $0.0964\ \text{in}$

Area required per UG-37(c)

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

= $6.065 \cdot 0.0964 \cdot 1 + 2 \cdot 0.28 \cdot 0.0964 \cdot 1 \cdot (1 - 0.9468)$

= 0.5874 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.55 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0964) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0964) \cdot (1 - 0.9468)$

= $0.55\ \text{in}^2$

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.0964) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0964) \cdot (1 - 0.9468)$

= $0.0825\ \text{in}^2$

A_2 = smaller of the following= 0.2333 in^2

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

= $5 \cdot (0.28 - 0.0172) \cdot 0.9468 \cdot 0.1875$

= $0.2333\ \text{in}^2$

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

= $2 \cdot (0.28 - 0.0172) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$

= $0.4106\ \text{in}^2$

A_3 = smaller of the following= 0.1326 in^2

CODEWARE EXAMPLE

$= 5 \cdot t \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.1875 \cdot 0.28 \cdot 0.9468$

$=$ 0.2485 in^2

$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

$=$ 0.3711 in^2

$= 2 \cdot h \cdot t_i \cdot f_{r2}$

$= 2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

$=$ 0.1326 in^2

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

$= 0.1875^{\ 2} \cdot 0.9468$

$=$ 0.0333 in^2

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

$= 0.125^{\ 2} \cdot 0.9468$

$=$ 0.0148 in^2

$A_{43} = Leg^2 \cdot f_{r2}$

$= 0.25^{\ 2} \cdot 0.9468$

$=$ 0.0592 in^2

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

$= (8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

$=$ 0.2367 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.55 + 0.2333 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

$=$ 1.2599 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\left[0.75,\ t_n,\ t_e\right] =$ 0.125 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\left[0.75,\ t_e,\ t\right] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

CODEWARE EXAMPLE

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

$$= \frac{100.326 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 100.326} + 0$$

$$= 0.0172 \text{ in}$$

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

$$= \max\left[0.0172,\ 0\right]$$

$$= 0.0172 \text{ in}$$

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

$$= \frac{100.326 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 100.326} + 0$$

$$= 0.0964 \text{ in}$$

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

$$= \max\left[0.0964,\ 0.0625\right]$$

$$= 0.0964 \text{ in}$$

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

$$= \min\left[0.245,\ 0.0964\right]$$

$$= 0.0964 \text{ in}$$

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

$$= \max\left[0.0172,\ 0.0964\right]$$

$$= 0.0964 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 18{,}800$ =	13,912 psi
Nozzle wall in shear:	$0.7 \cdot 17{,}800$ =	12,460 psi
Inner fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi
Outer fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi
Upper groove weld in tension:	$0.74 \cdot 17{,}800$ =	13,172 psi
Lower fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi

Strength of welded joints:

(1) Inner fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 8{,}722$ = 17,018.57 lb_f

(2) Outer fillet weld in shear

$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 8{,}722$ = 14,770.84 lb_f

CODEWARE EXAMPLE

(3) Nozzle wall in shear

$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 12{,}460$ = 34,771.83 lb_f

(4) Groove weld in tension

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 13{,}912$ = 27,145.42 lb_f

(5) Lower fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 8{,}722$ = 22,691.43 lb_f

(6) Upper groove weld in tension

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 13{,}172$ = 17,134.34 lb_f

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

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(0.5874 - 0.55 + 2 \cdot 0.28 \cdot 0.9468 \cdot (1 \cdot 0.1875 - 1 \cdot 0.0964)) \cdot 18{,}800$

= 1,610.65 lb_f

$W_{1\text{-}1}$ = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.2333 + 0.2367 + 0.0333 + 0.0148) \cdot 18{,}800$

= 9,740.28 lb_f

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

= $(0.2333 + 0.1326 + 0.0333 + 0.0592 + 2 \cdot 0.28 \cdot 0.1875 \cdot 0.9468) \cdot 18{,}800$

= 10,486 lb_f

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

= $(0.2333 + 0.1326 + 0.2367 + 0.0333 + 0.0148 + 0.0592 + 2 \cdot 0.28 \cdot 0.1875 \cdot 0.9468) \cdot 18{,}800$

= 15,214.2 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 1,610.65 lb_f
Path 1-1 through (2) & (3) = 14,770.84 + 34,771.83 = 49,542.67 lb_f
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 1,610.65 lb_f
Path 2-2 through (1), (4), (5), (6) = 17,018.57 + 27,145.42 + 22,691.43 + 17,134.34 = 83,989.77 lb_f
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 1,610.65 lb_f
Path 3-3 through (2), (4), (5) = 14,770.84 + 27,145.42 + 22,691.43 = 64,607.69 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 125.11 psi @ 650 °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}
0.733	1.1118	0.4057	0.2295	0.1326	0.2367	0.1073	0.1203	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
6,823.77	9,668.84	49,542.67	10,414.56	83,989.77	15,142.76	64,607.69

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for internal pressure 125.11 psi @ 650 °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

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$
$$= 0.4688\ \text{in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$
$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$
$$= 0.25\ \text{in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{125.1094 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 125.1094}$$
$$= 0.0214\ \text{in}$$

Required thickness t_r from UG-37(a)

CODEWARE EXAMPLE

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

= $\dfrac{125.1094 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 125.1094}$

= 0.1203 in

Area required per UG-37(c)

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

= $6.065 \cdot 0.1203 \cdot 1 + 2 \cdot 0.28 \cdot 0.1203 \cdot 1 \cdot (1 - 0.9468)$

= 0.733 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.4057 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1203) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1203) \cdot (1 - 0.9468)$

= 0.4057 in^2

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1203) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1203) \cdot (1 - 0.9468)$

= 0.0609 in^2

A_2 = smaller of the following= 0.2295 in^2

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

= $5 \cdot (0.28 - 0.0214) \cdot 0.9468 \cdot 0.1875$

= 0.2295 in^2

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

= $2 \cdot (0.28 - 0.0214) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$

= 0.404 in^2

A_3 = smaller of the following= 0.1326 in^2

CODEWARE EXAMPLE

$= 5 \cdot t \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.1875 \cdot 0.28 \cdot 0.9468$

$=$ 0.2485 in^2

$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

$=$ 0.3711 in^2

$= 2 \cdot h \cdot t_i \cdot f_{r2}$

$= 2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

$=$ 0.1326 in^2

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

$= 0.1875^2 \cdot 0.9468$

$=$ 0.0333 in^2

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

$= 0.125^2 \cdot 0.9468$

$=$ 0.0148 in^2

$A_{43} = Leg^2 \cdot f_{r2}$

$= 0.25^2 \cdot 0.9468$

$=$ 0.0592 in^2

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

$= (8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

$=$ 0.2367 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.4057 + 0.2295 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

$=$ 1.1118 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\,[0.75,\ t_n,\ t_e] =$ 0.125 in

$t_{c(\min)} = \min\,[0.25,\ 0.7 \cdot t_{\min}] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\,[0.75,\ t_e,\ t] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

CODEWARE EXAMPLE

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

$$= \frac{125.1094 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 125.1094} + 0$$

$$= 0.0214 \text{ in}$$

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

$$= \max\left[0.0214,\ 0\right]$$

$$= 0.0214 \text{ in}$$

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

$$= \frac{125.1094 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 125.1094} + 0$$

$$= 0.1203 \text{ in}$$

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

$$= \max\left[0.1203,\ 0.0625\right]$$

$$= 0.1203 \text{ in}$$

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

$$= \min\left[0.245,\ 0.1203\right]$$

$$= 0.1203 \text{ in}$$

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

$$= \max\left[0.0214,\ 0.1203\right]$$

$$= 0.1203 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 18{,}800$	=	13,912 psi
Nozzle wall in shear:	$0.7 \cdot 17{,}800$	=	12,460 psi
Inner fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi
Outer fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi
Upper groove weld in tension:	$0.74 \cdot 17{,}800$	=	13,172 psi
Lower fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi

Strength of welded joints:

(1) Inner fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 8{,}722$ = 17,018.57 lb_f

(2) Outer fillet weld in shear

CODEWARE EXAMPLE

$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 8{,}722$ = 14,770.84 lb_f

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 12{,}460$ = 34,771.83 lb_f

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 13{,}912$ = 27,145.42 lb_f

(5) Lower fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 8{,}722$ = 22,691.43 lb_f

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 13{,}172$ = 17,134.34 lb_f

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

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(0.733 - 0.4057 + 2 \cdot 0.28 \cdot 0.9468 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1203)) \cdot 18{,}800$

= 6,823.77 lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.2295 + 0.2367 + 0.0333 + 0.0148) \cdot 18{,}800$

= 9,668.84 lb_f

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

= $(0.2295 + 0.1326 + 0.0333 + 0.0592 + 2 \cdot 0.28 \cdot 0.1875 \cdot 0.9468) \cdot 18{,}800$

= 10,414.56 lb_f

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

= $(0.2295 + 0.1326 + 0.2367 + 0.0333 + 0.0148 + 0.0592 + 2 \cdot 0.28 \cdot 0.1875 \cdot 0.9468) \cdot 18{,}800$

= 15,142.76 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 6,823.77 lb_f
Path 1-1 through (2) & (3) = 14,770.84 + 34,771.83 = 49,542.67 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} = 6,823.77 lb_f
Path 2-2 through (1), (4), (5), (6) = 17,018.57 + 27,145.42 + 22,691.43 + 17,134.34 = 83,989.77 lb_f
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or W_{3-3} = 6,823.77 lb_f
Path 3-3 through (2), (4), (5) = 14,770.84 + 27,145.42 + 22,691.43 = 64,607.69 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

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 = 171.19 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}
0.9392	0.9393	0.198	0.238	0.14	0.25	0.1133	0.1549	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
15,190.09	10,776	55,665.92	11,614	92,748.16	16,926	70,970.54

Calculations for internal pressure 171.19 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

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$
$$= 0.4688 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$
$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$
$$= 0.25 \text{ in}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0.6 \cdot P}$$
$$= \frac{171.188 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 171.188}$$
$$= 0.0261 \text{ in}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0.6 \cdot P}$$
$$= \frac{171.188 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 171.188}$$
$$= 0.1549 \text{ in}$$

CODEWARE EXAMPLE

Area required per UG-37(c)

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

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

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

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 1

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

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

= $6.065 \cdot 0.1549 \cdot 1 + 2 \cdot 0.28 \cdot 0.1549 \cdot 1 \cdot (1 - 1)$

= 0.9392 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.198 in^2

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

= $6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549) \cdot (1 - 1)$

= $0.198 \ in^2$

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

= $2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549) \cdot (1 - 1)$

= $0.0305 \ in^2$

A_2 = smaller of the following= 0.238 in^2

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

= $5 \cdot (0.28 - 0.0261) \cdot 1 \cdot 0.1875$

= $0.238 \ in^2$

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

= $2 \cdot (0.28 - 0.0261) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 1$

= $0.4189 \ in^2$

A_3 = smaller of the following= 0.14 in^2

= $5 \cdot t \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.1875 \cdot 0.28 \cdot 1$

= 0.2625 in^2

CODEWARE EXAMPLE

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.28 \cdot 0.28 \cdot 1$

= 0.392 in^2

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.25 \cdot 0.28 \cdot 1$

= 0.14 in^2

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

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

= 0.0352 in^2

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

= $0.125^{\ 2} \cdot 1$

= 0.0156 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

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

= 0.0625 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 1$

= 0.25 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.198 + 0.238 + 0.14 + 0.0352 + 0.0156 + 0.0625 + 0.25$

= 0.9393 in^2

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$= \frac{171.188 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 171.188} + 0$$

$$= 0.0261 \text{ in}$$

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

$$= \max\left[0.0261,\ 0\right]$$

$$= 0.0261 \text{ in}$$

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

$$= \frac{171.188 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 171.188} + 0$$

$$= 0.1549 \text{ in}$$

CODEWARE EXAMPLE

$t_{b1} = \max[t_{b1},\ t_{bUG16}]$

$= \max[0.1549,\ 0.0625]$

$= 0.1549$ in

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

$= \min[0.245,\ 0.1549]$

$= 0.1549$ in

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

$= \max[0.0261,\ 0.1549]$

$=$ 0.1549 in

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 20{,}000$ =	14,800 psi
Nozzle wall in shear:	$0.7 \cdot 20{,}000$ =	14,000 psi
Inner fillet weld in shear:	$0.49 \cdot 20{,}000$ =	9,800 psi
Outer fillet weld in shear:	$0.49 \cdot 20{,}000$ =	9,800 psi
Upper groove weld in tension:	$0.74 \cdot 20{,}000$ =	14,800 psi
Lower fillet weld in shear:	$0.49 \cdot 20{,}000$ =	9,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 9{,}800$ = 19,121.99 lb_f

(2) Outer fillet weld in shear
$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 9{,}800$ = 16,596.44 lb_f

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 14{,}000$ = 39,069.47 lb_f

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 14{,}800$ = 28,878.11 lb_f

(5) Lower fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 9{,}800$ = 25,495.99 lb_f

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 14{,}800$ = 19,252.07 lb_f

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

CODEWARE EXAMPLE

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(0.9392 - 0.198 + 2 \cdot 0.28 \cdot 1 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1549)) \cdot 20{,}000$

= 15,190.09 lb_f

W_{1-1} = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.238 + 0.25 + 0.0352 + 0.0156) \cdot 20{,}000$

= 10,776 lb_f

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

= $(0.238 + 0.14 + 0.0352 + 0.0625 + 2 \cdot 0.28 \cdot 0.1875 \cdot 1) \cdot 20{,}000$

= 11,614 lb_f

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

= $(0.238 + 0.14 + 0.25 + 0.0352 + 0.0156 + 0.0625 + 2 \cdot 0.28 \cdot 0.1875 \cdot 1) \cdot 20{,}000$

= 16,926 lb_f

Load for path 1-1 lesser of W or W_{1-1} = 10,776 lb_f
Path 1-1 through (2) & (3) = 16,596.44 + 39,069.47 = 55,665.92 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} = 11,614 lb_f
Path 2-2 through (1), (4), (5), (6) = 19,121.99 + 28,878.11 + 25,495.99 + 19,252.07 = 92,748.16 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} = 15,190.09 lb_f
Path 3-3 through (2), (4), (5) = 16,596.44 + 28,878.11 + 25,495.99 = 70,970.54 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in²)							UG-45 Summary (in)	
For Pe = 15 psi @ 650 °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}
0.5267	0.7916	0.0884	0.2266	0.1326	0.2367	0.1073	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 size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for external pressure 15 psi @ 650 °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

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$
$$= 0.4688 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$
$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$
$$= 0.25 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0247 in

From UG-37(d)(1) required thickness t_r = 0.1729 in

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

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

CODEWARE EXAMPLE

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

A	=	$0.5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$
	=	$0.5 \cdot (6.065 \cdot 0.1729 \cdot 1 + 2 \cdot 0.28 \cdot 0.1729 \cdot 1 \cdot (1 - 0.9468))$
	=	0.5267 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.0884 in^2

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

$$= 6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1729) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1729) \cdot (1 - 0.9468)$$

$$= 0.0884 \ \text{in}^2$$

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

$$= 2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1729) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1729) \cdot (1 - 0.9468)$$

$$= 0.0133 \ \text{in}^2$$

A_2 = smaller of the following= 0.2266 in^2

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

$$= 5 \cdot (0.28 - 0.0247) \cdot 0.9468 \cdot 0.1875$$

$$= 0.2266 \ \text{in}^2$$

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

$$= 2 \cdot (0.28 - 0.0247) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$$

$$= 0.3989 \ \text{in}^2$$

A_3 = smaller of the following= 0.1326 in^2

$$= 5 \cdot t \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.1875 \cdot 0.28 \cdot 0.9468$$

= 0.2485 in^2

$$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$$

= 0.3711 in^2

$$= 2 \cdot h \cdot t_i \cdot f_{r2}$$

$$= 2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$$

= 0.1326 in^2

A_{41}	=	$Leg^2 \cdot f_{r3}$
	=	$0.1875^{\ 2} \cdot 0.9468$
	=	0.0333 in^2

CODEWARE EXAMPLE

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

= $0.125^2 \cdot 0.9468$

= 0.0148 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

= $0.25^2 \cdot 0.9468$

= 0.0592 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

= 0.2367 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.0884 + 0.2266 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

$=$ 0.7916 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\left[0.75,\ t_n,\ t_e\right] =$ 0.125 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\left[0.75,\ t_e,\ t\right] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}} = 0.0247$ in

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

$= \max\left[0.0247,\ 0\right]$

$= 0.0247$ in

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

= $\frac{15 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 15} + 0$

= 0.0144 in

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

$= \max\left[0.0144,\ 0.0625\right]$

$= 0.0625$ in

CODEWARE EXAMPLE

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

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

$$= 0.0625 \text{ in}$$

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

$$= \max[0.0247,\ 0.0625]$$

$$= 0.0625 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{8.3042}{6.625} = 1.2535$$

$$\frac{D_o}{t} = \frac{6.625}{0.0247} = 268.5437$$

From table G: $A = 0.000241$

From table CS-2: $B = 3{,}021.142$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 3{,}021.14}{3 \cdot (6.625/0.0247)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$t_a = t + \text{Corrosion} = 0.0247 + 0 =$ 0.0247"

CODEWARE EXAMPLE

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 18.38 psi @ 650 °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}
0.5714	0.7013	--	0.2247	0.1326	0.2367	0.1073	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 size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for external pressure 18.38 psi @ 650 °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

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

$$= \min\left[2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.4688 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.1875 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0269 in

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

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

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

CODEWARE EXAMPLE

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

A	=	$0.5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$
	=	$0.5 \cdot (6.065 \cdot 0.1875 \cdot 1 + 2 \cdot 0.28 \cdot 0.1875 \cdot 1 \cdot (1 - 0.9468))$
	=	0.5714 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0 in^2

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

$$= 6.065 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1875) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1875) \cdot (1 - 0.9468)$$

$$= 0 \ \text{in}^2$$

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

$$= 2 \cdot (0.1875 + 0.28) \cdot (1 \cdot 0.1875 - 1 \cdot 0.1875) - 2 \cdot 0.28 \cdot (1 \cdot 0.1875 - 1 \cdot 0.1875) \cdot (1 - 0.9468)$$

$$= 0 \ \text{in}^2$$

A_2 = smaller of the following= 0.2247 in^2

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

$$= 5 \cdot (0.28 - 0.0269) \cdot 0.9468 \cdot 0.1875$$

$$= 0.2247 \ \text{in}^2$$

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

$$= 2 \cdot (0.28 - 0.0269) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$$

$$= 0.3955 \ \text{in}^2$$

A_3 = smaller of the following= 0.1326 in^2

$$= 5 \cdot t \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.1875 \cdot 0.28 \cdot 0.9468$$

= 0.2485 in^2

$$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$$

= 0.3711 in^2

$$= 2 \cdot h \cdot t_i \cdot f_{r2}$$

$$= 2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$$

= 0.1326 in^2

A_{41}	=	$Leg^2 \cdot f_{r3}$
	=	$0.1875^2 \cdot 0.9468$
	=	0.0333 in^2

CODEWARE EXAMPLE

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

= $0.125^{\,2} \cdot 0.9468$

= 0.0148 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

= $0.25^{\,2} \cdot 0.9468$

= 0.0592 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

= 0.2367 in^2

$Area$ = $A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

= $0 + 0.2247 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

= 0.7013 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\,[0.75,\ t_n,\ t_e] =$ 0.125 in

$t_{c(\min)} = \min\,[0.25,\ 0.7 \cdot t_{\min}] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\,[0.75,\ t_e,\ t] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}} = 0.0269$ in

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

$= \max\,[0.0269,\ 0]$

$= 0.0269$ in

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

= $\dfrac{18.3834 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 18.3834} + 0$

= 0.0176 in

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

$= \max\,[0.0176,\ 0.0625]$

$= 0.0625$ in

CODEWARE EXAMPLE

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

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

$$= 0.0625 \text{ in}$$

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

$$= \max\left[0.0269,\ 0.0625\right]$$

$$= 0.0625 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{8.3042}{6.625} = 1.2535$$

$$\frac{D_o}{t} = \frac{6.625}{0.0269} = 246.6349$$

From table G: $A = 0.000272$

From table CS-2: $B = 3{,}400.4427$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 3{,}400.44}{3 \cdot (6.625/0.0269)} = 18.38 \text{ psi}$$

Design thickness for external pressure P_a = 18.38 psi

$t_a = t + \text{Corrosion} = 0.0269 + 0 =$ 0.0269"

CODEWARE EXAMPLE

Cylinder #1

ASME Section VIII Division 1, 2023 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	650	-20
External		15	650	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		2.17	60	1
Test horizontal		1.6	44.1875	1
Dimensions				
Inner Diameter		36"		
Length		36"		
Nominal Thickness		0.25"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		287.62		158.63
Corroded		287.62		158.63
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)	0.0982"
Design thickness due to external pressure (t_e)	0.1732"
Design thickness due to combined loadings + corrosion	0.0492"
Maximum allowable working pressure (MAWP)	256.79 psi
Maximum allowable pressure (MAP)	275.48 psi
Maximum allowable external pressure (MAEP)	36.93 psi
Rated MDMT	-55 °F

CODEWARE EXAMPLE

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.25"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{102.17 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 102.17} =$	0.0922"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0922 \cdot 1}{0.25 - 0} =$	0.3689
$\text{Stress ratio longitudinal} = \frac{3{,}683 \cdot 1}{20{,}000 \cdot 1} =$	0.1842
Reduction in MDMT, T_R from Fig UCS-66.1 =	118.9°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 118.9, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 650 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{102.17 \cdot 18}{18{,}800 \cdot 1.00 - 0.60 \cdot 102.17} + 0 = 0.0982"$$

Maximum allowable working pressure, (at 650 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{18{,}800 \cdot 1.00 \cdot 0.25}{18 + 0.60 \cdot 0.25} - 2.17 = 256.79 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 0.25}{18 + 0.60 \cdot 0.25} = 275.48 \text{ psi}$$

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{82}{36.5} = 2.2466$$

$$\frac{D_o}{t} = \frac{36.5}{0.1732} = 210.7700$$

From table G: $A = 0.000189$

From table CS-2: $B = 2{,}371.1712 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}371.17}{3 \cdot (36.5/0.1732)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.1732 + 0 = 0.1732"$$

Maximum Allowable External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{82}{36.5} = 2.2466$$

$$\frac{D_o}{t} = \frac{36.5}{0.25} = 146.0000$$

CODEWARE EXAMPLE

From table G: $A = 0.000324$

From table CS-2: $B = 4{,}043.3972$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 4{,}043.4}{3 \cdot (36.5/0.25)} = \underline{36.93} \text{ psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.25}{18.125}\right) \cdot \left(1 - \frac{18.125}{\infty}\right) = 0.6897\,\%$$

The extreme fiber elongation does not exceed 5%.

External Pressure + Weight + Seismic Loading Check (Bergman, ASME paper 54-A-104)

$$P_v = \frac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m} + \frac{M}{\pi \cdot R_m^2} = \frac{1.11 \cdot 669.4}{2 \cdot \pi \cdot 18.125} + \frac{23{,}614}{\pi \cdot 18.125^{\ 2}} = 29.4164 \ \text{lb/in}$$

$$\alpha = \frac{P_v}{P_e \cdot D_o} = \frac{29.4164}{15 \cdot 36.5} = 0.0537$$

$$n = 4$$

$$m = \frac{1.23}{\left(\frac{L}{D_o}\right)^2} = \frac{1.23}{\left(\frac{82}{36.5}\right)^2} = 0.2437$$

$$RatioP_e = \frac{n^2 - 1 + m + m \cdot \alpha}{n^2 - 1 + m} = \frac{4^2 - 1 + 0.2437 + 0.2437 \cdot 0.0537}{4^2 - 1 + 0.2437} = 1.0009$$

$$RatioP_e \cdot P_e \leq \text{MAEP}$$

$$(1.0009 \cdot 15 = 15.01) \leq 36.93$$

Cylinder thickness is satisfactory.

External Pressure + Weight + Seismic Loading Check at Bottom Seam(Bergman, ASME paper 54-A-104)

$$P_v = \frac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m} + \frac{M}{\pi \cdot R_m^2} = \frac{0.49 \cdot -2{,}619.1}{2 \cdot \pi \cdot 18.125} + \frac{297}{\pi \cdot 18.125^{\ 2}} = -10.9352 \ \text{lb/in}$$

$$\alpha = \frac{P_v}{P_e \cdot D_o} = -\frac{10.9352}{15 \cdot 36.5} = -0.02$$

$$n = 4$$

$$m = \frac{1.23}{\left(\frac{L}{D_o}\right)^2} = \frac{1.23}{\left(\frac{82}{36.5}\right)^2} = 0.2437$$

$$RatioP_e = \frac{n^2 - 1 + m + m \cdot \alpha}{n^2 - 1 + m} = \frac{4^2 - 1 + 0.2437 + 0.2437 \cdot -0.02}{4^2 - 1 + 0.2437} = 1$$

$$RatioP_e \cdot P_e \leq \text{MAEP}$$

$$(1 \cdot 15 = 15) \leq 36.93$$

Cylinder thickness is satisfactory.

CODEWARE EXAMPLE

Thickness Required Due to Pressure + External Loads									
Condition	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Location	Load	Pressure P (psi)	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
	S_t	S_c							
Operating, Hot & Corroded	18,800	9,465	650	0	Top	Seismic	100	0.0489	0.0463
					Bottom	Seismic	100	0.0492	0.0484
Operating, Hot & New	18,800	9,465	650	0	Top	Seismic	100	0.0489	0.0463
					Bottom	Seismic	100	0.0492	0.0484
Hot Shut Down, Corroded	18,800	9,465	650	0	Top	Seismic	0	0.0011	0.0031
					Bottom	Seismic	0	0.0014	0.0006
Hot Shut Down, New	18,800	9,465	650	0	Top	Seismic	0	0.0011	0.0031
					Bottom	Seismic	0	0.0014	0.0006
Empty, Corroded	20,000	14,348	70	0	Top	Seismic	0	0.0003	0.001
					Bottom	Seismic	0	0.0001	0
Empty, New	20,000	14,348	70	0	Top	Seismic	0	0.0003	0.001
					Bottom	Seismic	0	0.0001	0
Vacuum	18,800	9,465	650	0	Top	Seismic	-15	0.0121	0.0174
					Bottom	Seismic	-15	0.0115	0.0131
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	18,800	9,465	650	0	Top	Seismic	0	0.0004	0.0008
					Bottom	Seismic	0	0.0012	0.0012

CODEWARE EXAMPLE

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.25/0.25} = 0.001712$$

$$B = 9{,}465 \ \ \text{psi}$$

$$S = \frac{18{,}800}{1.00} = 18{,}800 \ \ \text{psi}$$

$S_{cHC} = \min(B, S) =$ 9,465 psi

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

$S_cHN = S_cHC =$ 9,465 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.25/0.25} = 0.001712$$

$$B = 14{,}348 \ \ \text{psi}$$

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

$S_{cCN} = \min(B, S) =$ 14,348 psi

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

$S_c\mathbb{C} = S_cCN =$ 14,348 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.25/0.25} = 0.001712$$

$$B = 9{,}465 \ \ \text{psi}$$

$$S = \frac{18{,}800}{1.00} = 18{,}800 \ \ \text{psi}$$

$S_{cVC} = \min(B, S) =$ 9,465 psi

Operating, Hot & Corroded, Seismic, Above Support Point

CODEWARE EXAMPLE

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

$$= \frac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$$

= 0.0478"

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

$$= \frac{23{,}614}{\pi \cdot 18.125^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0012"

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

$$= \frac{0.49*669.4}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0002"

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

$$= 0.0478 + 0.0012 - (0.0002)$$

= 0.0489"

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

$$= \frac{1.11*669.4}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0003"

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

$$= |0.0012 + (0.0003) - (0.0478)|$$

= 0.0463"

Maximum allowable working pressure, Longitudinal Stress

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

$$= \frac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.25 - 0.0012 + (0.0002))}{18 - 0.40 \cdot (0.25 - 0.0012 + (0.0002))}$$

= 522.89 psi

Operating, Hot & New, Seismic, Above Support Point

CODEWARE EXAMPLE

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

$= \frac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

$= \frac{23{,}614}{\pi \cdot 18.125^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0012"

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

$= \frac{0.49{*}669.4}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0002"

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

$= 0.0478 + 0.0012 - (0.0002)$

= 0.0489"

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

$= \frac{1.11{*}669.4}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0003"

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

$= |0.0012 + (0.0003) - (0.0478)|$

= 0.0463"

Maximum allowable working pressure, Longitudinal Stress

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

$= \frac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.25 - 0.0012 + (0.0002))}{18 - 0.40 \cdot (0.25 - 0.0012 + (0.0002))}$

= 522.89 psi

Hot Shut Down, Corroded, Seismic, Above Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$$= \frac{23{,}614}{\pi \cdot 18.125^{\,2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0012"

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

$$= \frac{0.49*669.4}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0.0002"

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

$= 0 + 0.0012 - (0.0002)$

= 0.0011"

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

$$= \frac{23{,}614}{\pi \cdot 18.125^{\,2} \cdot 9{,}464.71 \cdot 1.00}$$

= 0.0024"

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

$$= \frac{1.11*669.4}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$$

= 0.0007"

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

$= 0.0024 + (0.0007) - (0)$

= 0.0031"

Hot Shut Down, New, Seismic, Above Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{23{,}614}{\pi \cdot 18.125\ ^2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0012"

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

$= \dfrac{0.49 * 669.4}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0.0002"

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

$= 0 + 0.0012 - (0.0002)$

= 0.0011"

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

$= \dfrac{23{,}614}{\pi \cdot 18.125\ ^2 \cdot 9{,}464.71 \cdot 1.00}$

= 0.0024"

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

$= \dfrac{1.11 * 669.4}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$

= 0.0007"

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

$= 0.0024 + (0.0007) - (0)$

= 0.0031"

Empty, Corroded, Seismic, Above Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{8{,}479}{\pi \cdot 18.125^{\;2} \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0.0004"

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

$= \dfrac{0.49*669.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0.0001"

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

$= 0 + 0.0004 - (0.0001)$

= 0.0003"

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

$= \dfrac{8{,}479}{\pi \cdot 18.125^{\;2} \cdot 14{,}347.69 \cdot 1.00}$

= 0.0006"

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

$= \dfrac{1.11*669.4}{2 \cdot \pi \cdot 18.125 \cdot 14{,}347.69 \cdot 1.00}$

= 0.0005"

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

$= 0.0006 + (0.0005) - (0)$

= 0.001"

Empty, New, Seismic, Above Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$$= \frac{8{,}479}{\pi \cdot 18.125^{\ 2} \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$$

= 0.0004"

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

$$= \frac{0.49*669.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$$

= 0.0001"

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

= $0 + 0.0004 - (0.0001)$

= 0.0003"

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

$$= \frac{8{,}479}{\pi \cdot 18.125^{\ 2} \cdot 14{,}347.69 \cdot 1.00}$$

= 0.0006"

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

$$= \frac{1.11*669.4}{2 \cdot \pi \cdot 18.125 \cdot 14{,}347.69 \cdot 1.00}$$

= 0.0005"

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

= $0.0006 + (0.0005) - (0)$

= 0.001"

Vacuum, Seismic, Above Support Point

CODEWARE EXAMPLE

t_p = $\dfrac{P \cdot R}{2 \cdot S_c \cdot K_s + 0.40 \cdot |P|}$ (Pressure)

= $\dfrac{-15 \cdot 18}{2 \cdot 9{,}464.71 \cdot 1.00 + 0.40 \cdot |15|}$

= -0.0143

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

= $\dfrac{23{,}614}{\pi \cdot 18.125^{\;2} \cdot 9{,}464.71 \cdot 1.00}$

= 0.0024"

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

= $\dfrac{0.49*669.4}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$

= 0.0003"

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

= $|-0.0143 + 0.0024 - (0.0003)|$

= 0.0121"

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

= $\dfrac{1.11*669.4}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$

= 0.0007"

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

= $0.0024 + (0.0007) - (-0.0143)$

= 0.0174"

Maximum Allowable External Pressure, Longitudinal Stress

P = $\dfrac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0.40 \cdot (t - t_{mc} - t_{wc})}$

= $\dfrac{2 \cdot 9{,}464.71 \cdot 1.00 \cdot (0.25 - 0.0024 - 0.0007)}{18 - 0.40 \cdot (0.25 - 0.0024 - 0.0007)}$

= 261.07 psi

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Above Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \frac{1{,}800}{\pi \cdot 18.125^{\ 2} \cdot 9{,}464.71 \cdot 1.00}$

= 0.0002"

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

$= \frac{669.4}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$

= 0.0006"

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

$= |0 + 0.0002 - (0.0006)|$

= 0.0004"

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

$= 0.0002 + (0.0006) - (0)$

= 0.0008"

Operating, Hot & Corroded, Seismic, Below Support Point

CODEWARE EXAMPLE

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

$= \dfrac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

$= \dfrac{297}{\pi \cdot 18.125^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

$t_w = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.11\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0014"

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

$= 0.0478 + 0 - (-0.0014)$

= 0.0492"

$t_{w\ c} = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.49\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0006"

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

$= |0 + (-0.0006) - (0.0478)|$

= 0.0484"

Maximum allowable working pressure, Longitudinal Stress

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

$= \dfrac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.25 - 0 + (-0.0014))}{18 - 0.40 \cdot (0.25 - 0 + (-0.0014))}$

= 522.23 psi

Operating, Hot & New, Seismic, Below Support Point

CODEWARE EXAMPLE

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

= $\frac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

= $\frac{297}{\pi \cdot 18.125^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

= $\frac{1.11\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0014"

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

= $0.0478 + 0 - (-0.0014)$

= 0.0492"

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

= $\frac{0.49\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0006"

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

= $|0 + (-0.0006) - (0.0478)|$

= 0.0484"

Maximum allowable working pressure, Longitudinal Stress

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

= $\frac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.25 - 0 + (-0.0014))}{18 - 0.40 \cdot (0.25 - 0 + (-0.0014))}$

= 522.23 psi

Hot Shut Down, Corroded, Seismic, Below Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{297}{\pi \cdot 18.125^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

$t_w = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.11\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0014"

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

$= 0 + 0 - (-0.0014)$

= 0.0014"

$t_{w\,c} = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.49\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0006"

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

$= |0 + (-0.0006) - (0)|$

= 0.0006"

Hot Shut Down, New, Seismic, Below Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \frac{297}{\pi \cdot 18.125^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= \frac{1.11\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0014"

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

$= 0 + 0 - (-0.0014)$

= 0.0014"

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

$= \frac{0.49\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0006"

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

$= |0 + (-0.0006) - (0)|$

= 0.0006"

Empty, Corroded, Seismic, Below Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$$= \frac{83}{\pi \cdot 18.125^{\ 2} \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$$

= 0"

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

$$= \frac{1.11\text{*-}104.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$$

= -0.0001"

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

$= 0 + 0 - (-0.0001)$

= 0.0001"

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

$$= \frac{0.49\text{*-}104.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$$

= 0"

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

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

= 0"

Empty, New, Seismic, Below Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{83}{\pi \cdot 18.125\ ^2 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0"

$t_w = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.11\text{*-}104.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= -0.0001"

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

$= 0 + 0 - (-0.0001)$

= 0.0001"

$t_{w\,c} = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.49\text{*-}104.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0"

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

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

= 0"

Vacuum, Seismic, Below Support Point

CODEWARE EXAMPLE

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

$$= \frac{-15 \cdot 18}{2 \cdot 9{,}464.71 \cdot 1.00 + 0.40 \cdot |15|}$$

$$= -0.0143$$

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

$$= \frac{297}{\pi \cdot 18.125\ ^2 \cdot 9{,}464.71 \cdot 1.00}$$

$$= 0''$$

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

$$= \frac{1.11\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$$

$$= -0.0027''$$

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

$$= |-0.0143 + 0 - (-0.0027)|$$

= 0.0115"

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

$$= \frac{0.49\text{*-}2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$$

$$= -0.0012''$$

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

$$= 0 + (-0.0012) - (-0.0143)$$

= 0.0131"

Maximum Allowable External Pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0.40 \cdot (t - t_{mc} - t_{wc})}$$

$$= \frac{2 \cdot 9{,}464.71 \cdot 1.00 \cdot (0.25 - 0 - -0.0012)}{18 - 0.40 \cdot (0.25 - 0 - -0.0012)}$$

= 265.61 psi

Hot Shut Down, Corroded, Weight & Eccentric Moments Only, Below Support Point

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{0}{\pi \cdot 18.125\ ^2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= \dfrac{-2{,}619.1}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0012"

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

$= 0 + 0 - (-0.0012)$

= 0.0012"

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

$= |0 + (-0.0012) - (0)|$

= 0.0012"

CODEWARE EXAMPLE

Legs #1

Inputs	
Leg material	
Leg description	4 inch sch 40 pipe
Number of legs, N	4
Overall length	50"
Base to girth seam length	40"
User defined leg eccentricity	0"
Effective length coefficient, K	1.5
Coefficient, C_m	0.85
Leg yield stress, F_y	36,000 psi
Leg elastic modulus, E	29,000,000 psi
Angular Position	0°
Anchor Bolts	
Anchor bolt size	0.375" coarse threaded
Anchor bolt material	
Bolt circle, BC	38.375"
Anchor bolts/leg, n	1
Anchor bolt allowable stress, S_b	20,000 psi
Anchor bolt corrosion allowance	0"
Anchor bolt hole clearance	0.375"
Reinforcing Pad	
Pad length	10"
Pad width	6.5"
Pad thickness	0.1875"
Base Plate	
Base plate length	10"
Base plate width	8"
Base plate thickness	0.375" (0.1705" required)
Base plate allowable stress	24,000 psi
Foundation allowable bearing stress	1,658 psi
Welds	
Leg to pad fillet weld	0.1875" (0.0215" required)
Pad to shell fillet weld	0.125" (0.0126" required)
Legs braced	No

Note: The support attachment point is assumed to be 1 in up from the cylinder circumferential seam.

CODEWARE EXAMPLE

Weight operating corroded, Moment = 150.0 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	830.1	0.0	262	0	0	0.0137	0.0121
	90	878.9	0.0	277	0	0	0.0145	0.0128
	180	927.7	0.0	293	0	0	0.0153	0.0135
	270	878.9	0.0	277	0	0	0.0145	0.0128

Weight empty corroded, Moment = 150.0 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	201.5	0.0	64	0	0	0.0033	0.0029
	90	250.3	0.0	79	0	0	0.0041	0.0037
	180	299.1	0.0	94	0	0	0.0049	0.0044
	270	250.3	0.0	79	0	0	0.0041	0.0037

CODEWARE EXAMPLE

Weight vacuum corroded, Moment = 150.0 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	830.1	0.0	262	0	0	0.0137	0.0121
	90	878.9	0.0	277	0	0	0.0145	0.0128
	180	927.7	0.0	293	0	0	0.0153	0.0135
	270	878.9	0.0	277	0	0	0.0145	0.0128

Governing Condition : Seismic operating corroded, Moment = 1,943.0 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	-231.1	164.1	-73	2,100	0	0.0712	0.0850
	90	914.2	164.1	288	0	2,100	0.0904	0.1017
	180	1,546.5	164.1	488	2,100	0	0.1010	0.1110
	270	914.2	164.1	288	0	2,100	0.0904	0.1017
45	0	-231.1	164.1	-73	1,485	1,485	0.1023	0.1216
	90	-231.1	164.1	-73	1,485	1,485	0.1023	0.1216
	180	1,546.5	164.1	488	1,485	1,485	0.1323	0.1476
	270	1,546.5	164.1	488	1,485	1,485	0.1323	0.1476

CODEWARE EXAMPLE

Seismic empty corroded, Moment = 699.7 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	-133.3	42.0	-42	538	0	0.0170	0.0207
	90	215.1	42.0	68	0	538	0.0228	0.0258
	180	442.8	42.0	140	538	0	0.0266	0.0291
	270	215.1	42.0	68	0	538	0.0228	0.0258
45	0	-133.3	42.0	-42	380	380	0.0250	0.0301
	90	-133.3	42.0	-42	380	380	0.0250	0.0301
	180	442.8	42.0	140	380	380	0.0346	0.0385
	270	442.8	42.0	140	380	380	0.0346	0.0385

Seismic vacuum corroded, Moment = 1,943.0 lb_f-ft								
Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
0	0	-231.1	164.1	-73	2,100	0	0.0712	0.0850
	90	914.2	164.1	288	0	2,100	0.0904	0.1017
	180	1,546.5	164.1	488	2,100	0	0.1010	0.1110
	270	914.2	164.1	288	0	2,100	0.0904	0.1017
45	0	-231.1	164.1	-73	1,485	1,485	0.1023	0.1216
	90	-231.1	164.1	-73	1,485	1,485	0.1023	0.1216
	180	1,546.5	164.1	488	1,485	1,485	0.1323	0.1476
	270	1,546.5	164.1	488	1,485	1,485	0.1323	0.1476

CODEWARE EXAMPLE

Leg Calculations (AISC manual ninth edition)

Axial end load, P_1 **(Based on vessel total bending moment acting at leg attachment elevation)**

$$P_1 = (1 + 0.14 \cdot S_{DS}) \cdot \frac{W_t}{N} + \frac{48 \cdot M_t}{N \cdot D} = (1 + 0.14 \cdot 0.8) \cdot \frac{3{,}288.55}{4} + \frac{48 \cdot 1{,}943}{4 \cdot 36.875} = 1{,}546.52 \quad lb_f$$

Allowable axial compressive stress, F_a (AISC chapter E)

$$C_c = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{F_y}} = \sqrt{\frac{2 \cdot \pi^2 \cdot 29{,}000{,}000}{36{,}000}} = 126.0993$$

$$\frac{K \cdot l}{r} = \frac{1.5 \cdot 41.125}{1.5102} = 40.8468$$

$$F_a = \frac{1 \cdot \left(1 - \frac{(K \cdot l/r)^2}{2 \cdot C_c^2}\right) \cdot F_y}{\frac{5}{3} + \frac{3}{8} \cdot \frac{K \cdot l/r}{C_c} - \frac{(K \cdot l/r)^3}{8 \cdot C_c^3}} = \frac{1 \cdot \left(1 - \frac{(40.8468)^2}{2 \cdot 126.0993^2}\right) \cdot 36{,}000}{\frac{5}{3} + \frac{3}{8} \cdot \frac{40.8468}{126.0993} - \frac{(40.8468)^3}{8 \cdot 126.0993^3}} = 19{,}122 \quad \text{psi}$$

Allowable axial compression and bending (AISC chapter H)

$$F'_{ex} = \frac{1 \cdot 12 \cdot \pi^2 \cdot E}{23 \cdot (K \cdot l/r)^2} = \frac{1 \cdot 12 \cdot \pi^2 \cdot 29{,}000{,}000}{23 \cdot (40.8468)^2} = 89{,}503 \quad \text{psi}$$

$$F'_{ey} = \frac{1 \cdot 12 \cdot \pi^2 \cdot E}{23 \cdot (K \cdot l/r)^2} = \frac{1 \cdot 12 \cdot \pi^2 \cdot 29{,}000{,}000}{23 \cdot (40.8468)^2} = 89{,}503 \quad \text{psi}$$

$$F_b = 1 \cdot 0.66 \cdot F_y = 1 \cdot 0.66 \cdot 36{,}000 = 23{,}760 \quad \text{psi}$$

Compressive axial stress

$$f_a = \frac{P_1}{A} = \frac{1{,}546.52}{3.17} = 488 \quad \text{psi}$$

Bending stresses

$$f_{bx} = \frac{F \cdot \cos(\alpha) \cdot L}{I_x / C_x} + \frac{P_1 \cdot E_{cc}}{I_x / C_x} = \frac{164.07 \cdot \cos(45) \cdot 41.125}{7.23/2.25} + \frac{1{,}546.52 \cdot 0}{7.23/2.25} = 1{,}485 \quad \text{psi}$$

$$f_{by} = \frac{F \cdot \sin(\alpha) \cdot L}{I_y / C_y} = \frac{164.07 \cdot \sin(45) \cdot 41.125}{7.23/2.25} = 1{,}485 \quad \text{psi}$$

AISC equation $H_{1\text{-}1}$

$$H_{1-1} = \frac{f_a}{F_a} + \frac{C_{mx} \cdot f_{bx}}{(1 - f_a/F'_{ex}) \cdot F_{bx}} + \frac{C_{my} \cdot f_{by}}{(1 - f_a/F'_{ey}) \cdot F_{by}}$$
$$= \frac{488}{19{,}122} + \frac{0.85 \cdot 1{,}485}{(1 - 488/89{,}503) \cdot 23{,}760} + \frac{0.85 \cdot 1{,}485}{(1 - 488/89{,}503) \cdot 23{,}760}$$
$$= 0.1323$$

AISC equation $H_{1\text{-}2}$

$$H_{1-2} = \frac{f_a}{0.6 \cdot 1 \cdot F_y} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} = \frac{488}{0.6 \cdot 1 \cdot 36{,}000} + \frac{1{,}485}{23{,}760} + \frac{1{,}485}{23{,}760} = 0.1476$$

4, 4 inch sch 40 pipe legs are adequate.

Anchor bolts - Seismic operating corroded condition governs

Tensile loading per leg (1 bolt per leg)

$$R = \frac{48 \cdot M}{N \cdot BC} - \frac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{N} = \frac{48 \cdot 4{,}108.9}{4 \cdot 38.375} - \frac{(0.6 - 0.14 \cdot 0.8) \cdot 3{,}515.73}{4} = 855.96 \quad \text{lb}_f$$

Required area per bolt

$$A_b = \frac{R}{S_b \cdot n} = \frac{855.96}{20{,}000 \cdot 1} = 0.0428 \quad \text{in}^2$$

Area of a 0.375" coarse threaded bolt (corroded) = 0.0678 in^2

0.375" coarse threaded bolts are satisfactory.

Check the leg to pad fillet weld, Bednar 10.3, Seismic operating corroded governs

Note: continuous welding is assumed for all support leg fillet welds.

$$Z_w = \frac{2 \cdot b \cdot d + d^2}{3} = \frac{2 \cdot 4.5 \cdot 8.875 + 8.875^2}{3} = 52.8802 \quad \text{in}^2$$

$$J_w = \frac{(b + 2 \cdot d)^3}{12} - \frac{d^2 \cdot (b + d)^2}{b + 2 \cdot d}$$
$$= \frac{(4.5 + 2 \cdot 8.875)^3}{12} - \frac{8.875^2 \cdot (4.5 + 8.875)^2}{4.5 + 2 \cdot 8.875}$$
$$= 284.6505 \quad \text{in}^3$$

$$E = \frac{d^2}{b + 2 \cdot d} = \frac{8.875^2}{4.5 + 2 \cdot 8.875} = 3.540028 \quad \text{in}$$

Governing weld load $f_x = \text{Cos}(45) \cdot 164.07 = 116.01 \quad \text{lb}_f$

Governing weld load $f_y = \text{Sin}(45) \cdot 164.07 = 116.01 \quad \text{lb}_f$

CODEWARE EXAMPLE

$$f_1 = \frac{P_1}{L_{\text{weld}}} = \frac{1{,}546.52}{22.25} = 69.51 \ \ \text{lb}_f/\text{in}$$ (V$_L$ direct shear)

$$f_2 = \frac{f_y \cdot L_{\text{leg}} \cdot 0.5 \cdot b}{J_w} = \frac{116.01 \cdot 41.125 \cdot 0.5 \cdot 4.5}{284.6505} = 37.71 \ \ \text{lb}_f/\text{in}$$ (V$_L$ torsion shear)

$$f_3 = \frac{f_y}{L_{\text{weld}}} = \frac{116.01}{22.25} = 5.21 \ \ \text{lb}_f/\text{in}$$ (V$_c$ direct shear)

$$f_4 = \frac{f_y \cdot L_{\text{leg}} \cdot E}{J_w} = \frac{116.01 \cdot 41.125 \cdot 3.54}{284.6505} = 59.33 \ \ \text{lb}_f/\text{in}$$ (V$_c$ torsion shear)

$$f_5 = \frac{f_x \cdot L_{\text{leg}} + P_1 \cdot E_{\text{cc}}}{Z_w} = \frac{116.01 \cdot 41.125 + 1{,}546.52 \cdot 0}{52.8802} = 90.22 \ \ \text{lb}_f/\text{in}$$ (M$_L$ bending)

$$f_6 = \frac{f_x}{L_{\text{weld}}} = \frac{116.01}{22.25} = 5.21 \ \ \text{lb}_f/\text{in}$$ (Direct outward radial shear)

$$f = \sqrt{(f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2}$$

$$= \sqrt{(69.51 + 37.71)^2 + (5.21 + 59.33)^2 + (90.22 + 5.21)^2}$$

$$= 157.39 \ \ \text{lb}_f/\text{in}$$ (Resultant shear load)

Required leg to pad fillet weld leg size **(welded both sides + top)**

$$t_w = \frac{f}{0.707 \cdot 0.55 \cdot S_a} = \frac{157.39}{0.707 \cdot 0.55 \cdot 18{,}800} = \underline{0.0215} \ \ \text{in}$$

The 0.1875 in leg to pad attachment fillet weld size is adequate.

Check the pad to vessel fillet weld, Bednar 10.3, Seismic operating corroded governs

$$Z_w = b \cdot d + \frac{d^2}{3} = 6.5 \cdot 10 + \frac{10^2}{3} = 98.3333 \ \ \text{in}^2$$

$$J_w = \frac{(b + d)^3}{6} = \frac{(6.5 + 10)^3}{6} = 748.6875 \ \ \text{in}^3$$

$$f_1 = \frac{P_1}{L_{\text{weld}}} = \frac{1{,}546.52}{33} = 46.86 \ \ \text{lb}_f/\text{in}$$ (V$_L$ direct shear)

$$f_2 = \frac{f_y \cdot L_{\text{leg}} \cdot 0.5 \cdot b}{J_w} = \frac{116.01 \cdot 41.125 \cdot 0.5 \cdot 6.5}{748.6875} = 20.71 \ \ \text{lb}_f/\text{in}$$ (V$_L$ torsion shear)

$$f_3 = \frac{f_y}{L_{\text{weld}}} = \frac{116.01}{33} = 3.52 \ \ \text{lb}_f/\text{in}$$ (V$_c$ direct shear)

$$f_4 = \frac{f_y \cdot L_{\text{leg}} \cdot 0.5 \cdot d}{J_w} = \frac{116.01 \cdot 41.125 \cdot 0.5 \cdot 10}{748.6875} = 31.86 \ \ \text{lb}_f/\text{in}$$ (V$_c$ torsion shear)

$$f_5 = \frac{f_x \cdot L_{\text{leg}} + P_1 \cdot E_{\text{cc}}}{Z_w} = \frac{116.01 \cdot 41.125 + 1{,}546.52 \cdot 0}{98.3333} = 48.52 \ \ \text{lb}_f/\text{in}$$ (M$_L$ bending)

$$f_6 = \frac{f_x}{L_{\text{weld}}} = \frac{116.01}{33} = 3.52 \ \ \text{lb}_f/\text{in}$$ (Direct outward radial shear)

$$f = \sqrt{(f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2}$$

$$= \sqrt{(46.86 + 20.71)^2 + (3.52 + 31.86)^2 + (48.52 + 3.52)^2}$$

CODEWARE EXAMPLE

= $92.33 \ \text{lb}_f/\text{in}$ (Resultant shear load)

Required pad to vessel fillet weld leg size **(welded all around the pad edge)**

$$t_w = \frac{f}{0.707 \cdot 0.55 \cdot S_a} = \frac{92.33}{0.707 \cdot 0.55 \cdot 18{,}800} = 0.0126 \ \text{in}$$

0.125 in pad to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$$f_p = \frac{P}{B \cdot N} = \frac{2{,}262.25}{8 \cdot 10} = 28 \ \text{psi}$$

$$t_b = \frac{N - (d - t_L)}{2} \cdot \sqrt{\frac{3 \cdot f_p}{S_b}} = \frac{10 - (4.5 - 0.237)}{2} \cdot \sqrt{\frac{3 \cdot 28}{24{,}000}} = 0.1705 \ \text{in}$$

The base plate thickness is adequate.

CODEWARE EXAMPLE

Check the leg to vessel attachment stresses, WRC 537 (Seismic operating corroded governs)

Applied Loads	
Radial load, P_r	-164.07 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	6,747.3 lb_f-in
Longitudinal shear, V_L	-231.1 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	102.17 psi
Mean shell radius, R_m	18.125"
Local shell thickness, T	0.25"
Design factor	3

Maximum stresses due to the applied loads at the pad edge (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{18.125}{0.25} = 72.5$$

$$C_1 = 3.25, C_2 = 7.937 \text{ in}$$

Local circumferential pressure stress $= \frac{P \cdot R_i}{T} = 7{,}356 \text{ psi}$

Local longitudinal pressure stress $= \frac{P \cdot R_i}{2 \cdot T} = 3{,}678 \text{ psi}$

Maximum combined stress $(P_L + P_b + Q) = 9{,}852 \text{ psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 56{,}400 \text{ psi}$

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

Maximum local primary membrane stress $(P_L) = 8{,}300 \text{ psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 28{,}200 \text{ psi}$

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

CODEWARE EXAMPLE

Stresses at the pad edge per WRC Bulletin 537										
Figure	**Y**	**β**	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.7609	0.3861	0	0	0	0	64	64	64	64
4C*	6.2199	0.3243	225	225	225	225	0	0	0	0
1C	0.05	0.2537	0	0	0	0	788	-788	788	-788
2C-1	0.0142	0.2537	224	-224	224	-224	0	0	0	0
3A*	2.0477	0.2415	0	0	0	0	0	0	0	0
1A	0.0554	0.2689	0	0	0	0	0	0	0	0
3B*	3.7024	0.3252	-719	-719	719	719	0	0	0	0
1B-1	0.0108	0.2898	-1,328	1,328	1,328	-1,328	0	0	0	0
Pressure stress*			7,356	7,356	7,356	7,356	7,356	7,356	7,356	7,356
Total circumferential stress			5,758	7,966	9,852	6,748	8,208	6,632	8,208	6,632
Primary membrane circumferential stress*			6,862	6,862	8,300	8,300	7,420	7,420	7,420	7,420
3C*	2.3894	0.3243	87	87	87	87	0	0	0	0
4C*	5.1391	0.3861	0	0	0	0	186	186	186	186
1C-1	0.0204	0.3354	321	-321	321	-321	0	0	0	0
2C	0.03	0.3354	0	0	0	0	473	-473	473	-473
4A*	6.9606	0.2415	0	0	0	0	0	0	0	0
2A	0.0222	0.3333	0	0	0	0	0	0	0	0
4B*	2.0399	0.3252	-603	-603	603	603	0	0	0	0
2B-1	0.0158	0.3585	-1,572	1,572	1,572	-1,572	0	0	0	0
Pressure stress*			3,678	3,678	3,678	3,678	3,678	3,678	3,678	3,678
Total longitudinal stress			1,911	4,413	6,261	2,475	4,337	3,391	4,337	3,391
Primary membrane longitudinal stress*			3,162	3,162	4,368	4,368	3,864	3,864	3,864	3,864
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	29	29	-29	-29
Total Shear stress			0	0	0	0	29	29	-29	-29
Combined stress (P_L+P_b+Q)			5,758	7,966	9,852	6,748	8,208	6,632	8,208	6,632

* denotes primary stress.

Maximum stresses due to the applied loads at the leg edge (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{18.125}{0.4375} = 41.4286$$

$C_1 = 2.25, C_2 = 7.0441$ in

Local circumferential pressure stress $= \frac{P \cdot R_i}{T} = 7{,}356$ psi

Local longitudinal pressure stress $= \frac{P \cdot R_i}{2 \cdot T} = 3{,}678$ psi

Maximum combined stress $(P_L + P_b + Q) = 9{,}076$ psi

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 56{,}400$ psi

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

Maximum local primary membrane stress $(P_L) = 7{,}968$ psi

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 28{,}200$ psi

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

CODEWARE EXAMPLE

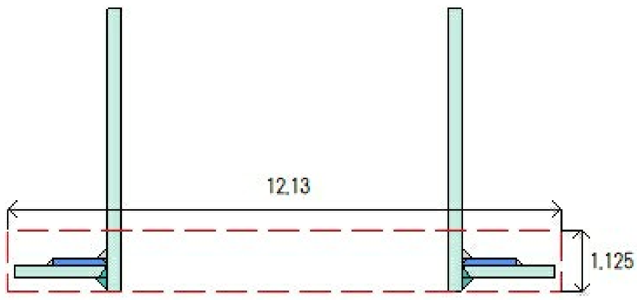
Stresses at the leg edge per WRC Bulletin 537										
Figure	Y	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	1.7721	0.3153	0	0	0	0	37	37	37	37
4C*	5.3424	0.2595	111	111	111	111	0	0	0	0
1C	0.0674	0.1957	0	0	0	0	347	-347	347	-347
2C-1	0.0355	0.1957	182	-182	182	-182	0	0	0	0
3A*	1.603	0.1816	0	0	0	0	0	0	0	0
1A	0.0711	0.2195	0	0	0	0	0	0	0	0
3B*	3.9247	0.2657	-501	-501	501	501	0	0	0	0
1B-1	0.0188	0.2374	-926	926	926	-926	0	0	0	0
Pressure stress*			7,356	7,356	7,356	7,356	7,356	7,356	7,356	7,356
Total circumferential stress			6,222	7,710	9,076	6,860	7,740	7,046	7,740	7,046
Primary membrane circumferential stress*			6,966	6,966	7,968	7,968	7,393	7,393	7,393	7,393
3C*	2.225	0.2595	46	46	46	46	0	0	0	0
4C*	4.7054	0.3153	0	0	0	0	97	97	97	97
1C-1	0.0462	0.2695	238	-238	238	-238	0	0	0	0
2C	0.03	0.2695	0	0	0	0	154	-154	154	-154
4A*	2.9122	0.1816	0	0	0	0	0	0	0	0
2A	0.0269	0.2863	0	0	0	0	0	0	0	0
4B*	1.4665	0.2657	-309	-309	309	309	0	0	0	0
2B-1	0.0284	0.3082	-1,076	1,076	1,076	-1,076	0	0	0	0
Pressure stress*			3,678	3,678	3,678	3,678	3,678	3,678	3,678	3,678
Total longitudinal stress			2,577	4,253	5,347	2,719	3,929	3,621	3,929	3,621
Primary membrane longitudinal stress*			3,415	3,415	4,033	4,033	3,775	3,775	3,775	3,775
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	19	19	-19	-19
Total Shear stress			0	0	0	0	19	19	-19	-19
Combined stress (P_L+P_b+Q)			6,222	7,710	9,076	6,860	7,740	7,046	7,740	7,046

* denotes primary stress.

CODEWARE EXAMPLE

Nozzle #1 (N1)

ASME Section VIII Division 1, 2023 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	22"
End of nozzle to shell center	26.1875"
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	4.4375"
Internal projection, h_{new}	0.25"
Projection available outside vessel to flange face, Lf	7.9375"
Local vessel minimum thickness	0.25"
Liquid static head included	1.48 psi

Reinforcing Pad	
Material specification	SA-105 (II-D p. 20, ln. 31)
Diameter, D_p	8.625"
Thickness, t_e	0.125"
Is split	No

Welds	
Inner fillet, Leg_{41}	0.1875"
Outer fillet, Leg_{42}	0.125"
Lower fillet, Leg_{43}	0.25"
Nozzle to vessel groove weld	0.25"
Pad groove weld	0.125"

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

CODEWARE EXAMPLE

ASME B16.5-2020 Flange	
Description	NPS 6 Class 150 WN A105
Bolt Material	SA-193 B7 Bolt <= 2 1/2 (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	1.37 psi
MAWP rating	125 psi @ 650°F
MAP rating	285 psi @ 70°F
Hydrotest rating	450 psi @ 70°F
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Factor, m	2
Seating Stress, y	2,500 psi
Thickness, T	0.175"
Inner Diameter	6.125"
Outer Diameter	6.25"
Notes	
Flange rated MDMT per UCS-66(b)(1)(b) = -55°F (Coincident ratio = 0.3557) Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

CODEWARE EXAMPLE

ASME PCC-1 Appendix O Joint Component Approach	
$Sb_{sel} = \dfrac{Sg_T A_g}{n_b A_b}$	(O-1)
$Sb_{sel} = \min\left[Sb_{sel}, Sb_{\max}\right]$	(O-4)
$Sb_{sel} = \max\left[Sb_{sel}, Sb_{\min}\right]$	(O-5)
$Sb_{sel} = \min\left[Sb_{sel}, Sf_{\max}\left(\dfrac{S_{yo}}{S_{ya}}\right)\right]$	(O-6)
$Sb_{sel} \geq Sg_{\min-S}\left[\dfrac{A_g}{A_b n_b}\right]$	(O-7)
$Sb_{sel} \geq \dfrac{Sg_{\min-O} A_g + \frac{\pi}{4} P_{\max} G_{I.D.}^2}{\phi_g A_b n_b}$	(O-8)
$Sb_{sel} \leq Sg_{\max}\left[\dfrac{A_g}{A_b n_b}\right]$	(O-9)
$Sb_{sel} \leq Sf_{\max}\left(\dfrac{S_{yo}}{S_{ya}}\right)\left(\dfrac{\theta_{g\max}}{\theta_{f\max}}\right)$	(O-10)
$T_b = Sb_{sel} K A_b \phi_b$	(O-2)

Results		
$A_g = \dfrac{\pi}{4} \cdot \left(6.25^{\,2} - 6.125^{\,2}\right) =$	1.21 in^2	
$Sb_{sel} = \dfrac{30{,}000 \cdot 1.21}{8 \cdot 0.302} =$	15,086 psi	
$Sb_{sel} = \min\left[15{,}086, 73{,}500\right] =$	15,086 psi	
$Sb_{sel} = \max\left[15{,}086, 42{,}000\right] =$	42,000 psi	
$Sb_{sel} = \min\left[42{,}000, 60{,}000 \cdot \left(\dfrac{26{,}700}{36{,}000}\right)\right] =$	42,000 psi	
$Sb_{sel} \geq 20{,}000 \cdot \left[\dfrac{1.21}{0.302 \cdot 8}\right] =$	10,057 psi	✔
$Sb_{sel} \geq \dfrac{15{,}000 \cdot 1.21 + \frac{\pi}{4} \cdot 100 \cdot 6.125^{\,2}}{0.7 \cdot 0.302 \cdot 8} =$	12,518 psi	✔
$Sb_{sel} \leq 35{,}000 \cdot \left[\dfrac{1.21}{0.302 \cdot 8}\right] =$	17,600 psi	✘
$Sb_{sel} \leq 60{,}000 \cdot \left(\dfrac{26{,}700}{36{,}000}\right) \cdot \left(\dfrac{1}{0.32}\right) =$	139,063 psi	✔
$T_b = 42{,}000 \cdot 0.172 \cdot 0.302 \cdot \dfrac{0.75}{12} =$	136.4 lb_f-ft	

CODEWARE EXAMPLE

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, t_g =	0.25"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{101.48 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 101.48} =$	0.0916"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0916 \cdot 1}{0.25 - 0} =$	0.3664
$\text{Stress ratio longitudinal} = \frac{3{,}619 \cdot 1}{20{,}000 \cdot 1} =$	0.1809
Reduction in MDMT, T_R from Fig UCS-66.1 =	121.5°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 121.5, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

UCS-66 Material Toughness Requirements Nozzle	
$t_r = \frac{101.48 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 101.48} =$	0.0154"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0154 \cdot 1}{0.28 - 0} =$	0.0551
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.	

UCS-66 Material Toughness Requirements Pad	
Governing thickness, t_g =	0.125"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{101.48 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 101.48} =$	0.0916"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0916 \cdot 1}{0.25 - 0} =$	0.3664
$\text{Stress ratio longitudinal} = \frac{3{,}619 \cdot 1}{20{,}000 \cdot 1} =$	0.1809
Reduction in MDMT, T_R from Fig UCS-66.1 =	121.5°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 121.5, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

CODEWARE EXAMPLE

Reinforcement Calculations for Internal Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 101.48 psi @ 650 °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}
0.5941	1.708	0.9205	0.3109	0.1326	0.2367	0.1073	0.0975	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
-4,615.63	11,199.16	49,542.67	12,567.88	93,038.24	17,296.08	73,656.16

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for internal pressure 101.48 psi @ 650 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.25 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.625 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

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

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

$$= \frac{101.4812 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 101.4812}$$

$$= 0.0173 \text{ in}$$

Required thickness t_r from UG-37(a)

CODEWARE EXAMPLE

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

$= \frac{101.4812 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 101.4812}$

$= 0.0975$ in

Area required per UG-37(c)

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

$= 6.065 \cdot 0.0975 \cdot 1 + 2 \cdot 0.28 \cdot 0.0975 \cdot 1 \cdot (1 - 0.9468)$

= 0.5941 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.9205 in^2

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

$= 6.065 \cdot (1 \cdot 0.25 - 1 \cdot 0.0975) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.0975) \cdot (1 - 0.9468)$

$= 0.9205$ in^2

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

$= 2 \cdot (0.25 + 0.28) \cdot (1 \cdot 0.25 - 1 \cdot 0.0975) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.0975) \cdot (1 - 0.9468)$

$= 0.1571$ in^2

A_2 = smaller of the following= 0.3109 in^2

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

$= 5 \cdot (0.28 - 0.0173) \cdot 0.9468 \cdot 0.25$

$= 0.3109$ in^2

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

$= 2 \cdot (0.28 - 0.0173) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$

$= 0.4104$ in^2

A_3 = smaller of the following= 0.1326 in^2

CODEWARE EXAMPLE

$= 5 \cdot t \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

$=$ 0.3314 in^2

$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

$=$ 0.3711 in^2

$= 2 \cdot h \cdot t_i \cdot f_{r2}$

$= 2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

$=$ 0.1326 in^2

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

$= 0.1875^{\,2} \cdot 0.9468$

$=$ 0.0333 in^2

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

$= 0.125^{\,2} \cdot 0.9468$

$=$ 0.0148 in^2

$A_{43} = Leg^2 \cdot f_{r2}$

$= 0.25^{\,2} \cdot 0.9468$

$=$ 0.0592 in^2

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

$= (8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

$=$ 0.2367 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.9205 + 0.3109 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

$=$ 1.708 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\,[0.75,\ t_n,\ t_e] =$ 0.125 in

$t_{c(\min)} = \min\,[0.25,\ 0.7 \cdot t_{\min}] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\,[0.75,\ t_e,\ t] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

CODEWARE EXAMPLE

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

$$= \frac{101.4812 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 101.4812} + 0$$

$$= 0.0173 \text{ in}$$

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

$$= \max\left[0.0173,\ 0\right]$$

$$= 0.0173 \text{ in}$$

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

$$= \frac{101.4812 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 101.4812} + 0$$

$$= 0.0975 \text{ in}$$

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

$$= \max\left[0.0975,\ 0.0625\right]$$

$$= 0.0975 \text{ in}$$

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

$$= \min\left[0.245,\ 0.0975\right]$$

$$= 0.0975 \text{ in}$$

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

$$= \max\left[0.0173,\ 0.0975\right]$$

$$= 0.0975 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 18{,}800$	=	13,912 psi
Nozzle wall in shear:	$0.7 \cdot 17{,}800$	=	12,460 psi
Inner fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi
Outer fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi
Upper groove weld in tension:	$0.74 \cdot 17{,}800$	=	13,172 psi
Lower fillet weld in shear:	$0.49 \cdot 17{,}800$	=	8,722 psi

Strength of welded joints:

(1) Inner fillet weld in shear

$$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 8{,}722 = 17{,}018.57 \text{ lb}_f$$

(2) Outer fillet weld in shear

CODEWARE EXAMPLE

$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 8{,}722$ = 14,770.84 lb_f

(3) Nozzle wall in shear
$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 12{,}460$ = 34,771.83 lb_f

(4) Groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 13{,}912$ = 36,193.9 lb_f

(5) Lower fillet weld in shear
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 8{,}722$ = 22,691.43 lb_f

(6) Upper groove weld in tension
$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 13{,}172$ = 17,134.34 lb_f

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

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(0.5941 - 0.9205 + 2 \cdot 0.28 \cdot 0.9468 \cdot (1 \cdot 0.25 - 1 \cdot 0.0975)) \cdot 18{,}800$

= -4,615.63 lb_f

$W_{1\text{-}1}$ = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.3109 + 0.2367 + 0.0333 + 0.0148) \cdot 18{,}800$

= 11,199.16 lb_f

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

= $(0.3109 + 0.1326 + 0.0333 + 0.0592 + 2 \cdot 0.28 \cdot 0.25 \cdot 0.9468) \cdot 18{,}800$

= 12,567.88 lb_f

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

= $(0.3109 + 0.1326 + 0.2367 + 0.0333 + 0.0148 + 0.0592 + 2 \cdot 0.28 \cdot 0.25 \cdot 0.9468) \cdot 18{,}800$

= 17,296.08 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = -4,615.63 lb_f
Path 1-1 through (2) & (3) = 14,770.84 + 34,771.83 = 49,542.67 lb_f
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = -4,615.63 lb_f
Path 2-2 through (1), (4), (5), (6) = 17,018.57 + 36,193.9 + 22,691.43 + 17,134.34 = 93,038.24 lb_f
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = -4,615.63 lb_f
Path 3-3 through (2), (4), (5) = 14,770.84 + 36,193.9 + 22,691.43 = 73,656.16 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

Reinforcement Calculations for MAWP

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For P = 125.11 psi @ 650 °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}
0.733	1.5656	0.7829	0.3061	0.1326	0.2367	0.1073	0.1203	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
355.4	11,108.92	49,542.67	12,477.64	93,038.24	17,205.84	73,656.16

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for internal pressure 125.11 psi @ 650 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.25 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.625 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

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

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

$$= \frac{125.1095 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 125.1095}$$

$$= 0.0214 \text{ in}$$

Required thickness t_r from UG-37(a)

CODEWARE EXAMPLE

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

$$= \frac{125.1095 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 125.1095}$$

$$= 0.1203 \text{ in}$$

Area required per UG-37(c)

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

$$= 6.065 \cdot 0.1203 \cdot 1 + 2 \cdot 0.28 \cdot 0.1203 \cdot 1 \cdot (1 - 0.9468)$$

= 0.733 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.7829 in^2

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

$$= 6.065 \cdot (1 \cdot 0.25 - 1 \cdot 0.1203) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.1203) \cdot (1 - 0.9468)$$

$$= 0.7829 \text{ in}^2$$

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

$$= 2 \cdot (0.25 + 0.28) \cdot (1 \cdot 0.25 - 1 \cdot 0.1203) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.1203) \cdot (1 - 0.9468)$$

$$= 0.1336 \text{ in}^2$$

A_2 = smaller of the following= 0.3061 in^2

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

$$= 5 \cdot (0.28 - 0.0214) \cdot 0.9468 \cdot 0.25$$

$$= 0.3061 \text{ in}^2$$

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

$$= 2 \cdot (0.28 - 0.0214) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$$

$$= 0.404 \text{ in}^2$$

A_3 = smaller of the following= 0.1326 in^2

CODEWARE EXAMPLE

$= 5 \cdot t \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

= 0.3314 in^2

$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$

$= 5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

= 0.3711 in^2

$= 2 \cdot h \cdot t_i \cdot f_{r2}$

$= 2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

= 0.1326 in^2

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

$= 0.1875^2 \cdot 0.9468$

= 0.0333 in^2

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

$= 0.125^2 \cdot 0.9468$

= 0.0148 in^2

$A_{43} = Leg^2 \cdot f_{r2}$

$= 0.25^2 \cdot 0.9468$

= 0.0592 in^2

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

$= (8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

= 0.2367 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.7829 + 0.3061 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

= 1.5656 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min[0.75,\ t_n,\ t_e] =$ 0.125 in

$t_{c(\min)} = \min[0.25,\ 0.7 \cdot t_{\min}] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min[0.75,\ t_e,\ t] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

CODEWARE EXAMPLE

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

$$= \frac{125.1095 \cdot 3.0325}{17{,}800 \cdot 1 - 0.6 \cdot 125.1095} + 0$$

$$= 0.0214 \text{ in}$$

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

$$= \max\left[0.0214,\ 0\right]$$

$$= 0.0214 \text{ in}$$

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

$$= \frac{125.1095 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 125.1095} + 0$$

$$= 0.1203 \text{ in}$$

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

$$= \max\left[0.1203,\ 0.0625\right]$$

$$= 0.1203 \text{ in}$$

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

$$= \min\left[0.245,\ 0.1203\right]$$

$$= 0.1203 \text{ in}$$

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

$$= \max\left[0.0214,\ 0.1203\right]$$

$$= 0.1203 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 18{,}800$ =	13,912 psi
Nozzle wall in shear:	$0.7 \cdot 17{,}800$ =	12,460 psi
Inner fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi
Outer fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi
Upper groove weld in tension:	$0.74 \cdot 17{,}800$ =	13,172 psi
Lower fillet weld in shear:	$0.49 \cdot 17{,}800$ =	8,722 psi

Strength of welded joints:

(1) Inner fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 8{,}722$ = 17,018.57 lb_f

(2) Outer fillet weld in shear

$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 8{,}722$ = 14,770.84 lb_f

CODEWARE EXAMPLE

(3) Nozzle wall in shear

$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 12{,}460$ = 34,771.83 lb_f

(4) Groove weld in tension

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 13{,}912$ = 36,193.9 lb_f

(5) Lower fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 8{,}722$ = 22,691.43 lb_f

(6) Upper groove weld in tension

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 13{,}172$ = 17,134.34 lb_f

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

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(0.733 - 0.7829 + 2 \cdot 0.28 \cdot 0.9468 \cdot (1 \cdot 0.25 - 1 \cdot 0.1203)) \cdot 18{,}800$

= 355.4 lb_f

$W_{1\text{-}1}$ = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.3061 + 0.2367 + 0.0333 + 0.0148) \cdot 18{,}800$

= 11,108.92 lb_f

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

= $(0.3061 + 0.1326 + 0.0333 + 0.0592 + 2 \cdot 0.28 \cdot 0.25 \cdot 0.9468) \cdot 18{,}800$

= 12,477.64 lb_f

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

= $(0.3061 + 0.1326 + 0.2367 + 0.0333 + 0.0148 + 0.0592 + 2 \cdot 0.28 \cdot 0.25 \cdot 0.9468) \cdot 18{,}800$

= 17,205.84 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 355.4 lb_f
Path 1-1 through (2) & (3) = 14,770.84 + 34,771.83 = 49,542.67 lb_f
Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 355.4 lb_f
Path 2-2 through (1), (4), (5), (6) = 17,018.57 + 36,193.9 + 22,691.43 + 17,134.34 = 93,038.24 lb_f
Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 355.4 lb_f
Path 3-3 through (2), (4), (5) = 14,770.84 + 36,193.9 + 22,691.43 = 73,656.16 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

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 = 211.98 psi @ 70 °F The opening is adequately reinforced							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
1.1645	1.1646	0.3517	0.3096	0.14	0.25	0.1133	0.192	0.28

UG-41 Weld Failure Path Analysis Summary (lb_f)						
All failure paths are stronger than the applicable weld loads						
Weld load W	Weld load W_{1-1}	Path 1-1 strength	Weld load W_{2-2}	Path 2-2 strength	Weld load W_{3-3}	Path 3-3 strength
16,906.3	12,208	55,665.92	13,746	102,374.2	19,058	80,596.58

Calculations for internal pressure 211.98 psi @ 70 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.25 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.625 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

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

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

$$= \frac{211.9842 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 211.9842}$$

$$= 0.0323 \text{ in}$$

Required thickness t_r from UG-37(a)

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

$$= \frac{211.9842 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 211.9842}$$

$$= 0.192 \text{ in}$$

CODEWARE EXAMPLE

Area required per UG-37(c)

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

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

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

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 1

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

A	=	$d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$
	=	$6.065 \cdot 0.192 \cdot 1 + 2 \cdot 0.28 \cdot 0.192 \cdot 1 \cdot (1 - 1)$
	=	1.1645 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.3517 in^2

=	$d \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$
=	$6.065 \cdot (1 \cdot 0.25 - 1 \cdot 0.192) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.192) \cdot (1 - 1)$
=	$0.3517 \ \text{in}^2$
=	$2 \cdot (t + t_n) \cdot (E_1 \cdot t - F \cdot t_r) - 2 \cdot t_n \cdot (E_1 \cdot t - F \cdot t_r) \cdot (1 - f_{r1})$
=	$2 \cdot (0.25 + 0.28) \cdot (1 \cdot 0.25 - 1 \cdot 0.192) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.192) \cdot (1 - 1)$
=	$0.0615 \ \text{in}^2$

A_2 = smaller of the following= 0.3096 in^2

=	$5 \cdot (t_n - t_{rn}) \cdot f_{r2} \cdot t$
=	$5 \cdot (0.28 - 0.0323) \cdot 1 \cdot 0.25$
=	$0.3096 \ \text{in}^2$
=	$2 \cdot (t_n - t_{rn}) \cdot (2.5 \cdot t_n + t_e) \cdot f_{r2}$
=	$2 \cdot (0.28 - 0.0323) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 1$
=	$0.4087 \ \text{in}^2$

A_3 = smaller of the following= 0.14 in^2

=	$5 \cdot t \cdot t_i \cdot f_{r2}$
=	$5 \cdot 0.25 \cdot 0.28 \cdot 1$
=	0.35 in^2

CODEWARE EXAMPLE

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.28 \cdot 0.28 \cdot 1$

= 0.392 in^2

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.25 \cdot 0.28 \cdot 1$

= 0.14 in^2

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

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

= 0.0352 in^2

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

= $0.125^{\ 2} \cdot 1$

= 0.0156 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

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

= 0.0625 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 1$

= 0.25 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0.3517 + 0.3096 + 0.14 + 0.0352 + 0.0156 + 0.0625 + 0.25$

= 1.1646 in^2

As Area >= A the reinforcement is adequate.

UG-45 Nozzle Neck Thickness Check

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

$$= \frac{211.9842 \cdot 3.0325}{20{,}000 \cdot 1 - 0.6 \cdot 211.9842} + 0$$

$$= 0.0323 \text{ in}$$

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

$$= \max\left[0.0323,\ 0\right]$$

$$= 0.0323 \text{ in}$$

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

$$= \frac{211.9842 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 211.9842} + 0$$

$$= 0.192 \text{ in}$$

CODEWARE EXAMPLE

$$t_{b1} = \max\left[t_{b1},\ t_{bUG16}\right]$$

$$= \max\left[0.192,\ 0.0625\right]$$

$$= 0.192 \text{ in}$$

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

$$= \min\left[0.245,\ 0.192\right]$$

$$= 0.192 \text{ in}$$

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

$$= \max\left[0.0323,\ 0.192\right]$$

$$= 0.192 \text{ in}$$

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

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

Groove weld in tension:	$0.74 \cdot 20{,}000$	=	14,800 psi
Nozzle wall in shear:	$0.7 \cdot 20{,}000$	=	14,000 psi
Inner fillet weld in shear:	$0.49 \cdot 20{,}000$	=	9,800 psi
Outer fillet weld in shear:	$0.49 \cdot 20{,}000$	=	9,800 psi
Upper groove weld in tension:	$0.74 \cdot 20{,}000$	=	14,800 psi
Lower fillet weld in shear:	$0.49 \cdot 20{,}000$	=	9,800 psi

Strength of welded joints:

(1) Inner fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_i = \frac{\pi}{2} \cdot 6.625 \cdot 0.1875 \cdot 9{,}800$ = 19,121.99 lb_f

(2) Outer fillet weld in shear

$\frac{\pi}{2} \cdot \text{Pad OD} \cdot \text{Leg} \cdot S_o = \frac{\pi}{2} \cdot 8.625 \cdot 0.125 \cdot 9{,}800$ = 16,596.44 lb_f

(3) Nozzle wall in shear

$\frac{\pi}{2} \cdot \text{Mean nozzle dia} \cdot t_n \cdot S_n = \frac{\pi}{2} \cdot 6.345 \cdot 0.28 \cdot 14{,}000$ = 39,069.47 lb_f

(4) Groove weld in tension

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 14{,}800$ = 38,504.14 lb_f

(5) Lower fillet weld in shear

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot \text{Leg} \cdot S_l = \frac{\pi}{2} \cdot 6.625 \cdot 0.25 \cdot 9{,}800$ = 25,495.99 lb_f

(6) Upper groove weld in tension

$\frac{\pi}{2} \cdot \text{Nozzle OD} \cdot t_w \cdot S_g = \frac{\pi}{2} \cdot 6.625 \cdot 0.125 \cdot 14{,}800$ = 19,252.07 lb_f

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

CODEWARE EXAMPLE

W = $(A - A_1 + 2 \cdot t_n \cdot f_{r1} \cdot (E_1 \cdot t - F \cdot t_r)) \cdot S_v$

= $(1.1645 - 0.3517 + 2 \cdot 0.28 \cdot 1 \cdot (1 \cdot 0.25 - 1 \cdot 0.192)) \cdot 20{,}000$

= 16,906.3 lb_f

$W_{1\text{-}1}$ = $(A_2 + A_5 + A_{41} + A_{42}) \cdot S_v$

= $(0.3096 + 0.25 + 0.0352 + 0.0156) \cdot 20{,}000$

= 12,208 lb_f

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

= $(0.3096 + 0.14 + 0.0352 + 0.0625 + 2 \cdot 0.28 \cdot 0.25 \cdot 1) \cdot 20{,}000$

= 13,746 lb_f

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

= $(0.3096 + 0.14 + 0.25 + 0.0352 + 0.0156 + 0.0625 + 2 \cdot 0.28 \cdot 0.25 \cdot 1) \cdot 20{,}000$

= 19,058 lb_f

Load for path 1-1 lesser of W or $W_{1\text{-}1}$ = 12,208 lb_f
Path 1-1 through (2) & (3) = 16,596.44 + 39,069.47 = 55,665.92 lb_f
Path 1-1 is stronger than $W_{1\text{-}1}$ so it is acceptable per UG-41(b)(1).

Load for path 2-2 lesser of W or $W_{2\text{-}2}$ = 13,746 lb_f
Path 2-2 through (1), (4), (5), (6) = 19,121.99 + 38,504.14 + 25,495.99 + 19,252.07 = 102,374.2 lb_f
Path 2-2 is stronger than $W_{2\text{-}2}$ so it is acceptable per UG-41(b)(1).

Load for path 3-3 lesser of W or $W_{3\text{-}3}$ = 16,906.3 lb_f
Path 3-3 through (2), (4), (5) = 16,596.44 + 38,504.14 + 25,495.99 = 80,596.58 lb_f
Path 3-3 is stronger than W so it is acceptable per UG-41(b)(2).

CODEWARE EXAMPLE

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 15 psi @ 650 °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}
0.5277	1.2426	0.4637	0.3023	0.1326	0.2367	0.1073	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 size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for external pressure 15 psi @ 650 °F

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.25 - 0)\right]$$

$$= 6.065 \text{ in}$$

Outer Normal Limit of reinforcement per UG-40

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

$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$

$$= 0.625 \text{ in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$

$$= \min\left[0.25,\ 2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$

$$= 0.25 \text{ in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0246 in

From UG-37(d)(1) required thickness t_r = 0.1732 in

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

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

CODEWARE EXAMPLE

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

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

= $0.5 \cdot (6.065 \cdot 0.1732 \cdot 1 + 2 \cdot 0.28 \cdot 0.1732 \cdot 1 \cdot (1 - 0.9468))$

= 0.5277 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.4637 in^2

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

= $6.065 \cdot (1 \cdot 0.25 - 1 \cdot 0.1732) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.1732) \cdot (1 - 0.9468)$

= $0.4637 \ \ in^2$

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

= $2 \cdot (0.25 + 0.28) \cdot (1 \cdot 0.25 - 1 \cdot 0.1732) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.1732) \cdot (1 - 0.9468)$

= $0.0792 \ \ in^2$

A_2 = smaller of the following= 0.3023 in^2

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

= $5 \cdot (0.28 - 0.0246) \cdot 0.9468 \cdot 0.25$

= $0.3023 \ \ in^2$

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

= $2 \cdot (0.28 - 0.0246) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$

= $0.399 \ \ in^2$

A_3 = smaller of the following= 0.1326 in^2

= $5 \cdot t \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

= 0.3314 in^2

= $5 \cdot t_i \cdot t_i \cdot f_{r2}$

= $5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$

= 0.3711 in^2

= $2 \cdot h \cdot t_i \cdot f_{r2}$

= $2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$

= 0.1326 in^2

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

= $0.1875\ ^2 \cdot 0.9468$

= 0.0333 in^2

CODEWARE EXAMPLE

A_{42}	=	$Leg^2 \cdot f_{r4}$
	=	$0.125^{\ 2} \cdot 0.9468$
	=	0.0148 in^2

A_{43}	=	$Leg^2 \cdot f_{r2}$
	=	$0.25^{\ 2} \cdot 0.9468$
	=	0.0592 in^2

A_5	=	$(D_p - d - 2 \cdot t_n) \cdot t_e \cdot f_{r4}$
	=	$(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$
	=	0.2367 in^2

$Area$	$=$	$A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$
	$=$	$0.4637 + 0.3023 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$
	$=$	1.2426 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\left[0.75,\ t_n,\ t_e\right] =$ 0.125 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\left[0.75,\ t_e,\ t\right] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}}$	$=$	0.0246 in
t_a	$=$	$\max\left[t_{a\text{UG-28}},\ t_{a\text{UG-22}}\right]$
	$=$	$\max\left[0.0246,\ 0\right]$
	$=$	0.0246 in

t_{b2}	=	$\dfrac{P \cdot R}{S \cdot E - 0.6 \cdot P} + \text{Corrosion}$
	=	$\dfrac{15 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 15} + 0$
	=	0.0144 in

t_{b2}	$=$	$\max\left[t_{b2},\ t_{b\text{UG16}}\right]$
	$=$	$\max\left[0.0144,\ 0.0625\right]$
	$=$	0.0625 in

CODEWARE EXAMPLE

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

$= \min[0.245, \ 0.0625]$

$= 0.0625 \ \text{in}$

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

$= \max[0.0246, \ 0.0625]$

$=$ 0.0625 in

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{8.2406}{6.625} = 1.2439$$

$$\frac{D_o}{t} = \frac{6.625}{0.0246} = 269.4202$$

From table G: $A = 0.000242$

From table CS-2: $B = 3{,}031.0531 \ \text{psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 3{,}031.05}{3 \cdot (6.625/0.0246)} = 15 \ \text{psi}$$

Design thickness for external pressure P_a = 15 psi

$t_a = t + \text{Corrosion} = 0.0246 + 0 =$ 0.0246"

CODEWARE EXAMPLE

Reinforcement Calculations for MAEP

UG-37 Area Calculation Summary (in^2)							UG-45 Summary (in)	
For Pe = 36.93 psi @ 650 °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}
0.7618	0.7664	--	0.2898	0.1326	0.2367	0.1073	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 size (in)	Actual weld size (in)	Status
Nozzle to pad fillet (Leg_{41})	0.0875	0.1313	weld size is adequate
Pad to shell fillet (Leg_{42})	0.0625	0.0875	weld size is adequate

Calculations for external pressure 36.93 psi @ 650 °F

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[6.065,\ 3.0325 + (0.28 - 0) + (0.25 - 0)\right]$$
$$= 6.065 \ \text{in}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2.5 \cdot (t - C),\ 2.5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0) + 0.125\right]$$
$$= 0.625 \ \text{in}$$

Inner Normal Limit of reinforcement per UG-40

$$L_I = \min\left[h,\ 2.5 \cdot (t - C),\ 2.5 \cdot (t_i - C_n - C)\right]$$
$$= \min\left[0.25,\ 2.5 \cdot (0.25 - 0),\ 2.5 \cdot (0.28 - 0 - 0)\right]$$
$$= 0.25 \ \text{in}$$

Nozzle required thickness per UG-28 t_{rn} = 0.0352 in

From UG-37(d)(1) required thickness t_r = 0.25 in

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

Allowable stresses: S_n = 17,800, S_v = 18,800, S_p = 17,800 psi

f_{r1} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r2} = lesser of 1 or $\frac{S_n}{S_v}$ = 0.9468

f_{r3} = lesser of f_{r2} or $\frac{S_p}{S_v}$ = 0.9468

CODEWARE EXAMPLE

f_{r4} = lesser of 1 or $\frac{S_p}{S_v}$ = 0.9468

A	=	$0.5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$
	=	$0.5 \cdot (6.065 \cdot 0.25 \cdot 1 + 2 \cdot 0.28 \cdot 0.25 \cdot 1 \cdot (1 - 0.9468))$
	=	0.7618 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0 in^2

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

$$= 6.065 \cdot (1 \cdot 0.25 - 1 \cdot 0.25) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.25) \cdot (1 - 0.9468)$$

$$= 0 \ \text{in}^2$$

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

$$= 2 \cdot (0.25 + 0.28) \cdot (1 \cdot 0.25 - 1 \cdot 0.25) - 2 \cdot 0.28 \cdot (1 \cdot 0.25 - 1 \cdot 0.25) \cdot (1 - 0.9468)$$

$$= 0 \ \text{in}^2$$

A_2 = smaller of the following= 0.2898 in^2

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

$$= 5 \cdot (0.28 - 0.0352) \cdot 0.9468 \cdot 0.25$$

$$= 0.2898 \ \text{in}^2$$

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

$$= 2 \cdot (0.28 - 0.0352) \cdot (2.5 \cdot 0.28 + 0.125) \cdot 0.9468$$

$$= 0.3825 \ \text{in}^2$$

A_3 = smaller of the following= 0.1326 in^2

$$= 5 \cdot t \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.25 \cdot 0.28 \cdot 0.9468$$

= 0.3314 in^2

$$= 5 \cdot t_i \cdot t_i \cdot f_{r2}$$

$$= 5 \cdot 0.28 \cdot 0.28 \cdot 0.9468$$

= 0.3711 in^2

$$= 2 \cdot h \cdot t_i \cdot f_{r2}$$

$$= 2 \cdot 0.25 \cdot 0.28 \cdot 0.9468$$

= 0.1326 in^2

A_{41}	=	$Leg^2 \cdot f_{r3}$
	=	$0.1875^{\ 2} \cdot 0.9468$
	=	0.0333 in^2

CODEWARE EXAMPLE

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

= $0.125^2 \cdot 0.9468$

= 0.0148 in^2

A_{43} = $Leg^2 \cdot f_{r2}$

= $0.25^2 \cdot 0.9468$

= 0.0592 in^2

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

= $(8.625 - 6.065 - 2 \cdot 0.28) \cdot 0.125 \cdot 0.9468$

= 0.2367 in^2

$Area = A_1 + A_2 + A_3 + A_{41} + A_{42} + A_{43} + A_5$

$= 0 + 0.2898 + 0.1326 + 0.0333 + 0.0148 + 0.0592 + 0.2367$

= 0.7664 in^2

As Area >= A the reinforcement is adequate.

UW-16(c)(2) Weld Check

Inner fillet: $t_{\min} = \min\left[0.75,\ t_n,\ t_e\right] =$ 0.125 in

$t_{c(\min)} = \min\left[0.25,\ 0.7 \cdot t_{\min}\right] =$ 0.0875 in

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

Outer fillet: $t_{\min} = \min\left[0.75,\ t_e,\ t\right] =$ 0.125 in

$t_{w(\min)} = 0.5 \cdot t_{\min} =$ 0.0625 in

$t_{w(actual)} = 0.7 \cdot \text{Leg} = 0.7 \cdot 0.125 = 0.0875$ in

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-28}} = 0.0352$ in

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

$= \max\left[0.0352,\ 0\right]$

$= 0.0352$ in

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

$= \dfrac{36.926 \cdot 18}{18{,}800 \cdot 1 - 0.6 \cdot 36.926} + 0$

$= 0.0354$ in

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

$= \max\left[0.0354,\ 0.0625\right]$

$= 0.0625$ in

CODEWARE EXAMPLE

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

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

$= \quad 0.0625 \text{ in}$

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

$= \quad \max\left[0.0352,\ 0.0625\right]$

$=$ 0.0625 in

Available nozzle wall thickness new, t_n = 0.28 in

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{8.2406}{6.625} = 1.2439$$

$$\frac{D_o}{t} = \frac{6.625}{0.0352} = 188.4577$$

From table G: $A = 0.000420$

From table CS-2: $B = 5{,}219.3502 \text{ psi}$

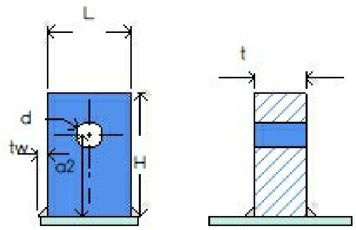
$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 5{,}219.35}{3 \cdot (6.625/0.0352)} = 36.93 \text{ psi}$$

Design thickness for external pressure P_a = 36.93 psi

$t_a = t + \text{Corrosion} = 0.0352 + 0 =$ 0.0352"

CODEWARE EXAMPLE

Tail lug

Geometry Inputs	
	
Attached To	Cylinder #1
Material	A36
Orientation	Longitudinal
Distance of Lift Point From Datum	6.25"
Angular Position	315°
Length, L	2"
Height, H	3"
Thickness, t	0.625"
Hole Diameter, d	0.625"
Pin Diameter, Dp	0.5"
Load Eccentricity, a_1	0"
Distance from Load to Shell or Pad, a_2	2"
Load Angle Normal to Vessel, β	0°
Load Angle from Vertical, ϕ	0°
Welds	
Size, t_w	0.25"

Intermediate Values	
Load Factor	1.5000
Vessel Weight (new, incl. Load Factor), W	1,501.5 lb
Lug Weight (new), W_{lug}	1.1 lb
Distance from Center of Gravity to Top Lug, l_1	58.931"
Distance from Center of Gravity to Tail Lug, l_2	16.819"
Distance from Vessel Center Line to Tail Lug, l_3	20.25"
Allowable Stress, Tensile, σ_t	19,980 psi
Allowable Stress, Shear, σ_s	13,320 psi
Allowable Stress, Bearing, σ_p	29,970 psi
Allowable Stress, Bending, σ_b	22,201 psi
Allowable Stress, Weld Shear, $\tau_{allowable}$	13,320 psi
Allowable Stress set to 1/3 Sy per ASME B30.20	No

CODEWARE EXAMPLE

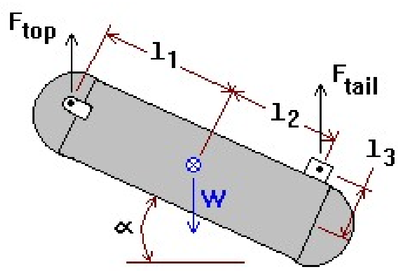
Summary Values	
Required Lift Pin Diameter, d_{reqd}	0.2363"
Required Lug Thickness, t_{reqd}	0.078"
Lug Stress Ratio, σ_{ratio}	0.17
Weld Shear Stress Ratio, τ_{ratio}	0.27
Lug Design	Acceptable
Local Stresses WRC 537	Acceptable

Lift Forces

Lift force on lugs during rotational lift (0°≤ α ≤ 90°):

$$2 \cdot F_{\top} = W \cdot \frac{l_2 \cdot \cos(\alpha) + l_3 \cdot \sin(\alpha)}{l_1 \cdot \cos(\alpha) + l_2 \cdot \cos(\alpha) + l_3 \cdot \sin(\alpha)}$$

$$F_{tail} = W - (2 \cdot F)$$



α [°]	F_{top}[lbf]	F_{tail}[lbf]
0	167	1,168
15	206	1,090
30	245	1,012
45	290	922
60	352	798
75	458	585
90	751	0
52[1]	316	870
50[2]	308	886
[1]Lift angle at maximum lug stress.		
[2]Lift angle at maximum weld stress.		

CODEWARE EXAMPLE

Lug loading at α = 0°	
Total lift force	
$F = \dfrac{F_{\text{top}}}{\cos(\phi)}$	
$F = \dfrac{1{,}168}{\cos(0.0)} =$	$1{,}168 \ \ \text{lb}_f$
Tensile force (parallel to lug normal)	
$F_t = F \cdot \cos(\beta)$	
$F_t = 1{,}168 \cdot \cos(0.0) =$	$1{,}168 \ \ \text{lb}_f$
Shear force (parallel to lug weld)	
$F_s = F \cdot \sin(\beta)$	
$F_s = 1{,}168 \cdot \sin(0.0) =$	$0 \ \ \text{lb}_f$

Lug Pin Diameter - Shear stress

$$d_{\text{reqd}} = \sqrt{\frac{2 \cdot F_v}{\pi \cdot \sigma_s}}$$

$$= \sqrt{\frac{2 \cdot 1{,}168}{\pi \cdot 13{,}320}} = 0.2363''$$

$$\frac{d_{reqd}}{D_p} = \frac{0.2363}{0.5} = 0.47$$ Acceptable

$$\sigma = \frac{F_v}{A}$$

$$= \frac{F_v}{2 \cdot \left(0.25 \cdot \pi \cdot D_p^2\right)}$$

$$= \frac{1{,}168}{2 \cdot \left(0.25 \cdot \pi \cdot 0.5^{\,2}\right)} = 2{,}975 \ \ \text{psi}$$

$$\frac{\sigma}{\sigma_s} = \frac{2{,}975}{13{,}320} = 0.22$$ Acceptable

Lug Thickness - Tensile stress

CODEWARE EXAMPLE

$$t_{\text{reqd}} = \frac{F_v}{(L-d)\cdot\sigma_t}$$

$$= \frac{1{,}168}{(2-0.625)\cdot 19{,}980} = 0.0425"$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.0425}{0.625} = 0.07 \quad \text{Acceptable}$$

$$\sigma = \frac{F_v}{A}$$

$$= \frac{F_v}{(L-d)\cdot t}$$

$$= \frac{1{,}168}{(2-0.625)\cdot 0.625} = 1{,}359 \text{ psi}$$

$$\frac{\sigma}{\sigma_t} = \frac{1{,}359}{19{,}980} = 0.07 \quad \text{Acceptable}$$

Lug Thickness - Bearing stress

$$t_{\text{reqd}} = \frac{F_v}{D_p\cdot\sigma_p}$$

$$= \frac{1{,}168}{0.5\cdot 29{,}970} = 0.078"$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.078}{0.625} = 0.12 \quad \text{Acceptable}$$

$$\sigma = \frac{F_v}{A_{\text{bearing}}}$$

$$= \frac{F_v}{D_p\cdot(t)}$$

$$= \frac{1{,}168}{0.5\cdot(0.625)} = 3{,}738 \text{ psi}$$

$$\frac{\sigma}{\sigma_p} = \frac{3{,}738}{29{,}970} = 0.12 \quad \text{Acceptable}$$

Lug Thickness - Shear stress

$$t_{\text{reqd}} = \frac{\frac{F_v}{\sigma_s}}{2\cdot L_{\text{shear}}}$$

$$= \frac{\frac{1{,}168}{13{,}320}}{2\cdot 0.7577} = 0.0579"$$

$$\frac{t_{\text{reqd}}}{t} = \frac{0.0579}{0.625} = 0.09 \quad \text{Acceptable}$$

CODEWARE EXAMPLE

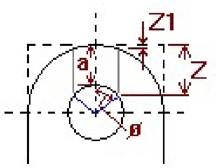
$$\tau = \frac{F_v}{A_{\text{shear}}}$$

$$= \frac{F_v}{2 \cdot t \cdot L_{\text{shear}}}$$

$$= \frac{1{,}168}{2 \cdot 0.625 \cdot 0.7577} = 1{,}233 \text{ psi}$$

$$\frac{\tau}{\sigma_s} = \frac{1{,}233}{13{,}320} = 0.09$$ Acceptable

Shear stress length (per Pressure Vessel and Stacks, A. Keith Escoe)



$$\phi = 55 \cdot \frac{D_p}{d}$$

$$= 55 \cdot \frac{0.5}{0.625}$$

$$= 44^\circ$$

$$L_{\text{shear}} = (H - a2 - 0.5 \cdot d) + 0.5 \cdot D_p \cdot (1 - \cos(\phi))$$

$$= (3 - 2 - 0.5 \cdot 0.625) + 0.5 \cdot 0.5 \cdot (1 - \cos(44))$$

$$= 0.7577"$$

Lug Plate Stress

Lug stress tensile + bending during lift:

$$\sigma_{\text{ratio}} = \left[\frac{F_{\text{ten}}}{A_{\text{ten}} \cdot \sigma_t}\right] + \left[\frac{M_{\text{bend}}}{Z_{\text{bend}} \cdot \sigma_b}\right] \le 1$$

$$= \left[\frac{F_{\text{tail}}(\alpha) \cdot \cos(\alpha)}{t \cdot L \cdot \sigma_t}\right] + \left[\frac{6 \cdot |F_{\text{tail}}(\alpha) \cdot \sin(\alpha) \cdot \text{Hght} - F_{\text{tail}}(\alpha) \cdot \cos(\alpha) \cdot a_1|}{t \cdot L_2 \cdot \sigma_b}\right] \le 1$$

$$= 870 \cdot \frac{\cos(52.0)}{0.625 \cdot 2 \cdot 19{,}980} + 6 \cdot \frac{|870 \cdot \sin(52.0) \cdot 2 - 870 \cdot \cos(52.0) \cdot 0|}{0.625 \cdot 2^2 \cdot 22{,}201}$$

$$= 0.17$$ Acceptable

Weld Stress

Weld stress, tensile, bending and shear during lift:

Direct shear:

Maximum shear stress occurs at lift angle 50.00°; lift force = 886 lb_f

$$F_{\text{lug}} = \frac{F_{\text{top}}}{\cos(\phi)}$$

$$= \frac{886}{\cos(0.0)} = 886 \text{ lb}_f$$

$$A_{\text{weld}} = 2 \cdot (0.707) \cdot t_w \cdot (L + t)$$

$$= 2 \cdot (0.707) \cdot 0.25 \cdot (2 + 0.625) = 0.9279 \text{ in}^2$$

CODEWARE EXAMPLE

$$\tau_t = F_{\text{tail}} \cdot \frac{\cos(\alpha)}{A_{\text{weld}}}$$

$$= 886 \cdot \frac{\cos(50.0)}{0.9279} = 614 \text{ psi}$$

$$\tau_s = F_{\text{tail}} \cdot \frac{\sin(\alpha)}{A_{\text{weld}}}$$

$$= 886 \cdot \frac{\sin(50.0)}{0.9279} = 731 \text{ psi}$$

$$\tau_b = M \cdot \frac{c}{I}$$

$$= 3 \cdot \frac{F_{\text{lug}} \cdot \sin(\beta) \cdot Hght - F_{\text{lug}} \cdot \cos(\beta) \cdot a_1}{0.707 \cdot h \cdot L \cdot (3 \cdot t + L)}$$

$$= 3 \cdot \frac{|886 \cdot \sin(50.0) \cdot 2 - 886 \cdot \cos(50.0) \cdot (0)|}{1.3698}$$

$$= 2{,}973 \text{ psi}$$

$$\tau_{\text{ratio}} = \frac{\sqrt{(\tau_t + \tau_b)^2 + \tau_s^2}}{\tau_{\text{allowable}}} \leq 1$$

$$= \frac{\sqrt{(614 + 2{,}973)^2 + (731)^2}}{13{,}320}$$

$= 0.27$ Acceptable

WRC 537 Analysis

Maximum stress ratio occurs at lift angle = 0.00° with lift force = 1,168 lb_f

Geometry	
Height (radial)	3"
Width (circumferential)	0.625"
Length	2"
Fillet Weld Size:	0.25"
Located On	Cylinder #1 (5.25" from bottom end)
Location Angle	315.00°

Applied Loads	
Radial load, P_r	-1,168.13 lb_f
Circumferential moment, M_c	0 lb_f-in
Circumferential shear, V_c	0 lb_f
Longitudinal moment, M_L	0 lb_f-in
Longitudinal shear, V_L	0 lb_f
Torsion moment, M_t	0 lb_f-in
Internal pressure, P	0 psi
Mean shell radius, R_m	18.125"
Design factor	3

Maximum stresses due to the applied loads at the lug edge

CODEWARE EXAMPLE

$\gamma = \frac{R_m}{T} = \frac{18.125}{0.25} = 72.5$

$C_1 = 0.5625, C_2 = 1.25 \ \ \text{in}$

Local circumferential pressure stress $= \frac{P \cdot R_i}{T} = 0 \ \ \text{psi}$

Local longitudinal pressure stress $= \frac{P \cdot R_i}{2 \cdot T} = 0 \ \ \text{psi}$

Maximum combined stress $(P_L + P_b + Q) = 24{,}682 \ \ \text{psi}$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 60{,}000 \ \ \text{psi}$

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

Maximum local primary membrane stress $(P_L) = 3{,}840 \ \ \text{psi}$

Allowable local primary membrane stress $(P_L) = \pm 1.5 \cdot S = \pm 30{,}000 \ \ \text{psi}$

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

CODEWARE EXAMPLE

Stresses at the lug edge per WRC Bulletin 537										
Figure	**Y**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	14.3778	0.0625	0	0	0	0	3,706	3,706	3,706	3,706
4C*	13.2791	0.053	3,423	3,423	3,423	3,423	0	0	0	0
1C	0.187	0.0422	0	0	0	0	20,976	-20,976	20,976	-20,976
2C-1	0.1432	0.0422	16,054	-16,054	16,054	-16,054	0	0	0	0
3A*	1.1335	0.0405	0	0	0	0	0	0	0	0
1A	0.102	0.0442	0	0	0	0	0	0	0	0
3B*	5.9633	0.0529	0	0	0	0	0	0	0	0
1B-1	0.0572	0.0475	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total circumferential stress			19,477	-12,631	19,477	-12,631	24,682	-17,270	24,682	-17,270
Primary membrane circumferential stress*			3,423	3,423	3,423	3,423	3,706	3,706	3,706	3,706
3C*	14.896	0.053	3,840	3,840	3,840	3,840	0	0	0	0
4C*	13.1549	0.0625	0	0	0	0	3,391	3,391	3,391	3,391
1C-1	0.1568	0.0547	17,578	-17,578	17,578	-17,578	0	0	0	0
2C	0.1206	0.0547	0	0	0	0	13,527	-13,527	13,527	-13,527
4A*	1.3582	0.0405	0	0	0	0	0	0	0	0
2A	0.0578	0.0542	0	0	0	0	0	0	0	0
4B*	1.5724	0.0529	0	0	0	0	0	0	0	0
2B-1	0.084	0.0578	0	0	0	0	0	0	0	0
Pressure stress*			0	0	0	0	0	0	0	0
Total longitudinal stress			21,418	-13,738	21,418	-13,738	16,918	-10,136	16,918	-10,136
Primary membrane longitudinal stress*			3,840	3,840	3,840	3,840	3,391	3,391	3,391	3,391
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			21,418	-13,738	21,418	-13,738	24,682	-17,270	24,682	-17,270

* denotes primary stress.

CODEWARE EXAMPLE

Straight Flange on Ellipsoidal Head #2

ASME Section VIII Division 1, 2023 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	650	-20
External		15	650	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		2.24	62	1
Test horizontal		1.6	44.1875	1
Dimensions				
Inner Diameter		36"		
Length		2"		
Nominal Thickness		0.25"		
Corrosion	**Inner**	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		**Capacity (US gal)**
New		16.11		8.81
Corroded		16.11		8.81
Radiography				
Longitudinal seam		Seamless No RT		
Top 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)	0.0983"
Design thickness due to external pressure (t_e)	0.1732"
Design thickness due to combined loadings + corrosion	0.0492"
Maximum allowable working pressure (MAWP)	256.72 psi
Maximum allowable pressure (MAP)	275.48 psi
Maximum allowable external pressure (MAEP)	36.93 psi
Rated MDMT	-55 °F

CODEWARE EXAMPLE

UCS-66 Material Toughness Requirements	
Governing thickness, t_g =	0.25"
Exemption temperature from Fig UCS-66 Curve B =	-20°F
$t_r = \frac{102.24 \cdot 18}{20{,}000 \cdot 1 - 0.6 \cdot 102.24} =$	0.0923"
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0923 \cdot 1}{0.25 - 0} =$	0.3692
$\text{Stress ratio longitudinal} = \frac{3{,}682 \cdot 1}{20{,}000 \cdot 1} =$	0.1841
Reduction in MDMT, T_R from Fig UCS-66.1 =	118.7°F
$MDMT = \max\left[MDMT - T_R, -55\right] = \max\left[-20 - 118.7, -55\right] =$	-55°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 650 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{102.24 \cdot 18}{18{,}800 \cdot 1.00 - 0.60 \cdot 102.24} + 0 = 0.0983"$$

Maximum allowable working pressure, (at 650 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{18{,}800 \cdot 1.00 \cdot 0.25}{18 + 0.60 \cdot 0.25} - 2.24 = 256.72 \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20{,}000 \cdot 1.00 \cdot 0.25}{18 + 0.60 \cdot 0.25} = 275.48 \text{ psi}$$

External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{82}{36.5} = 2.2466$$

$$\frac{D_o}{t} = \frac{36.5}{0.1732} = 210.7700$$

From table G: $A = 0.000189$

From table CS-2: $B = 2{,}371.1712 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2{,}371.17}{3 \cdot (36.5/0.1732)} = 15 \text{ psi}$$

Design thickness for external pressure P_a = 15 psi

$$t_a = t + \text{Corrosion} = 0.1732 + 0 = 0.1732"$$

Maximum Allowable External Pressure, (Corroded & at 650 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{82}{36.5} = 2.2466$$

$$\frac{D_o}{t} = \frac{36.5}{0.25} = 146.0000$$

CODEWARE EXAMPLE

From table G: $A = 0.000324$

From table CS-2: $B = 4{,}043.3972$ psi

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 4{,}043.4}{3 \cdot (36.5/0.25)} = \underline{36.93}\ \text{psi}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 0.25}{18.125}\right) \cdot \left(1 - \frac{18.125}{\infty}\right) = 0.6897\,\%$$

The extreme fiber elongation does not exceed 5%.

Thickness Required Due to Pressure + External Loads								
Condition	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Pressure P (psi)	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
	S_t	S_c						
Operating, Hot & Corroded	18,800	9,465	650	0	Seismic	522.27	0.0492	0.0484
Operating, Hot & New	18,800	9,465	650	0	Seismic	522.27	0.0492	0.0484
Hot Shut Down, Corroded	18,800	9,465	650	0	Seismic	0	0.0014	0.0006
Hot Shut Down, New	18,800	9,465	650	0	Seismic	0	0.0014	0.0006
Empty, Corroded	20,000	14,348	70	0	Seismic	0	0.0001	0
Empty, New	20,000	14,348	70	0	Seismic	0	0.0001	0
Vacuum	18,800	9,465	650	0	Seismic	265.6	0.0116	0.0131
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	18,800	9,465	650	0	Seismic	0	0.0012	0.0012

CODEWARE EXAMPLE

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.25/0.25} = 0.001712$$

$$B = 9{,}465 \quad \text{psi}$$

$$S = \frac{18{,}800}{1.00} = 18{,}800 \quad \text{psi}$$

$S_{cHC} = \min(B, S) =$ 9,465 psi

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

$S_cHN = S_cHC =$ 9,465 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.25/0.25} = 0.001712$$

$$B = 14{,}348 \quad \text{psi}$$

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

$S_{cCN} = \min(B, S) =$ 14,348 psi

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

$S_c\mathbb{C} = S_cCN =$ 14,348 psi

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

$$A = \frac{0.125}{R_o/t} = \frac{0.125}{18.25/0.25} = 0.001712$$

$$B = 9{,}465 \quad \text{psi}$$

$$S = \frac{18{,}800}{1.00} = 18{,}800 \quad \text{psi}$$

$S_{cVC} = \min(B, S) =$ 9,465 psi

Operating, Hot & Corroded, Seismic, Top Seam

CODEWARE EXAMPLE

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

= $\dfrac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

= $\dfrac{244}{\pi \cdot 18.125\ ^2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

t_w = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.11\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0013"

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

= $0.0478{+}0 - (-0.0013)$

= 0.0492"

$t_{w\,c}$ = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.49\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0006"

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

= $|0 + (-0.0006) - (0.0478)|$

= 0.0484"

Maximum allowable working pressure, Longitudinal Stress

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

= $\dfrac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.25 - 0 + (-0.0013))}{18 - 0.40 \cdot (0.25 - 0 + (-0.0013))}$

= 522.27 psi

Operating, Hot & New, Seismic, Top Seam

CODEWARE EXAMPLE

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

= $\dfrac{100 \cdot 18}{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 + 0.40 \cdot |100|}$

= 0.0478"

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

= $\dfrac{244}{\pi \cdot 18.125^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

t_w = $\dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{1.11\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0013"

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

= $0.0478 + 0 - (-0.0013)$

= 0.0492"

$t_{w\ c}$ = $\dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

= $\dfrac{0.49\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0006"

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

= $|0 + (-0.0006) - (0.0478)|$

= 0.0484"

Maximum allowable working pressure, Longitudinal Stress

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

= $\dfrac{2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00 \cdot (0.25 - 0 + (-0.0013))}{18 - 0.40 \cdot (0.25 - 0 + (-0.0013))}$

= 522.27 psi

Hot Shut Down, Corroded, Seismic, Top Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{244}{\pi \cdot 18.125\ ^2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

$t_w = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.11\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0013"

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

$= 0 + 0 - (-0.0013)$

= 0.0014"

$t_{w\,c} = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.49\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0006"

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

$= |0 + (-0.0006) - (0)|$

= 0.0006"

Hot Shut Down, New, Seismic, Top Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$$= \frac{244}{\pi \cdot 18.125\ ^2 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= 0"

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

$$= \frac{1.11\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= -0.0013"

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

= $0 + 0 - (-0.0013)$

= 0.0014"

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

$$= \frac{0.49\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$$

= -0.0006"

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

= $|0 + (-0.0006) - (0)|$

= 0.0006"

Empty, Corroded, Seismic, Top Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \frac{70}{\pi \cdot 18.125\ ^2 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= \frac{1.11\text{*-}96.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= 0 + 0 - (0)$

= 0.0001"

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

$= \frac{0.49\text{*-}96.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0"

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

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

= 0"

Empty, New, Seismic, Top Seam

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \dfrac{70}{\pi \cdot 18.125^{\ 2} \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0"

$t_w = \dfrac{(1 + 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{1.11\text{*-}96.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= 0 + 0 - (0)$

= 0.0001"

$t_{w\,c} = \dfrac{(0.6 - 0.14 \cdot S_{DS}) \cdot W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c}$ (Weight)

$= \dfrac{0.49\text{*-}96.4}{2 \cdot \pi \cdot 18.125 \cdot 20{,}000 \cdot 1.00 \cdot 1.00}$

= 0"

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

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

= 0"

Vacuum, Seismic, Top Seam

CODEWARE EXAMPLE

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

$= \frac{-15 \cdot 18}{2 \cdot 9{,}464.71 \cdot 1.00 + 0.40 \cdot |15|}$

= -0.0143

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

$= \frac{244}{\pi \cdot 18.125^{\ 2} \cdot 9{,}464.71 \cdot 1.00}$

= 0"

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

$= \frac{1.11\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$

= -0.0027"

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

$= |-0.0143 + 0 - (-0.0027)|$

= 0.0116"

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

$= \frac{0.49\text{*-}2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 9{,}464.71 \cdot 1.00}$

= -0.0012"

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

$= 0 + (-0.0012) - (-0.0143)$

= 0.0131"

Maximum Allowable External Pressure, Longitudinal Stress

$P = \frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0.40 \cdot (t - t_{mc} - t_{wc})}$

$= \frac{2 \cdot 9{,}464.71 \cdot 1.00 \cdot (0.25 - 0 - -0.0012)}{18 - 0.40 \cdot (0.25 - 0 - -0.0012)}$

= 265.6 psi

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

CODEWARE EXAMPLE

t_p = 0" (Pressure)

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

$= \frac{0}{\pi \cdot 18.125^{\ 2} \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= 0"

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

$= \frac{-2{,}594.8}{2 \cdot \pi \cdot 18.125 \cdot 18{,}800 \cdot 1.00 \cdot 1.00}$

= -0.0012"

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

$= 0 + 0 - (-0.0012)$

= 0.0012"

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

$= |0 + (-0.0012) - (0)|$

= 0.0012"

CODEWARE EXAMPLE

Ellipsoidal Head #2

ASME Section VIII Division 1, 2023 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		100	650	-20
External		15	650	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		2.56	71	1
Test horizontal		1.6	44.1875	1
Dimensions				
Inner Diameter		36"		
Head Ratio		2		
Minimum Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		
Length L_{sf}		2"		
Nominal Thickness t_{sf}		0.25"		
Weight and Capacity				
		Weight (lb)[1]		**Capacity (US gal)**[1]
New		96.37		35.25
Corroded		96.37		35.25
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	external pressure
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	0.0983"
Design thickness due to external pressure (t_e)	0.1007"
Maximum allowable working pressure (MAWP)	193.07 psi
Maximum allowable pressure (MAP)	208.12 psi
Maximum allowable external pressure (MAEP)	44.69 psi
Straight Flange governs MDMT	-55°F

Design thickness for internal pressure, (Corroded at 650 °F) UG-32(c)(1)

$$t = \frac{P \cdot D}{2 \cdot S \cdot E - 0.2 \cdot P} + \text{Corrosion} = \frac{102.56 \cdot 36}{2 \cdot 18{,}800 \cdot 1 - 0.2 \cdot 102.56} + 0 = 0.0983"$$

Maximum allowable working pressure, (Corroded at 650 °F) UG-32(c)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 18{,}800 \cdot 1 \cdot 0.1875}{36 + 0.2 \cdot 0.1875} - 2.56 = 193.07 \text{ psi}$$

CODEWARE EXAMPLE

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

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0.2 \cdot t} - P_s = \frac{2 \cdot 20{,}000 \cdot 1 \cdot 0.1875}{36 + 0.2 \cdot 0.1875} - 0 = 208.12 \text{ psi}$$

Design thickness for external pressure, (Corroded at 650 °F) UG-33(d)

Equivalent outside spherical radius

$$R_o = K_o \cdot D_o = 0.8908 \cdot 36.375 = 32.4034 \text{ in}$$

$$A = \frac{0.125}{R_o \;/\; t} = \frac{0.125}{32.4034 \;/\; 0.100651} = 0.000388$$

From Table CS-2: B = 4,829.0908 psi

$$P_a = \frac{B}{R_o \;/\; t} = \frac{4{,}829.0908}{32.4034 \;/\; 0.1007} = 15 \text{ psi}$$

$$t = 0.1007\text{"} + \text{Corrosion} = 0.1007\text{"} + 0\text{"} = 0.1007\text{"}$$

The head external pressure design thickness (t_e) is 0.1007".

Maximum Allowable External Pressure, (Corroded at 650 °F) UG-33(d)

Equivalent outside spherical radius

$$R_o = K_o \cdot D_o = 0.8908 \cdot 36.375 = 32.4034 \text{ in}$$

$$A = \frac{0.125}{R_o \;/\; t} = \frac{0.125}{32.4034 \;/\; 0.1875} = 0.000723$$

From Table CS-2: B = 7,722.4638 psi

$$P_a = \frac{B}{R_o \;/\; t} = \frac{7{,}722.4638}{32.4034 \;/\; 0.1875} = 44.6854 \text{ psi}$$

The maximum allowable external pressure (MAEP) is 44.69 psi.

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 0.25}{6.245}\right) \cdot \left(1 - \frac{6.245}{\infty}\right) = 3.0024\,\%$$

The extreme fiber elongation does not exceed 5%.

CODEWARE EXAMPLE

Nozzle #1 (N1) FEA Results

ASME Div. 2 Part 5 Design by Analysis, 5.2.2 Elastic Stress Analysis	
Finite element analysis (FEA) of flexible elements based on Div. 2 5.2.2. A 3-D FEA solid model of the nozzle, or group of nozzles, and parent component is analyzed to find the Von Mises stress distribution. The nodal component Von Mises stress is linearized per Div. 2 Annex 5-A and categorized per Div. 2 5.2.2.2.	
FEA Build	8510
FEA Type	Linear Elastic with Solid Lagrangian Cubic Elements

Cylinder #1				
Component		Cylinder		
Material		SA-516 70		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (deg F)**	**Design MDMT (deg F)**
Internal		100	650	-20
External		15	650	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		2.17	60	1
Horizontal test		1.6	44.1875	1
Dimensions				
Inner Diameter		36"		
Nominal Thickness		0.25"		
Corrosion	**Inner**	0"		
	Outer	0"		

Nozzle #1 (N1)				
Component		Nozzle		
Material		SA-105		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (deg F)**	**Design MDMT (deg F)**
Internal		100	650	-20
External		15	650	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		1.48	41.0325	1
Horizontal test		0.29	7.9375	1
Dimensions				
Outer Diameter		6.625"		
Nominal Thickness		0.28"		
Corrosion	**Inner**	0"		
	Outer	0"		

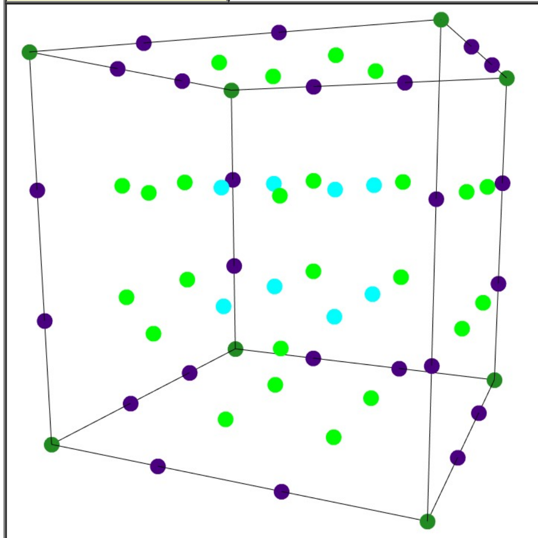
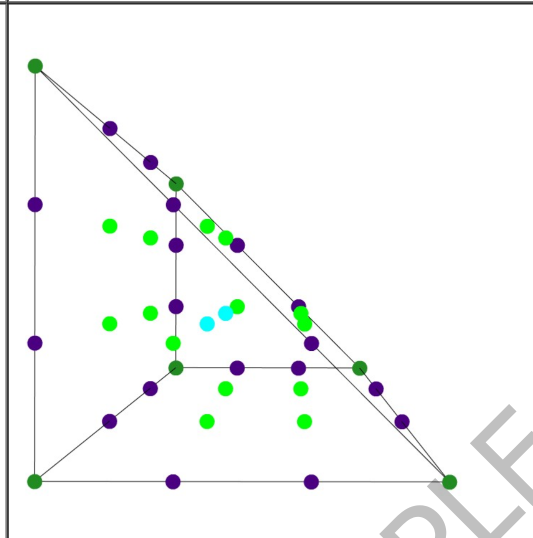
CODEWARE EXAMPLE

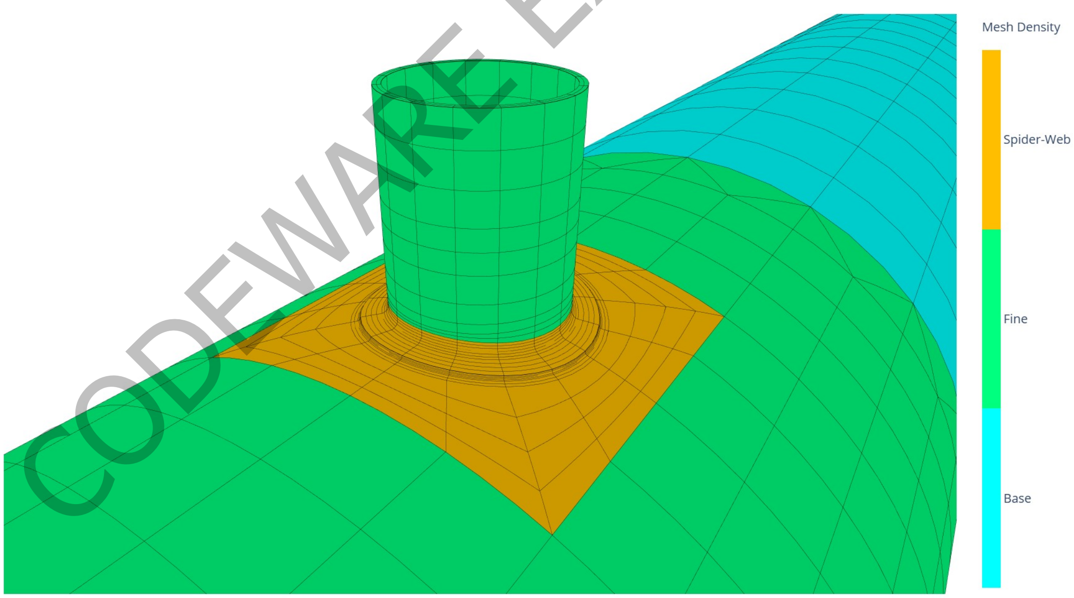
Elastic Analysis Summary														
			Equivalent Linearized Stresses					Stress Evaluation						
Load Case	Design Condition	SCL No.	Membrane (psi)	Class.	Bending (psi)	Class.	Membrane + Bending (psi)	P_m (psi)	S (psi)	$P_L + P_b$ (psi)	S_{PL} (psi)	$P_L + P_b + Q$ (psi)	S_{PS} (psi)	Pass/Fail
Load case 1*	Design	U-V	9,850 ± 29	PL	3,438 ± 28	Q	13,287 ± 9	N/A	17,800	9,879	26,700	13,297	53,400	Pass
* Governing Load Case														

FEA Model Dimensions	
Cylinder #1	
Outer Diameter	36.5000"
Thickness	0.2500"
Length	213.6001"
Shell length modified on both sides of the attachment to avoid boundary condition interference. 50 * sqrt(18.25*0.25)=106.8	
Nozzle #1 (N1)	
Orientation	Radial
Outer Diameter	6.6250"
Thickness	0.2800"
Projection outside of vessel to flange face	7.9375"
Internal Projection	0.2500"
Reinforcing Pad Width	1.0000"
Reinforcing Pad Thickness	0.1250"
Limit of reinforcement L_H	1.2965"
Limit of reinforcement L_I	0.2500"
Simplified Flange Length	3.5000"
The nozzle flange is approximated as equal length nozzle pipe with increased Modulus of Elasticity.	
Inner Fillet Weld Length	0.2500"
Weld lengths modified to maintain weld area when modelling welds with a concave curve.	
Outer Fillet Weld Length	0.1250"
Weld lengths modified to maintain weld area when modelling welds with a concave curve.	
Lower Fillet Weld Length	0.2500"
Weld lengths modified to maintain weld area when modelling welds with a concave curve.	

Material Properties		
	Modulus of Elasticity	**Poisson's Ratio**
Cylinder #1	26,000,000 psi	0.3
Nozzle #1 (N1)	25,850,000 psi	0.3
Nozzle #1 (N1) - Repad	25,850,000 psi	0.3
Nozzle #1 (N1) - Simplified Flange	157,896,551 psi	0.3
The equivalent flange Modulus of Elasticity is obtained by multiplying the nozzle flange's Modulus of Elasticity by the ratio of the rotational moments of inertia of the simplified flange and equivalent nozzle section.		
Nozzle #1 (N1) - Inner Fillet Weld	25,850,000 psi	0.3
Weld material is inherited from the stiffer of the two components being joined.		
Nozzle #1 (N1) - Outer Fillet Weld	26,000,000 psi	0.3
Weld material is inherited from the stiffer of the two components being joined.		
Nozzle #1 (N1) - Lower Fillet Weld	26,000,000 psi	0.3
Weld material is inherited from the stiffer of the two components being joined.		

CODEWARE EXAMPLE

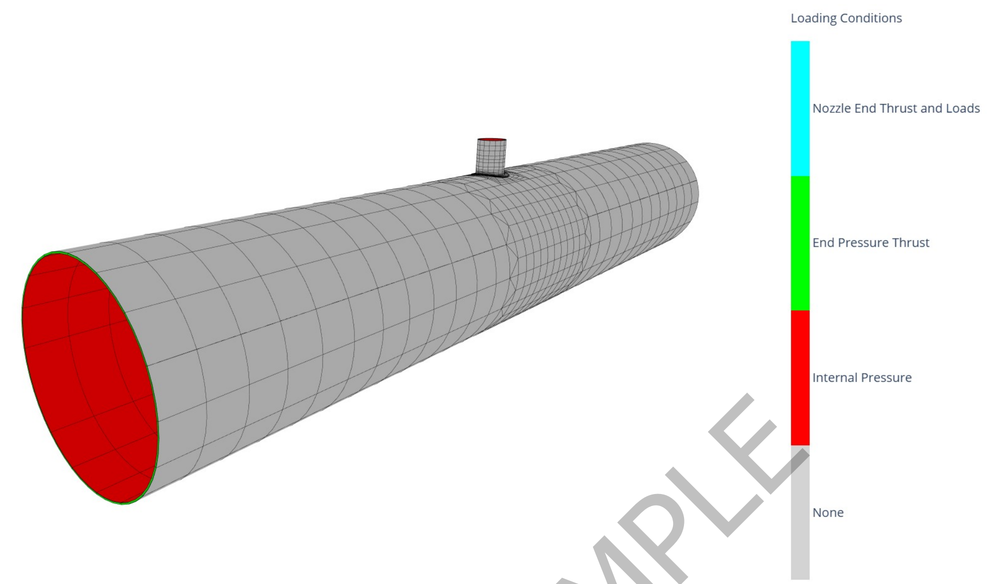
FEA Details		
Element Shape	3-D Hexagonal Solid	3-D Wedge Solid
Geometric Order	64-Node Cubic Lagrangian	40-Node Cubic Lagrangian
		
For more information, see the Reference Document.		

Mesh and Refinement Details			
Region	**Base**	**Fine**	**Spider-Web**
Elements Through the Thickness	1	2	2-4
Mesh Density Nozzle Front Isometric View			
			
Dynamic Image			

CODEWARE EXAMPLE

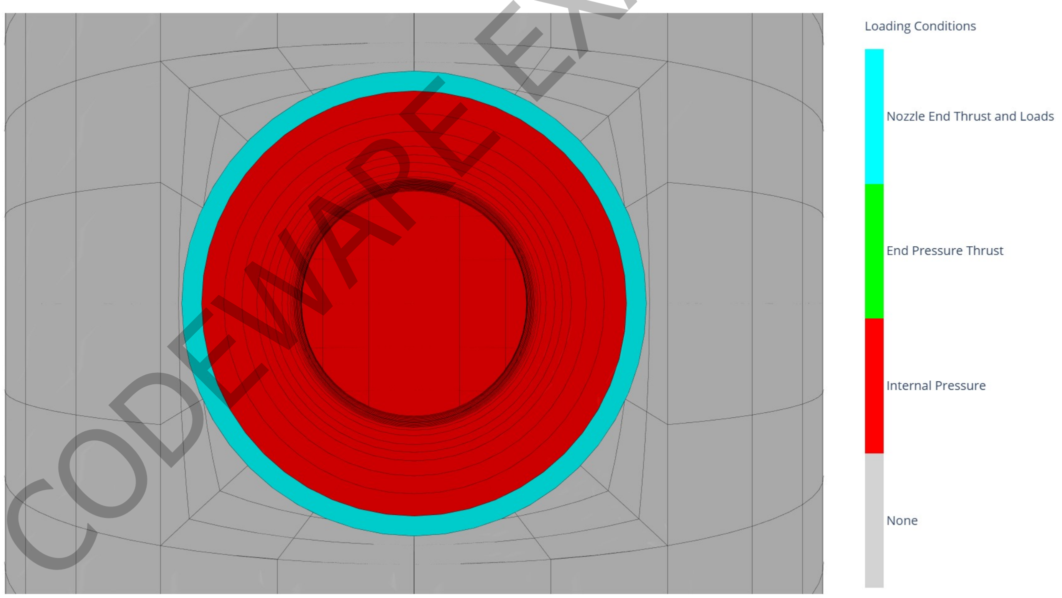
Boundary & Loading Conditions

Loading Conditions Vessel Front Isometric View



Dynamic Image

Loading Conditions Nozzle Outside-In View



Dynamic Image

CODEWARE EXAMPLE

Loading Conditions - Load case 1 - Design

Internal pressure applied to vessel inner surface = 101.48 psi

Pressure thrust applied to Cylinder #1 end surface(s) = 101.48 * 18^2 / (18.25^2 - 18^2) = 3,628.13 psi

Pressure thrust applied to Nozzle #1 (N1) end surface = 101.48 * 3.0325^2 / (3.3125^2 - 3.0325^2) = 525.29 psi

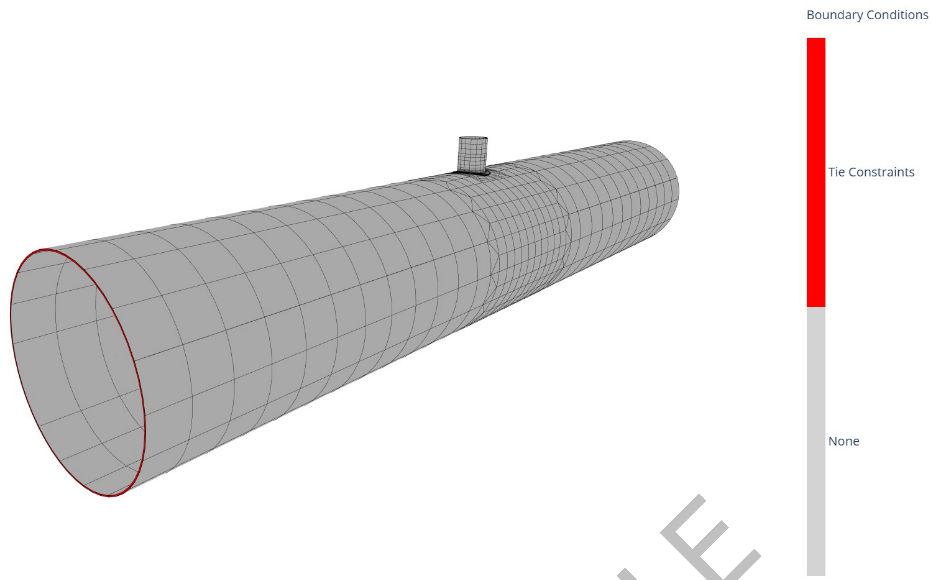
Nozzle #1 (N1)

Loading Condition	Pr (lbf)	Mc (lbf-in)	Vc (lbf)	ML (lbf-in)	VL (lbf)	Mt (lbf-in)
Load case 1 - Design*	100	200	300	0	0	0

* Nozzle moments and loads applied to the end surface.

Boundary Conditions - Design

Boundary Conditions Vessel Front Isometric View



Dynamic Image
Shell radial end surfaces are tie constrained to the shell axis, allowing equal radial growth and movement along the axis.

CODEWARE EXAMPLE

Governing Elastic Analysis Results - Load case 1 - Design															
			Equivalent Linearized Stresses						Stress Evaluation						
SCL No.	Location	Stress Type	Membrane (psi)	Class.	Bending (psi)	Class.	Membrane + Bending (psi)	Max Nodal Stress Error	P_m (psi)	S (psi)	$P_L + P_b$ (psi)	S_{PL} (psi)	$P_L + P_b + Q$ (psi)	S_{PS} (psi)	
A-B	Remote From Discontinuities	General Stress	6,389 ± 46	Pm	155 ± 63	Q	6,545 ± 109	1.22%	6,435	18,800	N/A	28,200	6,654	56,400	Pass
C-D	Remote From Discontinuities	General Stress	6,391 ± 46	Pm	153 ± 63	Q	6,543 ± 109	1.22%	6,436	18,800	N/A	28,200	6,652	56,400	Pass
E-F	Nozzle Neck	Geometric Discontinuity	8,367 ± 48	PL	3,294 ± 61	Q	11,661 ± 13	5.3%	N/A	17,800	8,415	26,700	11,675	53,400	Pass
G-H	Internal Projection	Geometric Discontinuity	9,851 ± 15	PL	3,437 ± 23	Q	13,289 ± 8	3.49%	N/A	17,800	9,866	26,700	13,297	53,400	Pass
I-J	Nozzle Neck	Geometric Discontinuity	3,467 ± 8	PL	512 ± 11	Q	3,979 ± 3	2.8%	N/A	17,800	3,474	26,700	3,982	53,400	Pass
K-L	Internal Projection	Geometric Discontinuity	3,327 ± 1	PL	1,015 ± 9	Q	4,342 ± 8	0.71%	N/A	17,800	3,328	26,700	4,350	53,400	Pass
M-N	Outside Limit of Reinforcement LI	General Stress	3,422 ± 4	Pm	1,091 ± 1	Q	4,513 ± 5	0.36%	3,426	17,800	N/A	26,700	4,518	53,400	Pass
O-P	Nozzle Neck	Geometric Discontinuity	4,291 ± 4	PL	421 ± 3	Q	4,712 ± 4	0.33%	N/A	17,800	4,295	26,700	4,716	53,400	Pass
Q-R	Internal Projection	Geometric Discontinuity	7,332 ± 0	PL	1,282 ± 11	Q	8,614 ± 10	0.4%	N/A	17,800	7,332	26,700	8,624	53,400	Pass
S-T	Nozzle Neck	Geometric Discontinuity	8,368 ± 24	PL	3,294 ± 61	Q	11,662 ± 37	5.3%	N/A	17,800	8,392	26,700	11,699	53,400	Pass
U-V*	Internal Projection	Geometric Discontinuity	9,850 ± 29	PL	3,438 ± 28	Q	13,287 ± 9	3.49%	N/A	17,800	9,879	26,700	13,297	53,400	Pass
W-X	Nozzle Neck	Geometric Discontinuity	7,991 ± 17	PL	3,134 ± 38	Q	11,126 ± 21	5.34%	N/A	17,800	8,008	26,700	11,147	53,400	Pass
Y-Z	Internal Projection	Geometric Discontinuity	9,185 ± 7	PL	2,708 ± 24	Q	11,893 ± 17	2.61%	N/A	17,800	9,192	26,700	11,910	53,400	Pass
A1-B1	Nozzle Neck	Geometric Discontinuity	6,375 ± 12	PL	2,213 ± 31	Q	8,587 ± 19	5.17%	N/A	17,800	6,387	26,700	8,607	53,400	Pass
C1-D1	Internal Projection	Geometric Discontinuity	7,382 ± 25	PL	1,088 ± 24	Q	8,469 ± 50	0.99%	N/A	17,800	7,407	26,700	8,519	53,400	Pass
E1-F1	Remote From Discontinuities	General Stress	6,347 ± 61	Pm	117 ± 99	Q	6,464 ± 159	1.78%	6,408	18,800	N/A	28,200	6,624	56,400	Pass
G1-H1	Remote From Discontinuities	General Stress	6,347 ± 61	Pm	117 ± 99	Q	6,465 ± 160	1.78%	6,409	18,800	N/A	28,200	6,625	56,400	Pass
I1-J1	Near Nozzle Opening	Geometric Discontinuity	7,469 ± 16	PL	473 ± 11	Q	7,941 ± 27	1.76%	N/A	18,800	7,485	28,200	7,968	56,400	Pass
K1-L1	Pad Outer Weld	Geometric Discontinuity	6,915 ± 48	PL	324 ± 79	Q	7,240 ± 103	5.46%	N/A	18,800	6,964	28,200	7,343	56,400	Pass
M1-N1	Near Nozzle Opening	Geometric Discontinuity	3,971 ± 2	PL	417 ± 2	Q	4,387 ± 4	0.3%	N/A	18,800	3,972	28,200	4,391	56,400	Pass
O1-P1	Pad Outer Weld	Geometric Discontinuity	5,068 ± 96	PL	6,761 ± 212	Q	11,828 ± 116	5.66%	N/A	18,800	5,164	28,200	11,945	56,400	Pass
Q1-R1	Near Nozzle Opening	Geometric Discontinuity	6,923 ± 0	PL	4,616 ± 0	Q	11,539 ± 0	0%	N/A	18,800	6,923	28,200	11,539	56,400	Pass
S1-T1	Pad Outer Weld	Geometric Discontinuity	8,474 ± 0	PL	1,927 ± 0	Q	10,401 ± 0	0%	N/A	18,800	8,474	28,200	10,401	56,400	Pass
U1-V1	Near Nozzle Opening	Geometric Discontinuity	7,469 ± 19	PL	472 ± 11	Q	7,941 ± 30	1.76%	N/A	18,800	7,488	28,200	7,971	56,400	Pass
W1-X1	Pad Outer Weld	Geometric Discontinuity	6,916 ± 46	PL	325 ± 79	Q	7,241 ± 100	5.46%	N/A	18,800	6,961	28,200	7,341	56,400	Pass
Y1-Z1	Near Nozzle Opening	Geometric Discontinuity	7,688 ± 0	PL	546 ± 0	Q	8,234 ± 0	0%	N/A	18,800	7,688	28,200	8,234	56,400	Pass
A2-B2	Pad Outer Weld	Geometric Discontinuity	7,719 ± 0	PL	1,297 ± 0	Q	9,016 ± 0	0%	N/A	18,800	7,719	28,200	9,016	56,400	Pass
C2-D2	Near Nozzle Opening	Geometric Discontinuity	7,558 ± 0	PL	1,312 ± 0	Q	8,870 ± 0	0%	N/A	18,800	7,558	28,200	8,870	56,400	Pass

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E2-F2	Pad Outer Weld	Geometric Discontinuity	8,584 ± 0	PL	2,570 ± 0	Q	11,154 ± 0	0%	N/A	18,800	8,584	28,200	11,154	56,400	Pass
* governing SCL															

CODEWARE EXAMPLE

Nozzle #1 (N1) 180.00 Degree SCP

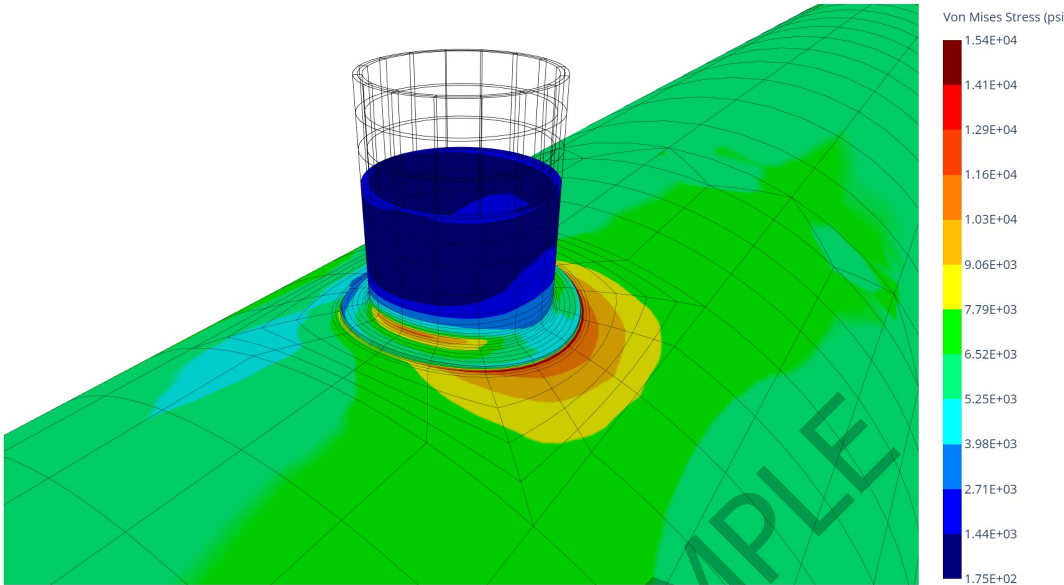
Neck SCP

Parent SCP

CODEWARE EXAMPLE

Governing Elastic Analysis Results - Design

Von Mises Stress Nozzle Front Isometric View



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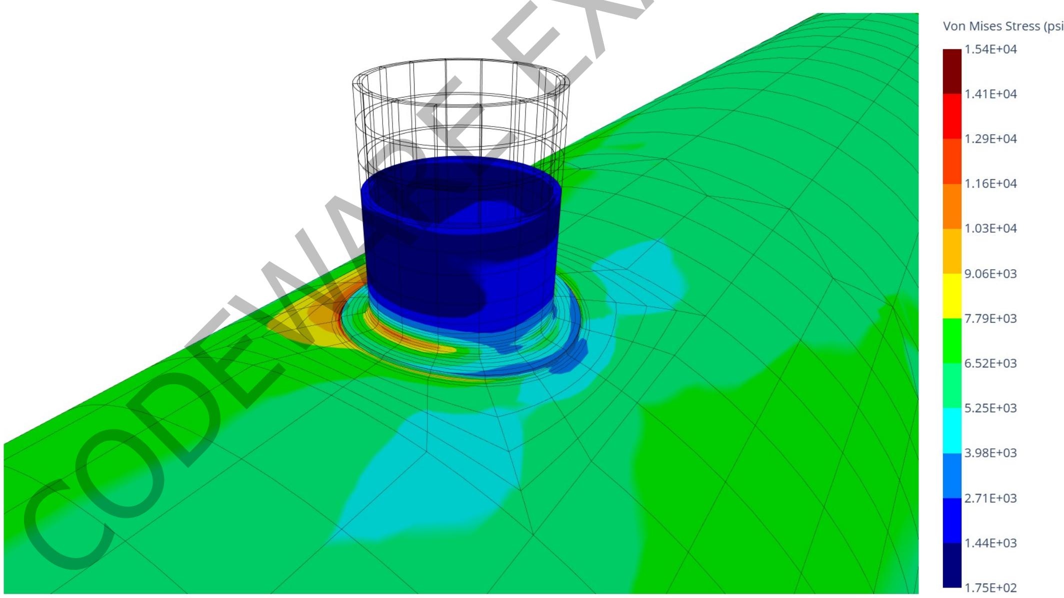
Von Mises Stress Nozzle Rear Isometric View



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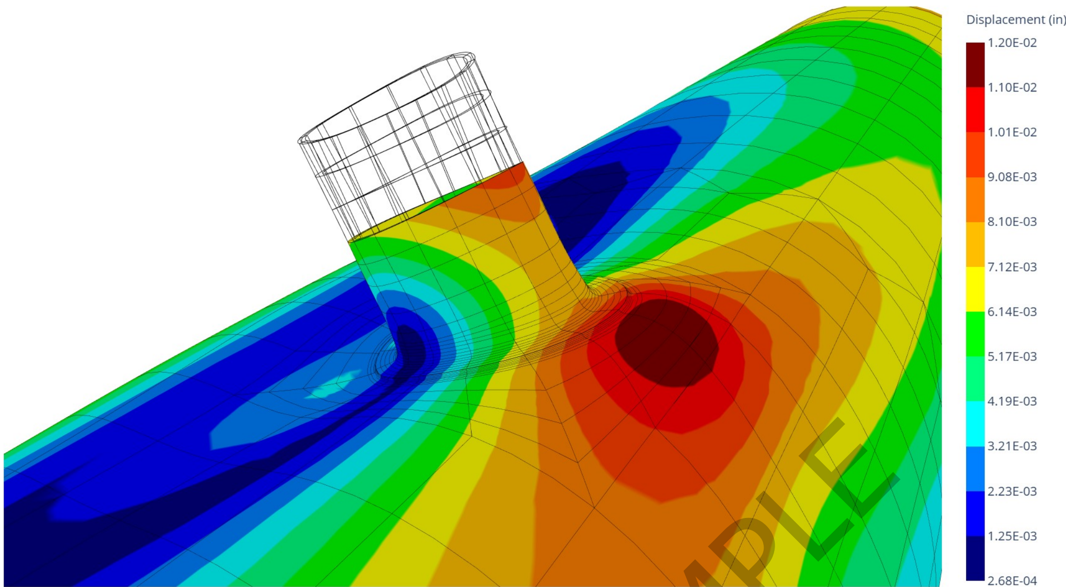
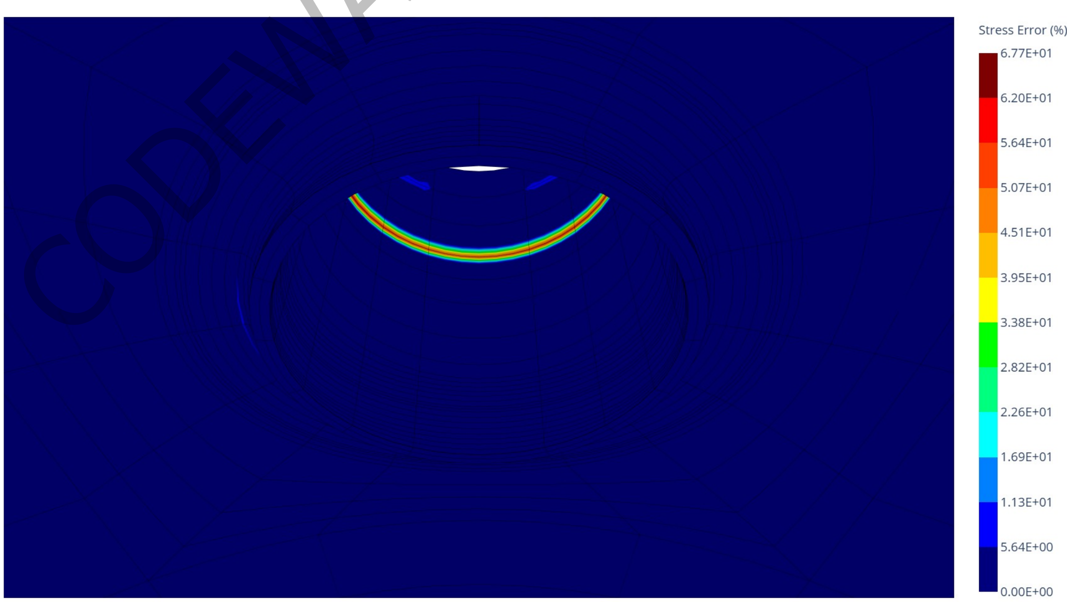
CODEWARE EXAMPLE

Governing Elastic Analysis Results - Design
Displacement Nozzle Front Isometric View

Dynamic Image
Note that the deformed plot has a scaled factor of 355x.

Model Stress Error			
Condition	**Load Case**	**Model Stress Error**	**Model Stress Error (%)**
Design	Load case 1*	943 psi	67.66%
*Max stress error was found at the nozzle-flange junction which has a sharp change in material properties.			

Governing Elastic Analysis Results - Design
Stress Error (%) Nozzle Inside-Iso View

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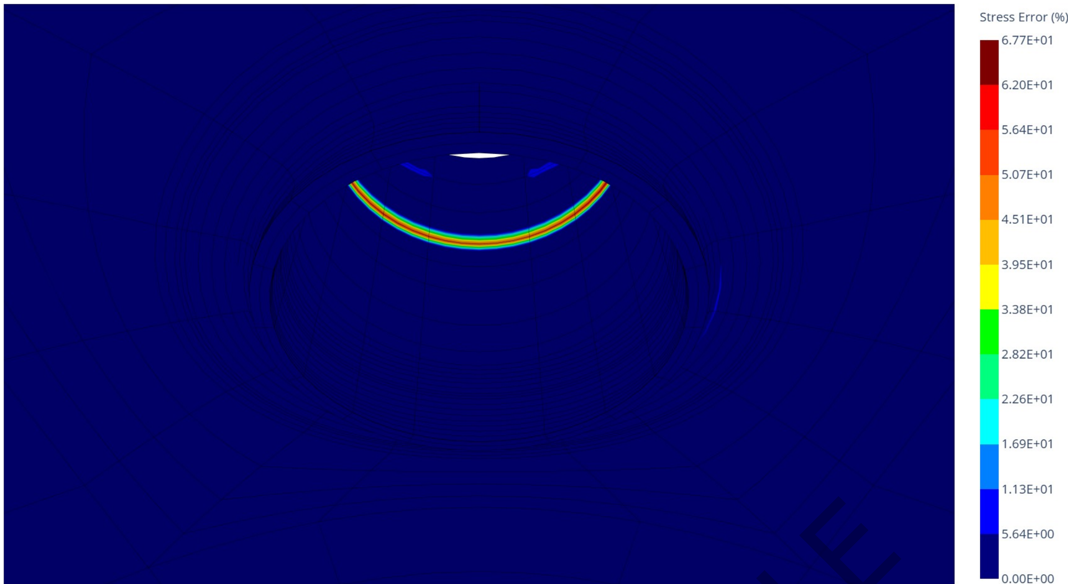
Stress Error (%) Nozzle Inside-Iso Reverse View

CODEWARE EXAMPLE



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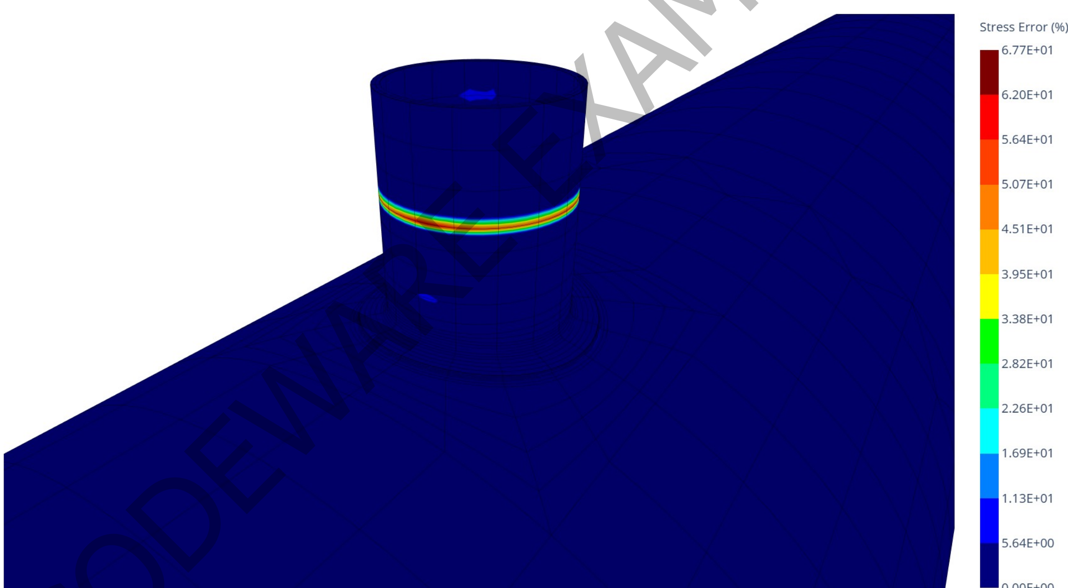
Stress Error (%) Nozzle Front Isometric View



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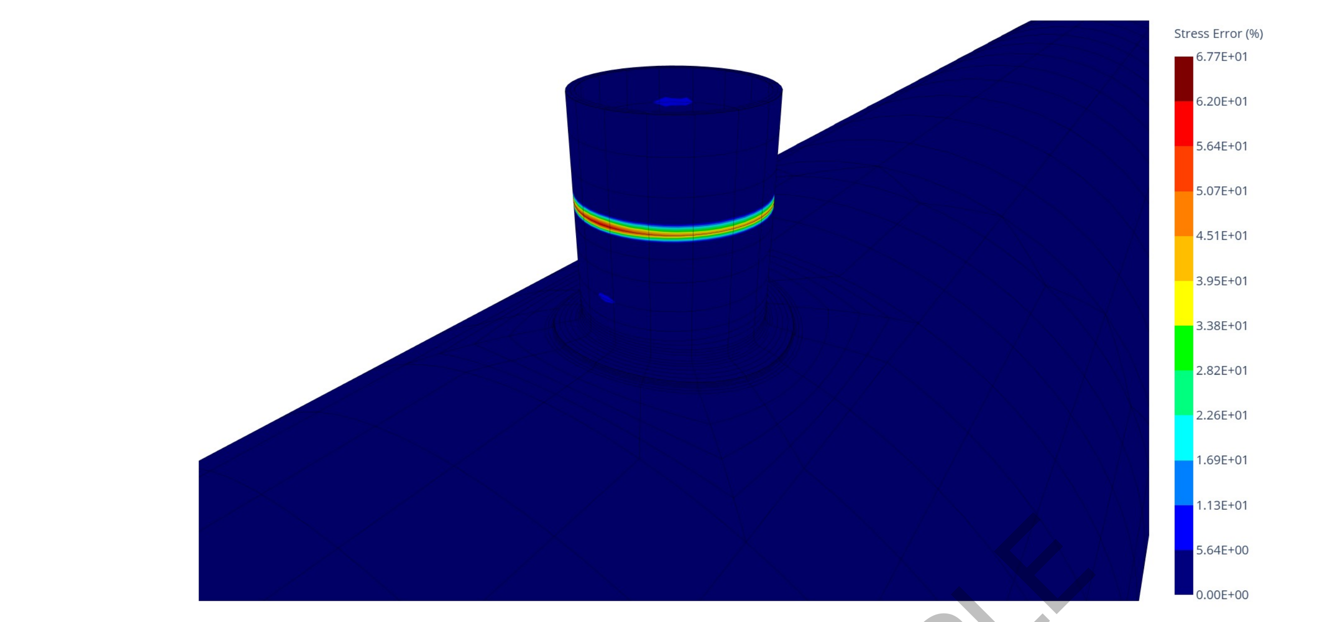
Stress Error (%) Nozzle Rear Isometric View

CODEWARE EXAMPLE



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The max computational stress error (element vs nodal) for the model is 67.6600%.

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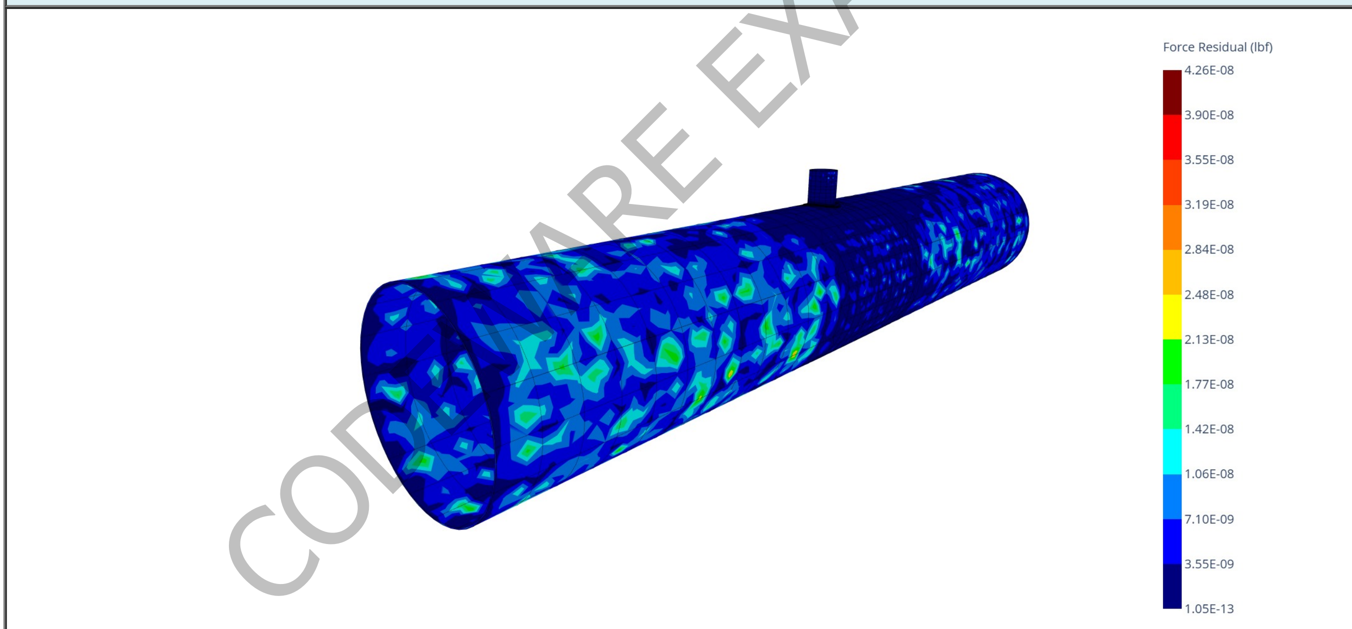
Governing Elastic Analysis Results - Design

Force Residual Vessel Front Isometric View



Reactionary forces compared to applied loads in the model have a max computational difference of 0 lbf

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Nozzle #2 (N2) FEA Results

ASME Div. 2 Part 5 Design by Analysis, 5.2.2 Elastic Stress Analysis	
Finite element analysis (FEA) of flexible elements based on Div. 2 5.2.2. A 3-D FEA solid model of the nozzle, or group of nozzles, and parent component is analyzed to find the Von Mises stress distribution. The nodal component Von Mises stress is linearized per Div. 2 Annex 5-A and categorized per Div. 2 5.2.2.2.	
FEA Build	8510
FEA Type	Linear Elastic with Solid Lagrangian Cubic Elements

Cylinder #2				
Component		Cylinder		
Material		SA-516 70		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (deg F)**	**Design MDMT (deg F)**
Internal		100	650	-20
External		15	650	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		0.87	24	1
Horizontal test		1.6	44.1875	1
Dimensions				
Inner Diameter		36"		
Nominal Thickness		0.1875"		
Corrosion	**Inner**	0"		
	Outer	0"		

Nozzle #2 (N2)				
Component		Nozzle		
Material		SA-105		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	No	No	No	No
		Design Pressure (psi)	**Design Temperature (deg F)**	**Design MDMT (deg F)**
Internal		100	650	-20
External		15	650	
Static Liquid Head				
Condition		**P_s (psi)**	**H_s (in)**	**SG**
Operating		0.18	5.0325	1
Horizontal test		1.05	29.22	1
Dimensions				
Outer Diameter		6.625"		
Nominal Thickness		0.28"		
Corrosion	**Inner**	0"		
	Outer	0"		

CODEWARE EXAMPLE

Elastic Analysis Summary														
			Equivalent Linearized Stresses					Stress Evaluation						
Load Case	Design Condition	SCL No.	Membrane (psi)	Class.	Bending (psi)	Class.	Membrane + Bending (psi)	P_m (psi)	S (psi)	$P_L + P_b$ (psi)	S_{PL} (psi)	$P_L + P_b + Q$ (psi)	S_{PS} (psi)	Pass/Fail
API 660*	Design	S3-T3	13,547 ± 470	PL	75,057 ± 2,038	Q	88,604 ± 1,567	N/A	18,800	14,017	28,200	90,171	56,400	Fail

* Governing Load Case

FEA Model Dimensions	
Cylinder #2	
Outer Diameter	36.3750"
Thickness	0.1875"
Length	184.6661"
Shell length modified on both sides of the attachment to avoid boundary condition interference. 50 * sqrt(18.1875*0.1875)=92.333	
Nozzle #2 (N2)	
Orientation	Radial
Outer Diameter	6.6250"
Thickness	0.2800"
Projection outside of vessel	63.4500"
Nozzle projection outside vessel set to 10*(mean diameter) to capture proper behavior at shell-nozzle junction.	
Internal Projection	0.2500"
Reinforcing Pad Width	1.0000"
Reinforcing Pad Thickness	0.1250"
Limit of reinforcement L_H	1.2340"
Limit of reinforcement L_I	0.2500"
Inner Fillet Weld Length	0.2500"
Weld lengths modified to maintain weld area when modelling welds with a concave curve.	
Outer Fillet Weld Length	0.1250"
Weld lengths modified to maintain weld area when modelling welds with a concave curve.	
Lower Fillet Weld Length	0.2500"
Weld lengths modified to maintain weld area when modelling welds with a concave curve.	

Material Properties		
	Modulus of Elasticity	**Poisson's Ratio**
Cylinder #2	26,000,000 psi	0.3
Nozzle #2 (N2)	25,850,000 psi	0.3
Nozzle #2 (N2) - Repad	25,850,000 psi	0.3
Nozzle #2 (N2) - Inner Fillet Weld	25,850,000 psi	0.3
Weld material is inherited from the stiffer of the two components being joined.		
Nozzle #2 (N2) - Outer Fillet Weld	26,000,000 psi	0.3
Weld material is inherited from the stiffer of the two components being joined.		
Nozzle #2 (N2) - Lower Fillet Weld	26,000,000 psi	0.3
Weld material is inherited from the stiffer of the two components being joined.		

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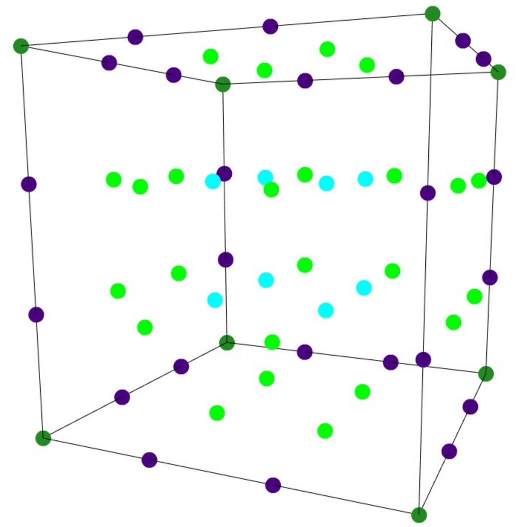
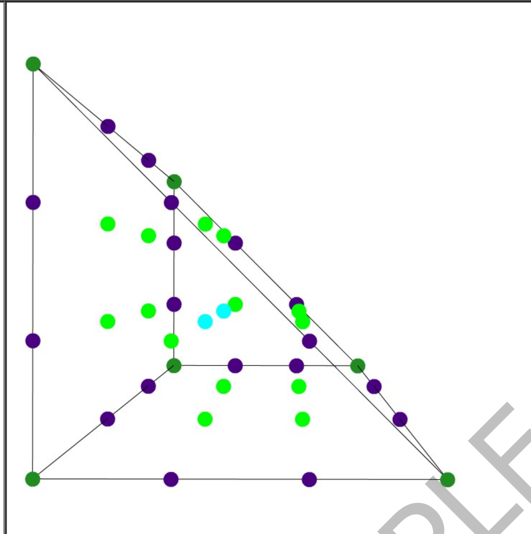
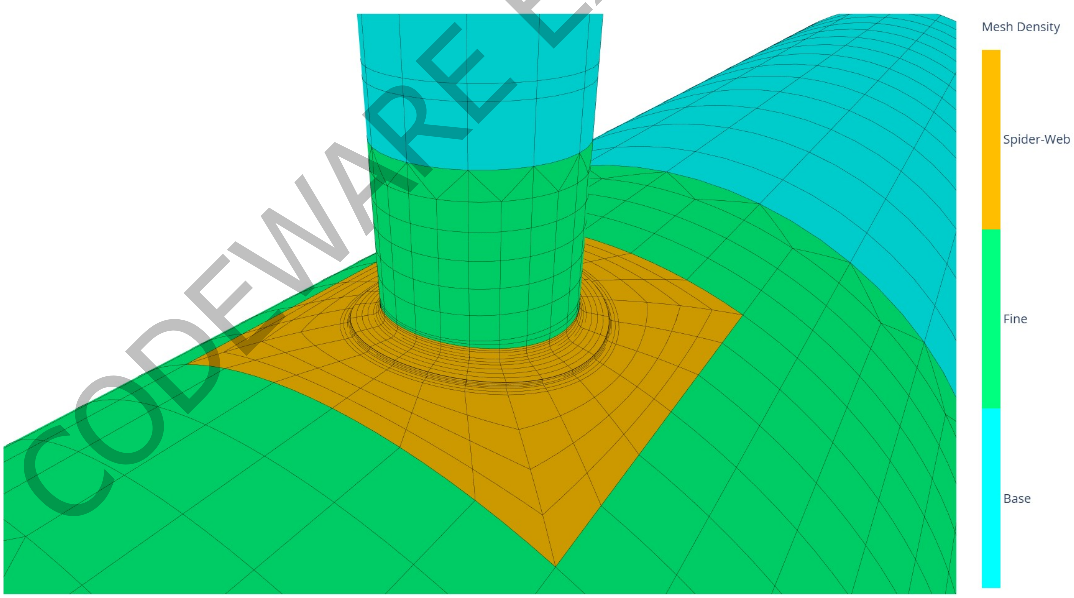
FEA Details		
Element Shape	3-D Hexagonal Solid	3-D Wedge Solid
Geometric Order	64-Node Cubic Lagrangian	40-Node Cubic Lagrangian
		
For more information, see the Reference Document.		

Mesh and Refinement Details			
Region	**Base**	**Fine**	**Spider-Web**
Elements Through the Thickness	1	2	2-4
Mesh Density Nozzle Front Isometric View			



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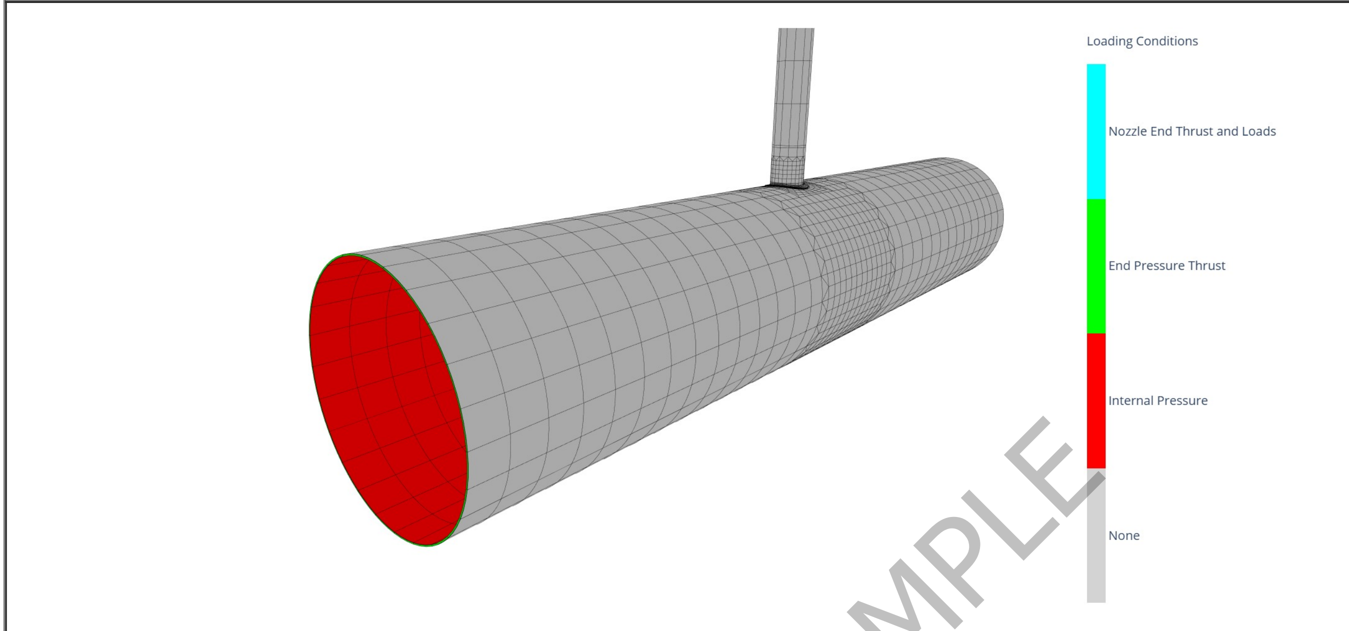
CODEWARE EXAMPLE

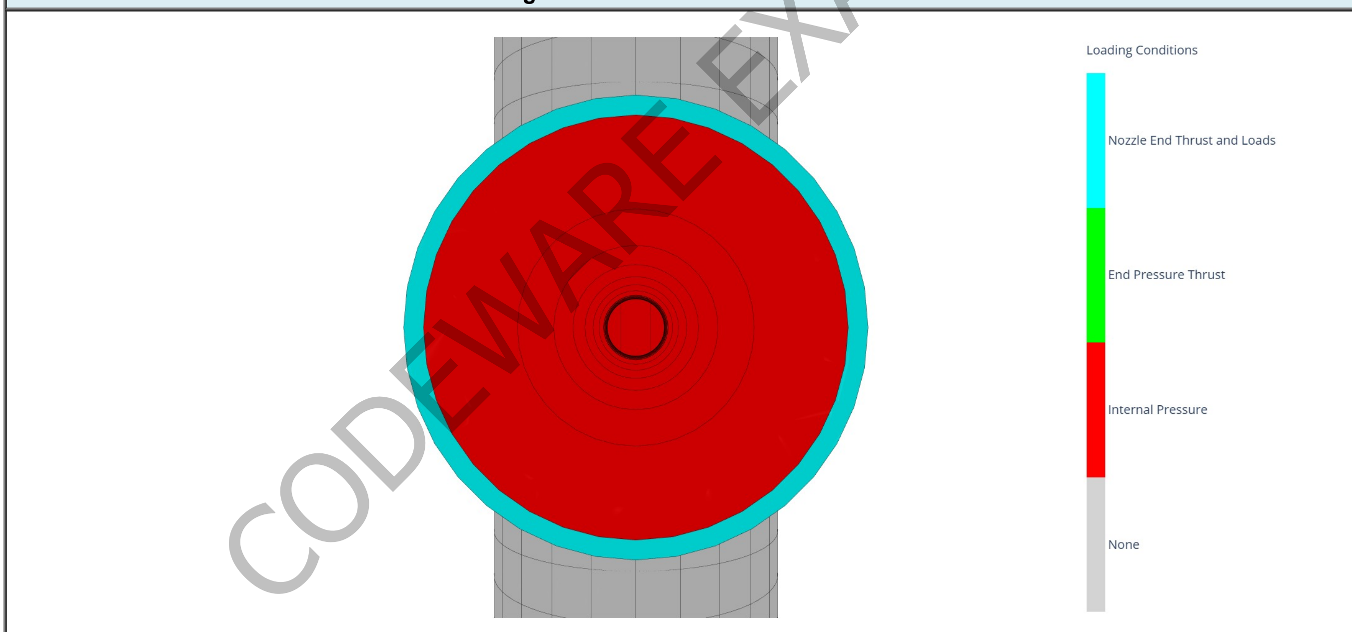
Boundary & Loading Conditions

Loading Conditions Vessel Front Isometric View



Dynamic Image

Loading Conditions Nozzle Outside-In View



Dynamic Image

CODEWARE EXAMPLE

Loading Conditions - API 660 - Design

Internal pressure applied to vessel inner surface = 100.18 psi

Pressure thrust applied to Cylinder #2 end surface(s) = 100.18 * 18^2 / (18.1875^2 - 18^2) = 4,783.8 psi

Pressure thrust applied to Nozzle #2 (N2) end surface = 100.18 * 3.0325^2 / (3.3125^2 - 3.0325^2) = 518.56 psi

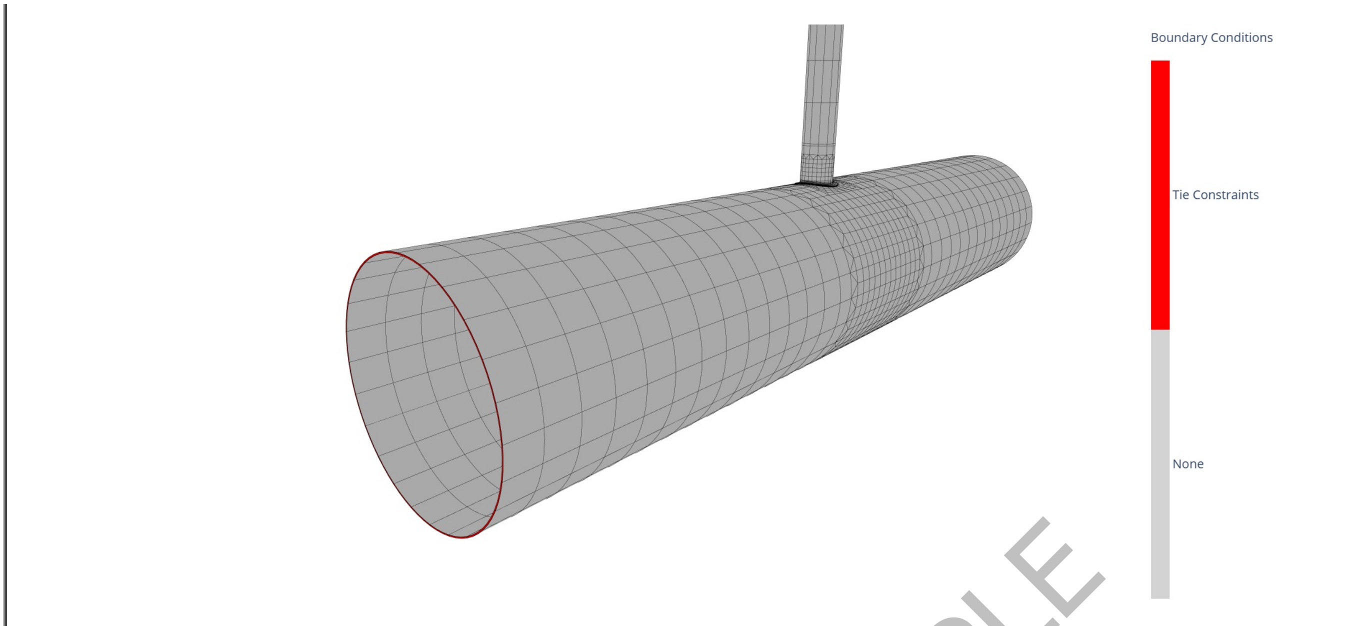
Nozzle #2 (N2)

Loading Condition	Pr (lbf)	Mc (lbf-in)	Vc (lbf)	ML (lbf-in)	VL (lbf)	Mt (lbf-in)
API 660 - Design*	-800	-45,090	1,000	-40,170	1,000	29,520

* Nozzle moments and loads applied to the end surface.

Boundary Conditions - Design

Boundary Conditions Vessel Front Isometric View



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Shell radial end surfaces are tie constrained to the shell axis, allowing equal radial growth and movement along the axis.

CODEWARE EXAMPLE

Governing Elastic Analysis Results - API 660 - Design

			Equivalent Linearized Stresses						Stress Evaluation						
SCL No.	Location	Stress Type	Membrane (psi)	Class.	Bending (psi)	Class.	Membrane + Bending (psi)	Max Nodal Stress Error	P_m (psi)	S (psi)	$P_L + P_b$ (psi)	S_{PL} (psi)	$P_L + P_b + Q$ (psi)	S_{PS} (psi)	
A-B	Remote From Discontinuities	General Stress	9,164 ± 1	Pm	1,411 ± 7	Q	10,574 ± 9	0.12%	9,165	18,800	N/A	28,200	10,583	56,400	Pass
C-D	Remote From Discontinuities	General Stress	9,036 ± 90	Pm	10,704 ± 238	Q	19,739 ± 148	1.9%	9,125	18,800	N/A	28,200	19,888	56,400	Pass
E-F	Nozzle Neck	Geometric Discontinuity	3,200 ± 3	PL	3,784 ± 134	Q	6,984 ± 137	4.38%	N/A	17,800	3,203	26,700	7,121	53,400	Pass
G-H	Internal Projection	Geometric Discontinuity	9,647 ± 9	PL	4,538 ± 28	Q	14,185 ± 19	3.82%	N/A	17,800	9,657	26,700	14,204	53,400	Pass
I-J	Within Limit of Reinforcement LH	General Stress	4,892 ± 6	Pm	1,200 ± 0	Pm	6,092 ± 6	0.12%	6,098	17,800	N/A	26,700	6,098	53,400	Pass
K-L	Outside Limit of Reinforcement LI	General Stress	10,435 ± 16	Pm	3,362 ± 3	Q	13,797 ± 19	0.24%	10,451	17,800	N/A	26,700	13,816	53,400	Pass
M-N	Outside Limit of Reinforcement LH	General Stress	6,796 ± 9	Pm	749 ± 5	Q	7,545 ± 14	0.17%	6,805	17,800	N/A	26,700	7,559	53,400	Pass
O-P	Nozzle Neck	Geometric Discontinuity	18,734 ± 31	PL	9,053 ± 121	Q	27,786 ± 90	4.81%	N/A	17,800	18,765	26,700	27,876	53,400	Pass
Q-R	Internal Projection	Geometric Discontinuity	13,005 ± 25	PL	3,519 ± 40	Q	16,524 ± 14	3.4%	N/A	17,800	13,030	26,700	16,538	53,400	Pass
S-T	Nozzle Neck	Geometric Discontinuity	11,154 ± 170	PL	22,313 ± 578	Q	33,468 ± 409	5.84%	N/A	17,800	11,324	26,700	33,876	53,400	Pass
U-V	Internal Projection	Geometric Discontinuity	8,445 ± 17	PL	1,797 ± 72	Q	10,242 ± 55	3.13%	N/A	17,800	8,462	26,700	10,298	53,400	Pass
W-X	Outside Limit of Reinforcement LI	General Stress	12,459 ± 0	Pm	1,920 ± 0	Q	14,379 ± 0	0.02%	12,460	17,800	N/A	26,700	14,380	53,400	Pass
Y-Z	Nozzle Neck	Geometric Discontinuity	11,390 ± 167	PL	21,764 ± 576	Q	33,154 ± 409	5.83%	N/A	17,800	11,557	26,700	33,563	53,400	Pass
A1-B1	Internal Projection	Geometric Discontinuity	8,727 ± 17	PL	1,645 ± 72	Q	10,373 ± 55	3.21%	N/A	17,800	8,745	26,700	10,428	53,400	Pass
C1-D1	Outside Limit of Reinforcement LI	General Stress	12,317 ± 9	Pm	1,816 ± 20	Q	14,133 ± 29	0.22%	12,326	17,800	N/A	26,700	14,163	53,400	Pass
E1-F1	Nozzle Neck	Geometric Discontinuity	16,787 ± 98	PL	18,267 ± 378	Q	35,054 ± 280	6.63%	N/A	17,800	16,885	26,700	35,334	53,400	Pass
G1-H1	Internal Projection	Geometric Discontinuity	4,900 ± 1	PL	1,615 ± 23	Q	6,515 ± 22	4.91%	N/A	17,800	4,902	26,700	6,537	53,400	Pass
I1-J1	Nozzle Neck	Geometric Discontinuity	11,649 ± 29	PL	14,720 ± 373	Q	26,369 ± 344	5.65%	N/A	17,800	11,678	26,700	26,713	53,400	Pass
K1-L1	Internal Projection	Geometric Discontinuity	9,853 ± 17	PL	3,638 ± 65	Q	13,491 ± 48	1.19%	N/A	17,800	9,870	26,700	13,540	53,400	Pass
M1-N1	Outside Limit of Reinforcement LI	General Stress	12,864 ± 19	Pm	1,155 ± 17	Q	14,019 ± 36	0.34%	12,883	17,800	N/A	26,700	14,054	53,400	Pass
O1-P1	Nozzle Neck	Geometric Discontinuity	15,067 ± 111	PL	19,440 ± 460	Q	34,507 ± 348	6.59%	N/A	17,800	15,178	26,700	34,855	53,400	Pass
Q1-R1	Internal Projection	Geometric Discontinuity	1,767 ± 10	PL	479 ± 66	Q	2,247 ± 76	16.73%	N/A	17,800	1,778	26,700	2,323	53,400	Pass
S1-T1	Nozzle Neck	Geometric Discontinuity	12,441 ± 7	PL	4,868 ± 52	Q	17,308 ± 59	1.86%	N/A	17,800	12,448	26,700	17,368	53,400	Pass
U1-V1	Internal Projection	Geometric Discontinuity	11,119 ± 2	PL	5,964 ± 21	Q	17,083 ± 19	0.42%	N/A	17,800	11,121	26,700	17,102	53,400	Pass
W1-X1	Nozzle Neck	Geometric Discontinuity	12,868 ± 3	PL	3,207 ± 9	Q	16,075 ± 12	0.16%	N/A	17,800	12,871	26,700	16,087	53,400	Pass
Y1-Z1	Internal Projection	Geometric Discontinuity	11,325 ± 5	PL	6,089 ± 18	Q	17,414 ± 13	0.38%	N/A	17,800	11,330	26,700	17,427	53,400	Pass

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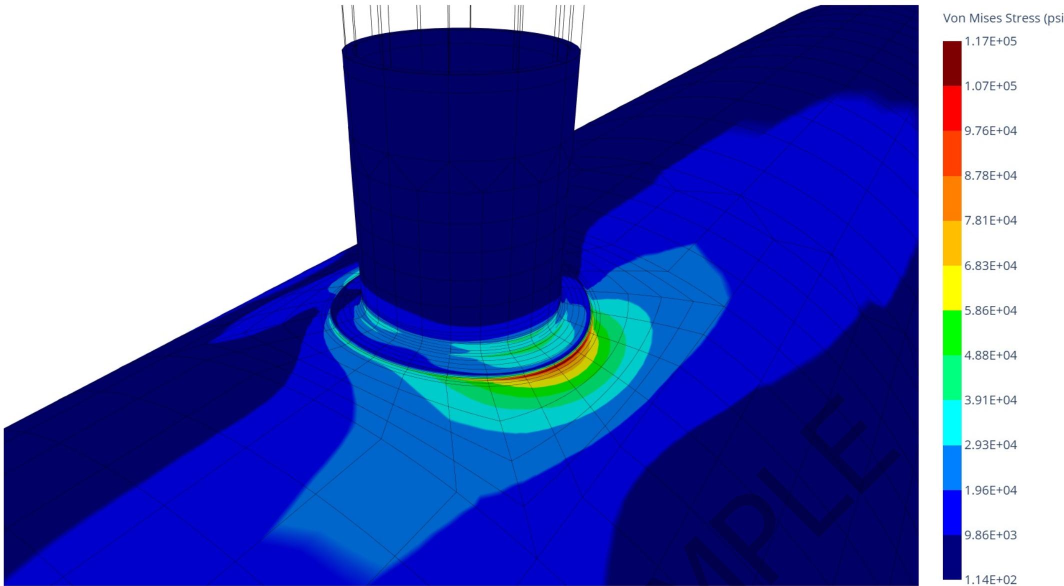
A2-B2	Remote From Discontinuities	General Stress	9,255 ± 412	Pm	4,849 ± 364	Q	14,104 ± 720	4.51%	9,667	18,800	N/A	28,200	14,823	56,400	Pass
C2-D2	Remote From Discontinuities	General Stress	10,117 ± 233	Pm	4,590 ± 248	Q	14,707 ± 15	2.14%	10,350	18,800	N/A	28,200	14,722	56,400	Pass
E2-F2	Near Nozzle Opening	Geometric Discontinuity	4,106 ± 189	PL	12,814 ± 379	Q	16,921 ± 191	7.66%	N/A	18,800	4,295	28,200	17,111	56,400	Pass
G2-H2	Pad Outer Weld	Geometric Discontinuity	7,027 ± 112	PL	11,215 ± 241	Q	18,242 ± 352	6.15%	N/A	18,800	7,138	28,200	18,594	56,400	Pass
I2-J2	Near Nozzle Opening	Geometric Discontinuity	15,283 ± 82	PL	7,350 ± 142	Q	22,633 ± 60	3.5%	N/A	18,800	15,366	28,200	22,693	56,400	Pass
K2-L2	Pad Outer Weld	Geometric Discontinuity	16,070 ± 195	PL	16,665 ± 663	Q	32,735 ± 468	6.79%	N/A	18,800	16,265	28,200	33,203	56,400	Pass
M2-N2	Near Nozzle Opening	Geometric Discontinuity	7,729 ± 0	PL	39,661 ± 0	Q	47,390 ± 0	0%	N/A	18,800	7,729	28,200	47,390	56,400	Pass
O2-P2	Pad Outer Weld	Geometric Discontinuity	10,293 ± 0	PL	54,662 ± 0	Q	64,955 ± 0	0%	N/A	18,800	10,293	28,200	64,955	56,400	Fail
Q2-R2	Near Nozzle Opening	Geometric Discontinuity	9,118 ± 0	PL	37,668 ± 0	Q	46,785 ± 0	0%	N/A	18,800	9,118	28,200	46,785	56,400	Pass
S2-T2	Pad Outer Weld	Geometric Discontinuity	12,324 ± 0	PL	50,885 ± 0	Q	63,208 ± 0	0%	N/A	18,800	12,324	28,200	63,208	56,400	Fail
U2-V2	Near Nozzle Opening	Geometric Discontinuity	13,602 ± 0	PL	29,536 ± 0	Q	43,138 ± 0	0%	N/A	18,800	13,602	28,200	43,138	56,400	Pass
W2-X2	Pad Outer Weld	Geometric Discontinuity	14,928 ± 0	PL	64,409 ± 0	Q	79,337 ± 0	0%	N/A	18,800	14,928	28,200	79,337	56,400	Fail
Y2-Z2	Near Nozzle Opening	Geometric Discontinuity	13,113 ± 10	PL	31,609 ± 14	Q	44,722 ± 6	0.06%	N/A	18,800	13,123	28,200	44,728	56,400	Pass
A3-B3	Pad Outer Weld	Geometric Discontinuity	19,436 ± 1	PL	44,810 ± 12	Q	64,247 ± 11	0.09%	N/A	18,800	19,438	28,200	64,257	56,400	Fail
C3-D3	Near Nozzle Opening	Geometric Discontinuity	12,288 ± 0	PL	33,948 ± 0	Q	46,236 ± 0	0%	N/A	18,800	12,288	28,200	46,236	56,400	Pass
E3-F3	Pad Outer Weld	Geometric Discontinuity	14,511 ± 0	PL	74,283 ± 0	Q	88,794 ± 0	0%	N/A	18,800	14,511	28,200	88,794	56,400	Fail
G3-H3	Near Nozzle Opening	Geometric Discontinuity	16,810 ± 0	PL	22,665 ± 0	Q	39,476 ± 0	0%	N/A	18,800	16,810	28,200	39,476	56,400	Pass
I3-J3	Pad Outer Weld	Geometric Discontinuity	24,975 ± 0	PL	25,712 ± 0	Q	50,686 ± 0	0%	N/A	18,800	24,975	28,200	50,686	56,400	Pass
K3-L3	Near Nozzle Opening	Geometric Discontinuity	17,366 ± 0	PL	19,842 ± 0	Q	37,208 ± 0	0%	N/A	18,800	17,366	28,200	37,208	56,400	Pass
M3-N3	Pad Outer Weld	Geometric Discontinuity	25,527 ± 0	PL	20,640 ± 0	Q	46,167 ± 0	0%	N/A	18,800	25,527	28,200	46,167	56,400	Pass
O3-P3	Pad Outer Weld	Geometric Discontinuity	19,336 ± 87	PL	43,702 ± 835	Q	63,039 ± 922	6.92%	N/A	18,800	19,424	28,200	63,961	56,400	Fail
Q3-R3	Pad Outer Weld	Geometric Discontinuity	9,900 ± 138	PL	53,186 ± 932	Q	63,086 ± 1,070	7.04%	N/A	18,800	10,038	28,200	64,156	56,400	Fail
S3-T3*	Pad Outer Weld	Geometric Discontinuity	13,547 ± 470	PL	75,057 ± 2,038	Q	88,604 ± 1,567	7.31%	N/A	18,800	14,017	28,200	90,171	56,400	Fail
* governing SCL															

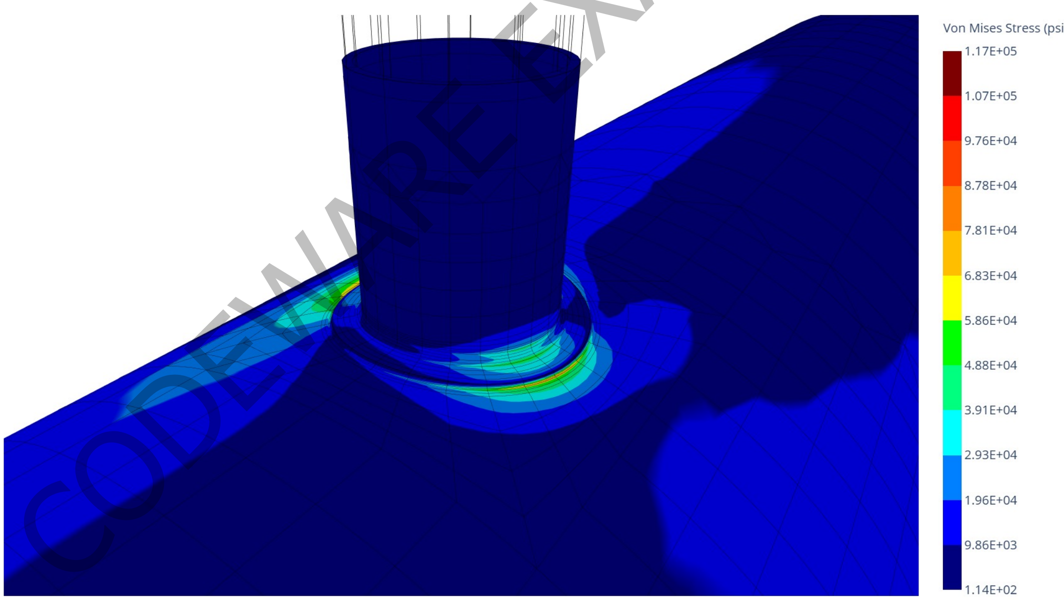
CODEWARE EXAMPLE

Governing Elastic Analysis Results - Design
Von Mises Stress Nozzle Front Isometric View



Dynamic Image

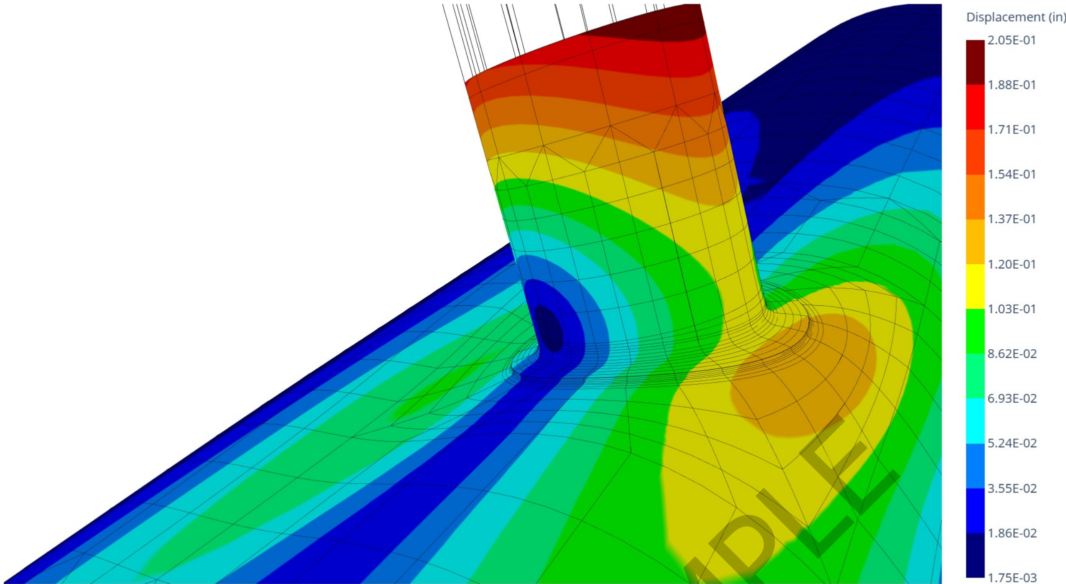
Von Mises Stress Nozzle Rear Isometric View



Dynamic Image

CODEWARE EXAMPLE

Governing Elastic Analysis Results - Design
Displacement Nozzle Front Isometric View



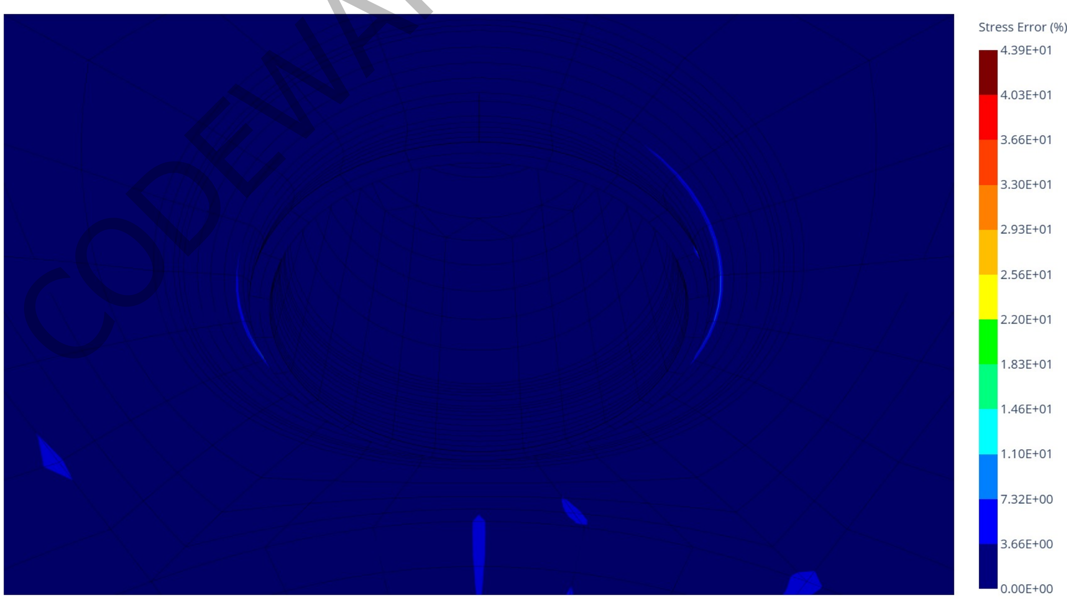
Dynamic Image

Note that the deformed plot has a scaled factor of 18x.

Model Stress Error			
Condition	**Load Case**	**Model Stress Error**	**Model Stress Error (%)**
Design	API 660	655 psi	43.95%

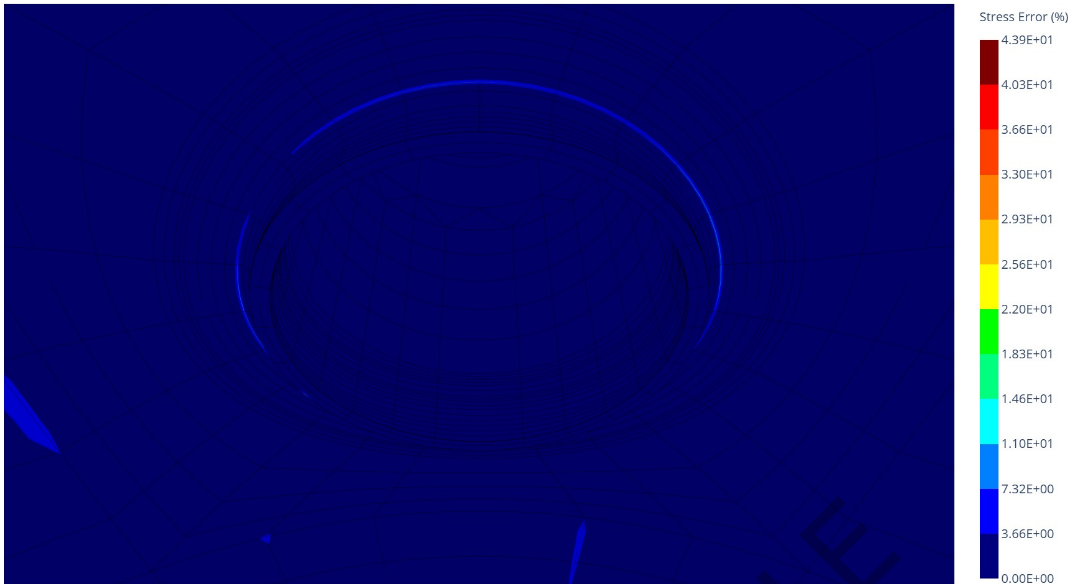
CODEWARE EXAMPLE

Governing Elastic Analysis Results - Design
Stress Error (%) Nozzle Inside-Iso View



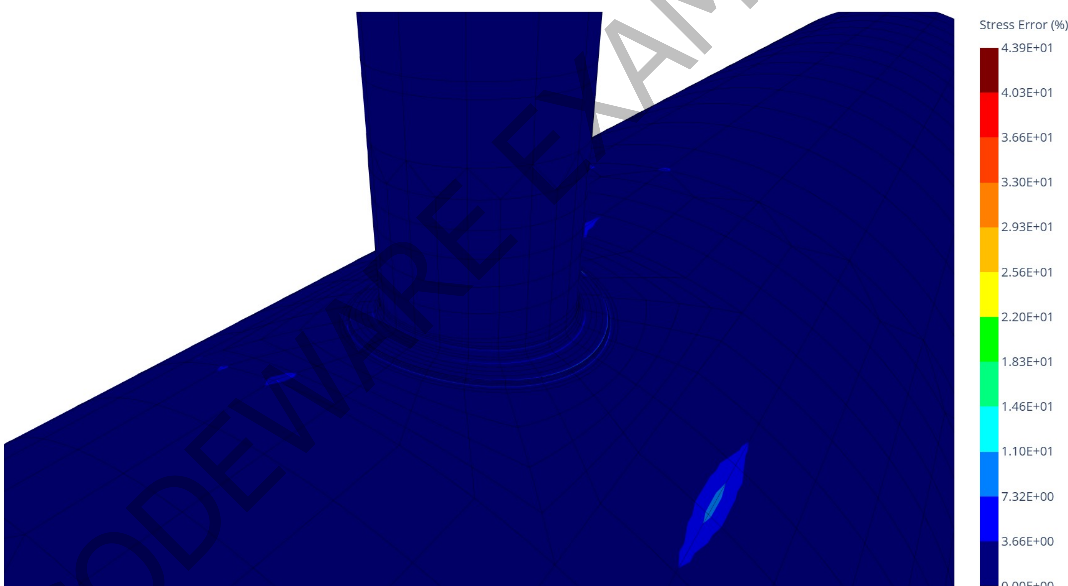
Dynamic Image

Stress Error (%) Nozzle Inside-Iso Reverse View



Dynamic Image

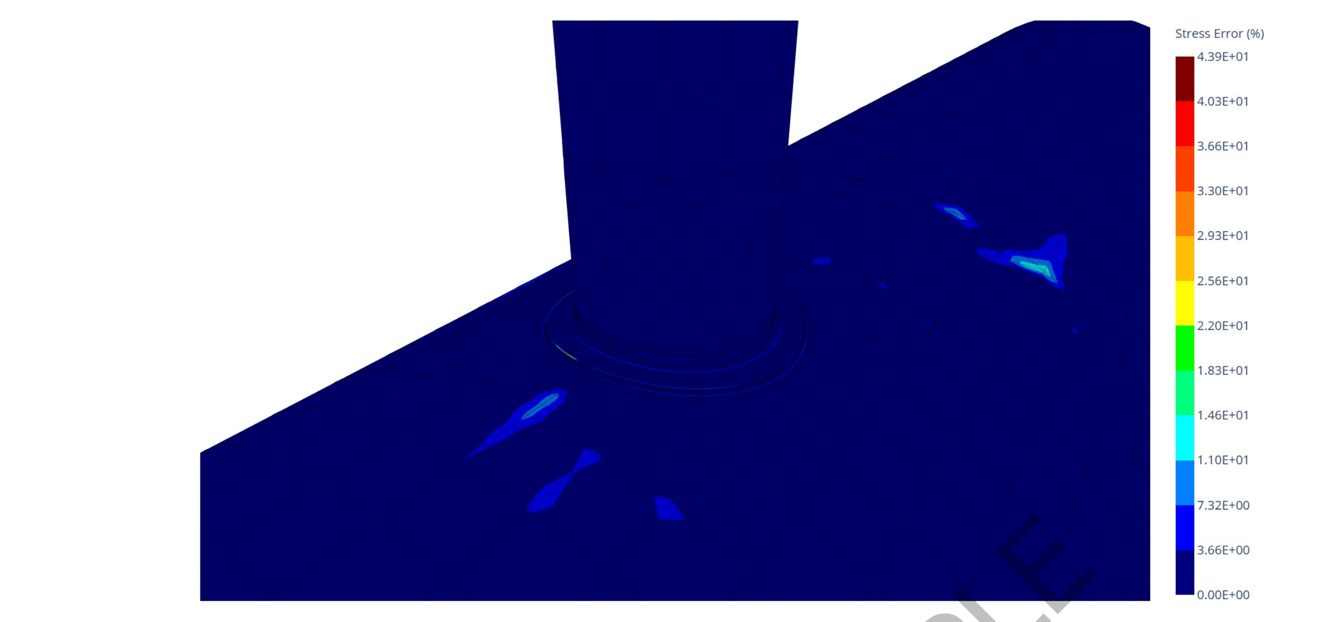
Stress Error (%) Nozzle Front Isometric View



Dynamic Image

Stress Error (%) Nozzle Rear Isometric View

CODEWARE EXAMPLE

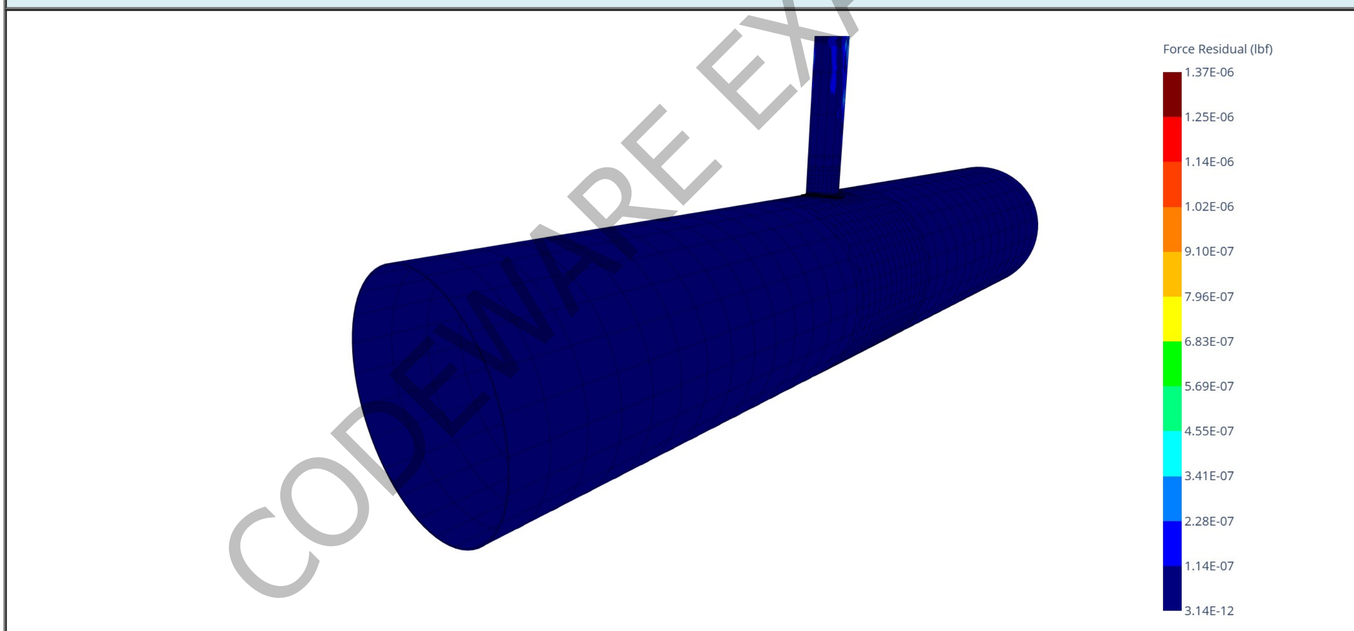


Dynamic Image

The max computational stress error (element vs nodal) for the model is 43.9500%.

Governing Elastic Analysis Results - Design

Force Residual Vessel Front Isometric View



Reactionary forces compared to applied loads in the model have a max computational difference of 0 lbf

CODEWARE EXAMPLE

CODEWARE EXAMPLE

Seismic Code

Building Code: ASCE 7-22 ground supported		
Risk Category (Table 1.5-1)		II
Site Class		C
Importance Factor, I_e		1.0000
Spectral Response Acceleration at short periods (% g), S_S		100.00%
Adjusted Spectral Response Acceleration at short periods (% g), S_{MS}		120.00%
Spectral Response Acceleration at 1 second period (% g), S_1		40.00%
Adjusted Spectral Response Acceleration at 1 second period (% g), S_{M1}		60.00%
Response Modification Coefficient from Table 15.4-2, R		3.0000
Long-period Transition Period, T_L		12.0000
Redundancy factor, ρ		1.0000
User Defined Vertical Accelerations Considered		No
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height		10.2584 ft
Weight	Operating, Corroded	3,516 lb
	Empty, Corroded	1,001 lb
	Vacuum, Corroded	3,516 lb
Period of Vibration Calculation		
Fundamental Period, T	Operating, Corroded	0.093 sec (f = 10.8 Hz)
	Empty, Corroded	0.045 sec (f = 22.0 Hz)
	Vacuum, Corroded	0.093 sec (f = 10.8 Hz)

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

$$T = 2 \cdot \pi \cdot \sqrt{\frac{\sum (W_i \cdot y_i^2)}{g \cdot \sum (W_i \cdot y_i)}}$$, where

W_i is the weight of the i^{th} lumped mass, and
y_i is its deflection when the system is treated as a cantilever beam.

12.4 Basic Load Combinations for Allowable Stress Design			
Load combinations considered in accordance with ASCE section 2.4.5:			
8.	$D + P + P_s + 0.7E$	$= (1.0 + 0.14 S_{DS})D + P + P_s + 0.7\rho Q_E$	
10.	$0.6D + P + P_s + 0.7E$	$= (0.6 - 0.14 S_{DS})D + P + P_s + 0.7\rho Q_E$	
Parameter description			
D	= Dead load		
P	= Internal or external pressure load		
P_s	= Static head load		
E	= Seismic load	$= E_h$ +/- E_v	$= \rho Q_E$ +/- $0.2 S_{DS} D$

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Base Shear Calculations

CODEWARE EXAMPLE

Seismic Shear Report: Operating, Corroded					
Component	Elevation of Bottom above Base (in)	Elastic Modulus E (10^6 psi)	Inertia I (ft^4)	Seismic Shear at Bottom (lb_f)	Bending Moment at Bottom (lb_f-ft)
Ellipsoidal Head #1	112	26.0	*	28	23
Cylinder #2	76	26.0	0.1683	323	534
Cylinder #1 (top)	40	26.0	0.2255	587	1,968
Legs #1	0	29.0	0.0014	656	4,109
Cylinder #1 (bottom)	40	26.0	0.2255	56	25
Ellipsoidal Head #2	40	26.0	*	51	20
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Empty, Corroded					
Component	Elevation of Bottom above Base (in)	Elastic Modulus E (10^6 psi)	Inertia I (ft^4)	Seismic Shear at Bottom (lb_f)	Bending Moment at Bottom (lb_f-ft)
Ellipsoidal Head #1	112	29.4	*	26	22
Cylinder #2	76	29.4	0.1683	94	286
Cylinder #1 (top)	40	29.4	0.2255	143	707
Legs #1	0	29.0	0.0014	168	1,240
Cylinder #1 (bottom)	40	29.4	0.2255	13	7
Ellipsoidal Head #2	40	29.4	*	12	6
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Vacuum, Corroded					
Component	Elevation of Bottom above Base (in)	Elastic Modulus E (10^6 psi)	Inertia I (ft^4)	Seismic Shear at Bottom (lb_f)	Bending Moment at Bottom (lb_f-ft)
Ellipsoidal Head #1	112	26.0	*	28	23
Cylinder #2	76	26.0	0.1683	323	534
Cylinder #1 (top)	40	26.0	0.2255	587	1,968
Legs #1	0	29.0	0.0014	656	4,109
Cylinder #1 (bottom)	40	26.0	0.2255	56	25
Ellipsoidal Head #2	40	26.0	*	51	20
*Moment of Inertia I varies over the length of the component					

CODEWARE EXAMPLE

11.4.4: Design spectral response acceleration parameters

Design earthquake spectral response acceleration at short period, S_{DS}

$$S_{DS} = \frac{2}{3} \cdot \frac{S_{MS}}{100} = \frac{2}{3} \cdot \frac{120.00}{100} = 0.8000$$

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

$$S_{D1} = \frac{2}{3} \cdot \frac{S_{M1}}{100} = \frac{2}{3} \cdot \frac{60.00}{100} = 0.4000$$

11.6 Seismic Design Category

The Risk Category is II.
From Table 11.6-1, the Seismic Design Category based on S_{DS} = 0.8000 is D.
From Table 11.6-2, the Seismic Design Category based on S_{D1} = 0.4000 is D.
This vessel is assigned to Seismic Design Category D.

12.4: Seismic Load Combinations: Vertical Term

Factor is applied to dead load.

Compressive Side: $= 1.0 + 0.14 \cdot S_{DS} = 1.0 + 0.14 \cdot 0.8000 = 1.1120$

Tensile Side: $= 0.6 - 0.14 \cdot S_{DS} = 0.6 - 0.14 \cdot 0.8000 = 0.4880$

Base Shear Calculations

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Base Shear Calculations: Operating, Corroded

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

$T = 0.0928 \text{ sec.}$

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is calculated with equation 15.4-1 and shall not be less than 0.03; in addition, if S_1 >= 0.6g, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-4 because (T = 0.0928) <= (T_L = 12.0000)

$$C_s = \frac{S_{DS}}{\frac{R}{I_e}} = \frac{0.8000}{\frac{3.0000}{1.0000}} = 0.2667$$

$$C_s\text{Min} = \max\left[0.044 \cdot S_{DS} \cdot I_e, 0.03\right] = \max\left[0.044 \cdot 0.8000 \cdot 1.0000, 0.03\right] = 0.0352$$

$$C_s\text{Max} = \frac{S_{D1}}{T \cdot \left(\frac{R}{I_e}\right)} = \frac{0.4000}{0.0928 \cdot \left(\frac{3.0000}{1.0000}\right)} = 1.4368$$

$$C_s = 0.2667$$

12.8.1: Calculation of Base Shear

$$V = C_s \cdot W = 0.2667 \cdot 3{,}515.7327 = 937.53 \text{ lb}$$

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h

$Q_E = V$

$E_h = 0.7 \cdot \rho \cdot Q_E$ (Only 70% of seismic load considered as per Section 2.4.5)

$= 0.7 \cdot 1.0000 \cdot 937.53$

$= 656.27 \text{ lb}$

Base Shear Calculations: Empty, Corroded

Paragraph 15.4.2: T < 0.06, so:

$V = 0.30 \cdot S_{DS} \cdot W \cdot I_e$

$= 0.30 \cdot 0.8000 \cdot 1{,}001.0082 \cdot 1.0000$

$= 240.24 \text{ lb}$

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h

$Q_E = V$

$E_h = 0.7 \cdot \rho \cdot Q_E$ (Only 70% of seismic load considered as per Section 2.4.5)

$= 0.7 \cdot 1.0000 \cdot 240.24$

$= 168.17 \text{ lb}$

Base Shear Calculations: Vacuum, Corroded

CODEWARE EXAMPLE

Paragraph 15.4.4: Period Determination

Fundamental Period is taken from the Rayleigh method listed previously in this report.

$T = 0.0928\,\text{sec}\,.$

12.8.1: Calculation of Seismic Response Coefficient

C_s is the value computed below, bounded by C_sMin and C_sMax:
C_sMin is calculated with equation 15.4-1 and shall not be less than 0.03; in addition, if S_1 >= 0.6g, C_sMin shall not be less than eqn 15.4-2.
C_sMax calculated with 12.8-4 because (T = 0.0928) <= (T_L = 12.0000)

$$C_s = \frac{S_{DS}}{\frac{R}{I_e}} = \frac{0.8000}{\frac{3.0000}{1.0000}} = 0.2667$$

$$C_s\text{Min} = \max\left[0.044 \cdot S_{DS} \cdot I_e, 0.03\right] = \max\left[0.044 \cdot 0.8000 \cdot 1.0000, 0.03\right] = 0.0352$$

$$C_s\text{Max} = \frac{S_{D1}}{T \cdot \left(\frac{R}{I_e}\right)} = \frac{0.4000}{0.0928 \cdot \left(\frac{3.0000}{1.0000}\right)} = 1.4368$$

$$C_s = 0.2667$$

12.8.1: Calculation of Base Shear

$$V = C_s \cdot W = 0.2667 \cdot 3{,}515.7327 = 937.53 \text{ lb}$$

12.4.2.1 Seismic Load Combinations: Horizontal Seismic Load Effect, E_h

$Q_E \quad = V$

$E_h \quad = 0.7 \cdot \rho \cdot Q_E$ (Only 70% of seismic load considered as per Section 2.4.5)

$= 0.7 \cdot 1.0000 \cdot 937.53$

$= 656.27 \text{ lb}$

CODEWARE EXAMPLE