ESCUELA POLITÉCNICA DE INGENIERÍA DE GIJÓN.

MÁSTER UNIVERSITARIO EN INGENIERÍA INDUSTRIAL

ÁREA DE INGENIERÍA DE LA CONSTRUCCIÓN

ANEXO I: INFORME DEL EQUIPO

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Table of Contents

Deficiencies Summary

No deficiencies found.

Warnings Summary

Warnings for B16.9 Elbow D
Table 1A, note W14: These S values do not include a weld factor. For Section VIII, Division 1, and Section XII applications using welds made without filler metal, the tabulated tensile stress values shall be multiplied by 0.85. For welds made with filler metal, consult UW-12 for Section VIII, Division 1, or TW-130.4 for Section XII, as applicable. (warning)

Warnings for Flange H
TEMA Table D-5: Current bolt circle (120,6 mm) does not provide sufficient wrench clearance, 125,57 mm recommended. (warning)
TEMA Table D-5: The actual edge distance (15,7 mm) is less than the minimum edge distance (19,05 mm). A flange outer diameter of 158,7 mm is recommended. (warning)

Warnings for Nozzle (A)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)
The attached ASME B16.5 flange limits the nozzle MAP. (warning)
The design of this nozzle does not include mill undertolerance because a minimum (as built) thickness was entered. (warning)

Warnings for Nozzle (B)
Gasket dimensions should be specified when external load pressure reduction consideration is active. (warning)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)

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

Warnings for Nozzle (D)
The design of this nozzle does not include mill undertolerance because a minimum (as built) thickness was entered. (warning)

Warnings for Nozzle (G)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)
The attached ASME B16.5 flange limits the nozzle MAP. (warning)

Warnings for Nozzle (H)
The design of this nozzle does not include mill undertolerance because a minimum (as built) thickness was entered. (warning)

Warnings for Nozzle (K2)
The attached ASME B16.5 flange limits the nozzle MAWP. (warning)
The attached ASME B16.5 flange limits the nozzle MAP. (warning)

Warnings for Nozzle (L2)
Gasket dimensions should be specified when external load pressure reduction consideration is active. (warning)

Warnings for Nozzle Pipe (D)
The design of this cylinder does not include mill undertolerance because a minimum (as built) thickness was entered. (warning)

Warnings for Support Skirt
The Skirt/Legs/Saddles Stress Increase factor is 1,00 (Set Mode Options dialog on the Calculation page). AISC paragraph A5 permits a stress increase factor of 1/3. For the specified building code the recommended stress increase factor is 1,30. (warning)

Warnings for Vessel
This vessel has one or more weld neck flanges with para UG-44(b) option active. The analysis therein relies on certain assumptions about the flange in question: The assembly bolt load must comply with ASME PCC-1, Appendix O; The method was developed using a spiral wound gasket; The allowable factor should potentially be reduced for a sustained load where the bolted flange joint operates at a temperature causing significant creep/relaxation, usually above 450 degF (232 degC) metal temperature. (warning)

ASME B16.5 / B16.47 Flange Warnings Summary

Flange	Applicable Warnings
Nozzle (A)	1
Nozzle (C)	1
Nozzle (B)	1
Nozzle (G)	1
Nozzle (K2)	1
Right end of Nozzle Pipe (D)	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	The nozzle external loads are not considered in the flange pressure rating of piping flanges. To comply with Interpretation VIII-1-16-85 user defined loads should be applied to the flange.

Nozzle Schedule

Specifications									
Nozzle mark	**Identifier**	**Size**	**Materials**		**Impact Tested**	**Normalized**	**Fine Grain**	**Flange**	**Blind**
A	Nozzle	NPS 10 Sch 80 DN 250	Nozzle	SA-333 6 Wld & smls pipe	No	Yes	Yes	NPS 10 Class 150 WN A350 LF2 Cl.1 N	No
B	Nozzle	355,18 OD x 26	Nozzle	SA-266 1	No	Yes	Yes	NPS 12 Class 150 WN A350 LF2 Cl.1 N	No
C	Nozzle	710,2 OD x 60	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 24 Class 150 WN A350 LF2 Cl.1 N	NPS 24 Class 150 A350 LF2 Cl.1 N
D	Nozzle	NPS 2 Sch 80 (XS) DN 50	Nozzle	SA-333 6 Wld & smls pipe	No	Yes	Yes	N/A	No
	B16.9 Elbow D	NPS 2 Sch 80 (XS) DN 50	B16.9 Elbow	SA-420 WPL6	No	Yes	Yes	N/A	No
	Nozzle Pipe (D)	NPS 2 Sch 80 (XS) DN 50	Nozzle Pipe	SA-333 6 Wld & smls pipe	No	Yes	Yes	NPS 2 Class 150 WN A350 LF2 Cl.1 N	No
E1	Nozzle	84,07 OD x 16,64	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 300 LWN A350 LF2 Cl.1 N	No
E2	Nozzle	84,07 OD x 16,64	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 300 LWN A350 LF2 Cl.1 N	No
F1	Nozzle	84,07 OD x 16,64	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 300 LWN A350 LF2 Cl.1 N	No
F2	Nozzle	84,07 OD x 16,64	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 300 LWN A350 LF2 Cl.1 N	No
G	Nozzle	77,72 OD x 13,46	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 150 LWN A350 LF2 Cl.1 N	No
H	Nozzle	NPS 2 Sch 80 (XS) DN 50	Nozzle	SA-333 6 Wld & smls pipe	No	Yes	Yes	App 2 Weld Neck Integral SA-350 LF2 Cl 1	No
K1	Nozzle	84,07 OD x 16,64	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 300 LWN A350 LF2 Cl.1 N	No
K2	Nozzle	77,72 OD x 13,46	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 150 LWN A350 LF2 Cl.1 N	No
L1	Nozzle	84,07 OD x 16,64	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 300 LWN A350 LF2 Cl.1 N	No
L2	Nozzle	84,07 OD x 16,64	Nozzle	SA-350 LF2 Cl 1	No	Yes	Yes	NPS 2 Class 300 LWN A350 LF2 Cl.1 N	No

Nozzle Summary

Dimensions												
Nozzle mark	OD (mm)	t_n (mm)	Req t_n (mm)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (mm)	A_a/A_r (%)
						Nom t (mm)	Design t (mm)	User t (mm)	Width (mm)	t_{pad} (mm)		
A	273,05	15,09	9,71	Yes	Yes	24*	18,82		N/A	N/A	1,6	100,0
B	355,18	26	9,93	Yes	Yes	21	14,75		N/A	N/A	1,6	100,0
C	710,2	60	7,67	Yes	Yes	21	20,14		N/A	N/A	1,6	100,0
D	60,33	5,54	5,02	Yes	Yes	24*	N/A		N/A	N/A	1,6	Exempt
E1	84,07	16,64	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
E2	84,07	16,64	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
F1	84,07	16,64	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
F2	84,07	16,64	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
G	77,72	13,46	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
H	60,33	5,54	5,02	Yes	Yes	24*	N/A		N/A	N/A	1,6	Exempt
K1	84,07	16,64	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
K2	77,72	13,46	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
L1	84,07	16,64	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
L2	84,07	16,64	6,4	Yes	Yes	21	N/A		N/A	N/A	1,6	Exempt
*Head minimum thickness after forming												

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

Pressure Summary

Component Summary										
Identifier	P Design (bar)	T Design (°C)	MAWP (bar)	MAP (bar)	MAEP (bar)	T_e external (°C)	MDMT (°C)	MDMT Exemption	Impact Tested
Top Head	15,5	121	29,3	31,38	13,66	23	-73,6	Note 1	Yes
Straight Flange on Top Head	15,5	121	28,94	30,97	15,58	23	-73,3	Note 2	Yes
Shell V1	15,5	121	25,07	27,15	12,77	23	-66,6	Note 3	Yes
Straight Flange on Bottom Head	15,5	121	28,89	30,97	15,58	23	-73,2	Note 5	Yes
Bottom Head	15,5	121	29,2	31,38	13,66	23	-73,4	Note 4	Yes
Nozzle (A)	15,5	121	16,9	19,6	9,76	23	-56,6	Note 6	No
Nozzle (B)	15,5	121	16,9	19,16	11,15	23	-48	Note 7	No
Nozzle (C)	15,5	121	16,9	18,62	11,92	23	-56,6	Note 6	No
Nozzle (D)	15,5	121	26,07	34,86	13,66	23	-105	Note 8	No
B16.9 Elbow D	15,5	121	132,53	202,56	81,5	23	-105	Note 9	No
Nozzle Pipe (D)	15,5	121	16,78	19,6	103,05	23	-56,2	Note 10, 11	No
Nozzle (E1)	15,5	121	25,07	27,15	12,77	23	-104	Note 12	No
Nozzle (E2)	15,5	121	25,11	27,15	12,77	23	-104	Note 13	No
Nozzle (F1)	15,5	121	25,11	27,15	12,77	23	-104	Note 13	No
Nozzle (F2)	15,5	121	25,11	27,15	12,77	23	-104	Note 13	No
Nozzle (G)	15,5	121	15,9	19,6	12,77	23	-53,7	Note 14	No
Nozzle (H)	15,5	121	25,67	34,86	13,66	23	-105	Note 8	No
Flange H	15,5	121	43,33	42,8	514,56	23	-49	Note 15	No
Flange H - Flange Hub	15,5	121	273,79	273,79	148,27	23	-105	Note 16	No
Nozzle (K1)	15,5	121	25,08	27,15	12,77	23	-104	Note 17	No
Nozzle (K2)	15,5	121	15,93	19,6	12,77	23	-53,8	Note 18	No
Nozzle (L1)	15,5	121	25,08	27,15	12,77	23	-104	Note 17	No
Nozzle (L2)	15,5	121	25,11	27,15	12,77	23	-99,3	Note 19	No

Chamber Summary	
Design MDMT	-15 °C
Rated MDMT	-48 °C @ 15,9 bar
MAWP hot & corroded	15,9 bar @ 121 °C
MAP cold & new	18,62 bar @ 7 °C
MAEP	9,76 bar @ 23 °C

Notes for MDMT Rating		
Note #	Exemption	Details
1.	Material is impact tested per UG-84 to -46°C.	UCS-66(i) reduction of 27,6°C applied (ratio = 0,5421).
2.	Material is impact tested per UG-84 to -46°C.	UCS-66(i) reduction of 27,3°C applied (ratio = 0,5458).
3.	Material is impact tested per UG-84 to -46°C.	UCS-66(i) reduction of 20,6°C applied (ratio = 0,632).
4.	Material is impact tested per UG-84 to -46°C.	UCS-66(i) reduction of 27,4°C applied (ratio = 0,5453).
5.	Material is impact tested per UG-84 to -46°C.	UCS-66(i) reduction of 27,2°C applied (ratio = 0,5475).
6.	Flange rating governs: Bolts rated MDMT per Fig UCS-66 note (c) = -104°C Flange is impact tested per material specification to -46°C.	UCS-66(i) reduction of 10,6°C applied (ratio = 0,8112).
7.	Nozzle impact test exemption temperature from Fig UCS-66M Curve C = -23,75°C 17°C MDMT reduction per UCS-68(c) applies. Fig UCS-66.1M MDMT reduction = 20,7°C, (coincident ratio = 0,6302) Rated MDMT of -61,45°C is limited to -48°C by UCS-66(b)(2)	UCS-66 governing thickness = 21 mm.
8.	Nozzle is impact test exempt per UCS-66(d) (NPS 4 or smaller pipe).	
9.	Material is impact tested per material specification to -45°C.	Stress ratio = 0,1255 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C.
10.	Material is impact test exempt per UCS-66(d) (NPS 4 or smaller pipe)	
11.	Flange rating governs: Flange is impact tested per material specification to -46°C. UCS-66(i) reduction of 10,2°C applied (ratio = 0,8175).	
12.	LWN rated MDMT per UCS-66(c)(1) Flange rated MDMT = -105°C Bolts rated MDMT per Fig UCS-66 note (c) = -104°C Flange is impact tested per material specification to -46°C.	Stress ratio = 0,3118 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C.
13.	LWN rated MDMT per UCS-66(c)(1) Flange rated MDMT = -105°C Bolts rated MDMT per Fig UCS-66 note (c) = -104°C Flange is impact tested per material specification to -46°C.	Stress ratio = 0,3112 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C.
14.	LWN rated MDMT per UCS-66(c)(1) Bolts rated MDMT per Fig UCS-66 note (c) = -104°C Flange is impact tested per material specification to -46°C.	UCS-66(i) reduction of 7,7°C applied (ratio = 0,8623).
15.	Flange is impact tested per material specification to -46°C with an additional 3°C reduction per UCS-66(g) UCS-66 governing thickness = 5,54 mm	Bolts rated MDMT per Fig UCS-66 note (c) = -104°C
16.	Material is impact tested per material specification to -46°C.	Stress ratio = 0,0624 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C.
17.	LWN rated MDMT per UCS-66(c)(1) Flange rated MDMT = -105°C Bolts rated MDMT per Fig UCS-66 note (c) = -104°C Flange is impact tested per material specification to -46°C.	Stress ratio = 0,3117 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C.
18.	LWN rated MDMT per UCS-66(c)(1) Bolts rated MDMT per Fig UCS-66 note (c) = -104°C Flange is impact tested per material specification to -46°C.	UCS-66(i) reduction of 7,8°C applied (ratio = 0,8607).
19.	LWN rated MDMT per UCS-66(c)(1) Bolts rated MDMT per Fig UCS-66 note (c) = -104°C Flange is impact tested per material specification to -46°C.	UCS-66(i) reduction of 53,3°C applied (ratio = 0,3959).

Revision History

Revisions			
No.	Date	Operator	Notes
0	3/25/2022	marina.diaz	New vessel created ASME Section VIII Division 1 [COMPRESS 2022 Build 8200]

Settings Summary

COMPRESS 2024 Build 8400	
ASME Section VIII Division 1, 2021 Edition Metric	
Units	MKS
Datum Line Location	-50,00 mm from bottom seam
Vessel Design Mode	Rating Mode (Analysis)
Minimum thickness	1,5 mm per UG-16(b)
Design for cold shut down only	No
Design for lethal service (full radiography required)	No
Design nozzles for	Chamber MAWP
Corrosion weight loss	100% of theoretical loss
UG-23 Stress Increase	1,20
Skirt/legs stress increase	1,0
Minimum nozzle projection	150 mm
Juncture calculations for α > 30 only	Yes
Preheat P-No 1 Materials > 1,25" and <= 1,50" thick	Yes
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	Yes
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 test at user defined pressure	24,21 bar
Test liquid specific gravity	1,00
Field test at user defined pressure	24,21 bar
Wind load present @ field	25% of design
Maximum stress during test	95% of yield
Required Marking - UG-116	
UG-116(e) Radiography	RT1
UG-116(f) Postweld heat treatment	HT
Code Cases\Interpretations	
Use Appendix 46	No
Use UG-44(b)	Yes
Use Code Case 3035	No
Apply interpretation VIII-1-83-66	No
Apply interpretation VIII-1-86-175	Yes
Apply interpretation VIII-1-01-37	Yes
Apply interpretation VIII-1-01-150	No
Apply interpretation VIII-1-07-50	No
Apply interpretation VIII-1-16-85	Yes
No UCS-66.1 MDMT reduction	No
No UCS-68(c) MDMT reduction	No
Disallow UG-20(f) exemptions	Yes
UG-22 Loadings	
UG-22(a) Internal or External Design Pressure	Yes
UG-22(b) Weight of the vessel and normal contents under operating or test conditions	Yes
UG-22(c) Superimposed static reactions from weight of attached equipment (external loads)	Yes
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs	Yes
UG-22(f) Wind reactions	Yes
UG-22(f) Seismic reactions	Yes
UG-22(j) Test pressure and coincident static head acting during the test:	Yes

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

License Information	
Company Name	Idesa
License	Commercial
License Key ID	24316
Support Expires	June 07, 2025
Account Number	411628768218139

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	
Top Head	A	Full UW-11(a) / Type 1	N/A	N/A	B	Full UW-11(a) / Type 1	RT1
Shell V1	A	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	B	Full UW-11(a) / Type 1	RT1
Bottom Head	A	Full UW-11(a) / Type 1	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 (A)	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
Nozzle (H)	N/A	Seamless No RT	D	N/A / Type 7	C	UW-11(a)(4) exempt / Type 1	N/A
Nozzle (C)	A	Full UW-11(a) / Type 1	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT1
Nozzle (B)	A	Full UW-11(a) / Type 1	D	N/A / Type 7	C	Full UW-11(a) / Type 1	RT1
Nozzle (E1)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (E2)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (F1)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (G)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (K2)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (F2)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (K1)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (L1)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (L2)	N/A	Seamless No RT	D	N/A / Type 7	C	N/A	N/A
Nozzle (D)	N/A	Seamless No RT	D	N/A / Type 7	B	UW-11(a)(4) exempt / Type 1	N/A
B16.9 Elbow D	A	Full UW-11(a) / Type 1	B	UW-11(a)(4) exempt / Type 1	B	UW-11(a)(4) exempt / Type 1	RT1
Nozzle Pipe (D)	N/A	Seamless No RT	B	UW-11(a)(4) exempt / Type 1	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 (A)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	UW-11(a)(4) exempt / Type 1	N/A
Flange H	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 (C)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
ASME B16.5/16.47 flange attached to Nozzle (B)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	Full UW-11(a) / Type 1	RT1
ASME B16.5/16.47 flange attached to Nozzle (E1)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle (E2)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle (F1)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle (G)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle (K2)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle (F2)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle (K1)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle (L1)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to Nozzle (L2)	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
ASME B16.5/16.47 flange attached to right end of Nozzle Pipe (D)	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**							

Thickness Summary

Component Data								
Component Identifier	Material	Diameter (mm)	Length (mm)	Nominal t (mm)	Design t (mm)	Total Corrosion (mm)	Joint E	Load
Top Head	SA-516 60	1.800 ID	474	24*	13,44	1,6	1,00	Internal
Straight Flange on Top Head	SA-516 60	1.800 ID	50	24	13,52	1,6	1,00	Internal
Shell V1	SA-516 60	1.800 ID	1.700	21	13,55	1,6	1,00	Internal
Straight Flange on Bottom Head	SA-516 60	1.800 ID	50	24	13,56	1,6	1,00	Internal
Bottom Head	SA-516 60	1.800 ID	474	24*	13,51	1,6	1,00	Internal
Support Skirt	SA-516 60	1.814 ID	1.070	10	1,9	1,6	0,55	Wind
*Head minimum thickness after forming								

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

Weight Summary

Weight (kg) Contributed by Vessel Elements											
Component	Metal New*	Metal Corroded	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid		Surface Area m^2
							New	Corroded	New	Corroded	
Top Head	767,6	714,9	0	0	87,9	0	0	0	885,3	885,4	4,37
Shell V1	1.510,4	1.394	82,1	0	230,3	0	1.161,3	1.161,4	4.346,2	4.346,8	9,29
Bottom Head	778,6	725,1	34,6	0	87,9	0	890,9	890,9	880,8	880,8	4,42
Support Skirt	471,3	395,5	113,9	0	110,5	0	0	0	0	0	12,33
Skirt Base Ring	127,5	127,5	0	0	0	0	0	0	0	0	1,87
TOTAL:	**3.655,3**	**3.357**	**230,7**	**0**	**516,5**	**0**	**2.052,2**	**2.052,4**	**6.112,3**	**6.113**	**32,28**

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

Weight (kg) Contributed by Attachments											
Component	Body Flanges		Nozzles & Flanges**		Packed Beds	Ladders & Platforms*	Trays	Tray Supports	Rings & Clips	Vertical Loads	Surface Area m^2
	New	Corroded	New	Corroded							
Top Head	0	0	47,3	45	0	1.002,6	0	0	0	1.324*	0,42
Shell V1	0	0	671,9	666,1	0	76,5	0	0	0	1.312,4*	2,71
Bottom Head	0	0	12,9	10	0	54,9	0	0	0	0	0,27
Support Skirt	0	0	40,8	34,2	0	0	0	0	0	53	0
TOTAL:	**0**	**0**	**772,9**	**755,2**	**0**	**1.134**	**0**	**0**	**0**	**2.689,4***	**3,39**

*** This number includes vertical loads which are not present in all conditions.
* Platforms and ladders are not included in surface area.
** Nozzle weight includes lining.

Vessel Totals		
	New	Corroded
Operating Weight (kg)	10.456	10.140
Empty Weight (kg)	8.404	8.088
Test Weight (kg)	13.245	12.930
Surface Area (m^2)	35,68	-
Capacity** (liters)	6.056	6.056

**The vessel capacity does not include volume of nozzle, piping or other attachments.

Vessel Lift Condition	
Vessel Lift Weight, New (kg)	6.591
Center of Gravity from Datum (mm)	665,72

Hydrostatic Test

Horizontal shop hydrostatic test based on user defined pressure

Gauge pressure at 7°C $=24{,}21 \text{ bar}$

Identifier	Local test pressure (bar)	Test liquid static head (bar)	Stress during test (kg_f/cm^2)	Allowable test stress (kg_f/cm^2)	Stress excessive?
Top Head	24,39	0,19	839,546	2.140,894	No
Straight Flange on Top Head	24,39	0,19	945,213	2.140,894	No
Shell V1	24,39	0,19	1.078,481	2.140,894	No
Straight Flange on Bottom Head	24,39	0,19	945,213	2.140,894	No
Bottom Head	24,39	0,19	839,546	2.140,894	No
Flange H - Flange Hub	24,31	0,1	122,046	2.402,452	No
Flange H	24,31	0,1	461,908	2.402,452	No
B16.9 Elbow D	24,31	0,1	138,012	2.334,64	No
Nozzle (A)	24,32	0,11	1.558,605	3.211,341	No
Nozzle (B)	24,32	0,12	1.909,161	3.211,341	No
Nozzle (C)	24,36	0,15	1.961,694	3.211,341	No
Nozzle (D)	24,31	0,1	1.467,305	3.211,341	No
Nozzle (E1)	24,23	0,02	1.262,678	3.211,341	No
Nozzle (E2)	24,23	0,02	1.262,678	3.211,341	No
Nozzle (F1)	24,27	0,06	1.264,816	3.211,341	No
Nozzle (F2)	24,39	0,18	1.270,84	3.211,341	No
Nozzle (G)	24,39	0,18	1.406,704	3.211,341	No
Nozzle (H)	24,31	0,1	1.496,122	3.211,341	No
Nozzle (K1)	24,24	0,04	1.263,452	3.211,341	No
Nozzle (K2)	24,24	0,04	1.398,527	3.211,341	No
Nozzle (L1)	24,41	0,21	1.272,268	3.211,341	No
Nozzle (L2)	24,41	0,21	1.272,268	3.211,341	No
Nozzle Pipe (D)	24,3	0,09	122,165	2.334,64	No

(1) P_L stresses at nozzle openings have been estimated using the method described in Division 2 Part 4.5.
(2) 1,5*0,95*S_y used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.
(3) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.
(4) UG-99(l): Custom flange assemblies shall be tested with gaskets having identical geometries and gasket factors, and bolting having identical allowable stress at room temperature as used in the design calculations.

The test temperature of 7 °C is warmer than the minimum recommended temperature of -31 °C so the brittle fracture provision of UG-99(h) has been met.

Vertical field hydrostatic test based on user defined pressure

Gauge pressure at 7°C $=24{,}21 \text{ bar}$

Vertical field hydrostatic test					
Identifier	Local test pressure (bar)	Test liquid static head (bar)	Stress during test (kg_f/cm^2)	Allowable test stress (kg_f/cm^2)	Stress excessive?
Top Head	24,28	0,08	835,759	2.140,894	No
Straight Flange on Top Head	24,28	0,08	940,948	2.140,894	No
Shell V1	24,45	0,25	1.080,98	2.140,894	No
Straight Flange on Bottom Head	24,46	0,25	947,592	2.140,894	No
Bottom Head	24,5	0,29	843,178	2.140,894	No
Flange H - Flange Hub	24,24	0,03	121,694	2.402,452	No
Flange H	24,24	0,03	460,577	2.402,452	No
B16.9 Elbow D	24,53	0,32	139,263	2.334,64	No
Nozzle (A)	24,23	0,03	1.553,131	3.211,341	No
Nozzle (B)	24,38	0,18	1.913,959	3.211,341	No
Nozzle (C)	24,42	0,22	1.967,107	3.211,341	No
Nozzle (D)	24,52	0,31	1.480,016	3.211,341	No
Nozzle (E1)	24,44	0,24	1.273,831	3.211,341	No
Nozzle (E2)	24,37	0,16	1.269,746	3.211,341	No
Nozzle (F1)	24,37	0,16	1.269,746	3.211,341	No
Nozzle (F2)	24,37	0,16	1.269,746	3.211,341	No
Nozzle (G)	24,44	0,23	1.409,732	3.211,341	No
Nozzle (H)	24,24	0,03	1.491,811	3.211,341	No
Nozzle (K1)	24,44	0,23	1.273,576	3.211,341	No
Nozzle (K2)	24,37	0,16	1.405,493	3.211,341	No
Nozzle (L1)	24,44	0,23	1.273,453	3.211,341	No
Nozzle (L2)	24,37	0,16	1.269,746	3.211,341	No
Nozzle Pipe (D)	24,53	0,32	123,324	2.334,64	No

(1) P_L stresses at nozzle openings have been estimated using the method described in Division 2 Part 4.5.
(2) 1,5*0,95*S_y used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.
(3) UG-99(l): Custom flange assemblies shall be tested with gaskets having identical geometries and gasket factors, and bolting having identical allowable stress at room temperature as used in the design calculations.

The test temperature of 7 °C is warmer than the minimum recommended temperature of -31 °C so the brittle fracture provision of UG-99(h) has been met.

Corroded Hydrostatic Test

Vertical field hydrostatic test based on MAWP per UG-99(b)

Gauge pressure at 7°C $= 1{,}3 \cdot MAWP \cdot LSR$

$= 1{,}3 \cdot 15{,}9 \cdot 1$

$= 20{,}67 \text{ bar}$

Vertical field hydrostatic test							
Identifier	Local test pressure (bar)	Test liquid static head (bar)	UG-99(b) stress ratio	UG-99(b) pressure factor	Stress during test (kg_f/cm^2)	Allowable test stress (kg_f/cm^2)	Stress excessive?
Top Head (1)	20,75	0,08	1	1,30	765,08	2.140,894	No
Straight Flange on Top Head	20,75	0,08	1	1,30	860,624	2.140,894	No
Shell V1	20,92	0,25	1	1,30	1.000,053	2.140,894	No
Straight Flange on Bottom Head	20,92	0,25	1	1,30	867,736	2.140,894	No
Bottom Head	20,96	0,29	1	1,30	773,028	2.140,894	No
Flange H - Flange Hub	20,7	0,03	1	1,30	103,942	2.402,452	No
Flange H	20,7	0,03	1	1,30	390,601	2.402,452	No
B16.9 Elbow D	20,99	0,32	1	1,30	188,065	2.334,64	No
Nozzle (A)	20,7	0,03	1	1,30	1.472,043	3.211,341	No
Nozzle (B)	20,85	0,18	1	1,30	1.797,341	3.211,341	No
Nozzle (C)	20,89	0,22	1	1,30	1.745,838	3.211,341	No
Nozzle (D)	20,98	0,31	1	1,30	1.410,038	3.211,341	No
Nozzle (E1)	20,91	0,24	1	1,30	1.221,594	3.211,341	No
Nozzle (E2)	20,83	0,16	1	1,30	1.217,014	3.211,341	No
Nozzle (F1)	20,83	0,16	1	1,30	1.217,014	3.211,341	No
Nozzle (F2)	20,83	0,16	1	1,30	1.217,014	3.211,341	No
Nozzle (G)	20,9	0,23	1	1,30	1.356,499	3.211,341	No
Nozzle (H)	20,7	0,03	1	1,30	1.418,554	3.211,341	No
Nozzle (K1)	20,9	0,23	1	1,30	1.221,308	3.211,341	No
Nozzle (K2)	20,83	0,16	1	1,30	1.351,73	3.211,341	No
Nozzle (L1)	20,9	0,23	1	1,30	1.221,17	3.211,341	No
Nozzle (L2)	20,83	0,16	1	1,30	1.217,014	3.211,341	No
Nozzle Pipe (D)	20,99	0,32	1	1,30	153,038	2.334,64	No

(1) Top Head limits the UG-99(b) stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in Division 2 Part 4.5.
(3) 1,5*0,95*S_y used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.
(4) UG-99(l): Custom flange assemblies shall be tested with gaskets having identical geometries and gasket factors, and bolting having identical allowable stress at room temperature as used in the design calculations.

Vacuum Summary

Largest Unsupported Length Le			
Component	Line of Support	Elevation above Datum (mm)	Length Le (mm)
Top Head	-	2.274	N/A
-	1/3 depth of Top Head	1.950	N/A
Straight Flange on Top Head Top	-	1.800	2.100
Straight Flange on Top Head Bottom	-	1.750	2.100
Shell V1 Top	-	1.750	2.100
Shell V1 Bottom	-	50	2.100
Straight Flange on Bottom Head Top	-	50	2.100
Straight Flange on Bottom Head Bottom	-	0	2.100
-	1/3 depth of Bottom Head	-150	N/A
Bottom Head	-	-474	N/A

Foundation Load Summary

Skirt Base Ring: Total Loading at Base				
Load	**Vessel Condition**	**Base Shear (kg_f)**	**Base Moment (kg_f-m)**	**Vertical Force (kg_f)**
Weight Only (D)	Operating, Corroded	0	593	10.155,2
Weight Only (D)	Operating, New	0	596,1	10.472,3
Weight Only (D)	Empty, Corroded	0	593	8.102,8
Weight Only (D)	Empty, New	0	596,1	8.420,1
Weight Only (D)	Field Hydrotest, Corroded	0	593	12.941,8
Weight Only (D)	Field Hydrotest, New	0	596,1	13.258,5
Wind Only (W)	Operating, Corroded	652,9	1.779	0
Wind Only (W)	Operating, New	652,9	1.779	0
Wind Only (W)	Empty, Corroded	652,9	1.779	0
Wind Only (W)	Empty, New	652,9	1.779	0
Wind Only (W)	External Pressure, Corroded	652,9	1.779	0
Seismic Only (E)	Operating, Corroded	599,2	1.534,6	0
Seismic Only (E)	Operating, New	617,9	1.573,2	0
Seismic Only (E)	Empty, Corroded	478,1	1.300,3	0
Seismic Only (E)	Empty, New	496,8	1.340	0
Seismic Only (E)	External Pressure, Corroded	599,2	1.534,6	0
25% Wind Only (0,25 * W)	Field Hydrotest, New	163,2	444,7	0
25% Wind Only (0,25 * W)	Field Hydrotest, Corroded	163,2	444,7	0

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

Support Information	
Support Type	Skirt Base Ring
Base Ring Inner Diameter	1.754 mm
Base Ring Outer Diameter	2.014 mm
Base Ring Thickness	20 mm
Number of Anchor Bolts	4
Bolt Circle Diameter	1.934 mm
Bolt Size and Type	M24 x 3
Bolt Hole Clearance	12 mm
Center of Gravity (Distance from Support Base)	1.835,72 mm

Liquid Level bounded by Bottom Head

ASME Section VIII Division 1, 2021 Edition Metric	
Location from Datum (mm)	505
Operating Liquid Specific Gravity	0,999

Top Head

ASME Section VIII Division 1, 2021 Edition Metric					
Component		Ellipsoidal Head			
Material		SA-516 60 (II-D Metric p. 16, ln. 3)			
Attached To		Shell V1			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**	
Yes (-46°C)	Yes	Yes	Yes	No	
		Design Pressure (bar)	**Design Temperature (°C)**	**Design MDMT (°C)**	
Internal		15,5	121	-15	
External		1	23		
Static Liquid Head					
Condition		**P_s (bar)**	**H_s (mm)**	**SG**	
Test horizontal		0,19	1.923,2	1	
Test vertical		0,07	750	1	
Dimensions					
Inner Diameter		1.800 mm			
Head Ratio		2			
Minimum Thickness		24 mm			
Corrosion	**Inner**	0 mm			
	Outer	1,6 mm			
Length L_{sf}		50 mm			
Nominal Thickness t_{sf}		24 mm			
Weight and Capacity					
		Weight (kg)[1]		**Capacity (liters)**[1]	
New		767,58		879,66	
Corroded		714,87		879,66	
Lining					
		Thickness (mm)	**Density (kg/m^3)**	**Weight (kg)**	
Lining		3	8.000	87,87	
Radiography					
Category A joints		Full UW-11(a) Type 1			
Head to shell seam		Full UW-11(a) Type 1			

[1] includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	1,5 mm + 1,6 mm = 3,1 mm
Design thickness due to internal pressure (t)	13,44 mm
Design thickness due to external pressure (t_e)	6,19 mm
Maximum allowable working pressure (MAWP)	29,3 bar
Maximum allowable pressure (MAP)	31,38 bar
Maximum allowable external pressure (MAEP)	13,66 bar
Rated MDMT	-73,6°C

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-46°C
$t_r = \frac{15{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 15{,}9} =$	12,14 mm
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{12{,}14 \cdot 1}{24 - 1{,}6} =$	0,5421
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1M =	27,6°C
$MDMT = \max\left[T_{impact} - T_R, -105\right] = \max\left[-46 - 27{,}6, -105\right] =$	-73,6°C
Design MDMT of -15°C is acceptable.	

Design thickness for internal pressure, (Corroded at 121 °C) UG-32(c)(1)

$$t = \frac{P \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P} + \text{Corrosion} = \frac{15{,}5 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 15{,}5} + 1{,}6 = 13{,}44 \text{ mm}$$

Maximum allowable working pressure, (Corroded at 121 °C) UG-32(c)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0{,}2 \cdot t} - P_s = \frac{2 \cdot 1.180 \cdot 1 \cdot 22{,}4}{1.800 + 0{,}2 \cdot 22{,}4} - 0 = 29{,}3 \text{ bar}$$

Maximum allowable pressure, (New at 7 °C) UG-32(c)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0{,}2 \cdot t} - P_s = \frac{2 \cdot 1.180 \cdot 1 \cdot 24}{1.800 + 0{,}2 \cdot 24} - 0 = 31{,}38 \text{ bar}$$

Design thickness for external pressure, (Corroded at 23 °C) UG-33(d)

Equivalent outside spherical radius

$R_o = K_o \cdot D_o = 0{,}8772 \cdot 1.848 = 1.621{,}09 \text{ mm}$

$$A = \frac{0{,}125}{R_o \;/\; t} = \frac{0{,}125}{1.621{,}09 \;/\; 4{,}59} = 0{,}000354$$

From Table CS-2 Metric: B = 360,063 kg_f/cm^2

$$P_a = \frac{B}{R_o \;/\; t} = \frac{353{,}1012}{1.621{,}09 \;/\; 4{,}59} = 1 \text{ bar}$$

$$t = 4{,}59 \text{ mm} + \text{Corrosion} = 4{,}59 \text{ mm} + 1{,}6 \text{ mm} = 6{,}19 \text{ mm}$$

The head external pressure design thickness (t_e) is 6,19 mm.

Maximum Allowable External Pressure, (Corroded at 23 °C) UG-33(d)

Equivalent outside spherical radius

$R_o = K_o \cdot D_o = 0{,}8772 \cdot 1.848 = 1.621{,}09 \text{ mm}$

$$A = \frac{0{,}125}{R_o \;/\; t} = \frac{0{,}125}{1.621{,}09 \;/\; 22{,}4} = 0{,}001727$$

From Table CS-2 Metric: B = 1.007,9818 kg_f/cm^2

$$P_a = \frac{B}{R_o \;/\; t} = \frac{988{,}4924}{1.621{,}09 \;/\; 22{,}4} = 13{,}6587 \text{ bar}$$

The maximum allowable external pressure (MAEP) is 13,66 bar.

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 24}{318}\right) \cdot \left(1 - \frac{318}{\text{infinity}}\right) = 5{,}6604\,\%$$

Straight Flange on Top Head

ASME Section VIII Division 1, 2021 Edition Metric					
Component		Cylinder			
Material		SA-516 60 (II-D Metric p. 16, ln. 3)			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**	
Yes (-46°C)	Yes	Yes	Yes	No	
		Design Pressure (bar)	**Design Temperature (°C)**	**Design MDMT (°C)**	
Internal		15,5	121	-15	
External		1	23		
Static Liquid Head					
Condition		**P_s (bar)**	**H_s (mm)**	**SG**	
Test horizontal		0,19	1.923,2	1	
Test vertical		0,08	800	1	
Dimensions					
Inner Diameter		1.800 mm			
Length		50 mm			
Nominal Thickness		24 mm			
Corrosion	**Inner**	0 mm			
	Outer	1,6 mm			
Weight and Capacity					
		Weight (kg)		**Capacity (liters)**	
New		53,86		126,39	
Corroded		50,23		126,39	
Lining					
		Thickness (mm)	**Density (kg/m^3)**	**Weight (kg)**	
Lining		3	8.000	0	
Radiography					
Longitudinal seam		Full UW-11(a) Type 1			
Bottom Circumferential seam		Full UW-11(a) Type 1			

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	1,5 mm + 1,6 mm = 3,1 mm
Design thickness due to internal pressure (t)	13,52 mm
Design thickness due to external pressure (t_e)	7,79 mm
Design thickness due to combined loadings + corrosion	6,48 mm
Maximum allowable working pressure (MAWP)	28,94 bar
Maximum allowable pressure (MAP)	30,97 bar
Maximum allowable external pressure (MAEP)	15,58 bar
Rated MDMT	-73,3 °C

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-46°C
$t_r = \frac{15{,}9 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}9} =$	12,23 mm
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{12{,}23 \cdot 1}{24 - 1{,}6} =$	0,5458
$\text{Stress ratio longitudinal} = \frac{266{,}878 \cdot 1}{1.203{,}265 \cdot 1} =$	0,2218
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1M =	27,3°C
$MDMT = \max\left[T_{impact} - T_R, -105\right] = \max\left[-46 - 27{,}3, -105\right] =$	-73,3°C
Design MDMT of -15°C is acceptable.	

Design thickness, (at 121 °C) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0{,}60 \cdot P} + \text{Corrosion} = \frac{15{,}5 \cdot 900}{1.180 \cdot 1{,}00 - 0{,}60 \cdot 15{,}5} + 1{,}6 = \underline{13{,}52} \text{ mm}$$

Maximum allowable working pressure, (at 121 °C) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0{,}60 \cdot t} - P_s = \frac{1.180 \cdot 1{,}00 \cdot 22{,}4}{900 + 0{,}60 \cdot 22{,}4} - 0 = \underline{28{,}94} \text{ bar}$$

Maximum allowable pressure, (at 7 °C) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0{,}60 \cdot t} = \frac{1.180 \cdot 1{,}00 \cdot 24}{900 + 0{,}60 \cdot 24} = \underline{30{,}97} \text{ bar}$$

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{2.100}{1.848} = 1{,}1364$$

$$\frac{D_o}{t} = \frac{1.848}{6{,}19} = 298{,}7497$$

From table G: $A = 0{,}000224$

From table CS-2 Metric: $B = 228{,}4802 \ \text{kg/cm}^2 (224{,}06 \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 224{,}06}{3 \cdot (1.848/6{,}19)} = 1 \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$$t_a = t + \text{Corrosion} = 6{,}19 + 1{,}6 = \underline{7{,}79} \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{2.100}{1.848} = 1{,}1364$$

$$\frac{D_o}{t} = \frac{1.848}{22{,}4} = 82{,}5007$$

From table G: $A = 0{,}001581$

From table CS-2 Metric: $B = 983{,}2359 \ \text{kg/cm}^2 (964{,}2233 \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 964{,}22}{3 \cdot (1.848/22{,}4)} = \underline{15{,}58} \text{ bar}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 24}{912}\right) \cdot \left(1 - \frac{912}{\text{infinity}}\right) = 1{,}3158\,\%$$

The extreme fiber elongation does not exceed 5%.

Thickness Required Due to Pressure + External Loads								
Condition	Allowable Stress Before UG-23 Stress Increase (kg/cm^2)		Temperature (°C)	Corrosion C (mm)	Load	Pressure P (bar)	Req'd Thk Due to Tension (mm)	Req'd Thk Due to Compression (mm)
	S_t	S_c						
Operating, Hot & Corroded	1.203,3	1.143,5	121	1,6	Wind	71,3	4,88	4,87
					Seismic	71,31	4,88	4,87
Operating, Hot & New	1.203,3	1.153,1	121	0	Wind	76,45	4,88	4,87
					Seismic	76,45	4,88	4,87
Hot Shut Down, Corroded	1.203,3	1.143,5	121	1,6	Wind	0	0,04	0,05
					Seismic	0	0,04	0,05
Hot Shut Down, New	1.203,3	1.153,1	121	0	Wind	0	0,04	0,05
					Seismic	0	0,04	0,05
Empty, Corroded	1.203,3	1.143,5	20	1,6	Wind	0	0,04	0,05
					Seismic	0	0,04	0,05
Empty, New	1.203,3	1.153,1	20	0	Wind	0	0,04	0,05
					Seismic	0	0,04	0,05
Vacuum	1.203,3	1.143,5	23	1,6	Wind	67,51	0,37	0,38
					Seismic	67,52	0,37	0,38
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	1.203,3	1.143,5	121	1,6	Wind	0	0,05	0,05
					Seismic	0	0	0

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{924/22{,}4} = 0{,}003030$$

$$B = 1.143{,}5 \ \text{kg/cm}^2$$

$$S = \frac{1.203{,}3}{1{,}00} = 1.203{,}3 \ \text{kg/cm}^2$$

$$S_{cHC} = \min(B, S) = \underline{1.143{,}5 \text{ kg/cm}^2}$$

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{924/24} = 0{,}003247$$

$$B = 1.153{,}1 \ \text{kg/cm}^2$$

$$S = \frac{1.203,3}{1,00} = 1.203,3 \ \ \text{kg/cm}^2$$

$$S_{cHN} = \min(B, S) = 1.153,1 \text{ kg/cm}^2$$

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

$$A = \frac{0,125}{R_o/t} = \frac{0,125}{924/24} = 0,003247$$

$$B = 1.153,1 \ \ \text{kg/cm}^2$$

$$S = \frac{1.203,3}{1,00} = 1.203,3 \ \ \text{kg/cm}^2$$

$$S_{cCN} = \min(B, S) = 1.153,1 \text{ kg/cm}^2$$

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2 Metric)

$$A = \frac{0,125}{R_o/t} = \frac{0,125}{924/22,4} = 0,003030$$

$$B = 1.143,5 \ \ \text{kg/cm}^2$$

$$S = \frac{1.203,3}{1,00} = 1.203,3 \ \ \text{kg/cm}^2$$

$$S_{cC} = \min(B, S) = 1.143,5 \text{ kg/cm}^2$$

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

$$A = \frac{0,125}{R_o/t} = \frac{0,125}{924/22,4} = 0,003030$$

$$B = 1.143,5 \ \ \text{kg/cm}^2$$

$$S = \frac{1.203,3}{1,00} = 1.203,3 \ \ \text{kg/cm}^2$$

$$S_{cVC} = \min(B, S) = 1.143,5 \text{ kg/cm}^2$$

Operating, Hot & Corroded, Wind, Bottom Seam

$$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|} \quad \text{(Pressure)}$$

$$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$$

= 4,92 mm

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

$$= \frac{206}{\pi \cdot 911{,}2^{\ 2} \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$$

= 0,01 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$$

= 0,04 mm

$$t_t = t_p + t_m - t_w \quad \text{(total required, tensile)}$$

$$= 4{,}92 + 0{,}01 - (0{,}04)$$

= 4,88 mm

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

$$= |0{,}01 + (0{,}04) - (4{,}92)|$$

= 4,87 mm

Maximum allowable working pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

$$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (22{,}4 - 0{,}01 + (0{,}04))}{900 - 0{,}40 \cdot (22{,}4 - 0{,}01 + (0{,}04))}$$

= 71,3 bar

Operating, Hot & New, Wind, Bottom Seam

t_p = $$\frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|}$$ (Pressure)

= $$\frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$$

= 4,92 mm

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

= $$\frac{206,4}{\pi \cdot 912^{\,2} \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$$

= 0,01 mm

t_w = $$\frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor}$$ (Weight)

= $$\frac{3.360,8}{2 \cdot \pi \cdot 912 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$$

= 0,04 mm

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

= $4{,}92 + 0{,}01 - (0{,}04)$

= 4,88 mm

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

= $|0{,}01 + (0{,}04) - (4{,}92)|$

= 4,87 mm

Maximum allowable working pressure, Longitudinal Stress

P = $$\frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

= $$\frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (24 - 0{,}01 + (0{,}04))}{900 - 0{,}40 \cdot (24 - 0{,}01 + (0{,}04))}$$

= 76,45 bar

Hot Shut Down, Corroded, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{206}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$$

= 0,01 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$$

= 0,04 mm

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

= $|0 + 0{,}01 - (0{,}04)|$

= 0,04 mm

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

= $0{,}01 + (0{,}04) - (0)$

= 0,05 mm

Hot Shut Down, New, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{206,4}{\pi \cdot 912\ ^2 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98066.5$$

= 0,01 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{3.360,8}{2 \cdot \pi \cdot 912 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98.0665$$

= 0,04 mm

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

= $|0 + 0{,}01 - (0{,}04)|$

= 0,04 mm

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

= $0{,}01 + (0{,}04) - (0)$

= 0,05 mm

Empty, Corroded, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{206}{\pi \cdot 911{,}2^{\ 2} \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$$

= 0,01 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$$

= 0,04 mm

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

= $|0 + 0{,}01 - (0{,}04)|$

= 0,04 mm

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

= $0{,}01 + (0{,}04) - (0)$

= 0,05 mm

Empty, New, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{206,4}{\pi \cdot 912^{\ 2} \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98066.5$$

= 0,01 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{3.360,8}{2 \cdot \pi \cdot 912 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98.0665$$

= 0,04 mm

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

= $|0 + 0{,}01 - (0{,}04)|$

= 0,04 mm

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

= $0{,}01 + (0{,}04) - (0)$

= 0,05 mm

Vacuum, Wind, Bottom Seam

$$t_p = \frac{P \cdot R}{2 \cdot S_c \cdot K_s + 0{,}40 \cdot |P|}$$ (Pressure)

$$= \frac{-1 \cdot 900}{2 \cdot 1.121{,}37 \cdot 1{,}20 + 0{,}40 \cdot |1|}$$

$= -0{,}33\ \mathrm{mm}$

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

$$= \frac{206}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$$

= 0,01 mm

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

$$= \frac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$$

= 0,04 mm

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

$= |-0{,}33 + 0{,}01 - (0{,}04)|$

= 0,37 mm

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

$= 0{,}01 + (0{,}04) - (-0{,}33)$

= 0,38 mm

Maximum Allowable External Pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0{,}40 \cdot (t - t_{mc} - t_{wc})}$$

$$= \frac{2 \cdot 1.121{,}37 \cdot 1{,}20 \cdot (22{,}4 - 0{,}01 - 0{,}04)}{900 - 0{,}40 \cdot (22{,}4 - 0{,}01 - 0{,}04)}$$

= 67,51 bar

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

t_p = 0 mm (Pressure)

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

$= \frac{2}{\pi \cdot 911{,}2^{\ 2} \cdot 1.121{,}37 \cdot 1{,}00} \cdot 98066.5$

= 0 mm

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

$= \frac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}00} \cdot 98.0665$

= 0,05 mm

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

$= |0 + 0 - (0{,}05)|$

= 0,05 mm

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

$= 0 + (0{,}05) - (0)$

= 0,05 mm

Operating, Hot & Corroded, Seismic, Bottom Seam

$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|}$ (Pressure)

$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$

= 4,92 mm

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

$= \frac{150}{\pi \cdot 911{,}2^{\ 2} \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$

= 0 mm

$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor}$ (Weight)

$= \frac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$

= 0,04 mm

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

$= 4{,}92 + 0 - (0{,}04)$

= 4,88 mm

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

$= |0 + (0{,}04) - (4{,}92)|$

= 4,87 mm

Maximum allowable working pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

$$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (22{,}4 - 0 + (0{,}04))}{900 - 0{,}40 \cdot (22{,}4 - 0 + (0{,}04))}$$

= 71,31 bar

Operating, Hot & New, Seismic, Bottom Seam

$$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|} \quad \text{(Pressure)}$$

$$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$$

= 4,92 mm

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

$$= \frac{152{,}9}{\pi \cdot 912^2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$$

= 0 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{3.360{,}8}{2 \cdot \pi \cdot 912 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$$

= 0,04 mm

$$t_t = t_p + t_m - t_w \quad \text{(total required, tensile)}$$

$$= 4{,}92 + 0 - (0{,}04)$$

= 4,88 mm

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

$$= |0 + (0{,}04) - (4{,}92)|$$

= 4,87 mm

Maximum allowable working pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

$$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (24 - 0 + (0{,}04))}{900 - 0{,}40 \cdot (24 - 0 + (0{,}04))}$$

= 76,45 bar

Hot Shut Down, Corroded, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$= \dfrac{150}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$

= 0 mm

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

$= \dfrac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$

= 0,04 mm

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

$= |0 + 0 - (0{,}04)|$

= 0,04 mm

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

$= 0 + (0{,}04) - (0)$

= 0,05 mm

Hot Shut Down, New, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$= \dfrac{152,9}{\pi \cdot 912\ ^2 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98066.5$

= 0 mm

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

$= \dfrac{3.360,8}{2 \cdot \pi \cdot 912 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98.0665$

= 0,04 mm

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

$= |0 + 0 - (0{,}04)|$

= 0,04 mm

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

$= 0 + (0{,}04) - (0)$

= 0,05 mm

Empty, Corroded, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

= $\frac{134,8}{\pi \cdot 911{,}2^{\;2} \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$

= 0 mm

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

= $\frac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$

= 0,04 mm

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

= $|0 + 0 - (0{,}04)|$

= 0,04 mm

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

= $0 + (0{,}04) - (0)$

= 0,05 mm

Empty, New, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

= $\frac{138,1}{\pi \cdot 912^{\;2} \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98066.5$

= 0 mm

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

= $\frac{3.360,8}{2 \cdot \pi \cdot 912 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98.0665$

= 0,04 mm

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

= $|0 + 0 - (0{,}04)|$

= 0,04 mm

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

= $0 + (0{,}04) - (0)$

= 0,05 mm

Vacuum, Seismic, Bottom Seam

$t_p = \frac{P \cdot R}{2 \cdot S_c \cdot K_s + 0{,}40 \cdot |P|}$ (Pressure)

$= \frac{-1 \cdot 900}{2 \cdot 1.121{,}37 \cdot 1{,}20 + 0{,}40 \cdot |1|}$

= -0,33 mm

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

$= \frac{150}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$

= 0 mm

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

$= \frac{3.305,7}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$

= 0,04 mm

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

$= | -0{,}33 + 0 - (0{,}04)|$

= 0,37 mm

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

$= 0 + (0{,}04) - (-0{,}33)$

= 0,38 mm

Maximum Allowable External Pressure, Longitudinal Stress

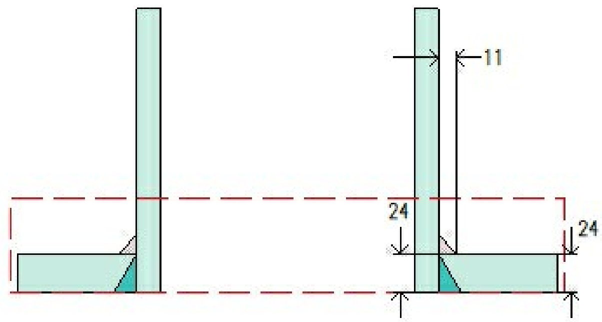
$P = \frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0{,}40 \cdot (t - t_{mc} - t_{wc})}$

$= \frac{2 \cdot 1.121{,}37 \cdot 1{,}20 \cdot (22{,}4 - 0 - 0{,}04)}{900 - 0{,}40 \cdot (22{,}4 - 0 - 0{,}04)}$

= 67,52 bar

Nozzle (A)

ASME Section VIII Division 1, 2021 Edition Metric	



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

Location and Orientation	
Located on	Top Head
Orientation	0°
End of nozzle to datum line	2.500 mm
Calculated as hillside	No
Distance to head center, R	0 mm
Passes through a Category A joint	No
Nozzle	
Description	NPS 10 Sch 80 DN 250
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D Metric p. 16, ln. 19) (normalized)
Inside diameter, new	242,87 mm
Pipe minimum wall thickness	15,09 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	129,6 mm
Projection available outside vessel to flange face, Lf	231,2 mm
Local vessel minimum thickness	24 mm
Liquid static head included	0 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	24 mm
Radiography	
Longitudinal seam	Seamless No RT
Circumferential seam	Full UW-11(a) Type 1

ASME B16.5-2017 Flange	
Description	NPS 10 Class 150 WN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-56,6°C
Liquid static head	0 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	20,02 bar
MAWP rating	16,9 bar @ 121°C
MAP rating	19,6 bar @ 7°C
Hydrotest rating	30 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	242,87 mm

MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 1.068{,}3 \cdot 1000}{\pi \cdot 303{,}76^{\ 3}} / 1{,}02 \cdot 100 =$	19,04 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot -724}{\pi \cdot 303{,}76^{\ 2}} / 1{,}02 \cdot 100 =$	0,98 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[19{,}04 + 0{,}98, 0\right] =$	20,02 bar
Table UG-44-1 Moment Factor, $F_M =$	1,2
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[16{,}9, 16{,}9 \cdot (1 + 1{,}2) - 20{,}02\right] - 0 =$	16,9 bar

Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Carbon windings with filler
Factor, m	2,5
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	287,3 mm
Outer Diameter	317,5 mm

Notes
(1) Flange is impact tested per material specification to -46°C. UCS-66(i) reduction of 10,6°C applied (ratio = 0,8112). Bolts rated MDMT per Fig UCS-66 note (c) = -104°C
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-45°C
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{2{,}92 \cdot 1}{15{,}09 - 1{,}6} =$	0,2165
Stress ratio ≤ 0,35, MDMT per UCS-66(b)(3) =	-105°C
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -105\right] = \min\left[-45 - 3, -105\right] =$	-105°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,78 bar @ 121 °C 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}
28,0135	35,0703	26,3903	7,9206	–	–	0,7594	9,71	15,09

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_1 (kg_f-m)	V_2 (kg_f)	M_2 (kg_f-m)	V_1 (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,78	-724	1.305	1.023,9	0	0	922,8	**2.183,594**	**3.609,796**	**1.428,778**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-724	1.305	1.023,9	0	0	922,8	990,625	3.609,796	235,81	1.804,898	No
Load case 1 (Pr Reversed)	16,78	724	1.305	1.023,9	0	0	922,8	2.089,101	3.609,796	1.384,906	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	724	1.305	1.023,9	0	0	922,8	-990,625	3.609,796	-235,81	1.804,898	No

Calculations for internal pressure 16,78 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[242{,}87,\ 121{,}44 + (15{,}09 - 1{,}6) + (24 - 1{,}6)\right]$$

$$= 242{,}87 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (24 - 1{,}6),\ 2{,}5 \cdot (15{,}09 - 1{,}6) + 0\right]$$

$$= 33{,}72 \text{ mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 121{,}44}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 1{,}74 \text{ mm}$$

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

t_r = $\frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P}$

= $\frac{16{,}7791 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 16{,}7791}$

= $11{,}53 \text{ mm}$

Area required per UG-37(c)

Allowable stresses: S_n = 1.203,265, S_v = 1.203,265 kg_f/cm^2

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

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

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

= $(242{,}87 \cdot 11{,}53 \cdot 1 + 2 \cdot 15{,}09 \cdot 11{,}53 \cdot 1 \cdot (1 - 1))/100$

= 28,0135 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 26,3903 cm^2

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

= $(242{,}87 \cdot (1 \cdot 22{,}4 - 1 \cdot 11{,}53) - 2 \cdot 15{,}09 \cdot (1 \cdot 22{,}4 - 1 \cdot 11{,}53) \cdot (1 - 1))/100$

= $26{,}3903 \text{ cm}^2$

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

= $(2 \cdot (22{,}4 + 13{,}49) \cdot (1 \cdot 22{,}4 - 1 \cdot 11{,}53) - 2 \cdot 15{,}09 \cdot (1 \cdot 22{,}4 - 1 \cdot 11{,}53) \cdot (1 - 1))/100$

= $7{,}7987 \text{ cm}^2$

A_2 = smaller of the following= 7,9206 cm^2

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

= $(5 \cdot (13{,}49 - 1{,}74) \cdot 1 \cdot 22{,}4)/100$

= $13{,}1542 \text{ cm}^2$

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

= $(5 \cdot (13{,}49 - 1{,}74) \cdot 1 \cdot 13{,}49)/100$

= $7{,}9206 \text{ cm}^2$

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

= $(8{,}71^2 \cdot 1)/100$

= 0,7594 cm^2

$$Area = A_1 + A_2 + A_{41}$$
$$= 26{,}3903 + 7{,}9206 + 0{,}7594$$
$$= 35{,}0703 \text{ cm}^2$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[19mm,\ t_n,\ t] =$ 13,49 mm

$t_{c(\min)} = \min\,[6\ \text{mm},\ 0{,}7 \cdot t_{\min}] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1\ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$
$$= \frac{16{,}7791 \cdot 121{,}44}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$
$$= 3{,}34\ \text{mm}$$

$$t_{a\text{UG-22}} = 4{,}57\ \text{mm}$$

$$t_a = \max\,[t_{a\text{UG-27}},\ t_{a\text{UG-22}}]$$
$$= \max\,[3{,}34,\ 4{,}57]$$
$$= 4{,}57\ \text{mm}$$

$$t_{b1} = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P} + \text{Corrosion}$$
$$= \frac{16{,}7791 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 16{,}7791} + 1{,}6$$
$$= 13{,}13\ \text{mm}$$

$$t_{b1} = \max\,[t_{b1},\ t_{b\text{UG16}}]$$
$$= \max\,[13{,}13,\ 3{,}1]$$
$$= 13{,}13\ \text{mm}$$

$$t_b = \min\,[t_{b3},\ t_{b1}]$$
$$= \min\,[9{,}71,\ 13{,}13]$$
$$= 9{,}71\ \text{mm}$$

$$t_{\text{UG-45}} = \max\,[t_a,\ t_b]$$
$$= \max\,[4{,}57,\ 9{,}71]$$
$$= 9{,}71\ \text{mm}$$

Available nozzle wall thickness new, t_n = 15,09 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-724 kg_f
Circumferential moment, M_1	1.305 kg_f-m
Circumferential shear, V_2	1.023,9 kg_f
Longitudinal moment, M_2	0 kg_f-m
Longitudinal shear, V_1	0 kg_f
Torsion moment, M_t	922,8 kg_f-m
Internal pressure, P	16,78 bar
Mean dish radius, R_m	1.639,3 mm
Local head thickness, T	22,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{r_m}{t} = \frac{128{,}18}{13{,}49} = 9{,}5038$$

$$\rho = \frac{T}{t} = \frac{22{,}4}{13{,}49} = 1{,}6608$$

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{134{,}92}{\sqrt{1.639{,}3 \cdot 22{,}4}} = 0{,}704$$

WRC 537 Nondimensional Coefficients

$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$

γ = 5 ρ = 1	SP-2				SM-2			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,6211	0,3627	4,244	0,147	11,647	3,0505	2,3258	-0,0608
b	21,6273	44,9628	2.909,7533	-1,6443	44,8126	18,7157	7,2896	-4,1861
c	2,9619	3,7254	670,6484	0,1238	-215,542	-13,8221	-10,6212	0,3339
d	29,2309	98,0346	7.883,0399	29,843	-990,6785	-19,0976	46,1723	9,0989
e	2,1842	-0,2704	-1.025,2729	5,3816	1.206,7112	24,6135	23,7824	-0,3729
f	86,1406	137,5921	-15.335,94	6,1433	5.063,1144	-108,1759	-198,2298	-7,5883
g	-0,3873	0	482,899	-3,3272	-398,6713	-6,4014	18,2767	0,2136
h	0	0	6.934,936	1,2597	5.228,5657	373,4437	767,1196	2,6114
i	0	0	-34,8626	0,5351	0	0	0	-0,0422
j	0	0	0	0	0	0	0	0
Y	0,0601	0,0221	0,0555	0,1096	0,123	0,056	0,0878	0,0963

WRC 537 Nondimensional Coefficients

$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$

γ = 5 ρ = 2	SP-3				SM-3			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,3656	0,6924	194,6898	0,1169	3.575,8953	-1.612,8152	1,1658	-0,2512
b	20,761	41,4599	35.425,74	0,0485	18.337,83	-16.367,04	6,6119	-4,0064
c	2,1174	6,5648	6.712,6521	1,0834	-148.402,8	19.145,7	-1,8023	1,206
d	39,8904	56,9657	67.541,61	6,5638	-1.113.150	231.710,9	-7,5795	11,6011
e	-1,5403	-10,362	-7.076,6023	-1,4491	1.808.340	174.103,8	0,7851	-0,9153
f	6,0842	50,3033	-38.750,21	-8,5622	1,9219E+07	969.880,3	-0,5602	-10,415
g	0,3004	5,2068	7.127,4907	0,6633	-121.264,6	74.723,92	0,0402	0,1529
h	0	-124,8434	52.813,19	4,7651	4.868.062	1.365.329	2,7493	3,6043
i	0	-0,8506	-976,6428	-0,1059	-427.941,1	-91.957,24	0	0
j	0	45,9146	0	-0,7887	8.286.525	1.729.110	0	0
Y	0,0319	0,0335	0,0632	0,1572	0,0737	0,0945	0,1262	0,1673

WRC 537 Nondimensional Coefficients

$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$

γ = 15 ρ = 1	SP-5				SM-5			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	2,5313	0,2573	0,2148	0,2565	5,0495	2,3071	1,3095	-0,0934
b	473,1618	0,6261	75,2962	-4,0038	9,0562	10,326	7,1691	-5,4435
c	188,3279	-3,2878	11,984	-1,0345	-14,0471	-11,3673	-4,9409	0,5761
d	3.838,2426	-118,1855	347,0785	5,3696	47,3217	26,4081	25,6386	18,6046
e	276,3502	12,6432	-2,8446	0,6823	32,2135	28,751	30,6153	-0,5013
f	3.999,8712	597,9902	-59,4988	-7,5639	-73,3031	-148,3722	362,4322	-21,4549
g	-70,677	-5,5092	0	1,7989	-10,377	-3,0892	-19,9268	0,5988
h	0	-163,2562	0	21,8984	206,2954	706,8852	-74,8696	13,0083
i	0	0,5296	0	-0,7141	2,0028	0	4,1492	0
j	0	0	0	-7,0392	0	0	0	0
Y	0,0681	0,0217	0,0353	0,1347	0,143	0,0522	0,0558	0,13

WRC 537 Nondimensional Coefficients

$$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$$

γ = 15 ρ = 2	SP-6				SM-6			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,4364	0,4568	0,5408	0,199	1,2527	1,9756	3,4348	-0,6545
b	23,8528	18,4406	86,1146	1,3701	-9,7364	-10,5872	32,542	2,3553
c	3,1218	0,5744	10,6552	0,9562	42,3407	-7,1545	-9,1948	3,7495
d	57,2195	2,9177	210,1066	4,8904	581,7506	267,0319	0,2003	6,5143
e	-1,23	0,2335	-2,8821	-0,1717	-11,5154	184,7135	14,4342	-2,6465
f	-0,5058	37,5435	66,5636	-0,1752	-363,3128	406,7564	-130,0729	-5,4867
g	0,4263	0	1,9553	0	4,4567	337,601	1,057	0,5907
h	16,5587	0	0	0	555,7041	5.118,1159	350,2929	1,9002
i	0	0	0	0	0	-155,8292	0	0
j	0	0	0	0	0	2.619,7988	0	0
Y	0,0434	0,0342	0,0386	0,1819	0,0921	0,0849	0,0693	0,1981

Pressure stress intensity factor, $I = 1{,}9185$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 1.192{,}968 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 2.183{,}59 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.428{,}78 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SP-1 to 10*	$\frac{N_x \cdot T}{P}$	0,0502	7,242	7,242	7,242	7,242	7,242	7,242	7,242	7,242
SP-1 to 10	$\frac{M_x}{P}$	0,0461	39,934	-39,934	39,934	-39,934	39,934	-39,934	39,934	-39,934
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0,0913	0	0	0	0	-123,951	-123,951	123,951	123,951
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0,0989	0	0	0	0	-805,718	805,718	805,718	-805,718
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0,0913	0	0	0	0	0	0	0	0
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0,0989	0	0	0	0	0	0	0	0
Pressure stress*			1.192,968	1.192,968	1.192,968	1.192,968	1.192,968	1.192,968	1.192,968	1.192,968
Total O_x stress			1.240,144	1.160,276	1.240,144	1.160,276	310,476	1.842,042	2.169,813	478,509
Membrane O_x stress*			1.200,21	1.200,21	1.200,21	1.200,21	1.076,259	1.076,259	1.324,161	1.324,161
SP-1 to 10*	$\frac{N_y \cdot T}{P}$	0,1522	21,936	21,936	21,936	21,936	21,936	21,936	21,936	21,936
SP-1 to 10	$\frac{M_y}{P}$	0,0298	25,803	-25,803	25,803	-25,803	25,803	-25,803	25,803	-25,803
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0,1576	0	0	0	0	-213,874	-213,874	213,874	213,874
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	0,078	0	0	0	0	-635,153	635,153	635,153	-635,153
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0,1576	0	0	0	0	0	0	0	0
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	0,078	0	0	0	0	0	0	0	0
Pressure stress*			1.192,968	1.192,968	1.192,968	1.192,968	1.192,968	1.192,968	1.192,968	1.192,968
Total O_y stress			1.240,707	1.189,102	1.240,707	1.189,102	391,68	1.610,381	2.089,734	767,822
Membrane O_y stress*			1.214,904	1.214,904	1.214,904	1.214,904	1.001,03	1.001,03	1.428,778	1.428,778
Shear from M_t			35,997	35,997	35,997	35,997	35,997	35,997	35,997	35,997
Shear from V_1			0	0	0	0	0	0	0	0
Shear from V_2			10,757	10,757	-10,757	-10,757	0	0	0	0
Total Shear stress			46,754	46,754	25,24	25,24	35,997	35,997	35,997	35,997
Combined stress (P_L+P_b+Q)			1.287,18	1.223,622	1.265,666	1.203,725	405,32	1.847,526	2.183,594	772,252
(1) * denotes primary stress. (2) The nozzle is analyzed as a hollow attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}78 \cdot 1{,}02 \cdot 121{,}44}{2 \cdot 13{,}49} - \frac{-724}{\pi \cdot \left(134{,}92^{\ 2} - 121{,}44^{\ 2}\right)} \cdot 100 + \frac{1.305.027{,}6 \cdot 134{,}92}{8{,}9485\text{E}{+}07} \cdot 100$$

$$= 280{,}464 \ \ \text{kg}_f/\text{cm}^2$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.203,265 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{0^2 + 1.023{,}9^{\ 2}}}{\pi \cdot 121{,}44 \cdot 13{,}49} \cdot 100 = 19{,}899 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\mathrm{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{922{,}8}{2 \cdot \pi \cdot 121{,}44^{\ 2} \cdot 13{,}49} \cdot 100000 = 73{,}844 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\mathrm{total}} = \sigma_{\mathrm{shear}} + \sigma_{\mathrm{torsion}} = 19{,}899 + 73{,}844 = 93{,}743 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

UG-45: The total combined shear stress (93,743 $\mathrm{kg_f/cm^2}$) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.203{,}265 = 842{,}286 \ \ \mathrm{kg}_f/\mathrm{cm}^2\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C 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}
5,5753	52,5696	43,2528	8,5574	–	–	0,7594	3,67	15,09

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[242{,}87,\ 121{,}44 + (15{,}09 - 1{,}6) + (24 - 1{,}6)\right]$$

$$= 242{,}87 \ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (24 - 1{,}6),\ 2{,}5 \cdot (15{,}09 - 1{,}6) + 0\right]$$

$$= 33{,}72 \ \text{mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,8 mm

From UG-37(d)(1) required thickness t_r = 4,59 mm

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

Allowable stresses: S_n = 1.203,265, S_v = 1.203,265 kg_f/cm^2

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

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

$$A = 0{,}5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$$

$$= (0{,}5 \cdot (242{,}87 \cdot 4{,}59 \cdot 1 + 2 \cdot 15{,}09 \cdot 4{,}59 \cdot 1 \cdot (1 - 1)))/100$$

= 5,5753 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 43,2528 cm^2

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

$$= (242{,}87 \cdot (1 \cdot 22{,}4 - 1 \cdot 4{,}59) - 2 \cdot 15{,}09 \cdot (1 \cdot 22{,}4 - 1 \cdot 4{,}59) \cdot (1 - 1))/100$$

$$= 43{,}2528 \ \text{cm}^2$$

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

$$= (2 \cdot (22{,}4 + 13{,}49) \cdot (1 \cdot 22{,}4 - 1 \cdot 4{,}59) - 2 \cdot 15{,}09 \cdot (1 \cdot 22{,}4 - 1 \cdot 4{,}59) \cdot (1 - 1))/100$$

$$= 12{,}7819 \ \text{cm}^2$$

A_2 = smaller of the following= 8,5574 cm^2

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

$$= (5 \cdot (13{,}49 - 0{,}8) \cdot 1 \cdot 22{,}4)/100$$

$$= 14{,}2122 \ \text{cm}^2$$

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

$$= (5 \cdot (13{,}49 - 0{,}8) \cdot 1 \cdot 13{,}49)/100$$

$$= 8{,}5574 \ \text{cm}^2$$

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

$$= (8{,}71^2 \cdot 1)/100$$

$$= 0{,}7594 \ \text{cm}^2$$

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

$$= 43{,}2528 + 8{,}5574 + 0{,}7594$$

$$= 52{,}5696 \ \text{cm}^2$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 13,49 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 2{,}4 \ \text{mm}$$

$$t_{a\text{UG-22}} = 3{,}67 \ \text{mm}$$

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

$$= \max\left[2{,}4,\ 3{,}67\right]$$

$$= 3{,}67 \ \text{mm}$$

t_{b2} = $\dfrac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P} + \text{Corrosion}$

= $\dfrac{1 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 1} + 1{,}6$

= $2{,}29 \ \text{mm}$

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

$= \max\left[2{,}29,\ 3{,}1\right]$

$= 3{,}1 \ \text{mm}$

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

$= \min\left[9{,}71,\ 3{,}1\right]$

$= 3{,}1 \ \text{mm}$

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

$= \max\left[3{,}67,\ 3{,}1\right]$

$=$ 3,67 mm

Available nozzle wall thickness new, t_n = 15,09 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{231{,}2}{273{,}05} = 0{,}8467$$

$$\frac{D_o}{t} = \frac{273{,}05}{0{,}8} = 342{,}3199$$

From table G: $A = 0{,}000257$

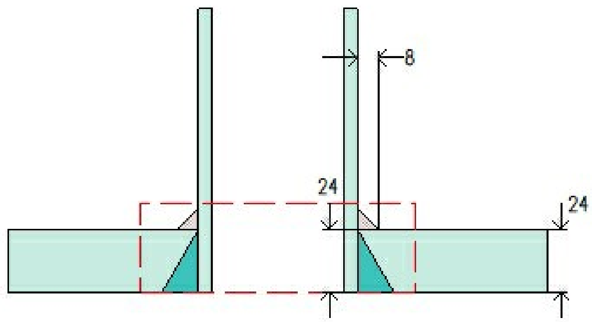
From table CS-2 Metric: $B = 261{,}8041 \ \text{kg/cm}^2 (256{,}74 \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 256{,}74}{3 \cdot (273{,}05/0{,}8)} = 1 \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}8 + 1{,}6 =$ 2,4 mm

Nozzle (H)

ASME Section VIII Division 1, 2021 Edition Metric	
	
Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Top Head
Orientation	270°
End of nozzle to datum line	2.550 mm
Calculated as hillside	Yes
Distance to head center, R	450 mm
Passes through a Category A joint	No
Nozzle	
Description	NPS 2 Sch 80 (XS) DN 50
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D Metric p. 16, ln. 19) (normalized)
Inside diameter, new	49,25 mm
Pipe minimum wall thickness	5,54 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Opening chord length	51,25 mm
Projection available outside vessel, Lpr	263,15 mm
Projection available outside vessel to flange face, Lf	327,75 mm
Local vessel minimum thickness	24 mm
Liquid static head included	0 bar
Welds	
Inner fillet, Leg_{41}	8 mm
Nozzle to vessel groove weld	24 mm
Radiography	
Longitudinal seam	Seamless No RT
Circumferential seam	Full UW-11(a) Type 1

UCS-66 Material Toughness Requirements Nozzle	
Governing thickness, t_g =	5,54 mm
Impact test exempt per UCS-66(d) (NPS 4 or smaller pipe) =	-105°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,78 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							5,02	5,54

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	2,76	4 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_1 (kg_f-m)	V_2 (kg_f)	M_2 (kg_f-m)	V_1 (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,78	-106,05	54,8	150	0	0	38,7	**1.600,538**	**3.609,796**	**1.187,274**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-106,05	54,8	150	0	0	38,7	435,411	3.609,796	22,147	1.804,898	No
Load case 1 (Pr Reversed)	16,78	106,05	54,8	150	0	0	38,7	1.585,633	3.609,796	1.183,336	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	106,05	54,8	150	0	0	38,7	-435,411	3.609,796	-22,147	1.804,898	No

Calculations for internal pressure 16,78 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[51{,}25,\ 25{,}63 + (5{,}54 - 1{,}6) + (24 - 1{,}6)\right]$$

$$= 51{,}96 \ \ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (24 - 1{,}6),\ 2{,}5 \cdot (5{,}54 - 1{,}6) + 0\right]$$

$$= 9{,}84 \ \ \text{mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 24{,}63}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 0{,}35 \ \ \text{mm}$$

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

$$t_r = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P}$$

$$= \frac{16{,}7791 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 16{,}7791}$$

$$= 11{,}53 \text{ mm}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 3,94 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 2,76 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 5{,}71 = 4 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 24{,}63}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 1{,}95 \text{ mm}$$

$$t_{a\text{UG-22}} = 3{,}84 \text{ mm}$$

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

$$= \max\left[1{,}95,\ 3{,}84\right]$$

$$= 3{,}84 \text{ mm}$$

$$t_{b1} = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 16{,}7791} + 1{,}6$$

$$= 13{,}13 \text{ mm}$$

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

$$= \max\left[13{,}13,\ 3{,}1\right]$$

$$= 13{,}13 \text{ mm}$$

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

$$= \min\left[5{,}02,\ 13{,}13\right]$$

$$= 5{,}02 \text{ mm}$$

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

$$= \max\left[3{,}84,\ 5{,}02\right]$$

$$= 5{,}02 \text{ mm}$$

Available nozzle wall thickness new, t_n = 5,54 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-106,05 kg_f
Circumferential moment, M_1	54,8 kg_f-m
Circumferential shear, V_2	150 kg_f
Longitudinal moment, M_2	0 kg_f-m
Longitudinal shear, V_1	0 kg_f
Torsion moment, M_t	38,7 kg_f-m
Internal pressure, P	16,78 bar
Mean dish radius, R_m	1.639,3 mm
Local head thickness, T	22,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{r_m}{t} = \frac{26{,}59}{3{,}94} = 6{,}7548$$

$$\rho = \frac{T}{t} = \frac{22{,}4}{3{,}94} = 5{,}6896$$

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{28{,}56}{\sqrt{1.639{,}3 \cdot 22{,}4}} = 0{,}149$$

WRC 537 Nondimensional Coefficients								
$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$								
γ = 5 ρ = 4	SP-4				SM-4			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,1955	0,7443	2,537	0,1606	-3,9242	12,6132	-0,9607	-6,9959
b	355,6102	7,533	1.071,7354	22,9473	-68,5346	29,9988	-43,2509	114,214
c	21,1677	-2,6223	127,4587	10,3372	228,2976	-129,5801	-7,5852	81,2222
d	1.539,5199	-7,6574	2.112,6475	-190,1285	9.214,6671	-214,241	8,1123	-726,9062
e	-9,9855	9,5634	-131,0041	-76,2413	341,9835	558,1185	5,3251	-296,5262
f	356,7674	64,1716	-8.161,6149	517,979	12.323,9	595,3023	11,1703	1.724,0898
g	0	-5,6615	-54,494	186,8225	-372,3161	-319,0507	0	427,4096
h	0	62,296	7.160,3101	-483,8102	0	2.813,0991	0	-1.948,4552
i	0	0	102,0928	-102,4669	0	0	0	-195,9934
j	0	0	-1.577,3732	408,8865	0	0	0	1.040,0273
Y	0,035	0,2492	0,1005	0,3381	0,1544	1,1406	0,3774	-0,0238
Note: ρ is outside the bounds. ρ = 4 used.								

WRC 537 Nondimensional Coefficients								
$Y = \dfrac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$								
γ = 15 ρ = 4	SP-7				SM-7			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,1225	1,1858	0,152	0,2586	81.160,67	54,8627	-7,2531E+09	-2.889,5632
b	10,2618	30,9469	6,4077	2,6992	2.773.928	313,4235	2,0933E+11	44.457,77
c	0,0628	0,7386	-0,2621	2,1956	11.224,63	-805,6348	2,2821E+11	31.259,89
d	2,5604	-22,7834	-20,1141	10,0386	-888.508,9	-5.199,714	6,2796E+12	-175.466,5
e	-9,8501E-04	0,8686	0,1324	0,3281	-4.806,5269	2.622,0799	1,5072E+12	-81.861,2
f	7,9918	86,4361	30,2989	-5,923	3.917.797	23.612,83	3,0942E+13	299.387,2
g	0	-0,3301	0,2529	-0,3719	0	4.442,2399	1,7691E+11	85.306,95
h	0	0	-12,616	4,2863	0	-21.199,17	3,2234E+12	-247.881,6
i	0	0	-0,0853	0	0	-1.946,6481	0	-22.718,26
j	0	0	1,8294	0	0	79.566,95	0	113.956,5
Y	0,0505	0,2437	0,0728	0,3682	0,2035	1,1743	0,2853	0,0615

WRC 537 Nondimensional Coefficients								
$Y = \dfrac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$								
γ = 15 ρ = 10	SP-8				SM-8			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,0089	0,7951	0,0353	0,3592	0,4473	5,8265	-4,7165	-0,0349
b	5,0204	9,416	-2,6917	5,4358	78,6107	2,5265	-597,0121	-2,3803
c	0,0154	-1,7189	-0,1634	3,4207	-8,384	-112,5814	161,5182	1,8888
d	5,3485	-15,6863	-0,3186	-8,1149	-1.801,6236	-368,7197	18.269,05	6,6619
e	0,0058	1,4218	0,3444	-8,9147	7,5876	81,5976	927,0814	-3,4378
f	8,4286	9,5447	7,5748	4,7756	1.641,4093	-166,4983	-9.902,5503	-8,1245
g	0	-0,4031	-0,4108	11,36	-2,1272	0	387,6637	1,9493
h	0	0	-8,8672	9,0287	-813,4468	0	675,9853	3,3625
i	0	0	0,2287	-4,7215	0	0	-69,6238	-0,3143
j	0	0	3,9087	0	0	0	2.942,6661	0
Y	0,006	0,2728	0,0283	0,428	0,0288	1,2413	0,1443	0,2299

Pressure stress intensity factor, $I = 1{,}8738$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 1.165{,}127 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 1.600{,}54 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.187{,}27 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SP-1 to 10*	$\frac{N_x \cdot T}{P}$	0,0934	1,969	1,969	1,969	1,969	1,969	1,969	1,969	1,969
SP-1 to 10	$\frac{M_x}{P}$	0,0355	4,5	-4,5	4,5	-4,5	4,5	-4,5	4,5	-4,5
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0,3543	0	0	0	0	-20,178	-20,178	20,178	20,178
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0,1544	0	0	0	0	-52,801	52,801	52,801	-52,801
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0,3543	0	0	0	0	0	0	0	0
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0,1544	0	0	0	0	0	0	0	0
Pressure stress*			1.165,127	1.165,127	1.165,127	1.165,127	1.165,127	1.165,127	1.165,127	1.165,127
Total O_x stress			1.171,595	1.162,596	1.171,595	1.162,596	1.098,617	1.195,218	1.244,574	1.129,973
Membrane O_x stress*			1.167,096	1.167,096	1.167,096	1.167,096	1.146,917	1.146,917	1.187,274	1.187,274
SP-1 to 10*	$\frac{N_y \cdot T}{P}$	0,3463	7,312	7,312	7,312	7,312	7,312	7,312	7,312	7,312
SP-1 to 10	$\frac{M_y}{P}$	0,2497	31,638	-31,638	31,638	-31,638	31,638	-31,638	31,638	-31,638
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	-0,0005	0	0	0	0	0	0	0	0
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	1,1498	0	0	0	0	-393,227	393,227	393,227	-393,227
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	-0,0005	0	0	0	0	0	0	0	0
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	1,1498	0	0	0	0	0	0	0	0
Pressure stress*			1.165,127	1.165,127	1.165,127	1.165,127	1.165,127	1.165,127	1.165,127	1.165,127
Total O_y stress			1.204,077	1.140,801	1.204,077	1.140,801	810,85	1.534,028	1.597,304	747,574
Membrane O_y stress*			1.172,439	1.172,439	1.172,439	1.172,439	1.172,439	1.172,439	1.172,439	1.172,439
Shear from M_t			33,747	33,747	33,747	33,747	33,747	33,747	33,747	33,747
Shear from V_1			0	0	0	0	0	0	0	0
Shear from V_2			7,453	7,453	-7,453	-7,453	0	0	0	0
Total Shear stress			41,2	41,2	26,295	26,295	33,747	33,747	33,747	33,747
Combined stress (P_L+P_b+Q)			1.232,129	1.194,304	1.218,771	1.180,173	1.102,554	1.537,332	1.600,538	1.132,926
(1) * denotes primary stress. (2) The nozzle is analyzed as a hollow attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}78 \cdot 1{,}02 \cdot 24{,}63}{2 \cdot 3{,}94} - \frac{-106{,}05}{\pi \cdot \left(28{,}56\ ^2 - 24{,}63\ ^2\right)} \cdot 100 + \frac{54.799{,}3 \cdot 28{,}56}{233.899{,}6} \cdot 100$$

$$= 738{,}807 \quad \text{kg}_f/\text{cm}^2$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.203,265 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{0^2 + 150^2}}{\pi \cdot 24{,}63 \cdot 3{,}94} \cdot 100 = 49{,}249 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{38{,}7}{2 \cdot \pi \cdot 24{,}63^2 \cdot 3{,}94} \cdot 100000 = 258{,}318 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 49{,}249 + 258{,}318 = 307{,}567 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

UG-45: The total combined shear stress (307,567 $\mathrm{kg_f/cm^2}$) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.203{,}265 = 842{,}286 \ \ \mathrm{kg}_f/\mathrm{cm}^2\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,64	5,54

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	2,76	4 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[51{,}26,\ 25{,}63 + (5{,}54 - 1{,}6) + (24 - 1{,}6)\right]$$
$$= 51{,}97\ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2{,}5 \cdot (24 - 1{,}6),\ 2{,}5 \cdot (5{,}54 - 1{,}6) + 0\right]$$
$$= 9{,}84\ \text{mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,4 mm

From UG-37(d)(1) required thickness t_r = 4,59 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 3,94 mm

$t_{c(\min)} = \min\left[6\ \text{mm},\ 0{,}7 \cdot t_{\min}\right] =$ 2,76 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 5{,}71 = 4\ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 2\ \text{mm}$$

$$t_{a\text{UG-22}} = 3{,}64\ \text{mm}$$

$$t_a = \max\left[t_{a\text{UG-28}},\ t_{a\text{UG-22}}\right]$$
$$= \max[2,\ 3{,}64]$$
$$= 3{,}64 \text{ mm}$$

$$t_{b2} = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P} + \text{Corrosion}$$
$$= \frac{1 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 1} + 1{,}6$$
$$= 2{,}29 \text{ mm}$$

$$t_{b2} = \max\left[t_{b2},\ t_{b\text{UG16}}\right]$$
$$= \max[2{,}29,\ 3{,}1]$$
$$= 3{,}1 \text{ mm}$$

$$t_b = \min\left[t_{b3},\ t_{b2}\right]$$
$$= \min[5{,}02,\ 3{,}1]$$
$$= 3{,}1 \text{ mm}$$

$$t_{\text{UG-45}} = \max\left[t_a,\ t_b\right]$$
$$= \max[3{,}64,\ 3{,}1]$$
$$= 3{,}64 \text{ mm}$$

Available nozzle wall thickness new, t_n = 5,54 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{345{,}03}{60{,}33} = 5{,}7195$$

$$\frac{D_o}{t} = \frac{60{,}33}{0{,}4} = 150{,}8388$$

From table G: $A = 0{,}000113$

From table CS-2 Metric: $B = 115{,}3628 \text{ kg/cm}^2 (113{,}13 \text{ bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 113{,}13}{3 \cdot (60{,}33/0{,}4)} = 1 \text{ bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}4 + 1{,}6 = 2$ mm

Flange H

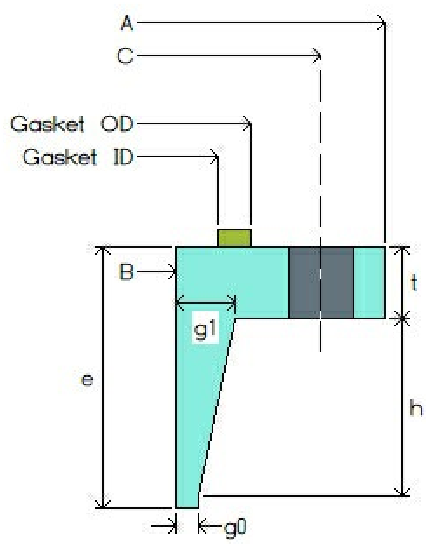
ASME Section VIII Division 1, 2021 Edition Metric , Appendix 2 Flange Calculations	
Flange Type	Weld neck integral
Attachment Type	Figure 2-4 sketch (6)
Flange Material	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36)
Attached To	Nozzle (H)

Impact Tested	Normalized	Fine Grain Practice	PWHT	Maximize MDMT/ No MAWP
No	Yes	Yes	Yes	No

	Design Pressure (bar)	Design Temperature (°C)	Design MDMT (°C)
Internal	15,5	121	-15
External	1	23	

Static Liquid Head	
Condition	**P_s (bar)**
Operating	0

Dimensions	
Flange OD, A	152 mm
Flange ID, B	49,2 mm
Bolt Circle, C	120,6 mm
Gasket OD	85,9 mm
Gasket ID	69,9 mm
Flange Thickness, t	17,5 mm
Hub Thickness, g_1	14,37 mm
Hub Thickness, g_0	5,54 mm
Hub Length, h	44 mm
Length, e	64,6 mm
Corrosion Bore	0 mm
Corrosion Flange	0 mm



Bolting	
Material	SA-320 L7 Bolt ≤ 65 (II-D Metric p. 410, ln. 33)
Description	4 - 0,625" coarse threaded
Corrosion on root	0 mm

Gasket	
Type	Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm

Weight (kg)	
New	2,9 kg
Corroded	2,9 kg

Radiography	
Longitudinal seam	Seamless No RT
Left Circumferential seam	Full UW-11(a) Type 1

User Defined Loads	
Moment	54,8 kg_f-m

Axial Load	-106,05 kg_f

Results Summary	
Flange design thickness:	16,45 mm
Maximum allowable working pressure, MAWP:	43,33 bar @ 121 °C
Maximum allowable pressure, MAP:	42,8 bar @ 7 °C
Maximum allowable external pressure, MAEP:	514,57 bar @ 23 °C
Rated MDMT	-49 °C

Note: this flange is calculated as an integral type.

UCS-66 Material Toughness Requirements	
Impact test temperature per material specification =	-46°C
Additional reduction per UCS-66(g) =	3°C
Bolts rated MDMT per Fig UCS-66 note (c) =	-104°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Stress Summary

			P (bar)	S_H (kg_f/ cm^2)	Allow (kg_f/ cm^2)	S_R (kg_f/ cm^2)	S_T (kg_f/ cm^2)	(S_H + S_R) / 2 (kg_f/ cm^2)	(S_H + S_T) / 2 (kg_f/ cm^2)	Allow (kg_f/ cm^2)
MAWP	Wind	Oper	43,33	1.121,519	2.110,813	1.407,208	659,289	1.264,363	890,404	1.407,208
		Seating		1.010,039	2.110,813	1.267,331	593,755	1.138,685	801,897	1.407,208
MAP	Wind	Oper	42,8	1.129,235	2.110,813	1.407,207	642,297	1.268,221	885,766	1.407,208
		Seating		1.020,747	2.110,813	1.272,014	580,59	1.146,381	800,669	1.407,208
MAEP	Wind	Oper	514,57	1.121,519	2.110,813	1.407,208	659,289	1.264,364	890,404	1.407,208
		Seating		965,548	2.110,813	1.211,506	567,601	1.088,527	766,574	1.407,208

Bolt Summary

			P (bar)	W (kg_f)	A_m (cm^2)	A_b (cm^2)
MAWP	Wind	Oper	43,33	7.617,28	4,34	5,21
		Seating		6.879	3,92	
MAP	Wind	Oper	42,8	7.559,91	4,31	5,21
		Seating		6.879	3,92	
MAEP	Wind	Oper	514,57	58.505,47	1,66	5,21
		Seating		6.879	3,92	

Rigidity Summary

			P (bar)	J	Allow
MAWP	Wind	Oper	43,33	0,1298	1
		Seating		0,1136	1
MAP	Wind	Oper	42,8	0,1207	1
		Seating		0,1096	1
MAEP	Wind	Oper	514,57	0,1263	1
		Seating		0,1086	1

Flange calculations for MAWP + Wind

Longitudinal bending moment on flange

$$P_m = \frac{16 \cdot M_b}{\pi \cdot G^3} = \frac{16 \cdot 54{,}8 \cdot \frac{10^5}{1{,}02}}{\pi \cdot 77{,}9^{\ 3}} = 57{,}8969 \ \ \text{bar}$$

Axial load on flange

$$P_r = \frac{-4 \cdot F}{\pi \cdot G^2} = \frac{-4 \cdot \ -106{,}05 \cdot \frac{10^2}{1{,}02}}{\pi \cdot 77{,}9^{\ 2}} = 2{,}1821 \ \ \text{bar}$$

Total design load on flange (used for H - ref. III-1 NC-3658.1)

$$= P + P_s + P_m + P_r = 43{,}3318 + 0 + 57{,}8969 + 2{,}1821 = 103{,}4108 \ \ \text{bar}$$

Gasket details from facing sketch 1(a) or (b), Column II

Gasket width N = 8 mm

$b_0 = \frac{N}{2} = 4$ mm

Effective gasket seating width, b = b_0 = 4 mm

$$G = \frac{\text{gasket OD+gasket ID}}{2} = \frac{85{,}9+69{,}9}{2} = 77{,}9 \ \ \text{mm}$$

$$h_G = \frac{C-G}{2} = \frac{120{,}6-77{,}9}{2} = 21{,}35 \ \ \text{mm}$$

$$h_D = R + \frac{g_1}{2} = 21{,}33 + \frac{14{,}37}{2} = 28{,}52 \ \ \text{mm}$$

$$h_T = \frac{R + g_1 + h_G}{2} = \frac{21{,}33+14{,}37+21{,}35}{2} = 28{,}53 \ \ \text{mm}$$

$$H_p = 2 \cdot b \cdot 3{,}14 \cdot G \cdot m \cdot P = 0.01 \cdot 2 \cdot 4 \cdot 3{,}14 \cdot 77{,}9 \cdot 3 \cdot 44{,}1862 = 2.593{,}97 \ \ \text{kg}_f$$

$$H = 0{,}785 \cdot G^2 \cdot P = 0{,}785 \cdot 77{,}9^{\ 2} \cdot 105{,}4497 = 5.023{,}31 \ \ \text{kg}_f$$

$$H_D = 0{,}785 \cdot B^2 \cdot P = 0{,}785 \cdot 49{,}2^{\ 2} \cdot 44{,}1862 = 839{,}63 \ \ \text{kg}_f$$

$$H_T = H - H_D = 5.023{,}31 - 839{,}63 = 4.183{,}68 \ \ \text{kg}_f$$

$W_{m1} = H + H_p = 5.023{,}31 + 2.593{,}97 =$ 7.617,28 kg_f

$W_{m2} = 3{,}14 \cdot b \cdot G \cdot y = 3{,}14 \cdot 4 \cdot 77{,}9 \cdot 703{,}0696 =$ 6.879 kg_f

Required bolt area, A_m = greater of A_{m1}, A_{m2} = 4,343 cm^2

$A_{m1} = \frac{W_{m1}}{S_b} = \frac{7.617{,}28}{1.753{,}912} =$ 4,343 cm^2

$A_{m2} = \frac{W_{m2}}{S_a} = \frac{6.879}{1.753{,}912} =$ 3,9221 cm^2

Total area for 4 - 0,625" coarse threaded bolts, corroded, A_b = 5,2129 cm^2

$$W = \frac{(A_m + A_b) \cdot S_a}{2} = \frac{(4{,}343 + 5{,}2129) \cdot 1.753{,}912}{2} = 8.380{,}12 \ \ \text{kg}_f$$

$$M_D = H_D \cdot h_D = 839{,}63 \cdot 0{,}0285 = 23{,}9 kg_f - m$$

$$M_T = H_T \cdot h_T = 4.183{,}68 \cdot 0{,}0285 = 119{,}3 kg_f - m$$

$$H_G = W_{m1} - H = 7.617{,}28 - 5.023{,}31 = 2.593{,}97 \ \ \text{kg}_f$$

$M_G = H_G \cdot h_G = 2.593{,}97 \cdot 0{,}0214 = 55{,}4 kg_f - m$

$M_o = M_D + M_T + M_G = 23{,}9 + 119{,}3 + 55{,}4 = 198{,}7 kg_f - m$

$M_g = W \cdot h_G = 8.380{,}12 \cdot 0{,}0214 = 178{,}9 kg_f - m$

Hub and Flange Factors

$g_0 = \min(g_0, t_n) = \min(5{,}54, 3{,}94) = 3{,}94 \text{ mm}$

$h_0 = \sqrt{B \cdot g_0} = \sqrt{49{,}2 \cdot 3{,}94} = 13{,}92 \text{ mm}$

From FIG. 2-7.1, where $K = \frac{A}{B} = \frac{152}{49{,}2} = 3{,}0894$

$T = 1{,}1845 \quad Z = 1{,}2341 \quad Y = 1{,}8171 \quad U = 1{,}9969$

$\frac{h}{h_0} = 3{,}1615 \quad \frac{g_1}{g_0} = 3{,}65$

$F = 0{,}5148 \quad V = 0{,}0284 \quad e = \frac{F}{h_0} = 0{,}3699$

$$d = \left(\frac{U}{V}\right) \cdot h_0 \cdot g_0^2 = \left(\frac{1{,}9969}{0{,}0284}\right) \cdot 1{,}3918 \cdot 0{,}3937^{\,2} = 15{,}1874 \text{ cm}^3$$

Stresses at operating conditions - VIII-1 Appendix 2-7

$f = 1$

$$L = \frac{t \cdot e + 1}{T} + \frac{t^3}{d} = \frac{1{,}75 \cdot 0{,}3699 + 1}{1{,}1845} + \frac{1{,}75^{\,3}}{15{,}1874} = 1{,}7435$$

$$S_H = \frac{f \cdot M_o}{L \cdot g_1^2 \cdot B} = \frac{1e5 \cdot 1 \cdot 198{,}7}{1{,}7435 \cdot 14{,}37^{\,2} \cdot 49{,}2} = 1.121{,}519 \text{ kg}_f/\text{cm}^2$$

$$S_R = \frac{(1{,}33 \cdot t \cdot e + 1) \cdot M_o}{L \cdot t^2 \cdot B} = \frac{(1{,}33 \cdot 17{,}5 \cdot 0{,}037 + 1) \cdot 1e5 \cdot 198{,}7}{1{,}7435 \cdot 17{,}5^{\,2} \cdot 49{,}2} = 1.407{,}208 \text{ kg}_f/\text{cm}^2$$

$$S_T = \frac{Y \cdot M_o}{t^2 \cdot B} - Z \cdot S_R = \frac{1e5 \cdot 1{,}8171 \cdot 198{,}7}{17{,}5^{\,2} \cdot 49{,}2} - 1{,}2341 \cdot 1.407{,}208 = 659{,}289 \text{ kg}_f/\text{cm}^2$$

Allowable stress S_{fo} = 1.407,208 kg_f/cm^2
Allowable stress S_{no} = 1.203,265 kg_f/cm^2

S_T does not exceed S_{fo}
S_H does not exceed $\min[1{,}5 \cdot S_{fo}, 2{,}5 \cdot S_{no}] = 2.110{,}813 \text{ kg}_f/\text{cm}^2$
S_R does not exceed S_{fo}
$\frac{S_H + S_R}{2} =$ 1.264,363 kg_f/cm^2 does not exceed S_{fo}
$\frac{S_H + S_T}{2} =$ 890,404 kg_f/cm^2 does not exceed S_{fo}

Flange rigidity at operating per VIII-1 Appendix 2-14

$$J = 52{,}14 \cdot V \cdot \frac{M_o}{L \cdot E \cdot g_0^2 \cdot K_I \cdot h_0} = 52{,}14 \cdot 0{,}0284 \cdot \frac{198{,}7}{1{,}7435 \cdot 20{,}06E{+}05 \cdot 3{,}94^{\,2} \cdot 0{,}3 \cdot 13{,}92} = 0{,}1298$$

The flange rigidity index J does not exceed 1; satisfactory.

Stresses at gasket seating - VIII-1 Appendix 2-7

$$S_H = \frac{f \cdot M_g}{L \cdot g_1^2 \cdot B} = \frac{1e5 \cdot 1 \cdot 178{,}9}{1{,}7435 \cdot 14{,}37^{\ 2} \cdot 49{,}2} = 1.010{,}039 \text{ kg}_f/\text{cm}^2$$

$$S_R = \frac{(1{,}33 \cdot t \cdot e + 1) \cdot M_g}{L \cdot t^2 \cdot B} = \frac{(1{,}33 \cdot 17{,}5 \cdot 0{,}037 + 1) \cdot 1e5 \cdot 178{,}9}{1{,}7435 \cdot 17{,}5^{\ 2} \cdot 49{,}2} = 1.267{,}331 \text{ kg}_f/\text{cm}^2$$

$$S_T = \frac{Y \cdot M_g}{t^2 \cdot B} - Z \cdot S_R = \frac{1{,}8171 \cdot 1e5 \cdot 178{,}9}{17{,}5^{\ 2} \cdot 49{,}2} - 1{,}2341 \cdot 1.267{,}331 = 593{,}755 \text{ kg}_f/\text{cm}^2$$

Allowable stress S_{fa} = 1.407,208 kg_f/cm^2
Allowable stress S_{na} = 1.203,265 kg_f/cm^2

S_T does not exceed S_{fa}
S_H does not exceed $\min\left[1{,}5 \cdot S_{fa}, 2{,}5 \cdot S_{na}\right] = 2.110{,}813 \ \text{kg}_f/\text{cm}^2$
S_R does not exceed S_{fa}
$\frac{S_H + S_R}{2} =$ 1.138,685 kg_f/cm^2 does not exceed S_{fa}
$\frac{S_H + S_T}{2} =$ 801,897 kg_f/cm^2 does not exceed S_{fa}

Flange rigidity at gasket seating per VIII-1 Appendix 2-14

$$J = 52{,}14 \cdot V \cdot \frac{M_g}{L \cdot E \cdot g_0^2 \cdot K_I \cdot h_0} = 52{,}14 \cdot 0{,}0284 \cdot \frac{178{,}9}{1{,}7435 \cdot 20{,}63\text{E}{+}05 \cdot 3{,}94^{\ 2} \cdot 0{,}3 \cdot 13{,}92} = 0{,}1136$$

The flange rigidity index J does not exceed 1; satisfactory.

Flange calculations for MAP + Wind

Longitudinal bending moment on flange

$$P_m = \frac{16 \cdot M_b}{\pi \cdot G^3} = \frac{16 \cdot 54{,}8 \cdot \frac{10^5}{1{,}02}}{\pi \cdot 77{,}9^{\ 3}} = 57{,}8969 \ \text{bar}$$

Axial load on flange

$$P_r = \frac{-4 \cdot F}{\pi \cdot G^2} = \frac{-4 \cdot -106{,}05 \cdot \frac{10^2}{1{,}02}}{\pi \cdot 77{,}9^{\ 2}} = 2{,}1821 \ \text{bar}$$

Total design load on flange (used for H - ref. III-1 NC-3658.1)

$$= P + P_s + P_m + P_r = 42{,}8028 + 0 + 57{,}8969 + 2{,}1821 = 102{,}8817 \ \text{bar}$$

Gasket details from facing sketch 1(a) or (b), Column II

Gasket width N = 8 mm

$b_0 = \frac{N}{2}$ = 4 mm

Effective gasket seating width, b = b_0 = 4 mm

$$G = \frac{\text{gasket OD} + \text{gasket ID}}{2} = \frac{85{,}9 + 69{,}9}{2} = 77{,}9 \ \text{mm}$$

$$h_G = \frac{C - G}{2} = \frac{120{,}6 - 77{,}9}{2} = 21{,}35 \ \text{mm}$$

$$h_D = R + \frac{g_1}{2} = 21{,}33 + \frac{14{,}37}{2} = 28{,}52 \ \text{mm}$$

$$h_T = \frac{R + g_1 + h_G}{2} = \frac{21{,}33 + 14{,}37 + 21{,}35}{2} = 28{,}53 \ \text{mm}$$

$H_p = 2 \cdot b \cdot 3{,}14 \cdot G \cdot m \cdot P = 0.01 \cdot 2 \cdot 4 \cdot 3{,}14 \cdot 77{,}9 \cdot 3 \cdot 43{,}6467 = 2.562{,}3 \ \ \text{kg}_f$

$H = 0{,}785 \cdot G^2 \cdot P = 0{,}785 \cdot 77{,}9^{\,2} \cdot 104{,}9102 = 4.997{,}61 \ \ \text{kg}_f$

$H_D = 0{,}785 \cdot B^2 \cdot P = 0{,}785 \cdot 49{,}2^{\,2} \cdot 43{,}6467 = 829{,}38 \ \ \text{kg}_f$

$H_T = H - H_D = 4.997{,}61 - 829{,}38 = 4.168{,}23 \ \ \text{kg}_f$

$W_{m1} = H + H_p = 4.997{,}61 + 2.562{,}3 =$ 7.559,91 kg_f

$W_{m2} = 3{,}14 \cdot b \cdot G \cdot y = 3{,}14 \cdot 4 \cdot 77{,}9 \cdot 703{,}0696 =$ 6.879 kg_f

Required bolt area, A_m = greater of A_{m1}, A_{m2} = 4,3103 cm^2

$A_{m1} = \dfrac{W_{m1}}{S_b} = \dfrac{7.559{,}91}{1.753{,}912} =$ 4,3103 cm^2

$A_{m2} = \dfrac{W_{m2}}{S_a} = \dfrac{6.879}{1.753{,}912} =$ 3,9221 cm^2

Total area for 4 - 0,625" coarse threaded bolts, corroded, A_b = 5,2129 cm^2

$W = \dfrac{(A_m + A_b) \cdot S_a}{2} = \dfrac{(4{,}3103 + 5{,}2129) \cdot 1.753{,}912}{2} = 8.351{,}43 \ \ \text{kg}_f$

$M_D = H_D \cdot h_D = 829{,}38 \cdot 0{,}0285 = 23{,}7 kg_f - m$

$M_T = H_T \cdot h_T = 4.168{,}23 \cdot 0{,}0285 = 118{,}9 kg_f - m$

$H_G = W_{m1} - H = 7.559{,}91 - 4.997{,}61 = 2.562{,}3 \ \ \text{kg}_f$

$M_G = H_G \cdot h_G = 2.562{,}3 \cdot 0{,}0214 = 54{,}7 kg_f - m$

$M_o = M_D + M_T + M_G = 23{,}7 + 118{,}9 + 54{,}7 = 197{,}3 kg_f - m$

$M_g = W \cdot h_G = 8.351{,}43 \cdot 0{,}0214 = 178{,}3 kg_f - m$

Hub and Flange Factors

$g_0 = \min\,(g_0, t_n) = \min\,(5{,}54, 5{,}54) = 5{,}54 \ \ \text{mm}$

$h_0 = \sqrt{B \cdot g_0} = \sqrt{49{,}2 \cdot 5{,}54} = 16{,}51 \ \ \text{mm}$

From FIG. 2-7.1, where $K = \dfrac{A}{B} = \dfrac{152}{49{,}2} = 3{,}0894$

$T = 1{,}1845 \quad Z = 1{,}2341 \quad Y = 1{,}8171 \quad U = 1{,}9969$

$\dfrac{h}{h_0} = 2{,}6658 \quad \dfrac{g_1}{g_0} = 2{,}5952$

$F = 0{,}6015 \quad V = 0{,}0635 \quad e = \dfrac{F}{h_0} = 0{,}3644$

$d = \left(\dfrac{U}{V}\right) \cdot h_0 \cdot g_0^2 = \left(\dfrac{1{,}9969}{0{,}0635}\right) \cdot 1{,}6505 \cdot 0{,}5537^{\,2} = 15{,}9146 \ \ \text{cm}^3$

Stresses at operating conditions - VIII-1 Appendix 2-7

$f = 1$

$$L = \frac{t \cdot e + 1}{T} + \frac{t^3}{d} = \frac{1{,}75 \cdot 0{,}3644 + 1}{1{,}1845} + \frac{1{,}75^{\ 3}}{15{,}9146} = 1{,}7193$$

$$S_H = \frac{f \cdot M_o}{L \cdot g_1^2 \cdot B} = \frac{1e5 \cdot 1 \cdot 197{,}3}{1{,}7193 \cdot 14{,}37^{\ 2} \cdot 49{,}2} = \text{1.129,235 kg}_f\text{/cm}^2$$

$$S_R = \frac{(1{,}33 \cdot t \cdot e + 1) \cdot M_o}{L \cdot t^2 \cdot B} = \frac{(1{,}33 \cdot 17{,}5 \cdot 0{,}0364 + 1) \cdot 1e5 \cdot 197{,}3}{1{,}7193 \cdot 17{,}5^{\ 2} \cdot 49{,}2} = \text{1.407,207 kg}_f\text{/cm}^2$$

$$S_T = \frac{Y \cdot M_o}{t^2 \cdot B} - Z \cdot S_R = \frac{1e5 \cdot 1{,}8171 \cdot 197{,}3}{17{,}5^{\ 2} \cdot 49{,}2} - 1{,}2341 \cdot 1.407{,}207 = \text{642,297 kg}_f\text{/cm}^2$$

Allowable stress S_{fo} = 1.407,208 kg_f/cm^2
Allowable stress S_{no} = 1.203,265 kg_f/cm^2

S_T does not exceed S_{fo}

S_H does not exceed $\min\left[1{,}5 \cdot S_{fo}, 2{,}5 \cdot S_{no}\right] = 2.110{,}813 \ \ kg_f/cm^2$

S_R does not exceed S_{fo}

$\frac{S_H + S_R}{2} =$ 1.268,221 kg_f/cm^2 does not exceed S_{fo}

$\frac{S_H + S_T}{2} =$ 885,766 kg_f/cm^2 does not exceed S_{fo}

Flange rigidity at operating per VIII-1 Appendix 2-14

$$J = 52{,}14 \cdot V \cdot \frac{M_o}{L \cdot E \cdot g_0^2 \cdot K_I \cdot h_0} = 52{,}14 \cdot 0{,}0635 \cdot \frac{197{,}3}{1{,}7193 \cdot 20{,}73E{+}05 \cdot 5{,}54^{\ 2} \cdot 0{,}3 \cdot 16{,}51} = 0{,}1207$$

The flange rigidity index J does not exceed 1; satisfactory.

Stresses at gasket seating - VIII-1 Appendix 2-7

$$S_H = \frac{f \cdot M_g}{L \cdot g_1^2 \cdot B} = \frac{1e5 \cdot 1 \cdot 178{,}3}{1{,}7193 \cdot 14{,}37^{\ 2} \cdot 49{,}2} = \text{1.020,747 kg}_f\text{/cm}^2$$

$$S_R = \frac{(1{,}33 \cdot t \cdot e + 1) \cdot M_g}{L \cdot t^2 \cdot B} = \frac{(1{,}33 \cdot 17{,}5 \cdot 0{,}0364 + 1) \cdot 1e5 \cdot 178{,}3}{1{,}7193 \cdot 17{,}5^{\ 2} \cdot 49{,}2} = \text{1.272,014 kg}_f\text{/cm}^2$$

$$S_T = \frac{Y \cdot M_g}{t^2 \cdot B} - Z \cdot S_R = \frac{1{,}8171 \cdot 1e5 \cdot 178{,}3}{17{,}5^{\ 2} \cdot 49{,}2} - 1{,}2341 \cdot 1.272{,}014 = \text{580,59 kg}_f\text{/cm}^2$$

Allowable stress S_{fa} = 1.407,208 kg_f/cm^2
Allowable stress S_{na} = 1.203,265 kg_f/cm^2

S_T does not exceed S_{fa}

S_H does not exceed $\min\left[1{,}5 \cdot S_{fa}, 2{,}5 \cdot S_{na}\right] = 2.110{,}813 \ \ kg_f/cm^2$

S_R does not exceed S_{fa}

$\frac{S_H + S_R}{2} =$ 1.146,381 kg_f/cm^2 does not exceed S_{fa}

$\frac{S_H + S_T}{2} =$ 800,669 kg_f/cm^2 does not exceed S_{fa}

Flange rigidity at gasket seating per VIII-1 Appendix 2-14

$$J = 52{,}14 \cdot V \cdot \frac{M_g}{L \cdot E \cdot g_0^2 \cdot K_I \cdot h_0} = 52{,}14 \cdot 0{,}0635 \cdot \frac{178{,}3}{1{,}7193 \cdot 20{,}63E{+}05 \cdot 5{,}54^{\ 2} \cdot 0{,}3 \cdot 16{,}51} = 0{,}1096$$

The flange rigidity index J does not exceed 1; satisfactory.

Flange calculations for MAEP + Wind per VIII-1, Appendix 2-11

Longitudinal bending moment on flange

$$P_m = \frac{16 \cdot M_b}{\pi \cdot G^3} = \frac{16 \cdot 54{,}8 \cdot \frac{10^5}{1{,}02}}{\pi \cdot 77{,}9^{\ 3}} = 57{,}8969 \ \ \text{bar}$$

Axial load on flange

$$P_r = \frac{4 \cdot F}{\pi \cdot G^2} = \frac{4 \cdot \ -106{,}05 \cdot \frac{10^2}{1{,}02}}{\pi \cdot 77{,}9^{\ 2}} = -2{,}1821 \ \ \text{bar}$$

Total design load on flange (used for H - ref. III-1 NC-3658.1)

$$= P + P_s + P_m + P_r = 514{,}5656 + 0 + 57{,}8969 + \ -2{,}1821 = 570{,}2804 \ \ \text{bar}$$

Gasket details from facing sketch 1(a) or (b), Column II

Gasket width N = 8 mm

$b_0 = \frac{N}{2} = 4$ mm

Effective gasket seating width, $b = b_0 = 4$ mm

$$G = \frac{\text{gasket OD+gasket ID}}{2} = \frac{85{,}9+69{,}9}{2} = 77{,}9 \ \ \text{mm}$$

$$h_G = \frac{C - G}{2} = \frac{120{,}6-77{,}9}{2} = 21{,}35 \ \ \text{mm}$$

$$h_D = R + \frac{g_1}{2} = 21{,}33 + \frac{14{,}37}{2} = 28{,}52 \ \ \text{mm}$$

$$h_T = \frac{R + g_1 + h_G}{2} = \frac{21{,}33+14{,}37 + 21{,}35}{2} = 28{,}53 \ \ \text{mm}$$

$$H_p = 2 \cdot b \cdot 3{,}14 \cdot G \cdot m \cdot P = 0.01 \cdot 2 \cdot 4 \cdot 3{,}14 \cdot 77{,}9 \cdot 3 \cdot 524{,}7109 = 30.803{,}39 \ \ \text{kg}_f$$

$$H = 0{,}785 \cdot G^2 \cdot P = 0{,}785 \cdot 77{,}9^{\ 2} \cdot 581{,}5242 = 27.702{,}08 \ \ \text{kg}_f$$

$$H_D = 0{,}785 \cdot B^2 \cdot P = 0{,}785 \cdot 49{,}2^{\ 2} \cdot 524{,}7109 = 9.970{,}57 \ \ \text{kg}_f$$

$$H_T = H - H_D = 27.702{,}08 - 9.970{,}57 = 17.731{,}51 \ \ \text{kg}_f$$

$$W_{m1} = H + H_p = 27.702{,}08 + 30.803{,}39 = 58.505{,}47 \text{ kg}_f$$

$$W_{m2} = 3{,}14 \cdot b \cdot G \cdot y = 3{,}14 \cdot 4 \cdot 77{,}9 \cdot 703{,}0696 = 6.879 \text{ kg}_f$$

Required bolt area, A_m = greater of A_{m1}, A_{m2} = 3,9221 cm^2

$$A_{m1} = 0{,}785 \cdot G^2 \cdot \frac{P_m - P_r}{S_b} = 0{,}785 \cdot 77{,}9^{\ 2} \cdot \frac{57{,}9- -2{,}18}{1.753{,}912} = 1{,}6639 \text{ cm}^2$$

$$A_{m2} = \frac{W_{m2}}{S_a} = \frac{6.879}{1.753{,}912} = 3{,}9221 \text{ cm}^2$$

Total area for 4 - 0,625" coarse threaded bolts, corroded, A_b = 5,2129 cm^2

$$W = \frac{(A_{m2} + A_b) \cdot S_a}{2} = \frac{(3{,}9221 + 5{,}2129) \cdot 1.753{,}912}{2} = 8.010{,}98 \ \ \text{kg}_f$$

$$M_o = H_D \cdot (h_D - h_G) + H_T \cdot (h_T - h_G) = 9.970{,}57 \cdot (0{,}0285 - 0{,}0214) + 17.731{,}51 \cdot (0{,}0285 - 0{,}0214) = 198{,}7 kg_f - m$$

$$M_g = W \cdot h_G = 8.010{,}98 \cdot 0{,}0214 = 171 kg_f - m$$

Hub and Flange Factors

$$g_0 = \min(g_0, t_n) = \min(5{,}54{,}3{,}94) = 3{,}94 \ \text{mm}$$

$$h_0 = \sqrt{B \cdot g_0} = \sqrt{49{,}2 \cdot 3{,}94} = 13{,}92 \ \text{mm}$$

From FIG. 2-7.1, where $K = \frac{A}{B} = \frac{152}{49{,}2} = 3{,}0894$

$T = 1{,}1845$ $Z = 1{,}2341$ $Y = 1{,}8171$ $U = 1{,}9969$

$\frac{h}{h_0} = 3{,}1615$ $\frac{g_1}{g_0} = 3{,}65$

$F = 0{,}5148$ $V = 0{,}0284$ $e = \frac{F}{h_0} = 0{,}3699$

$$d = \left(\frac{U}{V}\right) \cdot h_0 \cdot g_0^2 = \left(\frac{1{,}9969}{0{,}0284}\right) \cdot 1{,}3918 \cdot 0{,}3937^2 = 15{,}1874 \ \text{cm}^3$$

Stresses at operating conditions - VIII-1 Appendix 2-7

$f = 1$

$$L = \frac{t \cdot e + 1}{T} + \frac{t^3}{d} = \frac{1{,}75 \cdot 0{,}3699 + 1}{1{,}1845} + \frac{1{,}75^3}{15{,}1874} = 1{,}7435$$

$$S_H = \frac{f \cdot M_o}{L \cdot g_1^2 \cdot B} = \frac{1e5 \cdot 1 \cdot 198{,}7}{1{,}7435 \cdot 14{,}37^2 \cdot 49{,}2} = 1.121{,}519 \ \text{kg}_f/\text{cm}^2$$

$$S_R = \frac{(1{,}33 \cdot t \cdot e + 1) \cdot M_o}{L \cdot t^2 \cdot B} = \frac{(1{,}33 \cdot 17{,}5 \cdot 0{,}037 + 1) \cdot 1e5 \cdot 198{,}7}{1{,}7435 \cdot 17{,}5^2 \cdot 49{,}2} = 1.407{,}208 \ \text{kg}_f/\text{cm}^2$$

$$S_T = \frac{Y \cdot M_o}{t^2 \cdot B} - Z \cdot S_R = \frac{1e5 \cdot 1{,}8171 \cdot 198{,}7}{17{,}5^2 \cdot 49{,}2} - 1{,}2341 \cdot 1.407{,}208 = 659{,}289 \ \text{kg}_f/\text{cm}^2$$

Allowable stress S_{fo} = 1.407,208 kg_f/cm^2
Allowable stress S_{no} = 1.203,265 kg_f/cm^2

S_T does not exceed S_{fo}
S_H does not exceed $\min[1{,}5 \cdot S_{fo}, 2{,}5 \cdot S_{no}] = 2.110{,}813 \ \text{kg}_f/\text{cm}^2$
S_R does not exceed S_{fo}
$\frac{S_H + S_R}{2} = 1.264{,}364$ kg_f/cm^2 does not exceed S_{fo}
$\frac{S_H + S_T}{2} = 890{,}404$ kg_f/cm^2 does not exceed S_{fo}

Flange rigidity at operating per VIII-1 Appendix 2-14

$$J = 52{,}14 \cdot V \cdot \frac{M_o}{L \cdot E \cdot g_0^2 \cdot K_I \cdot h_0} = 52{,}14 \cdot 0{,}0284 \cdot \frac{198{,}7}{1{,}7435 \cdot 20{,}61\text{E}{+}05 \cdot 3{,}94^2 \cdot 0{,}3 \cdot 13{,}92} = 0{,}1263$$

The flange rigidity index J does not exceed 1; satisfactory.

Stresses at gasket seating - VIII-1 Appendix 2-7

$$S_H = \frac{f \cdot M_g}{L \cdot g_1^2 \cdot B} = \frac{1e5 \cdot 1 \cdot 171}{1{,}7435 \cdot 14{,}37^2 \cdot 49{,}2} = 965{,}548 \ \text{kg}_f/\text{cm}^2$$

$$S_R = \frac{(1{,}33 \cdot t \cdot e + 1) \cdot M_g}{L \cdot t^2 \cdot B} = \frac{(1{,}33 \cdot 17{,}5 \cdot 0{,}037 + 1) \cdot 1e5 \cdot 171}{1{,}7435 \cdot 17{,}5^2 \cdot 49{,}2} = 1.211{,}506 \ \text{kg}_f/\text{cm}^2$$

$$S_T = \frac{Y \cdot M_g}{t^2 \cdot B} - Z \cdot S_R = \frac{1{,}8171 \cdot 1e5 \cdot 171}{17{,}5^{\ 2} \cdot 49{,}2} - 1{,}2341 \cdot 1.211{,}506 = 567{,}601\ kg_f/cm^2$$

Allowable stress S_{fa} = 1.407,208 kg_f/cm^2
Allowable stress S_{na} = 1.203,265 kg_f/cm^2

S_T does not exceed S_{fa}

S_H does not exceed $\min\left[1{,}5 \cdot S_{fa}, 2{,}5 \cdot S_{na}\right] = 2.110{,}813\ \ kg_f/cm^2$

S_R does not exceed S_{fa}

$\frac{S_H + S_R}{2} = 1.088{,}527$ kg_f/cm^2 does not exceed S_{fa}

$\frac{S_H + S_T}{2} = 766{,}574$ kg_f/cm^2 does not exceed S_{fa}

Flange rigidity at gasket seating per VIII-1 Appendix 2-14

$$J = 52{,}14 \cdot V \cdot \frac{M_g}{L \cdot E \cdot g_0^2 \cdot K_I \cdot h_0} = 52{,}14 \cdot 0{,}0284 \cdot \frac{171}{1{,}7435 \cdot 20{,}63E{+}05 \cdot 3{,}94^{\ 2} \cdot 0{,}3 \cdot 13{,}92} = 0{,}1086$$

The flange rigidity index J does not exceed 1; satisfactory.

Flange H - Flange hub

ASME Section VIII Division 1, 2021 Edition Metric					
Component		Flange Hub			
Material		SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36)			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**	
No	Yes	Yes	Yes	No	
		Design Pressure (bar)	**Design Temperature (°C)**	**Design MDMT (°C)**	
Internal		15,5	121	-15	
External		1	23		
Static Liquid Head					
Condition		**P_s (bar)**	**H_s (mm)**	**SG**	
Test horizontal		0,1	1.050,83	1	
Test vertical		0,03	336,01	1	
Dimensions					
Outer Diameter		60,28 mm			
Length		47,1 mm			
Nominal Thickness		5,54 mm			
Corrosion	**Inner**	0 mm			
	Outer	0 mm			
Weight and Capacity					
		Weight (kg)		**Capacity (liters)**	
New		0,86		0,09	
Corroded		0,86		0,09	
Cladding					
		Material	**Thickness (mm)**	**Thk Credit**	
		SA-240 304L (low stress)	3,18	No	
Radiography					
Longitudinal seam		Seamless No RT			
Bottom Circumferential seam		Full UW-11(a) Type 1			

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	1,5 mm + 0 mm = 1,5 mm
Design thickness due to internal pressure (t)	0,34 mm
Design thickness due to external pressure (t_e)	0,17 mm
Maximum allowable working pressure (MAWP)	273,79 bar
Maximum allowable pressure (MAP)	273,79 bar
Maximum allowable external pressure (MAEP)	148,27 bar
Rated MDMT	-105 °C

UCS-66 Material Toughness Requirements	
Impact test temperature per material specification =	-46°C
$t_r = \dfrac{15{,}9 \cdot 30{,}14}{1.380 \cdot 1 + 0{,}4 \cdot 15{,}9} =$	0,35 mm
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{0{,}35 \cdot 1}{5{,}54 - 0} =$	0,0624
Stress ratio ≤ 0,35, MDMT per UCS-66(b)(3) =	-105°C
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -105\right] = \min\left[-46 - 3, -105\right] =$	-105°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Design thickness, (at 121 °C) Appendix 1-1

$$t = \frac{P \cdot R_o}{S \cdot E + 0{,}40 \cdot P} + \text{Corrosion} = \frac{15{,}5 \cdot 30{,}14}{1.380 \cdot 1{,}00 + 0{,}40 \cdot 15{,}5} + 0 = 0{,}34 \text{ mm}$$

Maximum allowable working pressure, (at 121 °C) Appendix 1-1

$$P = \frac{S \cdot E \cdot t}{R_o - 0{,}40 \cdot t} - P_s = \frac{1.380 \cdot 1{,}00 \cdot 5{,}54}{30{,}14 - 0{,}40 \cdot 5{,}54} - 0 = 273{,}79 \text{ bar}$$

Maximum allowable pressure, (at 7 °C) Appendix 1-1

$$P = \frac{S \cdot E \cdot t}{R_o - 0{,}40 \cdot t} = \frac{1.380 \cdot 1{,}00 \cdot 5{,}54}{30{,}14 - 0{,}40 \cdot 5{,}54} = 273{,}79 \text{ bar}$$

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{47{,}1}{60{,}28} = 0{,}7814$$

$$\frac{D_o}{t} = \frac{60{,}28}{0{,}17} = 353{,}9838$$

From table G: $A = 0{,}000266$

From table CS-2 Metric: $B = 270{,}7284 \text{ kg/cm}^2 (265{,}49 \text{ bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 265{,}49}{3 \cdot (60{,}28/0{,}17)} = 1 \text{ bar}$$

Design thickness for external pressure P_a = 1 bar

$$t_a = t + \text{Corrosion} = 0{,}17 + 0 = 0{,}17 \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{47{,}1}{60{,}28} = 0{,}7814$$

$$\frac{D_o}{t} = \frac{60{,}28}{5{,}54} = 10{,}8809$$

From table G: $A = 0{,}057564$

From table CS-2 Metric: $B = 1.233{,}8567 \ \ \text{kg/cm}^{2} (1.209{,}9979 \ \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 1.210}{3 \cdot (60{,}28/5{,}54)} = 148{,}27 \text{ bar}$$

Top platform

Platform	
Distance from Base to Datum	2.286 mm
Attached To	Top Head
Orientation	0,00 degrees
Offset	981 mm
Width, W	2.557 mm (2,56 m)
Length, L	1.962 mm (1,96 m)
Wind Force Coefficient, C_f	2,00
Floor Grating	
Unit Weight	150,00 kg/m^2
Area	5,02 m^2
Railing	
Height, h	1.300 mm (1,30 m)
Length	9038,00 mm (9,04 m)
Unit Weight	25,00 kg/m
Ladder	
Distance from Start to Datum	-1.170 mm
Angle	0,00 degrees
Unit Weight	45,00 kg/m
Length	3.456 mm (3,46 m)
Allow Cage on Ladder	Yes
Weight	
Platform & Railing Weight	978,48 kg
Ladder Weight	155,52 kg
Total Weight	1134,00 kg
Included in Vessel Lift & Shipping Weight	No
Present When Vessel is Empty	Yes
Present During Test	Yes

Platform Wind Shear Calculation

Method and assumptions taken from *Wind Loads for Petrochemical and Other Industrial Facilities*, ASCE, 2011.

Platform depth: $H_p = 152{,}4$ mm

Railing effective height: $H_r = 243{,}84$ mm

Platform diagonal length: $L_d = \sqrt{L^2 + W^2} = \sqrt{1.962^2 + 2.557^2} = 3.222{,}99$ mm

Platform projected area: $A_{eP} = H_p \cdot L_d = 152{,}4 \cdot 3.222{,}99 = 4.911{,}84 \;\; \mathrm{cm}^2$

Front Railing projected area: $A_{eFR} = H_r \cdot L_d = 243{,}84 \cdot 3.222{,}99 = 7.858{,}95 \;\; \mathrm{cm}^2$

Rear Railing projected area: $A_{e\,\mathrm{RR}} = H_r \cdot L_d = 243{,}84 \cdot 3.222{,}99 = 7.858{,}95 \;\; \mathrm{cm}^2$

Total projected area: $A_e = A_{eP} + A_{eFR} + A_{e\,\mathrm{RR}} = 4.911{,}84 + 7.858{,}95 + 7.858{,}95 = 20.629{,}74 \;\; \mathrm{cm}^2$

Local wind pressure: $P_w = 861{,}17 Pa$

Wind shear: $V_p = P_w \cdot C_f \cdot A_e \cdot \mathrm{MetricFactor} = 861{,}17 \cdot 2{,}00 \cdot 20.629{,}74 \cdot 0{,}101972 = 362{,}32 \;\; \mathrm{kg}f$

Shell V1

ASME Section VIII Division 1, 2021 Edition Metric				
Component		Cylinder		
Material		SA-516 60 (II-D Metric p. 16, ln. 3)		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
Yes (-46°C)	Yes	Yes	Yes	No
		Design Pressure (bar)	**Design Temperature (°C)**	**Design MDMT (°C)**
Internal		15,5	121	-15
External		1	23	
Static Liquid Head				
Condition		**P_s (bar)**	**H_s (mm)**	**SG**
Operating		0,04	455	0,999
Test horizontal		0,19	1.923,2	1
Test vertical		0,25	2.500	1
Dimensions				
Inner Diameter		1.800 mm		
Length		1.700 mm		
Nominal Thickness		21 mm		
Corrosion	**Inner**	0 mm		
	Outer	1,6 mm		
Weight and Capacity				
		Weight (kg)		**Capacity (liters)**
New		1.510,35		4.297,18
Corroded		1.393,96		4.297,18
Insulation\Lining				
		Thickness (mm)	**Density (kg/m^3)**	**Weight (kg)**
Lining		3	8.000	230,33
Insulation		80	100	82,12
		Spacing(mm)	**Individual Weight (kg)**	**Total Weight (kg)**
Insulation Supports		0	0	0
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	Internal pressure
Minimum thickness per UG-16	1,5 mm + 1,6 mm = 3,1 mm
Design thickness due to internal pressure (t)	13,55 mm
Design thickness due to external pressure (t_e)	7,77 mm
Design thickness due to combined loadings + corrosion	6,48 mm
Maximum allowable working pressure (MAWP)	25,07 bar
Maximum allowable pressure (MAP)	27,15 bar
Maximum allowable external pressure (MAEP)	12,77 bar
Rated MDMT	-66,6 °C

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-46°C
$t_r = \dfrac{15{,}94 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}94} =$	12,26 mm
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{12{,}26 \cdot 1}{21 - 1{,}6} =$	0,632
$\text{Stress ratio longitudinal} = \dfrac{308{,}578 \cdot 1}{1.203{,}265 \cdot 1} =$	0,2565
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1M =	20,6°C
$MDMT = \max\left[T_{impact} - T_R, -105\right] = \max\left[-46 - 20{,}6, -105\right] =$	-66,6°C
Design MDMT of -15°C is acceptable.	

Design thickness, (at 121 °C) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0{,}60 \cdot P} + \text{Corrosion} = \frac{15{,}54 \cdot 900}{1.180 \cdot 1{,}00 - 0{,}60 \cdot 15{,}54} + 1{,}6 = \underline{13{,}55} \text{ mm}$$

Maximum allowable working pressure, (at 121 °C) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0{,}60 \cdot t} - P_s = \frac{1.180 \cdot 1{,}00 \cdot 19{,}4}{900 + 0{,}60 \cdot 19{,}4} - 0{,}04 = \underline{25{,}07} \text{ bar}$$

Maximum allowable pressure, (at 7 °C) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0{,}60 \cdot t} = \frac{1.180 \cdot 1{,}00 \cdot 21}{900 + 0{,}60 \cdot 21} = \underline{27{,}15} \text{ bar}$$

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{2.100}{1.842} = 1{,}1401$$

$$\frac{D_o}{t} = \frac{1.842}{6{,}17} = 298{,}4016$$

From table G: $A = 0{,}000224$

From table CS-2 Metric: $B = 228{,}2138 \ \text{kg/cm}^2 (223{,}8 \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 223{,}8}{3 \cdot (1.842/6{,}17)} = 1 \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$$t_a = t + \text{Corrosion} = 6{,}17 + 1{,}6 = \underline{7{,}77} \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{2.100}{1.842} = 1{,}1401$$

$$\frac{D_o}{t} = \frac{1.842}{19{,}4} = 94{,}9494$$

From table G: $A = 0{,}001284$

From table CS-2 Metric: $B = 927{,}4941 \ \ \mathrm{kg/cm}^{\ 2} (909{,}5594 \ \ \mathrm{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 909,56}{3 \cdot (1.842/19{,}4)} = \underline{12{,}77} \text{ bar}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 21}{910{,}5}\right) \cdot \left(1 - \frac{910{,}5}{\text{infinity}}\right) = 1{,}1532\,\%$$

The extreme fiber elongation does not exceed 5%.

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

$$P_v = \frac{W}{2 \cdot \pi \cdot R_m} + \frac{M}{\pi \cdot R_m^2} = \frac{10 \cdot 6.395,6}{2 \cdot \pi \cdot 909{,}7} + \frac{10000 \cdot 1.619,9}{\pi \cdot 909{,}7^{\ 2}} = 17{,}4200 \ \ \mathrm{kg/cm}$$

$$\alpha = \frac{P_v}{P_e \cdot D_o} = 9{,}803 \cdot \frac{17{,}42}{1 \cdot 1.842} = 0{,}0927$$

$$n = 5$$

$$m = \frac{1{,}23}{\left(\frac{L}{D_o}\right)^2} = \frac{1{,}23}{\left(\frac{2.100}{1.842}\right)^2} = 0{,}9463$$

$$RatioP_e = \frac{n^2 - 1 + m + m \cdot \alpha}{n^2 - 1 + m} = \frac{5^2 - 1 + 0{,}9463 + 0{,}9463 \cdot 0{,}0927}{5^2 - 1 + 0{,}9463} = 1{,}0035$$

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

$$(1{,}0035 \cdot 1 = 1) \leq 12{,}77$$

Cylinder thickness is satisfactory.

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

$$P_v = \frac{W}{2 \cdot \pi \cdot R_m} + \frac{M}{\pi \cdot R_m^2} = \frac{10 \cdot 6.395,6}{2 \cdot \pi \cdot 909{,}7} + \frac{10000 \cdot 1.446,2}{\pi \cdot 909{,}7^{\ 2}} = 16{,}7521 \ \ \mathrm{kg/cm}$$

$$\alpha = \frac{P_v}{P_e \cdot D_o} = 9{,}803 \cdot \frac{16{,}7521}{1 \cdot 1.842} = 0{,}0892$$

$$n = 5$$

$$m = \frac{1{,}23}{\left(\frac{L}{D_o}\right)^2} = \frac{1{,}23}{\left(\frac{2.100}{1.842}\right)^2} = 0{,}9463$$

$$RatioP_e = \frac{n^2 - 1 + m + m \cdot \alpha}{n^2 - 1 + m} = \frac{5^2 - 1 + 0{,}9463 + 0{,}9463 \cdot 0{,}0892}{5^2 - 1 + 0{,}9463} = 1{,}0034$$

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

$$(1{,}0034 \cdot 1 = 1) \leq 12{,}77$$

Cylinder thickness is satisfactory.

Thickness Required Due to Pressure + External Loads								
Condition	Allowable Stress Before UG-23 Stress Increase (kg/cm^2)		Temperature (°C)	Corrosion C (mm)	Load	Pressure P (bar)	Req'd Thk Due to Tension (mm)	Req'd Thk Due to Compression (mm)
	S_t	S_c						
Operating, Hot & Corroded	1.203,3	1.111,7	121	1,6	Wind	61,69	4,88	4,79
					Seismic	61,7	4,88	4,8
Operating, Hot & New	1.203,3	1.130,1	121	0	Wind	66,82	4,88	4,79
					Seismic	66,83	4,87	4,8
Hot Shut Down, Corroded	1.203,3	1.111,7	121	1,6	Wind	0	0,04	0,13
					Seismic	0	0,04	0,13
Hot Shut Down, New	1.203,3	1.130,1	121	0	Wind	0	0,04	0,13
					Seismic	0	0,04	0,13
Empty, Corroded	1.203,3	1.111,7	20	1,6	Wind	0	0,04	0,13
					Seismic	0	0,04	0,12
Empty, New	1.203,3	1.130,1	20	0	Wind	0	0,04	0,13
					Seismic	0	0,05	0,12
Vacuum	1.203,3	1.111,7	23	1,6	Wind	56,5	0,38	0,47
					Seismic	56,52	0,39	0,47
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	1.203,3	1.111,7	121	1,6	Wind	0	0,08	0,12
					Seismic	0	0	0

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{921/19{,}4} = 0{,}002633$$

$$B = 1.111{,}7 \ \text{kg/cm}^2$$

$$S = \frac{1.203{,}3}{1{,}00} = 1.203{,}3 \ \text{kg/cm}^2$$

$$S_{cHC} = \min(B, S) = 1.111{,}7 \ \text{kg/cm}^2$$

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{921/21} = 0{,}002850$$

$$B = 1.130{,}1 \ \text{kg/cm}^2$$

$$S = \frac{1.203{,}3}{1{,}00} = 1.203{,}3 \ \text{kg/cm}^2$$

$$S_{cHN} = \min(B, S) = 1.130{,}1 \ \text{kg/cm}^2$$

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{921/21} = 0{,}002850$$

$$B = 1.130{,}1 \ \text{kg/cm}^2$$

$$S = \frac{1.203,3}{1,00} = 1.203,3 \ \ \text{kg/cm}^{2}$$

$$S_{cCN} = \min(B, S) = 1.130,1 \text{ kg/cm}^{2}$$

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2 Metric)

$$A = \frac{0,125}{R_o/t} = \frac{0,125}{921/19,4} = 0,002633$$

$$B = 1.111,7 \ \ \text{kg/cm}^{2}$$

$$S = \frac{1.203,3}{1,00} = 1.203,3 \ \ \text{kg/cm}^{2}$$

$$S_{cC} = \min(B, S) = 1.111,7 \text{ kg/cm}^{2}$$

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

$$A = \frac{0,125}{R_o/t} = \frac{0,125}{921/19,4} = 0,002633$$

$$B = 1.111,7 \ \ \text{kg/cm}^{2}$$

$$S = \frac{1.203,3}{1,00} = 1.203,3 \ \ \text{kg/cm}^{2}$$

$$S_{cVC} = \min(B, S) = 1.111,7 \text{ kg/cm}^{2}$$

Operating, Hot & Corroded, Wind, Bottom Seam

$$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|} \quad \text{(Pressure)}$$

$$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$$

= 4,92 mm

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

$$= \frac{1.619,9}{\pi \cdot 909{,}7^{\ 2} \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$$

= 0,04 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$$

= 0,08 mm

$$t_t = t_p + t_m - t_w \quad \text{(total required, tensile)}$$

$$= 4{,}92 + 0{,}04 - (0{,}08)$$

= 4,88 mm

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

$$= |0{,}04 + (0{,}08) - (4{,}92)|$$

= 4,79 mm

Maximum allowable working pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

$$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (19{,}4 - 0{,}04 + (0{,}08))}{900 - 0{,}40 \cdot (19{,}4 - 0{,}04 + (0{,}08))}$$

= 61,69 bar

Operating, Hot & New, Wind, Bottom Seam

t_p = $$\frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|}$$ (Pressure)

= $$\frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$$

= 4,92 mm

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

= $$\frac{1.622,9}{\pi \cdot 910{,}5\ ^2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$$

= 0,04 mm

t_w = $$\frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor}$$ (Weight)

= $$\frac{6.572,9}{2 \cdot \pi \cdot 910{,}5 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$$

= 0,08 mm

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

= $4{,}92 + 0{,}04 - (0{,}08)$

= 4,88 mm

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

= $|0{,}04 + (0{,}08) - (4{,}92)|$

= 4,79 mm

Maximum allowable working pressure, Longitudinal Stress

P = $$\frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

= $$\frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (21 - 0{,}04 + (0{,}08))}{900 - 0{,}40 \cdot (21 - 0{,}04 + (0{,}08))}$$

= 66,82 bar

Hot Shut Down, Corroded, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.619,9}{\pi \cdot 909{,}7\ ^2 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98066.5$$

= 0,05 mm

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

$$= \frac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

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

$= |0 + 0{,}05 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}05 + (0{,}08) - (0)$

= 0,13 mm

Hot Shut Down, New, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.622,9}{\pi \cdot 910{,}5\ ^2 \cdot 1.108{,}2 \cdot 1{,}20} \cdot 98066.5$$

= 0,05 mm

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

$$= \frac{6.572,9}{2 \cdot \pi \cdot 910{,}5 \cdot 1.108{,}2 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

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

$= |0 + 0{,}05 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}05 + (0{,}08) - (0)$

= 0,13 mm

Empty, Corroded, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.619,9}{\pi \cdot 909{,}7\ ^2 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98066.5$$

= 0,05 mm

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

$$= \frac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

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

= $|0 + 0{,}05 - (0{,}08)|$

= 0,04 mm

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

= $0{,}05 + (0{,}08) - (0)$

= 0,13 mm

Empty, New, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.622,9}{\pi \cdot 910{,}5\ ^2 \cdot 1.108{,}2 \cdot 1{,}20} \cdot 98066.5$$

= 0,05 mm

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

$$= \frac{6.572,9}{2 \cdot \pi \cdot 910{,}5 \cdot 1.108{,}2 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

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

= $|0 + 0{,}05 - (0{,}08)|$

= 0,04 mm

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

= $0{,}05 + (0{,}08) - (0)$

= 0,13 mm

Vacuum, Wind, Bottom Seam

$t_p = \frac{P \cdot R}{2 \cdot S_c \cdot K_s + 0{,}40 \cdot |P|}$ (Pressure)

$= \frac{-1 \cdot 900}{2 \cdot 1.090{,}21 \cdot 1{,}20 + 0{,}40 \cdot |1|}$

= -0,34 mm

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

$= \frac{1.619,9}{\pi \cdot 909{,}7\ ^2 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98066.5$

= 0,05 mm

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

$= \frac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98.0665$

= 0,08 mm

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

$= | - 0{,}34 + 0{,}05 - (0{,}08)|$

= 0,38 mm

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

$= 0{,}05 + (0{,}08) - (- 0{,}34)$

= 0,47 mm

Maximum Allowable External Pressure, Longitudinal Stress

$P = \frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0{,}40 \cdot (t - t_{mc} - t_{wc})}$

$= \frac{2 \cdot 1.090{,}21 \cdot 1{,}20 \cdot (19{,}4 - 0{,}05 - 0{,}08)}{900 - 0{,}40 \cdot (19{,}4 - 0{,}05 - 0{,}08)}$

= 56,5 bar

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

t_p = 0 mm (Pressure)

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

$= \frac{593}{\pi \cdot 909{,}7\ ^2 \cdot 1.090{,}21 \cdot 1{,}00} \cdot 98066.5$

= 0,02 mm

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

$= \frac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.090{,}21 \cdot 1{,}00} \cdot 98.0665$

= 0,1 mm

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

$= |0 + 0{,}02 - (0{,}1)|$

= 0,08 mm

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

$= 0{,}02 + (0{,}1) - (0)$

= 0,12 mm

Operating, Hot & Corroded, Seismic, Bottom Seam

$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|}$ (Pressure)

$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$

= 4,92 mm

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

$= \frac{1.446,2}{\pi \cdot 909{,}7\ ^2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$

= 0,04 mm

$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor}$ (Weight)

$= \frac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$

= 0,08 mm

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

$= 4{,}92 + 0{,}04 - (0{,}08)$

= 4,88 mm

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

$= |0{,}04 + (0{,}08) - (4{,}92)|$

= 4,8 mm

Maximum allowable working pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

$$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (19{,}4 - 0{,}04 + (0{,}08))}{900 - 0{,}40 \cdot (19{,}4 - 0{,}04 + (0{,}08))}$$

= 61,7 bar

Operating, Hot & New, Seismic, Bottom Seam

$$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|}$$ (Pressure)

$$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$$

= 4,92 mm

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

$$= \frac{1.472,1}{\pi \cdot 910{,}5^{\ 2} \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$$

= 0,04 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor}$$ (Weight)

$$= \frac{6.572,9}{2 \cdot \pi \cdot 910{,}5 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$$

= 0,08 mm

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

$$= 4{,}92 + 0{,}04 - (0{,}08)$$

= 4,87 mm

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

$$= |0{,}04 + (0{,}08) - (4{,}92)|$$

= 4,8 mm

Maximum allowable working pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

$$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (21 - 0{,}04 + (0{,}08))}{900 - 0{,}40 \cdot (21 - 0{,}04 + (0{,}08))}$$

= 66,83 bar

Hot Shut Down, Corroded, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.446,2}{\pi \cdot 909{,}7\ ^2 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98066.5$$

= 0,04 mm

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

$$= \frac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

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

$= |0 + 0{,}04 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}04 + (0{,}08) - (0)$

= 0,13 mm

Hot Shut Down, New, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.472,1}{\pi \cdot 910{,}5\ ^2 \cdot 1.108{,}2 \cdot 1{,}20} \cdot 98066.5$$

= 0,04 mm

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

$$= \frac{6.572,9}{2 \cdot \pi \cdot 910{,}5 \cdot 1.108{,}2 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

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

$= |0 + 0{,}04 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}04 + (0{,}08) - (0)$

= 0,13 mm

Empty, Corroded, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$= \dfrac{1.352,9}{\pi \cdot 909{,}7^{\ 2} \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98066.5$

= 0,04 mm

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

$= \dfrac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98.0665$

= 0,08 mm

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

$= |0 + 0{,}04 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}04 + (0{,}08) - (0)$

= 0,12 mm

Empty, New, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$= \dfrac{1.379,8}{\pi \cdot 910{,}5^{\ 2} \cdot 1.108{,}2 \cdot 1{,}20} \cdot 98066.5$

= 0,04 mm

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

$= \dfrac{6.572,9}{2 \cdot \pi \cdot 910{,}5 \cdot 1.108{,}2 \cdot 1{,}20} \cdot 98.0665$

= 0,08 mm

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

$= |0 + 0{,}04 - (0{,}08)|$

= 0,05 mm

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

$= 0{,}04 + (0{,}08) - (0)$

= 0,12 mm

Vacuum, Seismic, Bottom Seam

t_p = $\frac{P \cdot R}{2 \cdot S_c \cdot K_s + 0{,}40 \cdot |P|}$ (Pressure)

= $\frac{-1 \cdot 900}{2 \cdot 1.090{,}21 \cdot 1{,}20 + 0{,}40 \cdot |1|}$

= -0,34 mm

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

= $\frac{1.446,2}{\pi \cdot 909{,}7\ ^2 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98066.5$

= 0,04 mm

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

= $\frac{6.395,6}{2 \cdot \pi \cdot 909{,}7 \cdot 1.090{,}21 \cdot 1{,}20} \cdot 98.0665$

= 0,08 mm

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

= $| -0{,}34 + 0{,}04 - (0{,}08)|$

= 0,39 mm

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

= $0{,}04 + (0{,}08) - (-0{,}34)$

= 0,47 mm

Maximum Allowable External Pressure, Longitudinal Stress

P = $\frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0{,}40 \cdot (t - t_{mc} - t_{wc})}$

= $\frac{2 \cdot 1.090{,}21 \cdot 1{,}20 \cdot (19{,}4 - 0{,}04 - 0{,}08)}{900 - 0{,}40 \cdot (19{,}4 - 0{,}04 - 0{,}08)}$

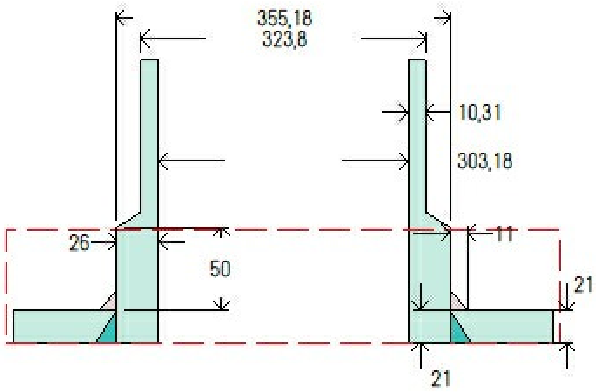
= 56,52 bar

MESH BLANKET

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Number of Trays in Group	2
Distance from Bottom Tray to Datum	1.200 mm
Space Between Trays	150 mm
Number of Passes	1
Weight	
Tray Weight	0,00 kg/m^2
Tray Diameter	1.500 mm
Support Weight	0 kg each
Operating Liquid Depth on Tray	0 mm
Tray Liquid Specific Gravity	1,00
Estimated Tray Weight, Empty	0 kg each
Estimated Tray Weight, Operating	0 kg each
Loading Conditions	
Included in Vessel Lift & Shipping Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

Nozzle (B)

ASME Section VIII Division 1, 2021 Edition Metric



Note: Per UW-16(b) minimum inside corner radius r_1 = min [1 / 4*t , 3 mm] = 3 mm

Location and Orientation	
Located on	Shell V1
Orientation	90°
Nozzle center line offset to datum line	900 mm
End of nozzle to shell center	1.150 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-266 1 (II-D Metric p. 12, ln. 40) (normalized)
Inside diameter, new	303,18 mm
Wall thickness, t_n	26 mm
Minimum wall thickness	10,31 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	114,7 mm
Heavy barrel length, L_{hb}	50 mm
Projection available outside vessel to flange face, Lf	229 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Full UW-11(a) Type 1
Circumferential seam	Full UW-11(a) Type 1

ASME B16.5-2017 Flange	
Description	NPS 12 Class 150 WN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-56,6°C
Liquid static head	0 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	19,51 bar
MAWP rating	16,9 bar @ 121°C
MAP rating	19,6 bar @ 7°C
Hydrotest rating	30 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	303,18 mm
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 1.486{,}4 \cdot 1000}{\pi \cdot 342{,}09^{\ 3}} / 1{,}02 \cdot 100 =$	18,54 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot -909{,}59}{\pi \cdot 342{,}09^{\ 2}} / 1{,}02 \cdot 100 =$	0,97 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[18{,}54 + 0{,}97, 0\right] =$	19,51 bar
Table UG-44-1 Moment Factor, $F_M =$	1,2
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[16{,}9, 16{,}9 \cdot (1 + 1{,}2) - 19{,}51\right] - 0 =$	16,9 bar
Gasket	
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Notes	
(1) Flange is impact tested per material specification to -46°C. UCS-66(i) reduction of 10,6°C applied (ratio = 0,8112). Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Governing thickness, t_g =	21 mm
Exemption temperature from Fig UCS-66M Curve C =	-23,75°C
$t_r = \frac{15{,}9 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}9} =$	12,23 mm
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{12{,}23 \cdot 1}{21 - 1{,}6} =$	0,6302
$\text{Stress ratio longitudinal} = \frac{308{,}497 \cdot 1}{1.203{,}265 \cdot 1} =$	0,2564
Reduction in MDMT, T_R from Fig UCS-66.1M =	20,7°C
Reduction in MDMT, T_{PWHT} from UCS-68(c) =	17°C
$MDMT = \max\left[MDMT - T_R - T_{PWHT}, -48\right] = \max\left[-23{,}75 - 20{,}7 - 17, -48\right] =$	-48°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

UCS-66 Material Toughness Requirements Nozzle	
External nozzle loadings per UG-22 govern the coincident ratio used.	
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{3{,}02 \cdot 1}{10{,}31 - 1{,}6} =$	0,3469
Stress ratio ≤ 0,35, MDMT per UCS-66(b)(3) =	-105°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,78 bar @ 121 °C 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}
39,1338	42,0006	19,6825	21,5587	–	–	0,7594	9,93	10,31

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,78	-909,59	1.259,3	909,59	1.259,3	909,59	1.259,3	**2.154,627**	**3.609,796**	**1.729,34**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-909,59	1.259,3	909,59	1.259,3	909,59	1.259,3	1.235,364	3.609,796	285,868	1.804,898	No
Load case 1 (Pr Reversed)	16,78	909,59	1.259,3	909,59	1.259,3	909,59	1.259,3	1.965,431	3.609,796	1.657,908	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	909,59	1.259,3	909,59	1.259,3	909,59	1.259,3	-1.232,973	3.609,796	-285,868	1.804,898	No

Calculations for internal pressure 16,78 bar @ 121 °C

Parallel Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-1)

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

$$= \max\left[303{,}18,\ \ 151{,}59 + (10{,}31 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 303{,}18\ \ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-1)

$$L_H = \min\left[2{,}5 \cdot (t - C),\ \ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ \ 2{,}5 \cdot (10{,}31 - 1{,}6) + 27{,}18\right]$$

$$= 48{,}5\ \ \text{mm}$$

$$t_e = \min\left[49{,}08 + 15{,}69 \cdot \tan(30),\ \ 15{,}69 \cdot \tan(60)\right]$$

$$= 27{,}18 \text{ mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 151{,}59}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 2{,}17\ \ \text{mm}$$

Required thickness t_r from UG-37(a)

t_r = $\frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$

= $\frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791}$

= $12{,}91 \text{ mm}$

Area required per UG-37(c)

Allowable stresses: S_n = 1.203,265, S_v = 1.203,265 kg_f/cm^2

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

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

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

= $(303{,}18 \cdot 12{,}91 \cdot 1 + 2 \cdot 26 \cdot 12{,}91 \cdot 1 \cdot (1 - 1))/100$

= 39,1338 cm^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 19,6825 cm^2

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

= $(303{,}18 \cdot (1 \cdot 19{,}4 - 1 \cdot 12{,}91) - 2 \cdot 26 \cdot (1 \cdot 19{,}4 - 1 \cdot 12{,}91) \cdot (1 - 1))/100$

= $19{,}6825 \text{ cm}^2$

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

= $(2 \cdot (19{,}4 + 8{,}71) \cdot (1 \cdot 19{,}4 - 1 \cdot 12{,}91) - 2 \cdot 26 \cdot (1 \cdot 19{,}4 - 1 \cdot 12{,}91) \cdot (1 - 1))/100$

= $3{,}6497 \text{ cm}^2$

A_2 = smaller of the following= 21,5587 cm^2

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

= $(5 \cdot (24{,}4 - 2{,}17) \cdot 1 \cdot 19{,}4)/100$

= $21{,}5587 \text{ cm}^2$

= $2 \cdot (t_n - t_{rn}) \cdot (2{,}5 \cdot t_p + t_e) \cdot f_{r2}$

= $(2 \cdot (24{,}4 - 2{,}17) \cdot (2{,}5 \cdot 8{,}71 + 27{,}18) \cdot 1)/100$

= $21{,}7587 \text{ cm}^2$

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

= $(8{,}71^2 \cdot 1)/100$

= 0,7594 cm^2

$$Area = A_1 + A_2 + A_{41}$$
$$= 19{,}6825 + 21{,}5587 + 0{,}7594$$
$$= 42{,}0006 \text{ cm}^2$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[19mm,\ t_n,\ t] =$ 19 mm

$t_{c(\min)} = \min\,[6\ \text{mm},\ 0{,}7 \cdot t_{\min}] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1\ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$
$$= \frac{16{,}7791 \cdot 151{,}59}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$
$$= 3{,}77\ \text{mm}$$

$$t_{a\text{UG-22}} = 4{,}68\ \text{mm}$$

$$t_a = \max\,[t_{a\text{UG-27}},\ t_{a\text{UG-22}}]$$
$$= \max\,[3{,}77,\ 4{,}68]$$
$$= 4{,}68\ \text{mm}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$
$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$
$$= 14{,}51\ \text{mm}$$

$$t_{b1} = \max\,[t_{b1},\ t_{b\text{UG16}}]$$
$$= \max\,[14{,}51,\ 3{,}1]$$
$$= 14{,}51\ \text{mm}$$

$$t_b = \min\,[t_{b3},\ t_{b1}]$$
$$= \min\,[9{,}93,\ 14{,}51]$$
$$= 9{,}93\ \text{mm}$$

$$t_{\text{UG-45}} = \max\,[t_a,\ t_b]$$
$$= \max\,[4{,}68,\ 9{,}93]$$
$$= 9{,}93\ \text{mm}$$

Available nozzle wall thickness new, t_n = 10,31 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-909,59 kg_f
Circumferential moment, M_c	1.259,3 kg_f-m
Circumferential shear, V_c	909,59 kg_f
Longitudinal moment, M_L	1.259,3 kg_f-m
Longitudinal shear, V_L	909,59 kg_f
Torsion moment, M_t	1.259,3 kg_f-m
Internal pressure, P	16,78 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 175{,}99}{909{,}7} = 0{,}1693$$

Pressure stress intensity factor, $I = 1{,}8185$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \dfrac{I \cdot P \cdot R_i}{T} = 1.443{,}472 \ \ \text{kg}_f/\text{cm}^2$

Local longitudinal pressure stress $= \dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 721{,}701 \ \ \text{kg}_f/\text{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 2.154{,}63 \ \ \text{kg}_f/\text{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ \text{kg}_f/\text{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.729{,}34 \ \ \text{kg}_f/\text{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ \text{kg}_f/\text{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	$\frac{N_\phi}{P \;/\; R_m}$	4,3636	0	0	0	0	22,498	22,498	22,498	22,498
4C*	$\frac{N_\phi}{P \;/\; R_m}$	6,928	35,716	35,716	35,716	35,716	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,0742	0	0	0	0	107,57	-107,57	107,57	-107,57
2C-1	$\frac{M_\phi}{P}$	0,0406	58,847	-58,847	58,847	-58,847	0	0	0	0
3A*	$\frac{N_\phi}{M_c \;/\; (R_m^2 \cdot \beta)}$	1,775	0	0	0	0	-82,259	-82,259	82,259	82,259
1A	$\frac{M_\phi}{M_c \;/\; (R_m \cdot \beta)}$	0,0782	0	0	0	0	-1.019,381	1.019,381	1.019,381	-1.019,381
3B*	$\frac{N_\phi}{M_L \;/\; (R_m^2 \cdot \beta)}$	5,3985	-250,152	-250,152	250,152	250,152	0	0	0	0
1B-1	$\frac{M_\phi}{M_L \;/\; (R_m \cdot \beta)}$	0,0281	-365,807	365,807	365,807	-365,807	0	0	0	0
Pressure stress*			1.443,472	1.443,472	1.443,472	1.443,472	793,766	793,766	793,766	793,766
Total circumferential stress			922,076	1.535,996	2.153,994	1.304,686	-177,806	1.645,816	2.025,473	-228,427
Primary membrane circumferential stress*			1.229,036	1.229,036	1.729,34	1.729,34	734,005	734,005	898,523	898,523
3C*	$\frac{N_x}{P \;/\; R_m}$	4,3636	22,498	22,498	22,498	22,498	0	0	0	0
4C*	$\frac{N_x}{P \;/\; R_m}$	6,928	0	0	0	0	35,716	35,716	35,716	35,716
1C-1	$\frac{M_x}{P}$	0,0787	114,179	-114,179	114,179	-114,179	0	0	0	0
2C	$\frac{M_x}{P}$	0,0388	0	0	0	0	56,246	-56,246	56,246	-56,246
4A*	$\frac{N_x}{M_c \;/\; (R_m^2 \cdot \beta)}$	3,3606	0	0	0	0	-155,73	-155,73	155,73	155,73
2A	$\frac{M_x}{M_c \;/\; (R_m \cdot \beta)}$	0,0389	0	0	0	0	-507,687	507,687	507,687	-507,687
4B*	$\frac{N_x}{M_L \;/\; (R_m^2 \cdot \beta)}$	1,4886	-68,971	-68,971	68,971	68,971	0	0	0	0
2B-1	$\frac{M_x}{M_L \;/\; (R_m \cdot \beta)}$	0,0444	-579,048	579,048	579,048	-579,048	0	0	0	0
Pressure stress*			396,883	396,883	396,883	396,883	721,701	721,701	721,701	721,701
Total longitudinal stress			-114,46	815,279	1.181,579	-204,874	150,246	1.053,128	1.477,079	349,215
Primary membrane longitudinal stress*			350,41	350,41	488,352	488,352	601,687	601,687	913,147	913,147
Shear from M_t			33,326	33,326	33,326	33,326	33,326	33,326	33,326	33,326
Circ shear from V_c			8,507	8,507	-8,507	-8,507	0	0	0	0
Long shear from V_L			0	0	0	0	-8,507	-8,507	8,507	8,507
Total Shear stress			41,833	41,833	24,818	24,818	24,818	24,818	41,833	41,833
Combined stress (P_L+P_b+Q)			1.039,91	1.538,387	2.154,627	1.510,404	331,779	1.646,87	2.028,637	583,688
* denotes primary stress.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}78 \cdot 1{,}02 \cdot 151{,}59}{2 \cdot 8{,}71} - \frac{-909{,}59}{\pi \cdot \left(160{,}3^{\ 2} - 151{,}59^{\ 2}\right)} \cdot 100 + \frac{1.780.982{,}1 \cdot 160{,}3}{1{,}0385E{+}08} \cdot 100$$

$$= 434{,}459 \ \ \text{kg}_f/\text{cm}^2$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.203,265 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^2}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{909{,}59^{\ 2} + 909{,}59^{\ 2}}}{\pi \cdot 151{,}59 \cdot 8{,}71} \cdot 100 = 31{,}012 \ \ \text{kg}_f/\text{cm}^2$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{1.259{,}3}{2 \cdot \pi \cdot 151{,}59^{\ 2} \cdot 8{,}71} \cdot 100000 = 100{,}142 \ \ \text{kg}_f/\text{cm}^2$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 31{,}012 + 100{,}142 = 131{,}154 \ \ \text{kg}_f/\text{cm}^2$$

UG-45: The total combined shear stress (131,154 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.203{,}265 = 842{,}286 \ \ \text{kg}_f/\text{cm}^2\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C 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}
9,3576	63,5999	40,1012	22,7393	–	–	0,7594	3,61	10,31

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-1)

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

$$= \max\left[303{,}18,\ 151{,}59 + (10{,}31 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 303{,}18 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-1)

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (10{,}31 - 1{,}6) + 27{,}18\right]$$

$$= 48{,}5 \text{ mm}$$

$$t_e = \min\left[49{,}08 + 15{,}69 \cdot \tan(30),\ 15{,}69 \cdot \tan(60)\right]$$

$$= 27{,}18 \text{ mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,96 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

Allowable stresses: S_n = 1.203,265, S_v = 1.203,265 kg_f/cm^2

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

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

$$A = 0{,}5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$$

$$= (0{,}5 \cdot (303{,}18 \cdot 6{,}17 \cdot 1 + 2 \cdot 26 \cdot 6{,}17 \cdot 1 \cdot (1 - 1)))/100$$

$$= 9{,}3576 \text{ cm}^2$$

Area available from FIG. UG-37.1

A_1 = larger of the following= 40,1012 cm^2

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

$$= (303{,}18 \cdot (1 \cdot 19{,}4 - 1 \cdot 6{,}17) - 2 \cdot 26 \cdot (1 \cdot 19{,}4 - 1 \cdot 6{,}17) \cdot (1 - 1))/100$$

$$= 40{,}1012 \ \ cm^2$$

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

$$= (2 \cdot (19{,}4 + 8{,}71) \cdot (1 \cdot 19{,}4 - 1 \cdot 6{,}17) - 2 \cdot 26 \cdot (1 \cdot 19{,}4 - 1 \cdot 6{,}17) \cdot (1 - 1))/100$$

$$= 7{,}4361 \ \ cm^2$$

A_2 = smaller of the following= 22,7393 cm^2

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

$$= (5 \cdot (24{,}4 - 0{,}96) \cdot 1 \cdot 19{,}4)/100$$

$$= 22{,}7393 \ \ cm^2$$

$$= 2 \cdot (t_n - t_{rn}) \cdot (2{,}5 \cdot t_p + t_e) \cdot f_{r2}$$

$$= (2 \cdot (24{,}4 - 0{,}96) \cdot (2{,}5 \cdot 8{,}71 + 27{,}18) \cdot 1)/100$$

$$= 22{,}9503 \ \ cm^2$$

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

$$= (8{,}71^2 \cdot 1)/100$$

$$= 0{,}7594 \ cm^2$$

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

$$= 40{,}1012 + 22{,}7393 + 0{,}7594$$

$$= 63{,}5999 \ cm^2$$

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[19mm,\ t_n,\ t] =$ 19 mm

$t_{c(\min)} = \min\,[6\ \ \text{mm},\ 0{,}7 \cdot t_{\min}] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1\ \ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 2{,}56\ \ \text{mm}$$

$$t_{a\text{UG-22}} = 3{,}61\ \ \text{mm}$$

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

$$= \max\,[2{,}56,\ \ 3{,}61]$$

$$= 3{,}61\ \ \text{mm}$$

t_{b2} = $\frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$

= $\frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$

= $2{,}36 \quad \text{mm}$

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

$= \max\left[2{,}36,\ 3{,}1\right]$

$= 3{,}1 \quad \text{mm}$

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

$= \min\left[9{,}93,\ 3{,}1\right]$

$= 3{,}1 \quad \text{mm}$

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

$= \max\left[3{,}61,\ 3{,}1\right]$

$=$ 3,61 mm

Available nozzle wall thickness new, t_n = 10,31 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{246{,}28}{355{,}18} = 0{,}6934$$

$$\frac{D_o}{t} = \frac{355{,}18}{0{,}96} = 371{,}0232$$

From table G: $A = 0{,}000279$

From table CS-2 Metric: $B = 283{,}7594 \quad \text{kg/cm}^2 (278{,}27 \quad \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 278,27}{3 \cdot (355{,}18/0{,}96)} = 1 \quad \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}96 + 1{,}6 =$ 2,56 mm

Nozzle (C)

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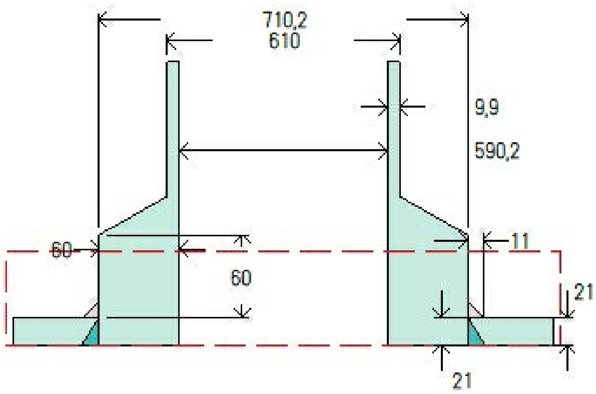

Note: Per UW-16(b) minimum inside corner radius r_1 = min [1 / 4*t , 3 mm] = 3 mm

Location and Orientation	
Located on	Shell V1
Orientation	260°
Nozzle center line offset to datum line	630 mm
End of nozzle to shell center	1.223,4 mm
Passes through a Category A joint	No
Nozzle	
Access opening	Yes
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	590,2 mm
Wall thickness, t_n	60 mm
Minimum wall thickness	9,9 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	150 mm
Heavy barrel length, L_{hb}	60 mm
Projection available outside vessel to flange face, Lf	302,4 mm
Local vessel minimum thickness	21 mm
User input radial limit of reinforcement	480 mm
Liquid static head included	0,02 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Full UW-11(a) Type 1
Circumferential seam	Full UW-11(a) Type 1

ASME B16.5-2017 Flange	
Description	NPS 24 Class 150 WN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	Yes
Rated MDMT	-56,6°C
Liquid static head	0 bar
MAWP rating	16,9 bar @ 121°C
MAP rating	19,6 bar @ 7°C
Hydrotest rating	30 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Bore diameter, B (specified by purchaser)	584 mm
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	628,7 mm
Outer Diameter	685,8 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. UCS-66(i) reduction of 10,6°C applied (ratio = 0,8112). Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	

UCS-66 Material Toughness Requirements Nozzle At Intersection	
Impact test temperature per material specification =	-46°C
$t_r = \frac{15{,}92 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}92} =$	12,24 mm
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{12{,}24 \cdot 1}{21 - 1{,}6} =$	0,6309
$\text{Stress ratio longitudinal} = \frac{308{,}357 \cdot 1}{1.203{,}265 \cdot 1} =$	0,2563
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1M =	20,7°C
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, \max\left[T_{impact} - T_R, -105\right]\right] = \min\left[-46 - 3, \max\left[-46 - 20{,}7, -105\right]\right] =$	-66,7°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

UCS-66 Material Toughness Requirements Nozzle	
Impact test temperature per material specification =	-46°C
$t_r = \frac{15{,}92 \cdot 295{,}1}{1.380 \cdot 1 - 0{,}6 \cdot 15{,}92} =$	3,43 mm
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{3{,}43 \cdot 1}{9{,}9 - 1{,}6} =$	0,413
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1M =	47,5°C
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, \max\left[T_{impact} - T_R, -105\right]\right] = \min\left[-46 - 3, \max\left[-46 - 47{,}5, -105\right]\right] =$	-93,5°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,8 bar @ 121 °C 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}
76,2581	77,8573	23,9593	53,1386	–	–	0,7594	5,22	9,9

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for internal pressure 16,8 bar @ 121 °C

Parallel Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-1)

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

$$= \max\left[590{,}2,\ \ 295{,}1 + (9{,}9 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 590{,}2 \ \ \text{mm}$$

L_R = 480 mm (User Defined)

Outer Normal Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-1)

$$L_H = \min\left[2{,}5 \cdot (t - C),\ \ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ \ 2{,}5 \cdot (9{,}9 - 1{,}6) + 86{,}78\right]$$

$$= 48{,}5 \ \ \text{mm}$$

$$t_e = \min\left[59{,}08 + 50{,}1 \cdot \tan(30),\ \ 50{,}1 \cdot \tan(60)\right]$$

= 86,78 mm

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7957 \cdot 295{,}1}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7957}$$

$$= 3{,}62 \ \ \text{mm}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7957 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7957}$$

$$= 12{,}92 \ \ \text{mm}$$

Area required per UG-37(c)

Allowable stresses: S_n = 1.407,208, S_v = 1.203,265 kg_f/cm^2

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

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

A	=	$d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1})$
	=	$(590{,}2 \cdot 12{,}92 \cdot 1 + 2 \cdot 60 \cdot 12{,}92 \cdot 1 \cdot (1-1))/100$
	=	76,2581 cm^2

Area available from FIG. UG-37.1

A_1: (specified limit governs) = 23,9593 cm^2

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

$$= ((2 \cdot 480 - 590{,}2) \cdot (1 \cdot 19{,}4 - 1 \cdot 12{,}92) - 2 \cdot 60 \cdot (1 \cdot 19{,}4 - 1 \cdot 12{,}92) \cdot (1-1))/100$$

= 23,9593 cm^2

A_2 = smaller of the following= 53,1386 cm^2

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

$$= (5 \cdot (58{,}4 - 3{,}62) \cdot 1 \cdot 19{,}4)/100$$

$$= 53{,}1386 \ \ cm^2$$

$$= 2 \cdot (t_n - t_{rn}) \cdot (2{,}5 \cdot t_p + t_e) \cdot f_{r2} - \left[(t_n - t_p)^2 \cdot \tan(30) + 2 \cdot (LIMIT - L_{hb} - L_{slope}) \cdot (t_n - t_p)\right] \cdot f_{r2}$$

$$= \left(2 \cdot (58{,}4 - 3{,}62) \cdot (2{,}5 \cdot 8{,}3 + 86{,}78) \cdot 1 - \left[(58{,}4 - 8{,}3)^2 \cdot \tan(30) + 2 \cdot (107{,}53 - 1{,}6 - 59{,}08 - 28{,}93) \cdot (58{,}4 - 8{,}3)\right] \cdot 1\right) \ / \ 100$$

$$= 85{,}3598 \ \ cm^2$$

A_{41}	=	$Leg^2 \cdot f_{r2}$
	=	$(8{,}71^2 \cdot 1)/100$
	=	0,7594 cm^2
$Area$	=	$A_1 + A_2 + A_{41}$
	=	$23{,}9593 + 53{,}1386 + 0{,}7594$
	=	77,8573 cm^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\ [19mm,\ t_n,\ t] =$ 19 mm

$t_{c(\min)} = \min\ [6\ \ mm,\ 0{,}7 \cdot t_{\min}] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1\ \ mm$

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 (Access Opening)

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7957 \cdot 295{,}1}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7957} + 1{,}6$$

$$= 5{,}22 \quad \text{mm}$$

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

$$= \max\left[5{,}22,\ 0\right]$$

$$= 5{,}22 \quad \text{mm}$$

Available nozzle wall thickness new, t_n = 9,9 mm

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C 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}
18,2164	104,6488	48,9128	54,9767	–	–	0,7594	3,32	9,9

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-1)

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

$$= \max\left[590{,}2,\ 295{,}1 + (9{,}9 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 590{,}2 \ \text{mm}$$

L_R = 480 mm (User Defined)

Outer Normal Limit of reinforcement per UG-40 and Fig. UG-40 sketch (e-1)

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (9{,}9 - 1{,}6) + 86{,}78\right]$$

$$= 48{,}5 \ \text{mm}$$

$$t_e = \min\left[59{,}08 + 50{,}1 \cdot \tan(30),\ 50{,}1 \cdot \tan(60)\right]$$

= 86,78 mm

Nozzle required thickness per UG-28 t_{rn} = 1,72 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

Allowable stresses: S_n = 1.407,208, S_v = 1.203,265 kg_f/cm^2

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

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

$$A = 0{,}5 \cdot (d \cdot t_r \cdot F + 2 \cdot t_n \cdot t_r \cdot F \cdot (1 - f_{r1}))$$

$$= (0{,}5 \cdot (590{,}2 \cdot 6{,}17 \cdot 1 + 2 \cdot 60 \cdot 6{,}17 \cdot 1 \cdot (1 - 1)))/100$$

= 18,2164 cm^2

Area available from FIG. UG-37.1

A_1: (specified limit governs) = 48,9128 cm^2

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

$$= ((2 \cdot 480 - 590{,}2) \cdot (1 \cdot 19{,}4 - 1 \cdot 6{,}17) - 2 \cdot 60 \cdot (1 \cdot 19{,}4 - 1 \cdot 6{,}17) \cdot (1 - 1))/100$$

= 48,9128 cm^2

A_2 = smaller of the following= 54,9767 cm^2

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

$$= (5 \cdot (58{,}4 - 1{,}72) \cdot 1 \cdot 19{,}4)/100$$

$$= 54{,}9767 \ \text{cm}^2$$

$$= 2 \cdot (t_n - t_{rn}) \cdot (2{,}5 \cdot t_p + t_e) \cdot f_{r2} - \left[(t_n - t_p)^2 \cdot \tan(30) + 2 \cdot (LIMIT - L_{hb} - L_{slope}) \cdot (t_n - t_p)\right] \cdot f_{r2}$$

$$= \left(2 \cdot (58{,}4 - 1{,}72) \cdot (2{,}5 \cdot 8{,}3 + 86{,}78) \cdot 1 - \left[(58{,}4 - 8{,}3)^2 \cdot \tan(30) + 2 \cdot (107{,}53 - 1{,}6 - 59{,}08 - 28{,}93) \cdot (58{,}4 - 8{,}3)\right] \cdot 1\right) / 100$$

$$= 89{,}4353 \ \text{cm}^2$$

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

$$= (8{,}71^2 \cdot 1)/100$$

= 0,7594 cm^2

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

$$= 48{,}9128 + 54{,}9767 + 0{,}7594$$

= 104,6488 cm^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[19mm,\ t_n,\ t] =$ 19 mm

$t_{c(\min)} = \min\,[6 \ \text{mm},\ 0{,}7 \cdot t_{\min}] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \ \text{mm}$

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 (Access Opening)

$$t_{a\text{UG-28}} = 3{,}32 \ \text{mm}$$

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

$$= \max\,[3{,}32,\ 0]$$

$$= 3{,}32 \ \text{mm}$$

Available nozzle wall thickness new, t_n = 9,9 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{373{,}61}{710{,}2} = 0{,}5261$$

$$\frac{D_o}{t} = \frac{710{,}2}{1{,}72} = 412{,}4399$$

From table G: $A = 0{,}000310$

From table CS-2 Metric: $B = 315{,}4276 \ \ \mathrm{kg/cm}^2 (309{,}33 \ \ \mathrm{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 309,33}{3 \cdot (710{,}2/1{,}72)} = 1 \ \ \mathrm{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \mathrm{Corrosion} = 1{,}72 + 1{,}6 = 3{,}32$ mm

Nozzle (E1)

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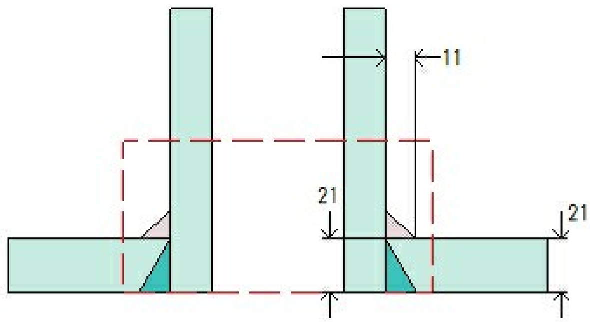


Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	Shell V1
Orientation	330°
Nozzle center line offset to datum line	150 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	16,64 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	181,65 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0,04 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-104°C
Liquid static head	0,03 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	21,25 bar
MAWP rating	45,97 bar @ 121°C
MAP rating	51,1 bar @ 7°C
Hydrotest rating	77 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 77{,}9^{\,3}} / 1{,}02 \cdot 100 =$	18,38 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot -139{,}7}{\pi \cdot 77{,}9^{\,2}} / 1{,}02 \cdot 100 =$	2,87 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[18{,}38 + 2{,}87, 0\right] =$	21,25 bar
Table UG-44-1 Moment Factor, $F_M =$	0,5
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[45{,}97, 45{,}97 \cdot (1 + 0{,}5) - 21{,}25\right] - 0{,}03 =$	45,94 bar
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. Stress ratio = 0,3118 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C. Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-104°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,82 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	16,64

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,82	-139,7	40,8	139,7	40,8	139,7	40,8	**1.163,158**	**3.609,796**	**1.012,842**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	259,362	3.609,796	21,303	1.804,898	No
Load case 1 (Pr Reversed)	16,82	139,7	40,8	139,7	40,8	139,7	40,8	1.121,537	3.609,796	998,499	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-255,566	3.609,796	-21,303	1.804,898	No

Calculations for internal pressure 16,82 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 59{,}84 \quad \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$

$$= 37{,}59 \quad \text{mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}8163 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}8163}$$

$$= 0{,}31 \quad \text{mm}$$

Required thickness t_r from UG-37(a)

$t_r = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$

$= \frac{16{,}8163 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}8163}$

$= 12{,}94 \text{ mm}$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$

$= \frac{16{,}8163 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}8163} + 1{,}6$

$= 1{,}91 \text{ mm}$

$t_{a\text{UG-22}} = 2{,}71 \text{ mm}$

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

$= \max\left[1{,}91,\ 2{,}71\right]$

$= 2{,}71 \text{ mm}$

$t_{b1} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$

$= \frac{16{,}8163 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}8163} + 1{,}6$

$= 14{,}54 \text{ mm}$

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

$= \max\left[14{,}54,\ 3{,}1\right]$

$= 14{,}54 \text{ mm}$

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

$= \min\left[6{,}4,\ 14{,}54\right]$

$= 6{,}4 \text{ mm}$

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

$= \max\left[2{,}71,\ 6{,}4\right]$

$= 6{,}4 \text{ mm}$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	16,82 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 40{,}44}{909{,}7} = 0{,}0389$$

Pressure stress intensity factor, $I = 1{,}2464$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \frac{I \cdot P \cdot R_i}{T} = 991{,}539 \ \ kg_f/cm^2$

Local longitudinal pressure stress $= \frac{I \cdot P \cdot R_i}{2 \cdot T} = 495{,}805 \ \ kg_f/cm^2$

Maximum combined stress $(P_L + P_b + Q) = 1.163{,}16 \ \ kg_f/cm^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ kg_f/cm^2$

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

Maximum local primary membrane stress $(P_L) = 1.012{,}84 \ \ kg_f/cm^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ kg_f/cm^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	$\frac{N_\phi}{P \ / \ R_m}$	9,0035	0	0	0	0	7,101	7,101	7,101	7,101
4C*	$\frac{N_\phi}{P \ / \ R_m}$	9,0286	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2092	0	0	0	0	46,614	-46,614	46,614	-46,614
2C-1	$\frac{M_\phi}{P}$	0,1632	36,349	-36,349	36,349	-36,349	0	0	0	0
3A*	$\frac{N_\phi}{M_c \ / \ (R_m^2 \cdot \beta)}$	0,4576	0	0	0	0	-3,023	-3,023	3,023	3,023
1A	$\frac{M_\phi}{M_c \ / \ (R_m \cdot \beta)}$	0,1064	0	0	0	0	-195,594	195,594	195,594	-195,594
3B*	$\frac{N_\phi}{M_L \ / \ (R_m^2 \cdot \beta)}$	2,1599	-14,132	-14,132	14,132	14,132	0	0	0	0
1B-1	$\frac{M_\phi}{M_L \ / \ (R_m \cdot \beta)}$	0,0618	-113,546	113,546	113,546	-113,546	0	0	0	0
Pressure stress*			991,539	991,539	991,539	991,539	795,523	795,523	795,523	795,523
Total circumferential stress			907,382	1.061,776	1.162,736	862,948	650,621	948,581	1.047,855	563,44
Primary membrane circumferential stress*			984,579	984,579	1.012,842	1.012,842	799,601	799,601	805,647	805,647
3C*	$\frac{N_x}{P \ / \ R_m}$	9,0035	7,101	7,101	7,101	7,101	0	0	0	0
4C*	$\frac{N_x}{P \ / \ R_m}$	9,0286	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2145	47,738	-47,738	47,738	-47,738	0	0	0	0
2C	$\frac{M_x}{P}$	0,1608	0	0	0	0	35,786	-35,786	35,786	-35,786
4A*	$\frac{N_x}{M_c \ / \ (R_m^2 \cdot \beta)}$	0,7155	0	0	0	0	-4,64	-4,64	4,64	4,64
2A	$\frac{M_x}{M_c \ / \ (R_m \cdot \beta)}$	0,0621	0	0	0	0	-114,108	114,108	114,108	-114,108
4B*	$\frac{N_x}{M_L \ / \ (R_m^2 \cdot \beta)}$	0,5274	-3,445	-3,445	3,445	3,445	0	0	0	0
2B-1	$\frac{M_x}{M_L \ / \ (R_m \cdot \beta)}$	0,1029	-189,196	189,196	189,196	-189,196	0	0	0	0
Pressure stress*			397,797	397,797	397,797	397,797	495,805	495,805	495,805	495,805
Total longitudinal stress			259,995	542,91	645,277	171,408	420,014	576,658	657,511	357,722
Primary membrane longitudinal stress*			401,453	401,453	408,343	408,343	498,336	498,336	507,616	507,616
Shear from M_t			20,459	20,459	20,459	20,459	20,459	20,459	20,459	20,459
Circ shear from V_c			5,695	5,695	-5,695	-5,695	0	0	0	0
Long shear from V_L			0	0	0	0	-5,695	-5,695	5,695	5,695
Total Shear stress			26,154	26,154	14,764	14,764	14,764	14,764	26,154	26,154
Combined stress (P_L+P_b+Q)			908,436	1.063,112	1.163,158	863,229	651,535	949,144	1.049,613	566,744
* denotes primary stress.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}82 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 15{,}04} - \frac{-139{,}7}{\pi \cdot \left(40{,}44^{\,2} - 25{,}4^{\,2}\right)} \cdot 100 + \frac{57.698{,}1 \cdot 40{,}44}{1.772.985} \cdot 100$$

$$= 150{,}568 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^{\,2}}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\,2} + 139{,}7^{\,2}}}{\pi \cdot 25{,}4 \cdot 15{,}04} \cdot 100 = 16{,}466 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

$$\sigma_{\mathrm{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\,2} \cdot 15{,}04} \cdot 100000 = 66{,}934 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

$$\sigma_{\mathrm{total}} = \sigma_{\mathrm{shear}} + \sigma_{\mathrm{torsion}} = 16{,}466 + 66{,}934 = 83{,}399 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

UG-45: The total combined shear stress (83,399 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	16,64

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$
$$= 59{,}84 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$
$$= 37{,}59 \text{ mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,38 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}98 \text{ mm}$$

$$t_{a\text{UG-22}} = 2{,}48 \text{ mm}$$

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

$= \quad \max\left[1{,}98,\ \ 2{,}48\right]$

$= \quad 2{,}48 \ \ \text{mm}$

$$t_{b2} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$$

$$= 2{,}36 \ \ \text{mm}$$

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

$= \quad \max\left[2{,}36,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

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

$= \quad \min\left[6{,}4,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

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

$= \quad \max\left[2{,}48,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}96}{84{,}07} = 2{,}4379$$

$$\frac{D_o}{t} = \frac{84{,}07}{0{,}38} = 219{,}2887$$

From table G: $A = 0{,}000164$

From table CS-2 Metric: $B = 167{,}7082 \ \ \text{kg/cm}^2 (164{,}47 \ \ \text{bar})$

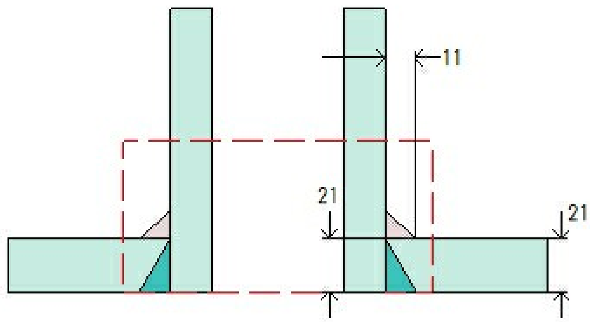
$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 164{,}47}{3 \cdot (84{,}07/0{,}38)} = 1 \ \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}38 + 1{,}6 = 1{,}98$ mm

Nozzle (E2)

ASME Section VIII Division 1, 2021 Edition Metric	



Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Shell V1
Orientation	330°
Nozzle center line offset to datum line	950 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	16,64 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	181,65 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-104°C
Liquid static head	0 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	21,25 bar
MAWP rating	45,97 bar @ 121°C
MAP rating	51,1 bar @ 7°C
Hydrotest rating	77 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 77{,}9^{\ 3}} / 1{,}02 \cdot 100 =$	18,38 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot -139{,}7}{\pi \cdot 77{,}9^{\ 2}} / 1{,}02 \cdot 100 =$	2,87 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[18{,}38 + 2{,}87, 0\right] =$	21,25 bar
Table UG-44-1 Moment Factor, $F_M =$	0,5
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[45{,}97, 45{,}97 \cdot (1 + 0{,}5) - 21{,}25\right] - 0 =$	45,97 bar
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. Stress ratio = 0,3112 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C. Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-104°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,78 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	16,64

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,78	-139,7	40,8	139,7	40,8	139,7	40,8	**1.160,979**	**3.609,796**	**1.010,663**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	259,362	3.609,796	21,303	1.804,898	No
Load case 1 (Pr Reversed)	16,78	139,7	40,8	139,7	40,8	139,7	40,8	1.119,357	3.609,796	996,32	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-255,566	3.609,796	-21,303	1.804,898	No

Calculations for internal pressure 16,78 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 59{,}84 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$

$$= 37{,}59 \text{ mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 0{,}31 \text{ mm}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 12{,}91 \quad \text{mm}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\text{min}} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\text{min})} = \min\left[6 \ \text{mm},\ 0{,}7 \cdot t_{\text{min}}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 1{,}91 \quad \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}71 \quad \text{mm}$$

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

$$= \max\left[1{,}91,\ 2{,}71\right]$$

$$= 2{,}71 \quad \text{mm}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 14{,}51 \quad \text{mm}$$

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

$$= \max\left[14{,}51,\ 3{,}1\right]$$

$$= 14{,}51 \quad \text{mm}$$

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

$$= \min\left[6{,}4,\ 14{,}51\right]$$

$$= 6{,}4 \quad \text{mm}$$

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

$$= \max\left[2{,}71,\ 6{,}4\right]$$

$$= 6{,}4 \quad \text{mm}$$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	16,78 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 40{,}44}{909{,}7} = 0{,}0389$$

Pressure stress intensity factor, $I = 1{,}2464$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \frac{I \cdot P \cdot R_i}{T} = 989{,}36 \ \ \text{kg}_f/\text{cm}^2$

Local longitudinal pressure stress $= \frac{I \cdot P \cdot R_i}{2 \cdot T} = 494{,}68 \ \ \text{kg}_f/\text{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 1.160{,}98 \ \ \text{kg}_f/\text{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ \text{kg}_f/\text{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.010{,}66 \ \ \text{kg}_f/\text{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ \text{kg}_f/\text{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	$\frac{N_\phi}{P \ / \ R_m}$	9,0035	0	0	0	0	7,101	7,101	7,101	7,101
4C*	$\frac{N_\phi}{P \ / \ R_m}$	9,0286	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2092	0	0	0	0	46,614	-46,614	46,614	-46,614
2C-1	$\frac{M_\phi}{P}$	0,1632	36,349	-36,349	36,349	-36,349	0	0	0	0
3A*	$\frac{N_\phi}{M_c \ / \ (R_m^2 \cdot \beta)}$	0,4576	0	0	0	0	-3,023	-3,023	3,023	3,023
1A	$\frac{M_\phi}{M_c \ / \ (R_m \cdot \beta)}$	0,1064	0	0	0	0	-195,594	195,594	195,594	-195,594
3B*	$\frac{N_\phi}{M_L \ / \ (R_m^2 \cdot \beta)}$	2,1599	-14,132	-14,132	14,132	14,132	0	0	0	0
1B-1	$\frac{M_\phi}{M_L \ / \ (R_m \cdot \beta)}$	0,0618	-113,546	113,546	113,546	-113,546	0	0	0	0
Pressure stress*			989,36	989,36	989,36	989,36	793,766	793,766	793,766	793,766
Total circumferential stress			905,202	1.059,596	1.160,557	860,768	648,863	946,824	1.046,097	561,682
Primary membrane circumferential stress*			982,399	982,399	1.010,663	1.010,663	797,843	797,843	803,89	803,89
3C*	$\frac{N_x}{P \ / \ R_m}$	9,0035	7,101	7,101	7,101	7,101	0	0	0	0
4C*	$\frac{N_x}{P \ / \ R_m}$	9,0286	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2145	47,738	-47,738	47,738	-47,738	0	0	0	0
2C	$\frac{M_x}{P}$	0,1608	0	0	0	0	35,786	-35,786	35,786	-35,786
4A*	$\frac{N_x}{M_c \ / \ (R_m^2 \cdot \beta)}$	0,7155	0	0	0	0	-4,64	-4,64	4,64	4,64
2A	$\frac{M_x}{M_c \ / \ (R_m \cdot \beta)}$	0,0621	0	0	0	0	-114,108	114,108	114,108	-114,108
4B*	$\frac{N_x}{M_L \ / \ (R_m^2 \cdot \beta)}$	0,5274	-3,445	-3,445	3,445	3,445	0	0	0	0
2B-1	$\frac{M_x}{M_L \ / \ (R_m \cdot \beta)}$	0,1029	-189,196	189,196	189,196	-189,196	0	0	0	0
Pressure stress*			396,883	396,883	396,883	396,883	494,68	494,68	494,68	494,68
Total longitudinal stress			259,081	541,996	644,363	170,494	418,889	575,533	656,386	356,597
Primary membrane longitudinal stress*			400,539	400,539	407,429	407,429	497,211	497,211	506,491	506,491
Shear from M_t			20,459	20,459	20,459	20,459	20,459	20,459	20,459	20,459
Circ shear from V_c			5,695	5,695	-5,695	-5,695	0	0	0	0
Long shear from V_L			0	0	0	0	-5,695	-5,695	5,695	5,695
Total Shear stress			26,154	26,154	14,764	14,764	14,764	14,764	26,154	26,154
Combined stress (P_L+P_b+Q)			906,257	1.060,932	1.160,979	861,049	649,777	947,386	1.047,855	564,987

* denotes primary stress.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}78 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 15{,}04} - \frac{-139{,}7}{\pi \cdot \left(40{,}44^{\,2} - 25{,}4^{\,2}\right)} \cdot 100 + \frac{57.698{,}1 \cdot 40{,}44}{1.772.985} \cdot 100$$

$$= 150{,}536 \;\; \mathrm{kg}_f/\mathrm{cm}^2$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^2}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\,2} + 139{,}7^{\,2}}}{\pi \cdot 25{,}4 \cdot 15{,}04} \cdot 100 = 16{,}466 \;\; \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\mathrm{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\,2} \cdot 15{,}04} \cdot 100000 = 66{,}934 \;\; \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\mathrm{total}} = \sigma_{\mathrm{shear}} + \sigma_{\mathrm{torsion}} = 16{,}466 + 66{,}934 = 83{,}399 \;\; \mathrm{kg}_f/\mathrm{cm}^2$$

UG-45: The total combined shear stress (83,399 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \;\; \mathrm{kg}_f/\mathrm{cm}^2\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	16,64

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$
$$= 59{,}84 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$
$$= 37{,}59 \text{ mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,38 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}98 \text{ mm}$$

$$t_{a\text{UG-22}} = 2{,}48 \text{ mm}$$

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

$$= \max\left[1{,}98,\ 2{,}48\right]$$

$$= 2{,}48 \text{ mm}$$

$$t_{b2} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$$

$$= 2{,}36 \text{ mm}$$

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

$$= \max\left[2{,}36,\ 3{,}1\right]$$

$$= 3{,}1 \text{ mm}$$

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

$$= \min\left[6{,}4,\ 3{,}1\right]$$

$$= 3{,}1 \text{ mm}$$

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

$$= \max\left[2{,}48,\ 3{,}1\right]$$

$$= 3{,}1 \text{ mm}$$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}96}{84{,}07} = 2{,}4379$$

$$\frac{D_o}{t} = \frac{84{,}07}{0{,}38} = 219{,}2887$$

From table G: $A = 0{,}000164$

From table CS-2 Metric: $B = 167{,}7082 \text{ kg/cm}^2 (164{,}47 \text{ bar})$

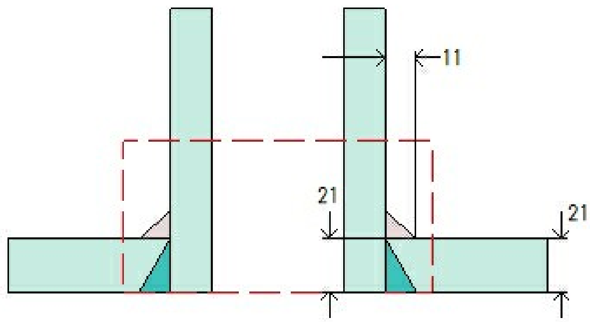
$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 164{,}47}{3 \cdot (84{,}07/0{,}38)} = 1 \text{ bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}38 + 1{,}6 = 1{,}98$ mm

Nozzle (F1)

ASME Section VIII Division 1, 2021 Edition Metric	



Note: round inside edges per UG-76(c)	
Location and Orientation	
Located on	Shell V1
Orientation	295°
Nozzle center line offset to datum line	950 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	16,64 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	181,65 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-104°C
Liquid static head	0 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	21,25 bar
MAWP rating	45,97 bar @ 121°C
MAP rating	51,1 bar @ 7°C
Hydrotest rating	77 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 77{,}9^{\ 3}} / 1{,}02 \cdot 100 =$	18,38 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot\ -139{,}7}{\pi \cdot 77{,}9^{\ 2}} / 1{,}02 \cdot 100 =$	2,87 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[18{,}38 + 2{,}87, 0\right] =$	21,25 bar
Table UG-44-1 Moment Factor, $F_M =$	0,5
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[45{,}97, 45{,}97 \cdot (1 + 0{,}5) - 21{,}25\right] - 0 =$	45,97 bar
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. Stress ratio = 0,3112 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C. Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-104°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,78 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	16,64

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,78	-139,7	40,8	139,7	40,8	139,7	40,8	**1.160,979**	**3.609,796**	**1.010,663**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	259,362	3.609,796	21,303	1.804,898	No
Load case 1 (Pr Reversed)	16,78	139,7	40,8	139,7	40,8	139,7	40,8	1.119,357	3.609,796	996,32	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-255,566	3.609,796	-21,303	1.804,898	No

Calculations for internal pressure 16,78 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ \ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 59{,}84 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ \ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ \ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$

$$= 37{,}59 \text{ mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 0{,}31 \text{ mm}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 12{,}91 \quad \text{mm}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6\ \text{mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \quad \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 1{,}91 \quad \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}71 \quad \text{mm}$$

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

$$= \max\left[1{,}91,\ 2{,}71\right]$$

$$= 2{,}71 \quad \text{mm}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 14{,}51 \quad \text{mm}$$

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

$$= \max\left[14{,}51,\ 3{,}1\right]$$

$$= 14{,}51 \quad \text{mm}$$

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

$$= \min\left[6{,}4,\ 14{,}51\right]$$

$$= 6{,}4 \quad \text{mm}$$

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

$$= \max\left[2{,}71,\ 6{,}4\right]$$

$$= 6{,}4 \quad \text{mm}$$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	16,78 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 40{,}44}{909{,}7} = 0{,}0389$$

Pressure stress intensity factor, $I = 1{,}2464$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \dfrac{I \cdot P \cdot R_i}{T} = 989{,}36 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Local longitudinal pressure stress $= \dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 494{,}68 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 1.160{,}98 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.010{,}66 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	$\frac{N_\phi}{P \ / \ R_m}$	9,0035	0	0	0	0	7,101	7,101	7,101	7,101
4C*	$\frac{N_\phi}{P \ / \ R_m}$	9,0286	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2092	0	0	0	0	46,614	-46,614	46,614	-46,614
2C-1	$\frac{M_\phi}{P}$	0,1632	36,349	-36,349	36,349	-36,349	0	0	0	0
3A*	$\frac{N_\phi}{M_c \ / \ (R_m^2 \cdot \beta)}$	0,4576	0	0	0	0	-3,023	-3,023	3,023	3,023
1A	$\frac{M_\phi}{M_c \ / \ (R_m \cdot \beta)}$	0,1064	0	0	0	0	-195,594	195,594	195,594	-195,594
3B*	$\frac{N_\phi}{M_L \ / \ (R_m^2 \cdot \beta)}$	2,1599	-14,132	-14,132	14,132	14,132	0	0	0	0
1B-1	$\frac{M_\phi}{M_L \ / \ (R_m \cdot \beta)}$	0,0618	-113,546	113,546	113,546	-113,546	0	0	0	0
Pressure stress*			989,36	989,36	989,36	989,36	793,766	793,766	793,766	793,766
Total circumferential stress			905,202	1.059,596	1.160,557	860,768	648,863	946,824	1.046,097	561,682
Primary membrane circumferential stress*			982,399	982,399	1.010,663	1.010,663	797,843	797,843	803,89	803,89
3C*	$\frac{N_x}{P \ / \ R_m}$	9,0035	7,101	7,101	7,101	7,101	0	0	0	0
4C*	$\frac{N_x}{P \ / \ R_m}$	9,0286	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2145	47,738	-47,738	47,738	-47,738	0	0	0	0
2C	$\frac{M_x}{P}$	0,1608	0	0	0	0	35,786	-35,786	35,786	-35,786
4A*	$\frac{N_x}{M_c \ / \ (R_m^2 \cdot \beta)}$	0,7155	0	0	0	0	-4,64	-4,64	4,64	4,64
2A	$\frac{M_x}{M_c \ / \ (R_m \cdot \beta)}$	0,0621	0	0	0	0	-114,108	114,108	114,108	-114,108
4B*	$\frac{N_x}{M_L \ / \ (R_m^2 \cdot \beta)}$	0,5274	-3,445	-3,445	3,445	3,445	0	0	0	0
2B-1	$\frac{M_x}{M_L \ / \ (R_m \cdot \beta)}$	0,1029	-189,196	189,196	189,196	-189,196	0	0	0	0
Pressure stress*			396,883	396,883	396,883	396,883	494,68	494,68	494,68	494,68
Total longitudinal stress			259,081	541,996	644,363	170,494	418,889	575,533	656,386	356,597
Primary membrane longitudinal stress*			400,539	400,539	407,429	407,429	497,211	497,211	506,491	506,491
Shear from M_t			20,459	20,459	20,459	20,459	20,459	20,459	20,459	20,459
Circ shear from V_c			5,695	5,695	-5,695	-5,695	0	0	0	0
Long shear from V_L			0	0	0	0	-5,695	-5,695	5,695	5,695
Total Shear stress			26,154	26,154	14,764	14,764	14,764	14,764	26,154	26,154
Combined stress (P_L+P_b+Q)			906,257	1.060,932	1.160,979	861,049	649,777	947,386	1.047,855	564,987
* denotes primary stress.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}78 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 15{,}04} - \frac{-139{,}7}{\pi \cdot \left(40{,}44^{\,2} - 25{,}4^{\,2}\right)} \cdot 100 + \frac{57.699{,}7 \cdot 40{,}44}{1.772.985} \cdot 100$$

$$= 150{,}54 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^{\,2}}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\,2} + 139{,}7^{\,2}}}{\pi \cdot 25{,}4 \cdot 15{,}04} \cdot 100 = 16{,}465 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\,2} \cdot 15{,}04} \cdot 100000 = 66{,}936 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 16{,}465 + 66{,}936 = 83{,}401 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

UG-45: The total combined shear stress (83,401 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \;\; \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	16,64

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$
$$= 59{,}84 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$
$$= 37{,}59 \text{ mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,38 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}98 \text{ mm}$$

$$t_{a\text{UG-22}} = 2{,}48 \text{ mm}$$

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

$= \max\left[1{,}98,\ 2{,}48\right]$

$= 2{,}48\ \ \text{mm}$

$$t_{b2} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$$

$= 2{,}36\ \ \text{mm}$

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

$= \max\left[2{,}36,\ 3{,}1\right]$

$= 3{,}1\ \ \text{mm}$

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

$= \min\left[6{,}4,\ 3{,}1\right]$

$= 3{,}1\ \ \text{mm}$

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

$= \max\left[2{,}48,\ 3{,}1\right]$

$=$ 3,1 mm

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}96}{84{,}07} = 2{,}4379$$

$$\frac{D_o}{t} = \frac{84{,}07}{0{,}38} = 219{,}2887$$

From table G: $A = 0{,}000164$

From table CS-2 Metric: $B = 167{,}7082\ \ \text{kg/cm}^2 (164{,}47\ \ \text{bar})$

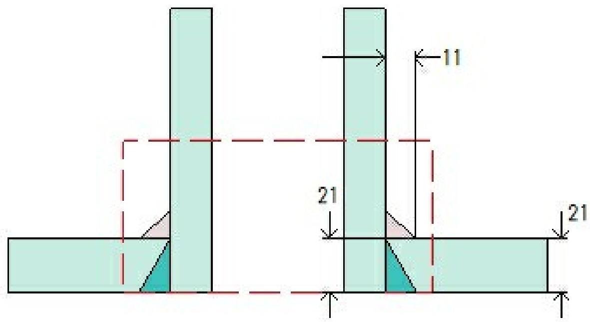
$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 164{,}47}{3 \cdot (84{,}07/0{,}38)} = 1\ \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}38 + 1{,}6 = 1{,}98$ mm

Nozzle (F2)

ASME Section VIII Division 1, 2021 Edition Metric	



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

Location and Orientation	
Located on	Shell V1
Orientation	225°
Nozzle center line offset to datum line	950 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	16,64 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	181,65 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-104°C
Liquid static head	0 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	21,25 bar
MAWP rating	45,97 bar @ 121°C
MAP rating	51,1 bar @ 7°C
Hydrotest rating	77 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 77{,}9^{\,3}} / 1{,}02 \cdot 100 =$	18,38 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot -139{,}7}{\pi \cdot 77{,}9^{\,2}} / 1{,}02 \cdot 100 =$	2,87 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[18{,}38 + 2{,}87, 0\right] =$	21,25 bar
Table UG-44-1 Moment Factor, $F_M =$	0,5
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[45{,}97, 45{,}97 \cdot (1 + 0{,}5) - 21{,}25\right] - 0 =$	45,97 bar
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. Stress ratio = 0,3112 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C. Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-104°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,78 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	16,64

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,78	-139,7	40,8	139,7	40,8	139,7	40,8	**1.160,979**	**3.609,796**	**1.010,663**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	259,362	3.609,796	21,303	1.804,898	No
Load case 1 (Pr Reversed)	16,78	139,7	40,8	139,7	40,8	139,7	40,8	1.119,357	3.609,796	996,32	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-255,566	3.609,796	-21,303	1.804,898	No

Calculations for internal pressure 16,78 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 59{,}84 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$

$$= 37{,}59 \text{ mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 0{,}31 \text{ mm}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 12{,}91 \quad \text{mm}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\text{min}} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\text{min})} = \min\left[6\ \text{mm},\ 0{,}7 \cdot t_{\text{min}}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1\ \ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 1{,}91 \quad \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}71 \quad \text{mm}$$

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

$$= \max\left[1{,}91,\ 2{,}71\right]$$

$$= 2{,}71 \quad \text{mm}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 14{,}51 \quad \text{mm}$$

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

$$= \max\left[14{,}51,\ 3{,}1\right]$$

$$= 14{,}51 \quad \text{mm}$$

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

$$= \min\left[6{,}4,\ 14{,}51\right]$$

$$= 6{,}4 \quad \text{mm}$$

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

$$= \max\left[2{,}71,\ 6{,}4\right]$$

$$= 6{,}4 \quad \text{mm}$$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	16,78 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 40{,}44}{909{,}7} = 0{,}0389$$

Pressure stress intensity factor, $I = 1{,}2464$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \frac{I \cdot P \cdot R_i}{T} = 989{,}36 \;\; kg_f/cm^2$

Local longitudinal pressure stress $= \frac{I \cdot P \cdot R_i}{2 \cdot T} = 494{,}68 \;\; kg_f/cm^2$

Maximum combined stress $(P_L + P_b + Q) = 1.160{,}98 \;\; kg_f/cm^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \;\; kg_f/cm^2$

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

Maximum local primary membrane stress $(P_L) = 1.010{,}66 \;\; kg_f/cm^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \;\; kg_f/cm^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	$\frac{N_\phi}{P\ /\ R_m}$	9,0035	0	0	0	0	7,101	7,101	7,101	7,101
4C*	$\frac{N_\phi}{P\ /\ R_m}$	9,0286	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2092	0	0	0	0	46,614	-46,614	46,614	-46,614
2C-1	$\frac{M_\phi}{P}$	0,1632	36,349	-36,349	36,349	-36,349	0	0	0	0
3A*	$\frac{N_\phi}{M_c\ /\ (R_m^2 \cdot \beta)}$	0,4576	0	0	0	0	-3,023	-3,023	3,023	3,023
1A	$\frac{M_\phi}{M_c\ /\ (R_m \cdot \beta)}$	0,1064	0	0	0	0	-195,594	195,594	195,594	-195,594
3B*	$\frac{N_\phi}{M_L\ /\ (R_m^2 \cdot \beta)}$	2,1599	-14,132	-14,132	14,132	14,132	0	0	0	0
1B-1	$\frac{M_\phi}{M_L\ /\ (R_m \cdot \beta)}$	0,0618	-113,546	113,546	113,546	-113,546	0	0	0	0
Pressure stress*			989,36	989,36	989,36	989,36	793,766	793,766	793,766	793,766
Total circumferential stress			905,202	1.059,596	1.160,557	860,768	648,863	946,824	1.046,097	561,682
Primary membrane circumferential stress*			982,399	982,399	1.010,663	1.010,663	797,843	797,843	803,89	803,89
3C*	$\frac{N_x}{P\ /\ R_m}$	9,0035	7,101	7,101	7,101	7,101	0	0	0	0
4C*	$\frac{N_x}{P\ /\ R_m}$	9,0286	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2145	47,738	-47,738	47,738	-47,738	0	0	0	0
2C	$\frac{M_x}{P}$	0,1608	0	0	0	0	35,786	-35,786	35,786	-35,786
4A*	$\frac{N_x}{M_c\ /\ (R_m^2 \cdot \beta)}$	0,7155	0	0	0	0	-4,64	-4,64	4,64	4,64
2A	$\frac{M_x}{M_c\ /\ (R_m \cdot \beta)}$	0,0621	0	0	0	0	-114,108	114,108	114,108	-114,108
4B*	$\frac{N_x}{M_L\ /\ (R_m^2 \cdot \beta)}$	0,5274	-3,445	-3,445	3,445	3,445	0	0	0	0
2B-1	$\frac{M_x}{M_L\ /\ (R_m \cdot \beta)}$	0,1029	-189,196	189,196	189,196	-189,196	0	0	0	0
Pressure stress*			396,883	396,883	396,883	396,883	494,68	494,68	494,68	494,68
Total longitudinal stress			259,081	541,996	644,363	170,494	418,889	575,533	656,386	356,597
Primary membrane longitudinal stress*			400,539	400,539	407,429	407,429	497,211	497,211	506,491	506,491
Shear from M_t			20,459	20,459	20,459	20,459	20,459	20,459	20,459	20,459
Circ shear from V_c			5,695	5,695	-5,695	-5,695	0	0	0	0
Long shear from V_L			0	0	0	0	-5,695	-5,695	5,695	5,695
Total Shear stress			26,154	26,154	14,764	14,764	14,764	14,764	26,154	26,154
Combined stress (P_L+P_b+Q)			906,257	1.060,932	1.160,979	861,049	649,777	947,386	1.047,855	564,987
* denotes primary stress.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}78 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 15{,}04} - \frac{-139{,}7}{\pi \cdot \left(40{,}44^{\,2} - 25{,}4^{\,2}\right)} \cdot 100 + \frac{57.698{,}1 \cdot 40{,}44}{1.772.985} \cdot 100$$

$$= 150{,}536 \ \ \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^{\,2}}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\,2} + 139{,}7^{\,2}}}{\pi \cdot 25{,}4 \cdot 15{,}04} \cdot 100 = 16{,}466 \ \ \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\,2} \cdot 15{,}04} \cdot 100000 = 66{,}934 \ \ \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 16{,}466 + 66{,}934 = 83{,}399 \ \ \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}$$

UG-45: The total combined shear stress (83,399 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \ \ \mathrm{kg}_{\,f}/\mathrm{cm}^{\,2}\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	16,64

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 59{,}84 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$

$$= 37{,}59 \text{ mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,38 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}98 \text{ mm}$$

$$t_{a\text{UG-22}} = 2{,}48 \text{ mm}$$

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

$=$ $\max\left[1{,}98,\ \ 2{,}48\right]$

$=$ $2{,}48\ \ \text{mm}$

$$t_{b2} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$$

$$= 2{,}36\ \ \text{mm}$$

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

$=$ $\max\left[2{,}36,\ \ 3{,}1\right]$

$=$ $3{,}1\ \ \text{mm}$

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

$=$ $\min\left[6{,}4,\ \ 3{,}1\right]$

$=$ $3{,}1\ \ \text{mm}$

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

$=$ $\max\left[2{,}48,\ \ 3{,}1\right]$

$=$ $3{,}1\ \ \text{mm}$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}96}{84{,}07} = 2{,}4379$$

$$\frac{D_o}{t} = \frac{84{,}07}{0{,}38} = 219{,}2887$$

From table G: $A = 0{,}000164$

From table CS-2 Metric: $B = 167{,}7082\ \ \text{kg/cm}^2 (164{,}47\ \ \text{bar})$

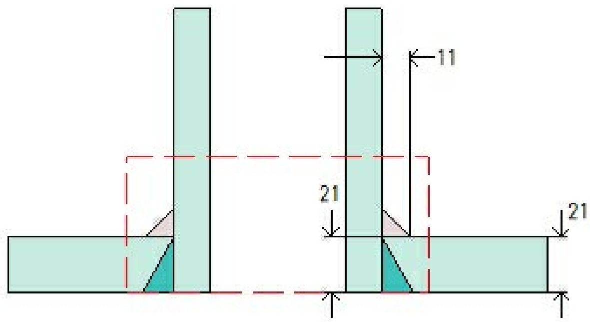
$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 164{,}47}{3 \cdot (84{,}07/0{,}38)} = 1\ \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}38 + 1{,}6 = 1{,}98$ mm

Nozzle (G)

ASME Section VIII Division 1, 2021 Edition Metric	



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

Location and Orientation	
Located on	Shell V1
Orientation	135°
Nozzle center line offset to datum line	200 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	13,46 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	184,95 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0,03 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 150 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-53,7°C
Liquid static head	0,03 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	21,25 bar
MAWP rating	16,9 bar @ 121°C
MAP rating	19,6 bar @ 7°C
Hydrotest rating	30 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No

MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 77{,}9^{\ 3}} / 1{,}02 \cdot 100 =$	18,38 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot \ -139{,}7}{\pi \cdot 77{,}9^{\ 2}} / 1{,}02 \cdot 100 =$	2,87 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[18{,}38 + 2{,}87, 0\right] =$	21,25 bar
Table UG-44-1 Moment Factor, $F_M =$	1,2
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[16{,}9, 16{,}9 \cdot (1 + 1{,}2) - 21{,}25\right] - 0{,}03 =$	15,9 bar

Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm

Notes
(1) Flange is impact tested per material specification to -46°C. UCS-66(i) reduction of 7,7°C applied (ratio = 0,8623). Bolts rated MDMT per Fig UCS-66 note (c) = -104°C
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-53,7°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 15,93 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	13,46

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	15,93	-139,7	40,8	139,7	40,8	139,7	40,8	**1.231,497**	**3.609,796**	**1.067,681**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	279,4	3.609,796	21,022	1.804,898	No
Load case 1 (Pr Reversed)	15,93	139,7	40,8	139,7	40,8	139,7	40,8	1.190,508	3.609,796	1.053,339	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-278,626	3.609,796	-21,022	1.804,898	No

Calculations for internal pressure 15,93 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (13{,}46 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 56{,}66 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (13{,}46 - 1{,}6) + 0\right]$$

$$= 29{,}65 \text{ mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{15{,}9324 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 15{,}9324}$$

$$= 0{,}29 \text{ mm}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$$

$$= \frac{15{,}9324 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}9324}$$

$$= 12{,}25 \quad \text{mm}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 11,86 mm

$t_{c(\min)} = \min\left[6\ \text{mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1\ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{15{,}9324 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 15{,}9324} + 1{,}6$$

$$= 1{,}89 \quad \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}84 \quad \text{mm}$$

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

$$= \max\left[1{,}89,\ 2{,}84\right]$$

$$= 2{,}84 \quad \text{mm}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{15{,}9324 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}9324} + 1{,}6$$

$$= 13{,}85 \quad \text{mm}$$

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

$$= \max\left[13{,}85,\ 3{,}1\right]$$

$$= 13{,}85 \quad \text{mm}$$

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

$$= \min\left[6{,}4,\ 13{,}85\right]$$

$$= 6{,}4 \quad \text{mm}$$

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

$$= \max\left[2{,}84,\ 6{,}4\right]$$

$$= 6{,}4 \quad \text{mm}$$

Available nozzle wall thickness new, t_n = 13,46 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	15,93 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 37{,}26}{909{,}7} = 0{,}0358$$

Pressure stress intensity factor, $I = 1{,}3888$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \dfrac{I \cdot P \cdot R_i}{T} = 1.046{,}66 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Local longitudinal pressure stress $= \dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 523{,}365 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 1.231{,}5 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.067{,}68 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	$\frac{N_\phi}{P \ / \ R_m}$	9,0998	0	0	0	0	7,171	7,171	7,171	7,171
4C*	$\frac{N_\phi}{P \ / \ R_m}$	9,0709	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2174	0	0	0	0	48,441	-48,441	48,441	-48,441
2C-1	$\frac{M_\phi}{P}$	0,1709	38,036	-38,036	38,036	-38,036	0	0	0	0
3A*	$\frac{N_\phi}{M_c \ / \ (R_m^2 \cdot \beta)}$	0,4136	0	0	0	0	-2,953	-2,953	2,953	2,953
1A	$\frac{M_\phi}{M_c \ / \ (R_m \cdot \beta)}$	0,1064	0	0	0	0	-212,257	212,257	212,257	-212,257
3B*	$\frac{N_\phi}{M_L \ / \ (R_m^2 \cdot \beta)}$	1,9568	-13,85	-13,85	13,85	13,85	0	0	0	0
1B-1	$\frac{M_\phi}{M_L \ / \ (R_m \cdot \beta)}$	0,0628	-125,217	125,217	125,217	-125,217	0	0	0	0
Pressure stress*			1.046,66	1.046,66	1.046,66	1.046,66	753,691	753,691	753,691	753,691
Total circumferential stress			952,8	1.127,161	1.230,934	904,429	594,094	921,724	1.024,513	503,117
Primary membrane circumferential stress*			1.039,981	1.039,981	1.067,681	1.067,681	757,909	757,909	763,815	763,815
3C*	$\frac{N_x}{P \ / \ R_m}$	9,0998	7,171	7,171	7,171	7,171	0	0	0	0
4C*	$\frac{N_x}{P \ / \ R_m}$	9,0709	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2227	49,566	-49,566	49,566	-49,566	0	0	0	0
2C	$\frac{M_x}{P}$	0,1677	0	0	0	0	37,333	-37,333	37,333	-37,333
4A*	$\frac{N_x}{M_c \ / \ (R_m^2 \cdot \beta)}$	0,6345	0	0	0	0	-4,5	-4,5	4,5	4,5
2A	$\frac{M_x}{M_c \ / \ (R_m \cdot \beta)}$	0,0623	0	0	0	0	-124,232	124,232	124,232	-124,232
4B*	$\frac{N_x}{M_L \ / \ (R_m^2 \cdot \beta)}$	0,4806	-3,375	-3,375	3,375	3,375	0	0	0	0
2B-1	$\frac{M_x}{M_L \ / \ (R_m \cdot \beta)}$	0,1047	-208,812	208,812	208,812	-208,812	0	0	0	0
Pressure stress*			376,845	376,845	376,845	376,845	523,365	523,365	523,365	523,365
Total longitudinal stress			221,397	539,887	645,769	129,013	439,137	612,936	696,601	373,471
Primary membrane longitudinal stress*			380,642	380,642	387,391	387,391	526,037	526,037	535,036	535,036
Shear from M_t			24,115	24,115	24,115	24,115	24,115	24,115	24,115	24,115
Circ shear from V_c			6,117	6,117	-6,117	-6,117	0	0	0	0
Long shear from V_L			0	0	0	0	-6,117	-6,117	6,117	6,117
Total Shear stress			30,232	30,232	17,999	17,999	17,999	17,999	30,232	30,232
Combined stress (P_L+P_b+Q)			954,065	1.128,708	1.231,497	904,851	596,133	922,779	1.027,255	509,796
* denotes primary stress.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{15{,}93 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 11{,}86} - \frac{-139{,}7}{\pi \cdot \left(37{,}26^{\,2} - 25{,}4^{\,2}\right)} \cdot 100 + \frac{57.699{,}7 \cdot 37{,}26}{1.187.160} \cdot 100$$

$$= 204{,}482 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^2}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\,2} + 139{,}7^{\,2}}}{\pi \cdot 25{,}4 \cdot 11{,}86} \cdot 100 = 20{,}873 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\mathrm{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\,2} \cdot 11{,}86} \cdot 100000 = 84{,}852 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\mathrm{total}} = \sigma_{\mathrm{shear}} + \sigma_{\mathrm{torsion}} = 20{,}873 + 84{,}852 = 105{,}725 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

UG-45: The total combined shear stress (105,725 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \ \ \mathrm{kg}_f/\mathrm{cm}^2\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	13,46

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (13{,}46 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 56{,}66 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (13{,}46 - 1{,}6) + 0\right]$$

$$= 29{,}65 \text{ mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,37 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 11,86 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}97 \text{ mm}$$

$$t_{a\text{UG-22}} = 2{,}64 \text{ mm}$$

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

$= \quad \max\left[1{,}97,\ \ 2{,}64\right]$

$= \quad 2{,}64\ \ \text{mm}$

$$t_{b2} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$$

$= \quad 2{,}36\ \ \text{mm}$

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

$= \quad \max\left[2{,}36,\ \ 3{,}1\right]$

$= \quad 3{,}1\ \ \text{mm}$

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

$= \quad \min\left[6{,}4,\ \ 3{,}1\right]$

$= \quad 3{,}1\ \ \text{mm}$

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

$= \quad \max\left[2{,}64,\ \ 3{,}1\right]$

$= \quad 3{,}1\ \ \text{mm}$

Available nozzle wall thickness new, t_n = 13,46 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}82}{77{,}72} = 2{,}6352$$

$$\frac{D_o}{t} = \frac{77{,}72}{0{,}37} = 211{,}7836$$

From table G: $A = 0{,}000159$

From table CS-2 Metric: $B = 161{,}9607\ \ \text{kg/cm}^2 (158{,}83\ \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 158{,}83}{3 \cdot (77{,}72/0{,}37)} = 1\ \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}37 + 1{,}6 = 1{,}97$ mm

Nozzle (K1)

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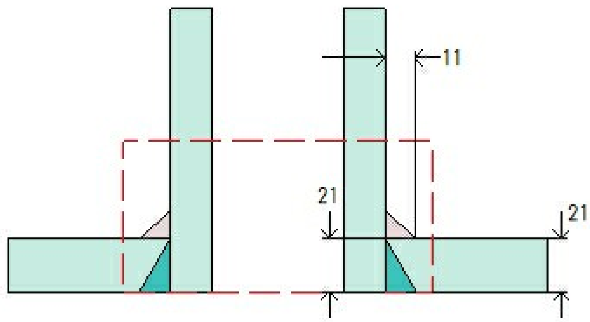

Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	Shell V1
Orientation	315°
Nozzle center line offset to datum line	200 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	16,64 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	181,65 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0,03 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-104°C
Liquid static head	0,03 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	21,25 bar
MAWP rating	45,97 bar @ 121°C
MAP rating	51,1 bar @ 7°C
Hydrotest rating	77 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 77{,}9^{\,3}} / 1{,}02 \cdot 100 =$	18,38 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot -139{,}7}{\pi \cdot 77{,}9^{\,2}} / 1{,}02 \cdot 100 =$	2,87 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[18{,}38 + 2{,}87, 0\right] =$	21,25 bar
Table UG-44-1 Moment Factor, $F_M =$	0,5
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[45{,}97, 45{,}97 \cdot (1 + 0{,}5) - 21{,}25\right] - 0{,}03 =$	45,94 bar
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. Stress ratio = 0,3117 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C. Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-104°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,81 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	16,64

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,81	-139,7	40,8	139,7	40,8	139,7	40,8	**1.162,877**	**3.609,796**	**1.012,561**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	259,362	3.609,796	21,303	1.804,898	No
Load case 1 (Pr Reversed)	16,81	139,7	40,8	139,7	40,8	139,7	40,8	1.121,255	3.609,796	998,218	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-255,566	3.609,796	-21,303	1.804,898	No

Calculations for internal pressure 16,81 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 59{,}84 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$

$$= 37{,}59 \text{ mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}8114 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}8114}$$

$$= 0{,}31 \text{ mm}$$

Required thickness t_r from UG-37(a)

$t_r \quad = \quad \dfrac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$

$= \quad \dfrac{16{,}8114 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}8114}$

$= \quad 12{,}93 \quad \text{mm}$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6\ \text{mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \quad \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-27}} \quad = \quad \dfrac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$

$= \quad \dfrac{16{,}8114 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}8114} + 1{,}6$

$= \quad 1{,}91 \quad \text{mm}$

$t_{a\text{UG-22}} \quad = \quad 2{,}71 \quad \text{mm}$

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

$= \quad \max\left[1{,}91,\ 2{,}71\right]$

$= \quad 2{,}71 \quad \text{mm}$

$t_{b1} \quad = \quad \dfrac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$

$= \quad \dfrac{16{,}8114 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}8114} + 1{,}6$

$= \quad 14{,}53 \quad \text{mm}$

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

$= \quad \max\left[14{,}53,\ 3{,}1\right]$

$= \quad 14{,}53 \quad \text{mm}$

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

$= \quad \min\left[6{,}4,\ 14{,}53\right]$

$= \quad 6{,}4 \quad \text{mm}$

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

$= \quad \max\left[2{,}71,\ 6{,}4\right]$

$= \quad 6{,}4 \quad \text{mm}$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	16,81 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 40{,}44}{909{,}7} = 0{,}0389$$

Pressure stress intensity factor, $I = 1{,}2464$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \frac{I \cdot P \cdot R_i}{T} = 991{,}258 \ \ kg_f/cm^2$

Local longitudinal pressure stress $= \frac{I \cdot P \cdot R_i}{2 \cdot T} = 495{,}594 \ \ kg_f/cm^2$

Maximum combined stress $(P_L + P_b + Q) = 1.162{,}88 \ \ kg_f/cm^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ kg_f/cm^2$

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

Maximum local primary membrane stress $(P_L) = 1.012{,}56 \ \ kg_f/cm^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ kg_f/cm^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	$\frac{N_\phi}{P\ /\ R_m}$	9,0035	0	0	0	0	7,101	7,101	7,101	7,101
4C*	$\frac{N_\phi}{P\ /\ R_m}$	9,0286	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2092	0	0	0	0	46,614	-46,614	46,614	-46,614
2C-1	$\frac{M_\phi}{P}$	0,1632	36,349	-36,349	36,349	-36,349	0	0	0	0
3A*	$\frac{N_\phi}{M_c\ /\ (R_m^2 \cdot \beta)}$	0,4576	0	0	0	0	-3,023	-3,023	3,023	3,023
1A	$\frac{M_\phi}{M_c\ /\ (R_m \cdot \beta)}$	0,1064	0	0	0	0	-195,594	195,594	195,594	-195,594
3B*	$\frac{N_\phi}{M_L\ /\ (R_m^2 \cdot \beta)}$	2,1599	-14,132	-14,132	14,132	14,132	0	0	0	0
1B-1	$\frac{M_\phi}{M_L\ /\ (R_m \cdot \beta)}$	0,0618	-113,546	113,546	113,546	-113,546	0	0	0	0
Pressure stress*			991,258	991,258	991,258	991,258	795,312	795,312	795,312	795,312
Total circumferential stress			907,1	1.061,494	1.162,455	862,666	650,41	948,371	1.047,644	563,229
Primary membrane circumferential stress*			984,297	984,297	1.012,561	1.012,561	799,39	799,39	805,437	805,437
3C*	$\frac{N_x}{P\ /\ R_m}$	9,0035	7,101	7,101	7,101	7,101	0	0	0	0
4C*	$\frac{N_x}{P\ /\ R_m}$	9,0286	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2145	47,738	-47,738	47,738	-47,738	0	0	0	0
2C	$\frac{M_x}{P}$	0,1608	0	0	0	0	35,786	-35,786	35,786	-35,786
4A*	$\frac{N_x}{M_c\ /\ (R_m^2 \cdot \beta)}$	0,7155	0	0	0	0	-4,64	-4,64	4,64	4,64
2A	$\frac{M_x}{M_c\ /\ (R_m \cdot \beta)}$	0,0621	0	0	0	0	-114,108	114,108	114,108	-114,108
4B*	$\frac{N_x}{M_L\ /\ (R_m^2 \cdot \beta)}$	0,5274	-3,445	-3,445	3,445	3,445	0	0	0	0
2B-1	$\frac{M_x}{M_L\ /\ (R_m \cdot \beta)}$	0,1029	-189,196	189,196	189,196	-189,196	0	0	0	0
Pressure stress*			397,656	397,656	397,656	397,656	495,594	495,594	495,594	495,594
Total longitudinal stress			259,855	542,77	645,137	171,268	419,803	576,447	657,3	357,511
Primary membrane longitudinal stress*			401,312	401,312	408,202	408,202	498,125	498,125	507,405	507,405
Shear from M_t			20,459	20,459	20,459	20,459	20,459	20,459	20,459	20,459
Circ shear from V_c			5,695	5,695	-5,695	-5,695	0	0	0	0
Long shear from V_L			0	0	0	0	-5,695	-5,695	5,695	5,695
Total Shear stress			26,154	26,154	14,764	14,764	14,764	14,764	26,154	26,154
Combined stress (P_L+P_b+Q)			908,155	1.062,83	1.162,877	862,948	651,324	948,933	1.049,402	566,533
* denotes primary stress.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}81 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 15{,}04} - \frac{-139{,}7}{\pi \cdot \left(40{,}44^{\ 2} - 25{,}4^{\ 2}\right)} \cdot 100 + \frac{57.698{,}1 \cdot 40{,}44}{1.772.985} \cdot 100$$

$$= 150{,}564 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^{\,2}}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\ 2} + 139{,}7^{\ 2}}}{\pi \cdot 25{,}4 \cdot 15{,}04} \cdot 100 = 16{,}466 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

$$\sigma_{\mathrm{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\ 2} \cdot 15{,}04} \cdot 100000 = 66{,}934 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

$$\sigma_{\mathrm{total}} = \sigma_{\mathrm{shear}} + \sigma_{\mathrm{torsion}} = 16{,}466 + 66{,}934 = 83{,}399 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

UG-45: The total combined shear stress (83,399 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	16,64

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ \ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 59{,}84 \ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ \ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ \ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$

$$= 37{,}59 \ \text{mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,38 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6 \ \text{mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}98 \ \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}48 \ \text{mm}$$

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

$= \quad \max\left[1{,}98,\ \ 2{,}48\right]$

$= \quad 2{,}48 \ \ \text{mm}$

$$t_{b2} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$$

$$= 2{,}36 \ \ \text{mm}$$

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

$= \quad \max\left[2{,}36,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

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

$= \quad \min\left[6{,}4,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

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

$= \quad \max\left[2{,}48,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}96}{84{,}07} = 2{,}4379$$

$$\frac{D_o}{t} = \frac{84{,}07}{0{,}38} = 219{,}2887$$

From table G: $A = 0{,}000164$

From table CS-2 Metric: $B = 167{,}7082 \ \ \text{kg/cm}^2 (164{,}47 \ \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 164{,}47}{3 \cdot (84{,}07/0{,}38)} = 1 \ \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}38 + 1{,}6 = 1{,}98$ mm

Nozzle (K2)

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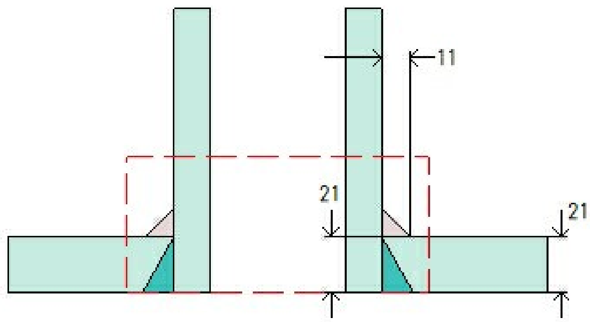


Note: round inside edges per UG-76(c)

Location and Orientation	
Located on	Shell V1
Orientation	315°
Nozzle center line offset to datum line	950 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	13,46 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	184,95 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 150 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-53,8°C
Liquid static head	0 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	21,25 bar
MAWP rating	16,9 bar @ 121°C
MAP rating	19,6 bar @ 7°C
Hydrotest rating	30 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 77{,}9^{\,3}} / 1{,}02 \cdot 100 =$	18,38 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot \; -139{,}7}{\pi \cdot 77{,}9^{\,2}} / 1{,}02 \cdot 100 =$	2,87 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[18{,}38 + 2{,}87, 0\right] =$	21,25 bar
Table UG-44-1 Moment Factor, $F_M =$	1,2
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s = \min\left[16{,}9, 16{,}9 \cdot (1 + 1{,}2) - 21{,}25\right] - 0 =$	15,93 bar
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. UCS-66(i) reduction of 7,8°C applied (ratio = 0,8607). Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-53,8°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 15,93 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	13,46

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	15,93	-139,7	40,8	139,7	40,8	139,7	40,8	**1.231,497**	**3.609,796**	**1.067,681**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	279,33	3.609,796	21,022	1.804,898	No
Load case 1 (Pr Reversed)	15,93	139,7	40,8	139,7	40,8	139,7	40,8	1.190,508	3.609,796	1.053,339	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-278,626	3.609,796	-21,022	1.804,898	No

Calculations for internal pressure 15,93 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (13{,}46 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 56{,}66 \quad \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (13{,}46 - 1{,}6) + 0\right]$$

$$= 29{,}65 \quad \text{mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{15{,}932 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 15{,}932}$$

$$= 0{,}29 \quad \text{mm}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$$

$$= \frac{15{,}932 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}932}$$

$$= 12{,}25 \quad \text{mm}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\text{min}} = \min\left[19mm,\ t_n,\ t\right] =$ 11,86 mm

$t_{c(\text{min})} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\text{min}}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \quad \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{15{,}932 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 15{,}932} + 1{,}6$$

$$= 1{,}89 \quad \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}84 \quad \text{mm}$$

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

$$= \max\left[1{,}89,\ 2{,}84\right]$$

$$= 2{,}84 \quad \text{mm}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{15{,}932 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}932} + 1{,}6$$

$$= 13{,}85 \quad \text{mm}$$

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

$$= \max\left[13{,}85,\ 3{,}1\right]$$

$$= 13{,}85 \quad \text{mm}$$

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

$$= \min\left[6{,}4,\ 13{,}85\right]$$

$$= 6{,}4 \quad \text{mm}$$

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

$$= \max\left[2{,}84,\ 6{,}4\right]$$

$$= 6{,}4 \quad \text{mm}$$

Available nozzle wall thickness new, t_n = 13,46 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	15,93 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 37{,}26}{909{,}7} = 0{,}0358$$

Pressure stress intensity factor, $I = 1{,}3888$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \frac{I \cdot P \cdot R_i}{T} = 1.046{,}66 \ \text{kg}_f/\text{cm}^2$

Local longitudinal pressure stress $= \frac{I \cdot P \cdot R_i}{2 \cdot T} = 523{,}365 \ \text{kg}_f/\text{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 1.231{,}5 \ \text{kg}_f/\text{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \text{kg}_f/\text{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.067{,}68 \ \text{kg}_f/\text{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \text{kg}_f/\text{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537

Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	$\frac{N_\phi}{P \;/\; R_m}$	9,0998	0	0	0	0	7,171	7,171	7,171	7,171
4C*	$\frac{N_\phi}{P \;/\; R_m}$	9,0709	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2174	0	0	0	0	48,441	-48,441	48,441	-48,441
2C-1	$\frac{M_\phi}{P}$	0,1709	38,036	-38,036	38,036	-38,036	0	0	0	0
3A*	$\frac{N_\phi}{M_c \;/\; (R_m^2 \cdot \beta)}$	0,4136	0	0	0	0	-2,953	-2,953	2,953	2,953
1A	$\frac{M_\phi}{M_c \;/\; (R_m \cdot \beta)}$	0,1064	0	0	0	0	-212,186	212,186	212,186	-212,186
3B*	$\frac{N_\phi}{M_L \;/\; (R_m^2 \cdot \beta)}$	1,9568	-13,85	-13,85	13,85	13,85	0	0	0	0
1B-1	$\frac{M_\phi}{M_L \;/\; (R_m \cdot \beta)}$	0,0628	-125,217	125,217	125,217	-125,217	0	0	0	0
Pressure stress*			1.046,66	1.046,66	1.046,66	1.046,66	753,691	753,691	753,691	753,691
Total circumferential stress			952,8	1.127,161	1.230,934	904,429	594,164	921,654	1.024,443	503,187
Primary membrane circumferential stress*			1.039,981	1.039,981	1.067,681	1.067,681	757,909	757,909	763,815	763,815
3C*	$\frac{N_x}{P \;/\; R_m}$	9,0998	7,171	7,171	7,171	7,171	0	0	0	0
4C*	$\frac{N_x}{P \;/\; R_m}$	9,0709	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2227	49,566	-49,566	49,566	-49,566	0	0	0	0
2C	$\frac{M_x}{P}$	0,1677	0	0	0	0	37,333	-37,333	37,333	-37,333
4A*	$\frac{N_x}{M_c \;/\; (R_m^2 \cdot \beta)}$	0,6345	0	0	0	0	-4,5	-4,5	4,5	4,5
2A	$\frac{M_x}{M_c \;/\; (R_m \cdot \beta)}$	0,0623	0	0	0	0	-124,232	124,232	124,232	-124,232
4B*	$\frac{N_x}{M_L \;/\; (R_m^2 \cdot \beta)}$	0,4806	-3,375	-3,375	3,375	3,375	0	0	0	0
2B-1	$\frac{M_x}{M_L \;/\; (R_m \cdot \beta)}$	0,1047	-208,812	208,812	208,812	-208,812	0	0	0	0
Pressure stress*			376,845	376,845	376,845	376,845	523,365	523,365	523,365	523,365
Total longitudinal stress			221,397	539,887	645,769	129,013	439,137	612,936	696,601	373,471
Primary membrane longitudinal stress*			380,642	380,642	387,391	387,391	526,037	526,037	535,036	535,036
Shear from M_t			24,115	24,115	24,115	24,115	24,115	24,115	24,115	24,115
Circ shear from V_c			6,117	6,117	-6,117	-6,117	0	0	0	0
Long shear from V_L			0	0	0	0	-6,117	-6,117	6,117	6,117
Total Shear stress			30,232	30,232	17,999	17,999	17,999	17,999	30,232	30,232
Combined stress (P_L+P_b+Q)			954,065	1.128,708	1.231,497	904,851	596,203	922,709	1.027,185	509,866

* denotes primary stress.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{15{,}93 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 11{,}86} - \frac{-139{,}7}{\pi \cdot \left(37{,}26^{\ 2} - 25{,}4^{\ 2}\right)} \cdot 100 + \frac{57.698{,}1 \cdot 37{,}26}{1.187.160} \cdot 100$$

$$= 204{,}476 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^{\,2}}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\ 2} + 139{,}7^{\ 2}}}{\pi \cdot 25{,}4 \cdot 11{,}86} \cdot 100 = 20{,}873 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

$$\sigma_{\mathrm{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\ 2} \cdot 11{,}86} \cdot 100000 = 84{,}85 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

$$\sigma_{\mathrm{total}} = \sigma_{\mathrm{shear}} + \sigma_{\mathrm{torsion}} = 20{,}873 + 84{,}85 = 105{,}722 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

UG-45: The total combined shear stress (105,722 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	13,46

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (13{,}46 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 56{,}66 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (13{,}46 - 1{,}6) + 0\right]$$

$$= 29{,}65 \text{ mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,37 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 11,86 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}97 \text{ mm}$$

$$t_{a\text{UG-22}} = 2{,}64 \text{ mm}$$

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

$=$ $\max\left[1{,}97,\ \ 2{,}64\right]$

$=$ $2{,}64\ \ \text{mm}$

t_{b2} = $\dfrac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$

= $\dfrac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$

= $2{,}36\ \ \text{mm}$

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

$=$ $\max\left[2{,}36,\ \ 3{,}1\right]$

$=$ $3{,}1\ \ \text{mm}$

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

$=$ $\min\left[6{,}4,\ \ 3{,}1\right]$

$=$ $3{,}1\ \ \text{mm}$

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

$=$ $\max\left[2{,}64,\ \ 3{,}1\right]$

$=$ $3{,}1\ \ \text{mm}$

Available nozzle wall thickness new, t_n = 13,46 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}82}{77{,}72} = 2{,}6352$$

$$\frac{D_o}{t} = \frac{77{,}72}{0{,}37} = 211{,}7836$$

From table G: $A = 0{,}000159$

From table CS-2 Metric: $B = 161{,}9607\ \ \text{kg/cm}^2 (158{,}83\ \ \text{bar})$

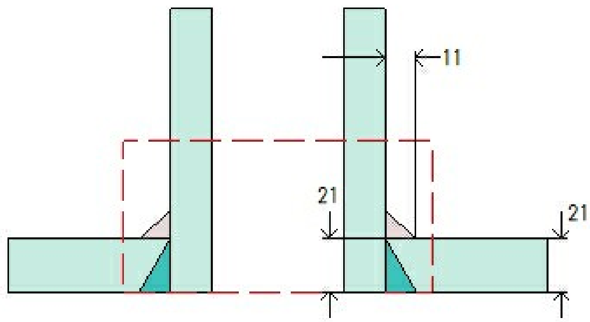
$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 158{,}83}{3 \cdot (77{,}72/0{,}37)} = 1\ \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}37 + 1{,}6 = 1{,}97$ mm

Nozzle (L1)

ASME Section VIII Division 1, 2021 Edition Metric	



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

Location and Orientation	
Located on	Shell V1
Orientation	195°
Nozzle center line offset to datum line	224 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	16,64 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	181,65 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0,03 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-104°C
Liquid static head	0,03 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	21,25 bar
MAWP rating	45,97 bar @ 121°C
MAP rating	51,1 bar @ 7°C
Hydrotest rating	77 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 77{,}9^{\ 3}} / 1{,}02 \cdot 100 =$	18,38 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot\ -139{,}7}{\pi \cdot 77{,}9^{\ 2}} / 1{,}02 \cdot 100 =$	2,87 bar
$MAWP_{reduction} = \max\ [P_m + P_r, 0] = \max\ [18{,}38 + 2{,}87, 0] =$	21,25 bar
Table UG-44-1 Moment Factor, $F_M =$	0,5
$MAWP = \min\ [MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\ ] - P_s$ $= \min\ [45{,}97, 45{,}97 \cdot (1 + 0{,}5) - 21{,}25] - 0{,}03 =$	45,94 bar
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. Stress ratio = 0,3117 ≤ 0,35, MDMT per UCS-66(b)(3) = -105°C. Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-104°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,81 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	16,64

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,81	-139,7	40,8	139,7	40,8	139,7	40,8	**1.162,666**	**3.609,796**	**1.012,35**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	259,362	3.609,796	21,303	1.804,898	No
Load case 1 (Pr Reversed)	16,81	139,7	40,8	139,7	40,8	139,7	40,8	1.121,044	3.609,796	998,007	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-255,566	3.609,796	-21,303	1.804,898	No

Calculations for internal pressure 16,81 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$

$$= 59{,}84 \quad \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$

$$= 37{,}59 \quad \text{mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}8091 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}8091}$$

$$= 0{,}31 \quad \text{mm}$$

Required thickness t_r from UG-37(a)

$t_r = \dfrac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$

$= \dfrac{16{,}8091 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}8091}$

$= 12{,}93 \text{ mm}$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\,[19mm,\; t_n,\; t] =$ 15,04 mm

$t_{c(\min)} = \min\,[6 \text{ mm},\; 0{,}7 \cdot t_{\min}] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$t_{a\text{UG-27}} = \dfrac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$

$= \dfrac{16{,}8091 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}8091} + 1{,}6$

$= 1{,}91 \text{ mm}$

$t_{a\text{UG-22}} = 2{,}71 \text{ mm}$

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

$= \max\,[1{,}91,\; 2{,}71]$

$= 2{,}71 \text{ mm}$

$t_{b1} = \dfrac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$

$= \dfrac{16{,}8091 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}8091} + 1{,}6$

$= 14{,}53 \text{ mm}$

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

$= \max\,[14{,}53,\; 3{,}1]$

$= 14{,}53 \text{ mm}$

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

$= \min\,[6{,}4,\; 14{,}53]$

$= 6{,}4 \text{ mm}$

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

$= \max\,[2{,}71,\; 6{,}4]$

$=$ 6,4 mm

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	16,81 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 40{,}44}{909{,}7} = 0{,}0389$$

Pressure stress intensity factor, $I = 1{,}2464$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \dfrac{I \cdot P \cdot R_i}{T} = 991{,}047 \ \ kg_f/cm^2$

Local longitudinal pressure stress $= \dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 495{,}523 \ \ kg_f/cm^2$

Maximum combined stress $(P_L + P_b + Q) = 1.162{,}67 \ \ kg_f/cm^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ kg_f/cm^2$

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

Maximum local primary membrane stress $(P_L) = 1.012{,}35 \ \ kg_f/cm^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ kg_f/cm^2$

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

Stresses at the nozzle OD per WRC Bulletin 537

Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	$\frac{N_\phi}{P \;/\; R_m}$	9,0035	0	0	0	0	7,101	7,101	7,101	7,101
4C*	$\frac{N_\phi}{P \;/\; R_m}$	9,0286	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2092	0	0	0	0	46,614	-46,614	46,614	-46,614
2C-1	$\frac{M_\phi}{P}$	0,1632	36,349	-36,349	36,349	-36,349	0	0	0	0
3A*	$\frac{N_\phi}{M_c \;/\; (R_m^2 \cdot \beta)}$	0,4576	0	0	0	0	-3,023	-3,023	3,023	3,023
1A	$\frac{M_\phi}{M_c \;/\; (R_m \cdot \beta)}$	0,1064	0	0	0	0	-195,594	195,594	195,594	-195,594
3B*	$\frac{N_\phi}{M_L \;/\; (R_m^2 \cdot \beta)}$	2,1599	-14,132	-14,132	14,132	14,132	0	0	0	0
1B-1	$\frac{M_\phi}{M_L \;/\; (R_m \cdot \beta)}$	0,0618	-113,546	113,546	113,546	-113,546	0	0	0	0
Pressure stress*			991,047	991,047	991,047	991,047	795,172	795,172	795,172	795,172
Total circumferential stress			906,889	1.061,284	1.162,244	862,455	650,269	948,23	1.047,503	563,088
Primary membrane circumferential stress*			984,086	984,086	1.012,35	1.012,35	799,25	799,25	805,296	805,296
3C*	$\frac{N_x}{P \;/\; R_m}$	9,0035	7,101	7,101	7,101	7,101	0	0	0	0
4C*	$\frac{N_x}{P \;/\; R_m}$	9,0286	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2145	47,738	-47,738	47,738	-47,738	0	0	0	0
2C	$\frac{M_x}{P}$	0,1608	0	0	0	0	35,786	-35,786	35,786	-35,786
4A*	$\frac{N_x}{M_c \;/\; (R_m^2 \cdot \beta)}$	0,7155	0	0	0	0	-4,64	-4,64	4,64	4,64
2A	$\frac{M_x}{M_c \;/\; (R_m \cdot \beta)}$	0,0621	0	0	0	0	-114,108	114,108	114,108	-114,108
4B*	$\frac{N_x}{M_L \;/\; (R_m^2 \cdot \beta)}$	0,5274	-3,445	-3,445	3,445	3,445	0	0	0	0
2B-1	$\frac{M_x}{M_L \;/\; (R_m \cdot \beta)}$	0,1029	-189,196	189,196	189,196	-189,196	0	0	0	0
Pressure stress*			397,586	397,586	397,586	397,586	495,523	495,523	495,523	495,523
Total longitudinal stress			259,784	542,699	645,066	171,197	419,733	576,376	657,229	357,441
Primary membrane longitudinal stress*			401,242	401,242	408,132	408,132	498,054	498,054	507,335	507,335
Shear from M_t			20,459	20,459	20,459	20,459	20,459	20,459	20,459	20,459
Circ shear from V_c			5,695	5,695	-5,695	-5,695	0	0	0	0
Long shear from V_L			0	0	0	0	-5,695	-5,695	5,695	5,695
Total Shear stress			26,154	26,154	14,764	14,764	14,764	14,764	26,154	26,154
Combined stress (P_L+P_b+Q)			907,944	1.062,619	1.162,666	862,737	651,183	948,792	1.049,261	566,393

* denotes primary stress.

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}81 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 15{,}04} - \frac{-139{,}7}{\pi \cdot \left(40{,}44^{\,2} - 25{,}4^{\,2}\right)} \cdot 100 + \frac{57.698{,}1 \cdot 40{,}44}{1.772.985} \cdot 100$$

$$= 150{,}562 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^2}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\,2} + 139{,}7^{\,2}}}{\pi \cdot 25{,}4 \cdot 15{,}04} \cdot 100 = 16{,}466 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\text{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\,2} \cdot 15{,}04} \cdot 100000 = 66{,}934 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\text{total}} = \sigma_{\text{shear}} + \sigma_{\text{torsion}} = 16{,}466 + 66{,}934 = 83{,}399 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

UG-45: The total combined shear stress (83,399 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \ \ \mathrm{kg}_f/\mathrm{cm}^2\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	16,64

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$
$$= 59{,}84 \ \ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$
$$= 37{,}59 \ \ \text{mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,38 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6 \ \text{mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \ \ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}98 \ \ \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}48 \ \ \text{mm}$$

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

$= \quad \max\left[1{,}98,\ \ 2{,}48\right]$

$= \quad 2{,}48 \ \ \text{mm}$

$$t_{b2} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$$

$$= 2{,}36 \ \ \text{mm}$$

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

$= \quad \max\left[2{,}36,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

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

$= \quad \min\left[6{,}4,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

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

$= \quad \max\left[2{,}48,\ \ 3{,}1\right]$

$= \quad 3{,}1 \ \ \text{mm}$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}96}{84{,}07} = 2{,}4379$$

$$\frac{D_o}{t} = \frac{84{,}07}{0{,}38} = 219{,}2887$$

From table G: $A = 0{,}000164$

From table CS-2 Metric: $B = 167{,}7082 \ \ \text{kg/cm}^2 (164{,}47 \ \ \text{bar})$

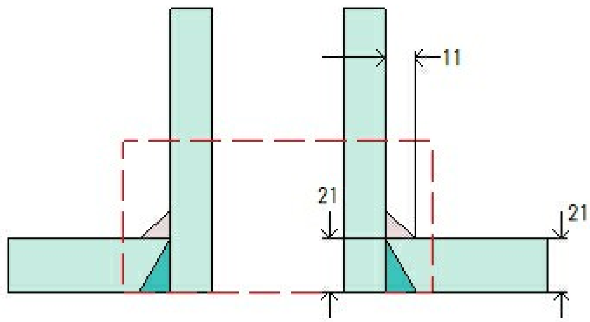
$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 164,47}{3 \cdot (84{,}07/0{,}38)} = 1 \ \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}38 + 1{,}6 = 1{,}98$ mm

Nozzle (L2)

ASME Section VIII Division 1, 2021 Edition Metric	



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

Location and Orientation	
Located on	Shell V1
Orientation	195°
Nozzle center line offset to datum line	950 mm
End of nozzle to shell center	1.125 mm
Passes through a Category A joint	No
Nozzle	
Access opening	No
Material specification	SA-350 LF2 Cl 1 (II-D Metric p. 20, ln. 36) (normalized)
Inside diameter, new	50,8 mm
Nominal wall thickness	16,64 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	181,65 mm
Projection available outside vessel to flange face, Lf	204 mm
Local vessel minimum thickness	21 mm
Liquid static head included	0 bar
Welds	
Inner fillet, Leg_{41}	11 mm
Nozzle to vessel groove weld	21 mm
Radiography	
Longitudinal seam	Seamless No RT

ASME B16.5-2017 Flange	
Description	NPS 2 Class 300 LWN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-99,3°C
Liquid static head	0 bar
Consider External Loads on Flange MAWP Rating	Yes
MAWP reduction due to external loads	27,32 bar
MAWP rating	45,97 bar @ 121°C
MAP rating	51,1 bar @ 7°C
Hydrotest rating	77 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
MAWP Reduction Due to External Loads	
$P_m = \frac{16 \cdot M}{\pi \cdot G^3} = \frac{16 \cdot 17{,}4 \cdot 1000}{\pi \cdot 71{,}37^{\,3}} / 1{,}02 \cdot 100 =$	23,89 bar
$P_r = \frac{-4 \cdot W}{\pi \cdot G^2} = \frac{-4 \cdot -139{,}7}{\pi \cdot 71{,}37^{\,2}} / 1{,}02 \cdot 100 =$	3,42 bar
$MAWP_{reduction} = \max\left[P_m + P_r, 0\right] = \max\left[23{,}89 + 3{,}42, 0\right] =$	27,32 bar
Table UG-44-1 Moment Factor, $F_M =$	0,5
$MAWP = \min\left[MAWP, MAWP \cdot (1 + F_M) - MAWP_{reduction}\right] - P_s$ $= \min\left[45{,}97, 45{,}97 \cdot (1 + 0{,}5) - 27{,}32\right] - 0 =$	41,64 bar
Notes	
(1) Flange is impact tested per material specification to -46°C. UCS-66(i) reduction of 53,3°C applied (ratio = 0,3959). Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	
(2) UG-44(b): The actual assembly bolt load (see Nonmandatory Appendix S) shall comply with ASME PCC-1, Nonmandatory Appendix O.	
(3) UG-44(b): The bolt material shall have an allowable stress equal to or greater than SA-193 B8 Cl. 2 at the specified bolt size and temperature.	

UCS-66 Material Toughness Requirements	
LWN rated MDMT per UCS-66(c)(1) =	-99,3°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,78 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							6,4	16,64

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_c (kg_f-m)	V_c (kg_f)	M_L (kg_f-m)	V_L (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,78	-139,7	40,8	139,7	40,8	139,7	40,8	**1.160,979**	**3.609,796**	**1.010,663**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-139,7	40,8	139,7	40,8	139,7	40,8	259,362	3.609,796	21,303	1.804,898	No
Load case 1 (Pr Reversed)	16,78	139,7	40,8	139,7	40,8	139,7	40,8	1.119,357	3.609,796	996,32	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	139,7	40,8	139,7	40,8	139,7	40,8	-255,566	3.609,796	-21,303	1.804,898	No

Calculations for internal pressure 16,78 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$
$$= 59{,}84\ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$
$$= 37{,}59\ \text{mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$
$$= \frac{16{,}7791 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$
$$= 0{,}31\ \text{mm}$$

Required thickness t_r from UG-37(a)

$$t_r = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791}$$

$$= 12{,}91 \text{ mm}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\text{min}} = \text{min}\,[19mm,\ t_n,\ t] =$ 15,04 mm

$t_{c(\text{min})} = \text{min}\,[6\ \text{mm},\ 0{,}7 \cdot t_{\text{min}}] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1\ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 25{,}4}{1.380 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 1{,}91\ \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}71\ \text{mm}$$

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

$$= \text{max}\,[1{,}91,\ 2{,}71]$$

$$= 2{,}71\ \text{mm}$$

$$t_{b1} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}7791 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}7791} + 1{,}6$$

$$= 14{,}51\ \text{mm}$$

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

$$= \text{max}\,[14{,}51,\ 3{,}1]$$

$$= 14{,}51\ \text{mm}$$

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

$$= \text{min}\,[6{,}4,\ 14{,}51]$$

$$= 6{,}4\ \text{mm}$$

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

$$= \text{max}\,[2{,}71,\ 6{,}4]$$

$$= 6{,}4\ \text{mm}$$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-139,7 kg_f
Circumferential moment, M_c	40,8 kg_f-m
Circumferential shear, V_c	139,7 kg_f
Longitudinal moment, M_L	40,8 kg_f-m
Longitudinal shear, V_L	139,7 kg_f
Torsion moment, M_t	40,8 kg_f-m
Internal pressure, P	16,78 bar
Mean shell radius, R_m	909,7 mm
Local shell thickness, T	19,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{R_m}{T} = \frac{909{,}7}{19{,}4} = 46{,}8922$$

$$\beta = \frac{0{,}875 \cdot r_o}{R_m} = \frac{0{,}875 \cdot 40{,}44}{909{,}7} = 0{,}0389$$

Pressure stress intensity factor, $I = 1{,}2464$ (derived from Division 2 Part 4.5)

Local circumferential pressure stress $= \dfrac{I \cdot P \cdot R_i}{T} = 989{,}36 \ \ \text{kg}_f/\text{cm}^2$

Local longitudinal pressure stress $= \dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 494{,}68 \ \ \text{kg}_f/\text{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 1.160{,}98 \ \ \text{kg}_f/\text{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ \text{kg}_f/\text{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.010{,}66 \ \ \text{kg}_f/\text{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ \text{kg}_f/\text{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	**Y**		**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	$\frac{N_\phi}{P \;/\; R_m}$	9,0035	0	0	0	0	7,101	7,101	7,101	7,101
4C*	$\frac{N_\phi}{P \;/\; R_m}$	9,0286	7,171	7,171	7,171	7,171	0	0	0	0
1C	$\frac{M_\phi}{P}$	0,2092	0	0	0	0	46,614	-46,614	46,614	-46,614
2C-1	$\frac{M_\phi}{P}$	0,1632	36,349	-36,349	36,349	-36,349	0	0	0	0
3A*	$\frac{N_\phi}{M_c \;/\; (R_m^2 \cdot \beta)}$	0,4576	0	0	0	0	-3,023	-3,023	3,023	3,023
1A	$\frac{M_\phi}{M_c \;/\; (R_m \cdot \beta)}$	0,1064	0	0	0	0	-195,594	195,594	195,594	-195,594
3B*	$\frac{N_\phi}{M_L \;/\; (R_m^2 \cdot \beta)}$	2,1599	-14,132	-14,132	14,132	14,132	0	0	0	0
1B-1	$\frac{M_\phi}{M_L \;/\; (R_m \cdot \beta)}$	0,0618	-113,546	113,546	113,546	-113,546	0	0	0	0
Pressure stress*			989,36	989,36	989,36	989,36	793,766	793,766	793,766	793,766
Total circumferential stress			905,202	1.059,596	1.160,557	860,768	648,863	946,824	1.046,097	561,682
Primary membrane circumferential stress*			982,399	982,399	1.010,663	1.010,663	797,843	797,843	803,89	803,89
3C*	$\frac{N_x}{P \;/\; R_m}$	9,0035	7,101	7,101	7,101	7,101	0	0	0	0
4C*	$\frac{N_x}{P \;/\; R_m}$	9,0286	0	0	0	0	7,171	7,171	7,171	7,171
1C-1	$\frac{M_x}{P}$	0,2145	47,738	-47,738	47,738	-47,738	0	0	0	0
2C	$\frac{M_x}{P}$	0,1608	0	0	0	0	35,786	-35,786	35,786	-35,786
4A*	$\frac{N_x}{M_c \;/\; (R_m^2 \cdot \beta)}$	0,7155	0	0	0	0	-4,64	-4,64	4,64	4,64
2A	$\frac{M_x}{M_c \;/\; (R_m \cdot \beta)}$	0,0621	0	0	0	0	-114,108	114,108	114,108	-114,108
4B*	$\frac{N_x}{M_L \;/\; (R_m^2 \cdot \beta)}$	0,5274	-3,445	-3,445	3,445	3,445	0	0	0	0
2B-1	$\frac{M_x}{M_L \;/\; (R_m \cdot \beta)}$	0,1029	-189,196	189,196	189,196	-189,196	0	0	0	0
Pressure stress*			396,883	396,883	396,883	396,883	494,68	494,68	494,68	494,68
Total longitudinal stress			259,081	541,996	644,363	170,494	418,889	575,533	656,386	356,597
Primary membrane longitudinal stress*			400,539	400,539	407,429	407,429	497,211	497,211	506,491	506,491
Shear from M_t			20,459	20,459	20,459	20,459	20,459	20,459	20,459	20,459
Circ shear from V_c			5,695	5,695	-5,695	-5,695	0	0	0	0
Long shear from V_L			0	0	0	0	-5,695	-5,695	5,695	5,695
Total Shear stress			26,154	26,154	14,764	14,764	14,764	14,764	26,154	26,154
Combined stress (P_L+P_b+Q)			906,257	1.060,932	1.160,979	861,049	649,777	947,386	1.047,855	564,987
* denotes primary stress.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}78 \cdot 1{,}02 \cdot 25{,}4}{2 \cdot 15{,}04} - \frac{-139{,}7}{\pi \cdot \left(40{,}44^{\ 2} - 25{,}4^{\ 2}\right)} \cdot 100 + \frac{57.698{,}1 \cdot 40{,}44}{1.772.985} \cdot 100$$

$$= 150{,}536 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.407,208 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_L^2 + V_c^{\,2}}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{139{,}7^{\ 2} + 139{,}7^{\ 2}}}{\pi \cdot 25{,}4 \cdot 15{,}04} \cdot 100 = 16{,}466 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

$$\sigma_{\mathrm{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{40{,}8}{2 \cdot \pi \cdot 25{,}4^{\ 2} \cdot 15{,}04} \cdot 100000 = 66{,}934 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

$$\sigma_{\mathrm{total}} = \sigma_{\mathrm{shear}} + \sigma_{\mathrm{torsion}} = 16{,}466 + 66{,}934 = 83{,}399 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}$$

UG-45: The total combined shear stress (83,399 kg_f/cm^2) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.407{,}208 = 985{,}046 \ \ \mathrm{kg}_{\ f}/\mathrm{cm}^{\ 2}\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,1	16,64

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	6	6,1 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

$$L_R = \max\left[d,\ R_n + (t_n - C_n) + (t - C)\right]$$
$$= \max\left[50{,}8,\ 25{,}4 + (16{,}64 - 1{,}6) + (21 - 1{,}6)\right]$$
$$= 59{,}84 \ \ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$
$$= \min\left[2{,}5 \cdot (21 - 1{,}6),\ 2{,}5 \cdot (16{,}64 - 1{,}6) + 0\right]$$
$$= 37{,}59 \ \ \text{mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,38 mm

From UG-37(d)(1) required thickness t_r = 6,17 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 15,04 mm

$t_{c(\min)} = \min\left[6 \ \text{mm},\ 0{,}7 \cdot t_{\min}\right] =$ 6 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 8{,}71 = 6{,}1 \ \ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 1{,}98 \ \ \text{mm}$$

$$t_{a\text{UG-22}} = 2{,}48 \ \ \text{mm}$$

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

$= \max\left[1{,}98,\ 2{,}48\right]$

$= 2{,}48\ \text{mm}$

$$t_{b2} = \frac{P \cdot R}{S \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 1} + 1{,}6$$

$= 2{,}36\ \text{mm}$

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

$= \max\left[2{,}36,\ 3{,}1\right]$

$= 3{,}1\ \text{mm}$

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

$= \min\left[6{,}4,\ 3{,}1\right]$

$= 3{,}1\ \text{mm}$

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

$= \max\left[2{,}48,\ 3{,}1\right]$

$= 3{,}1\ \text{mm}$

Available nozzle wall thickness new, t_n = 16,64 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{204{,}96}{84{,}07} = 2{,}4379$$

$$\frac{D_o}{t} = \frac{84{,}07}{0{,}38} = 219{,}2887$$

From table G: $A = 0{,}000164$

From table CS-2 Metric: $B = 167{,}7082\ \text{kg/cm}^2 (164{,}47\ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 164{,}47}{3 \cdot (84{,}07/0{,}38)} = 1\ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}38 + 1{,}6 = 1{,}98$ mm

Straight Flange on Bottom Head

ASME Section VIII Division 1, 2021 Edition Metric					
Component		Cylinder			
Material		SA-516 60 (II-D Metric p. 16, ln. 3)			
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**		**Maximize MDMT/ No MAWP**
Yes (-46°C)	Yes	Yes	Yes		No
		Design Pressure (bar)	**Design Temperature (°C)**		**Design MDMT (°C)**
Internal		15,5	121		-15
External		1	23		
Static Liquid Head					
Condition		**P_s (bar)**	**H_s (mm)**		**SG**
Operating		0,05	505		0,999
Test horizontal		0,19	1.923,2		1
Test vertical		0,25	2.550		1
Dimensions					
Inner Diameter		1.800 mm			
Length		50 mm			
Nominal Thickness		24 mm			
Corrosion	**Inner**	0 mm			
	Outer	1,6 mm			
Weight and Capacity					
		Weight (kg)			**Capacity (liters)**
New		53,86			126,39
Corroded		50,23			126,39
Insulation\Lining					
		Thickness (mm)	**Density (kg/m^3)**		**Weight (kg)**
Lining		3	8.000		0
Insulation		80	100		0
		Spacing(mm)	**Individual Weight (kg)**		**Total Weight (kg)**
Insulation Supports		0	0		0
Radiography					
Longitudinal seam		Full UW-11(a) Type 1			
Top Circumferential seam		Full UW-11(a) Type 1			

Results Summary	
Governing condition	Internal pressure
Minimum thickness per UG-16	1,5 mm + 1,6 mm = 3,1 mm
Design thickness due to internal pressure (t)	13,56 mm
Design thickness due to external pressure (t_e)	7,79 mm
Design thickness due to combined loadings + corrosion	6,48 mm
Maximum allowable working pressure (MAWP)	28,89 bar
Maximum allowable pressure (MAP)	30,97 bar
Maximum allowable external pressure (MAEP)	15,58 bar
Rated MDMT	-73,2 °C

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-46°C
$t_r = \dfrac{15{,}95 \cdot 900}{1.180 \cdot 1 - 0{,}6 \cdot 15{,}95} =$	12,26 mm
$\text{Stress ratio} = \dfrac{t_r \cdot E^*}{t_n - c} = \dfrac{12{,}26 \cdot 1}{24 - 1{,}6} =$	0,5475
$\text{Stress ratio longitudinal} = \dfrac{266{,}909 \cdot 1}{1.203{,}265 \cdot 1} =$	0,2218
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1M =	27,2°C
$MDMT = \max\ [T_{impact} - T_R, -105] = \max\ [-46 - 27{,}2, -105] =$	-73,2°C
Design MDMT of -15°C is acceptable.	

Design thickness, (at 121 °C) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0{,}60 \cdot P} + \text{Corrosion} = \frac{15{,}55 \cdot 900}{1.180 \cdot 1{,}00 - 0{,}60 \cdot 15{,}55} + 1{,}6 = 13{,}56 \text{ mm}$$

Maximum allowable working pressure, (at 121 °C) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0{,}60 \cdot t} - P_s = \frac{1.180 \cdot 1{,}00 \cdot 22{,}4}{900 + 0{,}60 \cdot 22{,}4} - 0{,}05 = 28{,}89 \text{ bar}$$

Maximum allowable pressure, (at 7 °C) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0{,}60 \cdot t} = \frac{1.180 \cdot 1{,}00 \cdot 24}{900 + 0{,}60 \cdot 24} = 30{,}97 \text{ bar}$$

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{2.100}{1.848} = 1{,}1364$$

$$\frac{D_o}{t} = \frac{1.848}{6{,}19} = 298{,}7497$$

From table G: $A = 0{,}000224$

From table CS-2 Metric: $B = 228{,}4802\ \text{kg/cm}^2 (224{,}06\ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 224{,}06}{3 \cdot (1.848/6{,}19)} = 1\ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$$t_a = t + \text{Corrosion} = 6{,}19 + 1{,}6 = 7{,}79 \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{2.100}{1.848} = 1{,}1364$$

$$\frac{D_o}{t} = \frac{1.848}{22{,}4} = 82{,}5007$$

From table G: $A = 0{,}001581$

From table CS-2 Metric: $B = 983{,}2359 \ \ \mathrm{kg/cm}^{2} (964{,}2233 \ \ \mathrm{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 964{,}22}{3 \cdot (1.848/22{,}4)} = 15{,}58 \text{ bar}$$

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{50 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{50 \cdot 24}{912}\right) \cdot \left(1 - \frac{912}{\text{infinity}}\right) = 1{,}3158\,\%$$

The extreme fiber elongation does not exceed 5%.

Thickness Required Due to Pressure + External Loads								
Condition	Allowable Stress Before UG-23 Stress Increase (kg/cm^2)		Temperature (°C)	Corrosion C (mm)	Load	Pressure P (bar)	Req'd Thk Due to Tension (mm)	Req'd Thk Due to Compression (mm)
	S_t	S_c						
Operating, Hot & Corroded	1.203,3	1.143,5	121	1,6	Wind	71,3	4,88	4,79
					Seismic	71,32	4,88	4,8
Operating, Hot & New	1.203,3	1.153,1	121	0	Wind	76,45	4,88	4,79
					Seismic	76,46	4,87	4,8
Hot Shut Down, Corroded	1.203,3	1.143,5	121	1,6	Wind	0	0,04	0,13
					Seismic	0	0,04	0,12
Hot Shut Down, New	1.203,3	1.153,1	121	0	Wind	0	0,04	0,13
					Seismic	0	0,04	0,13
Empty, Corroded	1.203,3	1.143,5	20	1,6	Wind	0	0,04	0,13
					Seismic	0	0,04	0,12
Empty, New	1.203,3	1.153,1	20	0	Wind	0	0,04	0,13
					Seismic	0	0,04	0,12
Vacuum	1.203,3	1.143,5	23	1,6	Wind	67,26	0,37	0,46
					Seismic	67,28	0,38	0,46
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	1.203,3	1.143,5	121	1,6	Wind	0	0,08	0,12
					Seismic	0	0	0

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{924/22{,}4} = 0{,}003030$$

$$B = 1.143{,}5 \ \ \mathrm{kg/cm}^{2}$$

$$S = \frac{1.203{,}3}{1{,}00} = 1.203{,}3 \ \ \mathrm{kg/cm}^{2}$$

$$S_{cHC} = \min(B, S) = 1.143{,}5 \ \mathrm{kg/cm}^2$$

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{924/24} = 0{,}003247$$

$$B = 1.153{,}1 \ \ \mathrm{kg/cm}^{2}$$

$$S = \frac{1.203{,}3}{1{,}00} = 1.203{,}3 \ \ \mathrm{kg/cm}^{2}$$

$S_{cHN} = \min(B, S) =$ 1.153,1 kg/cm^2

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{924/24} = 0{,}003247$$

$$B = 1.153{,}1 \ \ \mathrm{kg/cm}^{2}$$

$$S = \frac{1.203{,}3}{1{,}00} = 1.203{,}3 \ \ \mathrm{kg/cm}^{2}$$

$S_{cCN} = \min(B, S) =$ 1.153,1 kg/cm^2

Allowable Compressive Stress, Cold and Corroded- S_{cCC}, (table CS-2 Metric)

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{924/22{,}4} = 0{,}003030$$

$$B = 1.143{,}5 \ \ \mathrm{kg/cm}^{2}$$

$$S = \frac{1.203{,}3}{1{,}00} = 1.203{,}3 \ \ \mathrm{kg/cm}^{2}$$

$S_{cC} = \min(B, S) =$ 1.143,5 kg/cm^2

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

$$A = \frac{0{,}125}{R_o/t} = \frac{0{,}125}{924/22{,}4} = 0{,}003030$$

$$B = 1.143{,}5 \ \ \mathrm{kg/cm}^{2}$$

$$S = \frac{1.203{,}3}{1{,}00} = 1.203{,}3 \ \ \mathrm{kg/cm}^{2}$$

$S_{cVC} = \min(B, S) =$ 1.143,5 kg/cm^2

Operating, Hot & Corroded, Wind, Bottom Seam

t_p = $\dfrac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|}$ (Pressure)

= $\dfrac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$

= 4,92 mm

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

= $\dfrac{1.658,3}{\pi \cdot 911{,}2^{\ 2} \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$

= 0,04 mm

t_w = $\dfrac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor}$ (Weight)

= $\dfrac{6.445,8}{2 \cdot \pi \cdot 911{,}2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$

= 0,08 mm

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

= $4{,}92 + 0{,}04 - (0{,}08)$

= 4,88 mm

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

= $|0{,}04 + (0{,}08) - (4{,}92)|$

= 4,79 mm

Maximum allowable working pressure, Longitudinal Stress

P = $\dfrac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$

= $\dfrac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (22{,}4 - 0{,}04 + (0{,}08))}{900 - 0{,}40 \cdot (22{,}4 - 0{,}04 + (0{,}08))}$

= 71,3 bar

Operating, Hot & New, Wind, Bottom Seam

$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|}$ (Pressure)

$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$

= 4,92 mm

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

$= \frac{1.661,4}{\pi \cdot 912^2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$

= 0,04 mm

$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor}$ (Weight)

$= \frac{6.626,7}{2 \cdot \pi \cdot 912 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$

= 0,08 mm

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

$= 4{,}92 + 0{,}04 - (0{,}08)$

= 4,88 mm

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

$= |0{,}04 + (0{,}08) - (4{,}92)|$

= 4,79 mm

Maximum allowable working pressure, Longitudinal Stress

$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$

$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (24 - 0{,}04 + (0{,}08))}{900 - 0{,}40 \cdot (24 - 0{,}04 + (0{,}08))}$

= 76,45 bar

Hot Shut Down, Corroded, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.658,3}{\pi \cdot 911,2\ ^2 \cdot 1.121,37 \cdot 1,20} \cdot 98066.5$$

= 0,05 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{6.445,8}{2 \cdot \pi \cdot 911,2 \cdot 1.121,37 \cdot 1,20} \cdot 98.0665$$

= 0,08 mm

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

= $|0 + 0,05 - (0,08)|$

= 0,04 mm

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

= $0,05 + (0,08) - (0)$

= 0,13 mm

Hot Shut Down, New, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.661,4}{\pi \cdot 912\ ^2 \cdot 1.130,85 \cdot 1,20} \cdot 98066.5$$

= 0,05 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{6.626,7}{2 \cdot \pi \cdot 912 \cdot 1.130,85 \cdot 1,20} \cdot 98.0665$$

= 0,08 mm

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

= $|0 + 0,05 - (0,08)|$

= 0,04 mm

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

= $0,05 + (0,08) - (0)$

= 0,13 mm

Empty, Corroded, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.658,3}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$$

= 0,05 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{6.445,8}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

$$t_t = |t_p + t_m - t_w| \quad \text{(total, net compressive)}$$

$$= |0 + 0{,}05 - (0{,}08)|$$

= 0,04 mm

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

$$= 0{,}05 + (0{,}08) - (0)$$

= 0,13 mm

Empty, New, Wind, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.661,4}{\pi \cdot 912\ ^2 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98066.5$$

= 0,05 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{6.626,7}{2 \cdot \pi \cdot 912 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

$$t_t = |t_p + t_m - t_w| \quad \text{(total, net compressive)}$$

$$= |0 + 0{,}05 - (0{,}08)|$$

= 0,04 mm

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

$$= 0{,}05 + (0{,}08) - (0)$$

= 0,13 mm

Vacuum, Wind, Bottom Seam

t_p = $\frac{P \cdot R}{2 \cdot S_c \cdot K_s + 0{,}40 \cdot |P|}$ (Pressure)

= $\frac{-1 \cdot 900}{2 \cdot 1.121{,}37 \cdot 1{,}20 + 0{,}40 \cdot |1|}$

= -0,33 mm

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

= $\frac{1.658,3}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$

= 0,05 mm

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

= $\frac{6.445,8}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$

= 0,08 mm

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

= $|-0{,}33 + 0{,}05 - (0{,}08)|$

= 0,37 mm

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

= $0{,}05 + (0{,}08) - (-0{,}33)$

= 0,46 mm

Maximum Allowable External Pressure, Longitudinal Stress

P = $\frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0{,}40 \cdot (t - t_{mc} - t_{wc})}$

= $\frac{2 \cdot 1.121{,}37 \cdot 1{,}20 \cdot (22{,}4 - 0{,}05 - 0{,}08)}{900 - 0{,}40 \cdot (22{,}4 - 0{,}05 - 0{,}08)}$

= 67,26 bar

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

t_p = 0 mm (Pressure)

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

$$= \frac{593}{\pi \cdot 911{,}2^{\ 2} \cdot 1.121{,}37 \cdot 1{,}00} \cdot 98066.5$$

= 0,02 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_c \cdot K_s} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{6.445,8}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}00} \cdot 98.0665$$

= 0,1 mm

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

= $|0 + 0{,}02 - (0{,}1)|$

= 0,08 mm

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

= $0{,}02 + (0{,}1) - (0)$

= 0,12 mm

Operating, Hot & Corroded, Seismic, Bottom Seam

$$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|} \quad \text{(Pressure)}$$

$$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$$

= 4,92 mm

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

$$= \frac{1.474,3}{\pi \cdot 911{,}2^{\ 2} \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$$

= 0,04 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{6.445,8}{2 \cdot \pi \cdot 911{,}2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$$

= 0,08 mm

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

= $4{,}92 + 0{,}04 - (0{,}08)$

= 4,88 mm

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

= $|0{,}04 + (0{,}08) - (4{,}92)|$

= 4,8 mm

Maximum allowable working pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

$$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (22{,}4 - 0{,}04 + (0{,}08))}{900 - 0{,}40 \cdot (22{,}4 - 0{,}04 + (0{,}08))}$$

= 71,32 bar

Operating, Hot & New, Seismic, Bottom Seam

$$t_p = \frac{P \cdot R}{2 \cdot S_t \cdot K_s \cdot E_c + 0{,}40 \cdot |P|} \quad \text{(Pressure)}$$

$$= \frac{15{,}5 \cdot 900}{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 + 0{,}40 \cdot |15{,}5|}$$

= 4,92 mm

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

$$= \frac{1.501}{\pi \cdot 912^2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98066.5$$

= 0,04 mm

$$t_w = \frac{W}{2 \cdot \pi \cdot R_m \cdot S_t \cdot K_s \cdot E_c} \cdot \text{MetricFactor} \quad \text{(Weight)}$$

$$= \frac{6.626,7}{2 \cdot \pi \cdot 912 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00} \cdot 98.0665$$

= 0,08 mm

$$t_t = t_p + t_m - t_w \quad \text{(total required, tensile)}$$

$$= 4{,}92 + 0{,}04 - (0{,}08)$$

= 4,87 mm

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

$$= |0{,}04 + (0{,}08) - (4{,}92)|$$

= 4,8 mm

Maximum allowable working pressure, Longitudinal Stress

$$P = \frac{2 \cdot S_t \cdot K_s \cdot E_c \cdot (t - t_m + t_w)}{R - 0{,}40 \cdot (t - t_m + t_w)}$$

$$= \frac{2 \cdot 1.180 \cdot 1{,}20 \cdot 1{,}00 \cdot (24 - 0{,}04 + (0{,}08))}{900 - 0{,}40 \cdot (24 - 0{,}04 + (0{,}08))}$$

= 76,46 bar

Hot Shut Down, Corroded, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$= \dfrac{1.474,3}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$

= 0,04 mm

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

$= \dfrac{6.445,8}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$

= 0,08 mm

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

$= |0 + 0{,}04 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}04 + (0{,}08) - (0)$

= 0,12 mm

Hot Shut Down, New, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$= \dfrac{1.501}{\pi \cdot 912\ ^2 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98066.5$

= 0,04 mm

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

$= \dfrac{6.626,7}{2 \cdot \pi \cdot 912 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98.0665$

= 0,08 mm

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

$= |0 + 0{,}04 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}04 + (0{,}08) - (0)$

= 0,13 mm

Empty, Corroded, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.376,2}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$$

= 0,04 mm

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

$$= \frac{6.445,8}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

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

$= |0 + 0{,}04 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}04 + (0{,}08) - (0)$

= 0,12 mm

Empty, New, Seismic, Bottom Seam

t_p = 0 mm (Pressure)

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

$$= \frac{1.403,9}{\pi \cdot 912\ ^2 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98066.5$$

= 0,04 mm

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

$$= \frac{6.626,7}{2 \cdot \pi \cdot 912 \cdot 1.130{,}85 \cdot 1{,}20} \cdot 98.0665$$

= 0,08 mm

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

$= |0 + 0{,}04 - (0{,}08)|$

= 0,04 mm

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

$= 0{,}04 + (0{,}08) - (0)$

= 0,12 mm

Vacuum, Seismic, Bottom Seam

t_p = $\frac{P \cdot R}{2 \cdot S_c \cdot K_s + 0{,}40 \cdot |P|}$ (Pressure)

= $\frac{-1 \cdot 900}{2 \cdot 1.121{,}37 \cdot 1{,}20 + 0{,}40 \cdot |1|}$

= -0,33 mm

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

= $\frac{1.474,3}{\pi \cdot 911{,}2\ ^2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98066.5$

= 0,04 mm

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

= $\frac{6.445,8}{2 \cdot \pi \cdot 911{,}2 \cdot 1.121{,}37 \cdot 1{,}20} \cdot 98.0665$

= 0,08 mm

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

= $|-0{,}33 + 0{,}04 - (0{,}08)|$

= 0,38 mm

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

= $0{,}04 + (0{,}08) - (-0{,}33)$

= 0,46 mm

Maximum Allowable External Pressure, Longitudinal Stress

P = $\frac{2 \cdot S_c \cdot K_s \cdot (t - t_{mc} - t_{wc})}{R - 0{,}40 \cdot (t - t_{mc} - t_{wc})}$

= $\frac{2 \cdot 1.121{,}37 \cdot 1{,}20 \cdot (22{,}4 - 0{,}04 - 0{,}08)}{900 - 0{,}40 \cdot (22{,}4 - 0{,}04 - 0{,}08)}$

= 67,28 bar

Bottom Head

<table>
<tr><th colspan="5">ASME Section VIII Division 1, 2021 Edition Metric</th></tr>
<tr><td colspan="2">Component</td><td colspan="3">Ellipsoidal Head</td></tr>
<tr><td colspan="2">Material</td><td colspan="3">SA-516 60 (II-D Metric p. 16, ln. 3)</td></tr>
<tr><td colspan="2">Attached To</td><td colspan="3">Shell V1</td></tr>
<tr><td>Impact Tested</td><td>Normalized</td><td>Fine Grain Practice</td><td>PWHT</td><td>Maximize MDMT/ No MAWP</td></tr>
<tr><td>Yes (-46°C)</td><td>Yes</td><td>Yes</td><td>Yes</td><td>No</td></tr>
<tr><td colspan="2"></td><td>Design Pressure (bar)</td><td>Design Temperature (°C)</td><td>Design MDMT (°C)</td></tr>
<tr><td colspan="2">Internal</td><td>15,5</td><td>121</td><td rowspan="2">-15</td></tr>
<tr><td colspan="2">External</td><td>1</td><td>23</td></tr>
<tr><th colspan="5">Static Liquid Head</th></tr>
<tr><td colspan="2">Condition</td><td>P_s (bar)</td><td>H_s (mm)</td><td>SG</td></tr>
<tr><td colspan="2">Operating</td><td>0,09</td><td>955</td><td>0,999</td></tr>
<tr><td colspan="2">Test horizontal</td><td>0,19</td><td>1.923,2</td><td>1</td></tr>
<tr><td colspan="2">Test vertical</td><td>0,29</td><td>3.000</td><td>1</td></tr>
<tr><th colspan="5">Dimensions</th></tr>
<tr><td colspan="2">Inner Diameter</td><td colspan="3">1.800 mm</td></tr>
<tr><td colspan="2">Head Ratio</td><td colspan="3">2</td></tr>
<tr><td colspan="2">Minimum Thickness</td><td colspan="3">24 mm</td></tr>
<tr><td rowspan="2">Corrosion</td><td>Inner</td><td colspan="3">0 mm</td></tr>
<tr><td>Outer</td><td colspan="3">1,6 mm</td></tr>
<tr><td colspan="2">Length L_{sf}</td><td colspan="3">50 mm</td></tr>
<tr><td colspan="2">Nominal Thickness t_{sf}</td><td colspan="3">24 mm</td></tr>
<tr><th colspan="5">Weight and Capacity</th></tr>
<tr><td colspan="2"></td><td colspan="2">Weight (kg)[1]</td><td>Capacity (liters)[1]</td></tr>
<tr><td colspan="2">New</td><td colspan="2">778,59</td><td>879,66</td></tr>
<tr><td colspan="2">Corroded</td><td colspan="2">725,15</td><td>879,66</td></tr>
<tr><th colspan="5">Insulation\Lining</th></tr>
<tr><td colspan="2"></td><td>Thickness (mm)</td><td>Density (kg/m^3)</td><td>Weight (kg)</td></tr>
<tr><td colspan="2">Lining</td><td>3</td><td>8.000</td><td>87,87</td></tr>
<tr><td colspan="2">Insulation</td><td>80</td><td>100</td><td>34,62</td></tr>
<tr><td colspan="2"></td><td>Spacing(mm)</td><td>Individual Weight (kg)</td><td>Total Weight (kg)</td></tr>
<tr><td colspan="2">Insulation Supports</td><td>0</td><td>0</td><td>0</td></tr>
<tr><th colspan="5">Radiography</th></tr>
<tr><td colspan="2">Category A joints</td><td colspan="3">Full UW-11(a) Type 1</td></tr>
<tr><td colspan="2">Head to shell seam</td><td colspan="3">Full UW-11(a) Type 1</td></tr>
</table>

[1] includes straight flange

Results Summary	
Governing condition	internal pressure
Minimum thickness per UG-16	1,5 mm + 1,6 mm = 3,1 mm
Design thickness due to internal pressure (t)	13,51 mm
Design thickness due to external pressure (t_e)	6,19 mm
Maximum allowable working pressure (MAWP)	29,2 bar
Maximum allowable pressure (MAP)	31,38 bar
Maximum allowable external pressure (MAEP)	13,66 bar
Rated MDMT	-73,4°C

UCS-66 Material Toughness Requirements	
Material impact test temperature per UG-84 =	-46°C
$t_r = \frac{15{,}99 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 15{,}99} =$	12,22 mm
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{12{,}22 \cdot 1}{24 - 1{,}6} =$	0,5453
UCS-66(i) reduction in MDMT, T_R from Fig UCS-66.1M =	27,4°C
$MDMT = \max\,[T_{impact} - T_R, -105] = \max\,[-46 - 27{,}4, -105] =$	-73,4°C
Design MDMT of -15°C is acceptable.	

Design thickness for internal pressure, (Corroded at 121 °C) UG-32(c)(1)

$$t = \frac{P \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P} + \text{Corrosion} = \frac{15{,}59 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 15{,}59} + 1{,}6 = 13{,}51 \text{ mm}$$

Maximum allowable working pressure, (Corroded at 121 °C) UG-32(c)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0{,}2 \cdot t} - P_s = \frac{2 \cdot 1.180 \cdot 1 \cdot 22{,}4}{1.800 + 0{,}2 \cdot 22{,}4} - 0{,}09 = 29{,}2 \text{ bar}$$

Maximum allowable pressure, (New at 7 °C) UG-32(c)(1)

$$P = \frac{2 \cdot S \cdot E \cdot t}{D + 0{,}2 \cdot t} - P_s = \frac{2 \cdot 1.180 \cdot 1 \cdot 24}{1.800 + 0{,}2 \cdot 24} - 0 = 31{,}38 \text{ bar}$$

Design thickness for external pressure, (Corroded at 23 °C) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0{,}8772 \cdot 1.848 = 1.621{,}09 \text{ mm}$

$$A = \frac{0{,}125}{R_o \;/\; t} = \frac{0{,}125}{1.621{,}09 \;/\; 4{,}59} = 0{,}000354$$

From Table CS-2 Metric: B = 360,063 kg_f/cm^2

$$P_a = \frac{B}{R_o \;/\; t} = \frac{353{,}1012}{1.621{,}09 \;/\; 4{,}59} = 1 \text{ bar}$$

$$t = 4{,}59 \text{ mm} + \text{Corrosion} = 4{,}59 \text{ mm} + 1{,}6 \text{ mm} = 6{,}19 \text{ mm}$$

The head external pressure design thickness (t_e) is 6,19 mm.

Maximum Allowable External Pressure, (Corroded at 23 °C) UG-33(d)

Equivalent outside spherical radius
$R_o = K_o \cdot D_o = 0{,}8772 \cdot 1.848 = 1.621{,}09 \text{ mm}$

$$A = \frac{0{,}125}{R_o \;/\; t} = \frac{0{,}125}{1.621{,}09 \;/\; 22{,}4} = 0{,}001727$$

From Table CS-2 Metric: B = 1.007,9818 kg_f/cm^2

$$P_a = \frac{B}{R_o \;/\; t} = \frac{988{,}4924}{1.621{,}09 \;/\; 22{,}4} = 13{,}6587 \text{ bar}$$

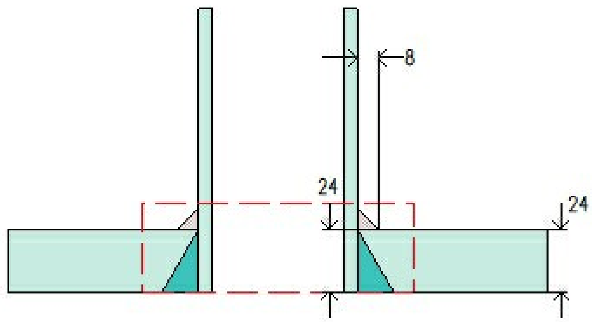
The maximum allowable external pressure (MAEP) is 13,66 bar.

% Extreme fiber elongation - UCS-79(d)

$$EFE = \left(\frac{75 \cdot t}{R_f}\right) \cdot \left(1 - \frac{R_f}{R_o}\right) = \left(\frac{75 \cdot 24}{318}\right) \cdot \left(1 - \frac{318}{\text{infinity}}\right) = 5{,}6604\,\%$$

Nozzle (D)

ASME Section VIII Division 1, 2021 Edition Metric	



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

Location and Orientation	
Located on	Bottom Head
Orientation	0°
End of nozzle to datum line	-650 mm
Calculated as hillside	No
Distance to head center, R	0 mm
Passes through a Category A joint	No
Nozzle	
Description	NPS 2 Sch 80 (XS) DN 50
Access opening	No
Material specification	SA-333 6 Wld & smls pipe (II-D Metric p. 16, ln. 19) (normalized)
Inside diameter, new	49,25 mm
Pipe minimum wall thickness	5,54 mm
Corrosion inner	0 mm
Corrosion outer	1,6 mm
Projection available outside vessel, Lpr	176,25 mm
Local vessel minimum thickness	24 mm
Liquid static head included	0,11 bar
Welds	
Inner fillet, Leg_{41}	8 mm
Nozzle to vessel groove weld	24 mm
Radiography	
Longitudinal seam	Seamless No RT
Circumferential seam	Full UW-11(a) Type 1

UCS-66 Material Toughness Requirements Nozzle	
Governing thickness, t_g =	5,54 mm
Impact test exempt per UCS-66(d) (NPS 4 or smaller pipe) =	-105°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Reinforcement Calculations for Chamber MAWP

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For P = 16,89 bar @ 121 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							5,02	5,54

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	2,76	4 (corroded)	weld size is adequate

WRC 537												
Load Case	P (bar)	P_r (kg_f)	M_1 (kg_f-m)	V_2 (kg_f)	M_2 (kg_f-m)	V_1 (kg_f)	M_t (kg_f-m)	Max Comb Stress (kg_f/cm^2)	Allow Comb Stress (kg_f/cm^2)	Max Local Primary Stress (kg_f/cm^2)	Allow Local Primary Stress (kg_f/cm^2)	Over stressed
Load case 1	16,89	-106,05	54,8	150	0	0	38,7	**1.585,563**	**3.609,796**	**1.172,298**	**1.804,898**	No
Load case 1 (Hot Shut Down)	0	-106,05	54,8	150	0	0	38,7	435,411	3.609,796	22,147	1.804,898	No
Load case 1 (Pr Reversed)	16,89	106,05	54,8	150	0	0	38,7	1.570,657	3.609,796	1.168,361	1.804,898	No
Load case 1 (Pr Reversed) (Hot Shut Down)	0	106,05	54,8	150	0	0	38,7	-435,411	3.609,796	-22,147	1.804,898	No

Calculations for internal pressure 16,89 bar @ 121 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[49{,}25,\ 24{,}63 + (5{,}54 - 1{,}6) + (24 - 1{,}6)\right]$$

$$= 50{,}96 \text{ mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (24 - 1{,}6),\ 2{,}5 \cdot (5{,}54 - 1{,}6) + 0\right]$$

$$= 9{,}84 \text{ mm}$$

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

$$t_{rn} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P}$$

$$= \frac{16{,}8898 \cdot 24{,}63}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}8898}$$

$$= 0{,}36 \text{ mm}$$

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

$$t_r = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P}$$

$$= \frac{16{,}8898 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 16{,}8898}$$

$$= 11{,}61 \text{ mm}$$

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 3,94 mm

$t_{c(\min)} = \min\left[6 \text{ mm},\ 0{,}7 \cdot t_{\min}\right] =$ 2,76 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 5{,}71 = 4 \text{ mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-27}} = \frac{P \cdot R_n}{S_n \cdot E - 0{,}6 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}8921 \cdot 24{,}63}{1.180 \cdot 1 - 0{,}6 \cdot 16{,}8921} + 1{,}6$$

$$= 1{,}96 \text{ mm}$$

$$t_{a\text{UG-22}} = 3{,}84 \text{ mm}$$

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

$$= \max\left[1{,}96,\ 3{,}84\right]$$

$$= 3{,}84 \text{ mm}$$

$$t_{b1} = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P} + \text{Corrosion}$$

$$= \frac{16{,}8898 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 16{,}8898} + 1{,}6$$

$$= 13{,}21 \text{ mm}$$

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

$$= \max\left[13{,}21,\ 3{,}1\right]$$

$$= 13{,}21 \text{ mm}$$

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

$$= \min\left[5{,}02,\ 13{,}21\right]$$

$$= 5{,}02 \text{ mm}$$

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

$$= \max\left[3{,}84,\ 5{,}02\right]$$

$$= 5{,}02 \text{ mm}$$

Available nozzle wall thickness new, t_n = 5,54 mm

The nozzle neck thickness is adequate.

WRC 537 Load case 1

Applied Loads	
Radial load, P_r	-106,05 kg_f
Circumferential moment, M_1	54,8 kg_f-m
Circumferential shear, V_2	150 kg_f
Longitudinal moment, M_2	0 kg_f-m
Longitudinal shear, V_1	0 kg_f
Torsion moment, M_t	38,7 kg_f-m
Internal pressure, P	16,89 bar
Mean dish radius, R_m	1.639,3 mm
Local head thickness, T	22,4 mm
Design factor	3

Maximum stresses due to the applied loads at the nozzle OD (includes pressure)

$$\gamma = \frac{r_m}{t} = \frac{26{,}59}{3{,}94} = 6{,}7548$$

$$\rho = \frac{T}{t} = \frac{22{,}4}{3{,}94} = 5{,}6896$$

$$U = \frac{r_o}{\sqrt{R_m \cdot T}} = \frac{28{,}56}{\sqrt{1.639{,}3 \cdot 22{,}4}} = 0{,}149$$

WRC 537 Nondimensional Coefficients								
$Y = \frac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$								
γ = 5 ρ = 4	SP-4				SM-4			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,1955	0,7443	2,537	0,1606	-3,9242	12,6132	-0,9607	-6,9959
b	355,6102	7,533	1.071,7354	22,9473	-68,5346	29,9988	-43,2509	114,214
c	21,1677	-2,6223	127,4587	10,3372	228,2976	-129,5801	-7,5852	81,2222
d	1.539,5199	-7,6574	2.112,6475	-190,1285	9.214,6671	-214,241	8,1123	-726,9062
e	-9,9855	9,5634	-131,0041	-76,2413	341,9835	558,1185	5,3251	-296,5262
f	356,7674	64,1716	-8.161,6149	517,979	12.323,9	595,3023	11,1703	1.724,0898
g	0	-5,6615	-54,494	186,8225	-372,3161	-319,0507	0	427,4096
h	0	62,296	7.160,3101	-483,8102	0	2.813,0991	0	-1.948,4552
i	0	0	102,0928	-102,4669	0	0	0	-195,9934
j	0	0	-1.577,3732	408,8865	0	0	0	1.040,0273
Y	0,035	0,2492	0,1005	0,3381	0,1544	1,1406	0,3774	-0,0238
Note: ρ is outside the bounds. ρ = 4 used.								

WRC 537 Nondimensional Coefficients								
$Y = \dfrac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$								
γ = 15 ρ = 4	SP-7				SM-7			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,1225	1,1858	0,152	0,2586	81.160,67	54,8627	-7,2531E+09	-2.889,5632
b	10,2618	30,9469	6,4077	2,6992	2.773.928	313,4235	2,0933E+11	44.457,77
c	0,0628	0,7386	-0,2621	2,1956	11.224,63	-805,6348	2,2821E+11	31.259,89
d	2,5604	-22,7834	-20,1141	10,0386	-888.508,9	-5.199,714	6,2796E+12	-175.466,5
e	-9,8501E-04	0,8686	0,1324	0,3281	-4.806,5269	2.622,0799	1,5072E+12	-81.861,2
f	7,9918	86,4361	30,2989	-5,923	3.917.797	23.612,83	3,0942E+13	299.387,2
g	0	-0,3301	0,2529	-0,3719	0	4.442,2399	1,7691E+11	85.306,95
h	0	0	-12,616	4,2863	0	-21.199,17	3,2234E+12	-247.881,6
i	0	0	-0,0853	0	0	-1.946,6481	0	-22.718,26
j	0	0	1,8294	0	0	79.566,95	0	113.956,5
Y	0,0505	0,2437	0,0728	0,3682	0,2035	1,1743	0,2853	0,0615

WRC 537 Nondimensional Coefficients								
$Y = \dfrac{a + c \cdot U + e \cdot U^2 + g \cdot U^3 + i \cdot U^4}{1 + b \cdot U + d \cdot U^2 + f \cdot U^3 + h \cdot U^4 + j \cdot U^5}$								
γ = 15 ρ = 10	SP-8				SM-8			
	M_x	M_y	N_x	N_y	M_x	M_y	N_x	N_y
a	0,0089	0,7951	0,0353	0,3592	0,4473	5,8265	-4,7165	-0,0349
b	5,0204	9,416	-2,6917	5,4358	78,6107	2,5265	-597,0121	-2,3803
c	0,0154	-1,7189	-0,1634	3,4207	-8,384	-112,5814	161,5182	1,8888
d	5,3485	-15,6863	-0,3186	-8,1149	-1.801,6236	-368,7197	18.269,05	6,6619
e	0,0058	1,4218	0,3444	-8,9147	7,5876	81,5976	927,0814	-3,4378
f	8,4286	9,5447	7,5748	4,7756	1.641,4093	-166,4983	-9.902,5503	-8,1245
g	0	-0,4031	-0,4108	11,36	-2,1272	0	387,6637	1,9493
h	0	0	-8,8672	9,0287	-813,4468	0	675,9853	3,3625
i	0	0	0,2287	-4,7215	0	0	-69,6238	-0,3143
j	0	0	3,9087	0	0	0	2.942,6661	0
Y	0,006	0,2728	0,0283	0,428	0,0288	1,2413	0,1443	0,2299

Pressure stress intensity factor, $I = 1{,}8376$ (derived from Division 2 Part 4.5)

Local pressure stress = $\dfrac{I \cdot P \cdot R_i}{2 \cdot T} = 1.150{,}152 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Maximum combined stress $(P_L + P_b + Q) = 1.585{,}56 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable combined stress $(P_L + P_b + Q) = \pm 3 \cdot S = \pm 3.609{,}8 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Maximum local primary membrane stress $(P_L) = 1.172{,}3 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

Allowable local primary membrane stress $(P_L) = \pm 1{,}5 \cdot S = \pm 1.804{,}9 \ \ \mathrm{kg}_f/\mathrm{cm}^2$

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

Stresses at the nozzle OD per WRC Bulletin 537										
Figure	Y		A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
SP-1 to 10*	$\frac{N_x \cdot T}{P}$	0,0934	1,969	1,969	1,969	1,969	1,969	1,969	1,969	1,969
SP-1 to 10	$\frac{M_x}{P}$	0,0355	4,5	-4,5	4,5	-4,5	4,5	-4,5	4,5	-4,5
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	0,3543	0	0	0	0	-20,178	-20,178	20,178	20,178
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_1}$	0,1544	0	0	0	0	-52,801	52,801	52,801	-52,801
SM-1 to 10*	$\frac{N_x \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	0,3543	0	0	0	0	0	0	0	0
SM-1 to 10	$\frac{M_x \cdot \sqrt{R_m \cdot T}}{M_2}$	0,1544	0	0	0	0	0	0	0	0
Pressure stress*			1.150,152	1.150,152	1.150,152	1.150,152	1.150,152	1.150,152	1.150,152	1.150,152
Total O_x stress			1.156,62	1.147,62	1.156,62	1.147,62	1.083,641	1.180,243	1.229,598	1.114,998
Membrane O_x stress*			1.152,12	1.152,12	1.152,12	1.152,12	1.131,942	1.131,942	1.172,298	1.172,298
SP-1 to 10*	$\frac{N_y \cdot T}{P}$	0,3463	7,312	7,312	7,312	7,312	7,312	7,312	7,312	7,312
SP-1 to 10	$\frac{M_y}{P}$	0,2497	31,638	-31,638	31,638	-31,638	31,638	-31,638	31,638	-31,638
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_1}$	-0,0005	0	0	0	0	0	0	0	0
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_1}$	1,1498	0	0	0	0	-393,227	393,227	393,227	-393,227
SM-1 to 10*	$\frac{N_y \cdot T \cdot \sqrt{R_m \cdot T}}{M_2}$	-0,0005	0	0	0	0	0	0	0	0
SM-1 to 10	$\frac{M_y \cdot \sqrt{R_m \cdot T}}{M_2}$	1,1498	0	0	0	0	0	0	0	0
Pressure stress*			1.150,152	1.150,152	1.150,152	1.150,152	1.150,152	1.150,152	1.150,152	1.150,152
Total O_y stress			1.189,102	1.125,825	1.189,102	1.125,825	795,875	1.519,052	1.582,328	732,599
Membrane O_y stress*			1.157,463	1.157,463	1.157,463	1.157,463	1.157,463	1.157,463	1.157,463	1.157,463
Shear from M_t			33,747	33,747	33,747	33,747	33,747	33,747	33,747	33,747
Shear from V_1			0	0	0	0	0	0	0	0
Shear from V_2			7,453	7,453	-7,453	-7,453	0	0	0	0
Total Shear stress			41,2	41,2	26,295	26,295	33,747	33,747	33,747	33,747
Combined stress (P_L+P_b+Q)			1.217,154	1.179,329	1.203,796	1.165,197	1.087,578	1.522,357	1.585,563	1.117,951
(1) * denotes primary stress. (2) The nozzle is analyzed as a hollow attachment.										

Longitudinal stress in the nozzle wall due to internal pressure + external loads

$$\sigma_{n(Pm)} = \frac{P \cdot R_i}{2 \cdot t_n} - \frac{P_r}{\pi \cdot \left(R_o^2 - R_i^2\right)} + \frac{M \cdot R_o}{I}$$

$$= \frac{16{,}89 \cdot 1{,}02 \cdot 24{,}63}{2 \cdot 3{,}94} - \frac{-106{,}05}{\pi \cdot \left(28{,}56^{\ 2} - 24{,}63^{\ 2}\right)} \cdot 100 + \frac{54.799{,}3 \cdot 28{,}56}{233.899{,}6} \cdot 100$$

$$= 739{,}16 \ \ \text{kg}_f/\text{cm}^2$$

The average primary stress P_m (see Division 2 5.6.a.1) across the nozzle wall due to internal pressure + external loads is acceptable (≤ S = 1.203,265 kg_f/cm^2)

Shear stress in the nozzle wall due to external loads

$$\sigma_{shear} = \frac{\sqrt{V_1^2 + V_2^2}}{\pi \cdot R_i \cdot t_n} \cdot 100 = \frac{\sqrt{0^2 + 150^2}}{\pi \cdot 24{,}63 \cdot 3{,}94} \cdot 100 = 49{,}249 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\mathrm{torsion}} = \frac{M_t}{2 \cdot \pi \cdot R_i^2 \cdot t_n} \cdot 100000 = \frac{38{,}7}{2 \cdot \pi \cdot 24{,}63^2 \cdot 3{,}94} \cdot 100000 = 258{,}318 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

$$\sigma_{\mathrm{total}} = \sigma_{\mathrm{shear}} + \sigma_{\mathrm{torsion}} = 49{,}249 + 258{,}318 = 307{,}567 \ \ \mathrm{kg}_f/\mathrm{cm}^2$$

UG-45: The total combined shear stress (307,567 $\mathrm{kg_f/cm^2}$) ≤ allowable $\left(0{,}7 \cdot S_n = 0{,}7 \cdot 1.203{,}265 = 842{,}286 \ \ \mathrm{kg}_f/\mathrm{cm}^2\right)$

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (cm^2)							UG-45 Summary (mm)	
For Pe = 1 bar @ 23 °C							The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							3,64	5,54

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 (mm)	Actual weld throat size (mm)	Status
Nozzle to shell fillet (Leg_{41})	2,76	4 (corroded)	weld size is adequate

Calculations for external pressure 1 bar @ 23 °C

Parallel Limit of reinforcement per UG-40

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

$$= \max\left[49{,}25,\ 24{,}63 + (5{,}54 - 1{,}6) + (24 - 1{,}6)\right]$$

$$= 50{,}96 \ \text{mm}$$

Outer Normal Limit of reinforcement per UG-40

$$L_H = \min\left[2{,}5 \cdot (t - C),\ 2{,}5 \cdot (t_n - C_n) + t_e\right]$$

$$= \min\left[2{,}5 \cdot (24 - 1{,}6),\ 2{,}5 \cdot (5{,}54 - 1{,}6) + 0\right]$$

$$= 9{,}84 \ \text{mm}$$

Nozzle required thickness per UG-28 t_{rn} = 0,52 mm

From UG-37(d)(1) required thickness t_r = 4,59 mm

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

UW-16(c) Weld Check

Fillet weld: $t_{\min} = \min\left[19mm,\ t_n,\ t\right] =$ 3,94 mm

$t_{c(\min)} = \min\left[6 \ \text{mm},\ 0{,}7 \cdot t_{\min}\right] =$ 2,76 mm

$t_{c(actual)} = 0{,}7 \cdot \text{Leg} = 0.7 \cdot 5{,}71 = 4 \ \text{mm}$

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$$t_{a\text{UG-28}} = 2{,}12 \ \text{mm}$$

$$t_{a\text{UG-22}} = 3{,}64 \ \text{mm}$$

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

$= \max\left[2{,}12,\ 3{,}64\right]$

$= 3{,}64\ \text{mm}$

$$t_{b2} = \frac{P \cdot K_1 \cdot D}{2 \cdot S \cdot E - 0{,}2 \cdot P} + \text{Corrosion}$$

$$= \frac{1 \cdot 0{,}9 \cdot 1.800}{2 \cdot 1.180 \cdot 1 - 0{,}2 \cdot 1} + 1{,}6$$

$= 2{,}29\ \text{mm}$

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

$= \max\left[2{,}29,\ 3{,}1\right]$

$= 3{,}1\ \text{mm}$

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

$= \min\left[5{,}02,\ 3{,}1\right]$

$= 3{,}1\ \text{mm}$

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

$= \max\left[3{,}64,\ 3{,}1\right]$

$= 3{,}64\ \text{mm}$

Available nozzle wall thickness new, t_n = 5,54 mm

The nozzle neck thickness is adequate.

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{1.309{,}45}{60{,}33} = 21{,}7065$$

$$\frac{D_o}{t} = \frac{60{,}33}{0{,}52} = 115{,}3648$$

From table G: $A = 0{,}000087$

From table CS-2 Metric: $B = 88{,}226\ \text{kg/cm}^2 (86{,}52\ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 86{,}52}{3 \cdot (60{,}33/0{,}52)} = 1\ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}52 + 1{,}6 = 2{,}12$ mm

B16.9 Elbow D

<table>
<tr><th colspan="6">ASME Section VIII Division 1, 2021 Edition Metric</th></tr>
<tr><td colspan="2">Component</td><td colspan="4">ASME B16.9 Elbow</td></tr>
<tr><td colspan="2">Type</td><td colspan="4">Long Radius 90-deg</td></tr>
<tr><td colspan="2">Material</td><td colspan="4">SA-420 WPL6 (II-D Metric p. 16, ln. 26)</td></tr>
<tr><td colspan="2">Pipe NPS and Schedule</td><td colspan="4">NPS 2 Sch 80 (XS) DN 50</td></tr>
<tr><td colspan="2">Attached To</td><td colspan="4">Nozzle (D)</td></tr>
<tr><td>Impact Tested</td><td>Normalized</td><td>Fine Grain Practice</td><td>PWHT</td><td colspan="2">Maximize MDMT/ No MAWP</td></tr>
<tr><td>No</td><td>Yes</td><td>Yes</td><td>Yes</td><td colspan="2">No</td></tr>
<tr><td colspan="2"></td><td>Design Pressure (bar)</td><td>Design Temperature (°C)</td><td colspan="2">Design MDMT (°C)</td></tr>
<tr><td colspan="2">Internal</td><td>15,5</td><td>121</td><td colspan="2" rowspan="2">-15</td></tr>
<tr><td colspan="2">External</td><td>1</td><td>23</td></tr>
<tr><th colspan="6">Static Liquid Head</th></tr>
<tr><td colspan="2">Condition</td><td>P_s (bar)</td><td>H_s (mm)</td><td colspan="2">SG</td></tr>
<tr><td colspan="2">Operating</td><td>0,12</td><td>1.255,83</td><td colspan="2">0,999</td></tr>
<tr><td colspan="2">Test horizontal</td><td>0,1</td><td>1.050,83</td><td colspan="2">1</td></tr>
<tr><td colspan="2">Test vertical</td><td>0,32</td><td>3.300,83</td><td colspan="2">1</td></tr>
<tr><th colspan="6">Dimensions</th></tr>
<tr><td colspan="2">Outer Diameter</td><td colspan="4">60,33 mm</td></tr>
<tr><td colspan="2">Nominal Thickness</td><td colspan="4">5,54 mm</td></tr>
<tr><td colspan="2">Minimum Thickness[1]</td><td colspan="4">4,85 mm</td></tr>
<tr><td colspan="2">Center-to-End, A</td><td colspan="4">76 mm</td></tr>
<tr><td rowspan="2">Corrosion</td><td>Inner</td><td colspan="4">0 mm</td></tr>
<tr><td>Outer</td><td colspan="4">1,6 mm</td></tr>
<tr><th colspan="6">Weight and Capacity</th></tr>
<tr><td colspan="2"></td><td colspan="2">Weight (kg)</td><td colspan="2">Capacity (liters)</td></tr>
<tr><td colspan="2">New</td><td colspan="2">0,89</td><td colspan="2">0,18</td></tr>
<tr><td colspan="2">Corroded</td><td colspan="2">0,62</td><td colspan="2">0,18</td></tr>
<tr><th colspan="6">Lining</th></tr>
<tr><td colspan="2"></td><td>Thickness (mm)</td><td>Density (kg/m^3)</td><td colspan="2">Weight (kg)</td></tr>
<tr><td colspan="2">Lining</td><td>3</td><td>8.000</td><td colspan="2">0</td></tr>
<tr><th colspan="6">Radiography</th></tr>
<tr><td colspan="2">Longitudinal seam</td><td colspan="4">Full UW-11(a) Type 1</td></tr>
<tr><td colspan="2">Left Circumferential seam</td><td colspan="4">Full UW-11(a) Type 1</td></tr>
<tr><td colspan="2">Right Circumferential seam</td><td colspan="4">Full UW-11(a) Type 1</td></tr>
</table>

[1] minimum thickness = nominal thickness times pipe tolerance factor of 0,875.

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	1,5 mm + 1,6 mm = 3,1 mm
Design thickness due to internal pressure (t)	2 mm
Design thickness due to external pressure (t_e)	2,12 mm
Maximum allowable working pressure (MAWP)	132,53 bar
Maximum allowable pressure (MAP)	202,56 bar
Maximum allowable external pressure (MAEP)	81,5 bar
Rated MDMT	-105 °C

UCS-66 Material Toughness Requirements	
Impact test temperature per material specification =	-45°C
$t_r = \frac{16{,}02 \cdot 30{,}16}{1.180 \cdot 1 + 0{,}4 \cdot 16{,}02} =$	0,41 mm
$\text{Stress ratio} = \frac{t_r \cdot E^*}{t_n - c} = \frac{0{,}41 \cdot 1}{4{,}85 - 1{,}6} =$	0,1255
Stress ratio ≤ 0,35, MDMT per UCS-66(b)(3) =	-105°C
$MDMT = \min\left[T_{impact} - T_{UCS-66(g)}, -105\right] = \min\left[-45 - 3, -105\right] =$	-105°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Design thickness, (at 121 °C) Appendix 1-1

$$t = \frac{P \cdot R_o}{S \cdot E + 0{,}40 \cdot P} + \text{Corrosion} = \frac{15{,}62 \cdot 30{,}16}{1.180 \cdot 1{,}00 + 0{,}40 \cdot 15{,}62} + 1{,}6 = 2 \text{ mm}$$

Maximum allowable working pressure, (at 121 °C) Appendix 1-1

$$P = \frac{S \cdot E \cdot t}{R_o - 0{,}40 \cdot t} - P_s = \frac{1.180 \cdot 1{,}00 \cdot (5{,}54 \cdot 0{,}875 - 1{,}6)}{30{,}16 - 0{,}40 \cdot (5{,}54 \cdot 0{,}875 - 1{,}6)} - 0{,}12 = 132{,}53 \text{ bar}$$

Maximum allowable pressure, (at 7 °C) Appendix 1-1

$$P = \frac{S \cdot E \cdot t}{R_o - 0{,}40 \cdot t} = \frac{1.180 \cdot 1{,}00 \cdot (5{,}54 \cdot 0{,}875)}{30{,}16 - 0{,}40 \cdot (5{,}54 \cdot 0{,}875)} = 202{,}56 \text{ bar}$$

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{1.309{,}45}{60{,}33} = 21{,}7065$$

$$\frac{D_o}{t} = \frac{60{,}33}{0{,}52} = 115{,}3648$$

From table G: $A = 0{,}000087$

From table CS-2 Metric: $B = 88{,}226 \text{ kg/cm}^2 (86{,}52 \text{ bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o / t)} = \frac{4 \cdot 86{,}52}{3 \cdot (60{,}33 / 0{,}52)} = 1 \text{ bar}$$

Design thickness for external pressure P_a = 1 bar

$$t_a = t + \text{Corrosion} = 0{,}52 + 1{,}6 = 2{,}12 \text{ mm}$$

Maximum Allowable External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{1.309{,}45}{60{,}33} = 21{,}7065$$

$$\frac{D_o}{t} = \frac{60{,}33}{5{,}54 \cdot 0{,}875 - 1{,}6} = 18{,}5910$$

From table G: $A = 0{,}003380$

From table CS-2 Metric: $B = 1.158{,}8304 \text{ kg/cm}^2 (1.136{,}4223 \text{ bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 1.136,42}{3 \cdot (60{,}33/(5{,}54 \cdot 0{,}875 - 1{,}6))} = 81{,}5 \text{ bar}$$

Nozzle Pipe (D)

ASME Section VIII Division 1, 2021 Edition Metric				
Component		Nozzle Pipe		
Material		SA-333 6 Wld & smls pipe (II-D Metric p. 16, ln. 19)		
Pipe NPS and Schedule		NPS 2 Sch 80 (XS) DN 50		
Attached To		B16.9 Elbow D		
Impact Tested	**Normalized**	**Fine Grain Practice**	**PWHT**	**Maximize MDMT/ No MAWP**
No	Yes	Yes	Yes	No
		Design Pressure (bar)	**Design Temperature (°C)**	**Design MDMT (°C)**
Internal		15,5	121	-15
External		1	23	
Static Liquid Head				
Condition		**P_s (bar)**	**H_s (mm)**	**SG**
Operating		0,12	1.255,83	0,999
Test horizontal		0,09	950	1
Test vertical		0,32	3.300,83	1
Dimensions				
Outer Diameter		60,33 mm		
Length		950 mm		
Pipe Minimum Thickness		5,54 mm		
Corrosion	**Inner**	0 mm		
	Outer	1,6 mm		
Weight and Capacity				
		Weight (kg)		**Capacity (liters)**
New		7,09		1,4
Corroded		4,9		1,4
Lining				
		Thickness (mm)	**Density (kg/m^3)**	**Weight (kg)**
Lining		3	8.000	0
Radiography				
Longitudinal seam		Seamless No RT		
Left Circumferential seam		Full UW-11(a) Type 1		
Right Circumferential seam		Full UW-11(a) Type 1		

ASME B16.5-2017 Flange	
Description	NPS 2 Class 150 WN A350 LF2 Cl.1 N
Bolt Material	SA-320 L7 Bolt <= 65 (II-D Metric p. 410, ln. 33)
Blind included	No
Rated MDMT	-56,2°C
Liquid static head	0,12 bar
MAWP rating	16,9 bar @ 121°C
MAP rating	19,6 bar @ 7°C
Hydrotest rating	30 bar @ 7°C
PWHT performed	Yes
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	Yes
Impact Tested	No
Circumferential joint radiography	Full UW-11(a) Type 1
Gasket	
Type	ASME B16.20 Spiral-Wound
Description	Spiral-wound Stainless, Monel, or nickel-base alloy windings with filler
Factor, m	3
Seating Stress, y	703,07 kg_f/cm^2
Thickness, T	4,5 mm
Inner Diameter	69,9 mm
Outer Diameter	85,9 mm
Notes	
(1) Flange is impact tested per material specification to -46°C. UCS-66(i) reduction of 10,2°C applied (ratio = 0,8175). Bolts rated MDMT per Fig UCS-66 note (c) = -104°C	

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	1,5 mm + 1,6 mm = 3,1 mm
Design thickness due to internal pressure (t)	2 mm
Design thickness due to external pressure (t_e)	2,12 mm
Maximum allowable working pressure (MAWP)	162,38 bar
Maximum allowable pressure (MAP)	233,79 bar
Maximum allowable external pressure (MAEP)	103,05 bar
Rated MDMT	-105 °C

UCS-66 Material Toughness Requirements	
Impact test exempt per UCS-66(d) (NPS 4 or smaller pipe) =	-105°C
Material is exempt from impact testing at the Design MDMT of -15°C.	

Design thickness, (at 121 °C) Appendix 1-1

$$t = \frac{P \cdot R_o}{S \cdot E + 0{,}40 \cdot P} + \text{Corrosion} = \frac{15{,}62 \cdot 30{,}16}{1.180 \cdot 1{,}00 + 0{,}40 \cdot 15{,}62} + 1{,}6 = 2 \text{ mm}$$

Maximum allowable working pressure, (at 121 °C) Appendix 1-1

$$P = \frac{S \cdot E \cdot t}{R_o - 0{,}40 \cdot t} - P_s = \frac{1.180 \cdot 1{,}00 \cdot 3{,}94}{30{,}16 - 0{,}40 \cdot 3{,}94} - 0{,}12 = 162{,}38 \text{ bar}$$

Maximum allowable pressure, (at 7 °C) Appendix 1-1

$$P = \frac{S \cdot E \cdot t}{R_o - 0{,}40 \cdot t} = \frac{1.180 \cdot 1{,}00 \cdot 5{,}54}{30{,}16 - 0{,}40 \cdot 5{,}54} = \underline{233{,}79} \text{ bar}$$

External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{1.309{,}45}{60{,}33} = 21{,}7065$$

$$\frac{D_o}{t} = \frac{60{,}33}{0{,}52} = 115{,}3648$$

From table G: $A = 0{,}000087$

From table CS-2 Metric: $B = 88{,}226 \ \ \text{kg/cm}^2 (86{,}52 \ \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 86,52}{3 \cdot (60{,}33/0{,}52)} = 1 \ \ \text{bar}$$

Design thickness for external pressure P_a = 1 bar

$t_a = t + \text{Corrosion} = 0{,}52 + 1{,}6 = \underline{2{,}12}$ mm

Maximum Allowable External Pressure, (Corroded & at 23 °C) UG-28(c)

$$\frac{L}{D_o} = \frac{1.309{,}45}{60{,}33} = 21{,}7065$$

$$\frac{D_o}{t} = \frac{60{,}33}{3{,}94} = 15{,}3226$$

From table G: $A = 0{,}004791$

From table CS-2 Metric: $B = 1.207{,}5615 \ \ \text{kg/cm}^2 (1.184{,}2111 \ \ \text{bar})$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 1.184,21}{3 \cdot (60{,}33/3{,}94)} = \underline{103{,}05} \text{ bar}$$

Support Skirt

ASME Section VIII Division 1, 2021 Edition Metric				
Component		Support Skirt		
Skirt is Attached To		Bottom Head		
Skirt Attachment Offset		150 mm down from the top seam		
Material		SA-516 60 (II-D Metric p. 16, ln. 3)		
		Impact Tested[1]	Normalized	Fine Grain Practice
		No	Yes	Yes
Design Temperature				
Internal		121°C		
External		121°C		
Dimensions				
Inner Diameter	Top	1.814 mm		
	Bottom	1.814 mm		
Length (includes base ring thickness)		1.070 mm		
Nominal Thickness		10 mm		
Corrosion	Inner	1,6 mm		
	Outer	0 mm		
Weight				
New		471,29 kg		
Corroded		395,54 kg		
Insulation\Lining				
		Thickness	Density	Weight
Lining		18,3 mm	1.000	110,46 kg
Insulation		18,3 mm	1.000	113,95 kg
		Spacing	Individual Weight	Total Weight
Insulation Supports		0 mm	0 kg	0 kg
Joint Efficiency				
Top		0,55		
Bottom		0,7		

[1]Impact testing requirements are not checked for supports

Skirt design thickness, largest of the following + corrosion = 1,9 mm

The governing condition is due to wind, compressive stress at the base, operating & corroded.

The skirt thickness of 10 mm is adequate.

Results Summary							
Loading	Condition	Tensile or Compressive Side	Governing Skirt Location	Temperature (°C)	Allowable Stress (kg_f/cm^2)	Calculated Stress/E (kg_f/cm^2)	Required thickness (mm)
Wind	operating, corroded	Tensile	top	121	898,2	-11,55	0,11
		Compressive	bottom			31,6	0,3
	operating, new	Tensile	top	121	943,22	-10,1	0,11
		Compressive	bottom			27,14	0,29
	empty, corroded	Tensile	top	7	898,2	-7,29	0,07
		Compressive	bottom			27,34	0,26
	empty, new	Tensile	top	7	943,22	-6,52	0,07
		Compressive	bottom			23,56	0,25
	test, corroded	Tensile	bottom	7	898,2	-21,88	0,2
		Compressive				31,32	0,29
	test, new	Tensile	bottom	7	943,22	-18,93	0,2
		Compressive				26,9	0,29
	vacuum, corroded	Tensile	top	121	898,2	-11,55	0,11
		Compressive	bottom			31,6	0,3
Seismic	operating, corroded	Tensile	top	121	898,2	-12,43	0,12
		Compressive	bottom			30,49	0,29
	operating, new	Tensile	top	121	943,22	-10,75	0,11
		Compressive	bottom			26,35	0,28
	empty, corroded	Tensile	top	7	898,2	-8,65	0,08
		Compressive	bottom			25,17	0,24
	empty, new	Tensile	top	7	943,22	-7,57	0,08
		Compressive	bottom			21,88	0,23
	vacuum, corroded	Tensile	top	121	898,2	-12,43	0,12
		Compressive	bottom			30,49	0,29

Loading due to wind, operating & corroded

Windward side (tensile)

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{10.027{,}72}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.372}{\pi \cdot 1.825{,}6\ ^2 \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}0938 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{9.320{,}59}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.714{,}2}{\pi \cdot 1.825{,}6\ ^2 \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}11 \quad \text{mm}$$

Leeward side (compressive)

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{10.027{,}72}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.372}{\pi \cdot 1.825{,}6\ ^2 \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}3 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{9.320{,}59}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.714{,}2}{\pi \cdot 1.825{,}6\ ^2 \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}25 \quad \text{mm}$$

Loading due to wind, operating & new

Windward side (tensile)

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{10.344{,}88}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.375{,}1}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}095 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{9.555{,}38}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.717{,}3}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}11 \quad \text{mm}$$

Leeward side (compressive)

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{10.344{,}88}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.375{,}1}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}29 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{9.555{,}38}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.717{,}3}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}25 \quad \text{mm}$$

Loading due to wind, empty & corroded

Windward side (tensile)

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{7.975{,}37}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.372}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}0539 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{7.268{,}23}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.714{,}2}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}0682 \quad \text{mm}$$

Leeward side (compressive)

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{7.975{,}37}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.372}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}26 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{7.268{,}23}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.714{,}2}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}21 \quad \text{mm}$$

Loading due to wind, empty & new

Windward side (tensile)

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{8.292{,}67}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.375{,}1}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}0571 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{7.503{,}16}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.717{,}3}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}0691 \ \ \text{mm}$$

Leeward side (compressive)

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{8.292{,}67}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.375{,}1}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}25 \ \ \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{7.503{,}16}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.717{,}3}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}21 \ \ \text{mm}$$

Loading due to wind, test & corroded

Windward side (tensile)

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{12.814{,}37}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.037{,}8}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}2 \ \ \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{12.107{,}24}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 873{,}3}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}2 \ \ \text{mm}$$

Leeward side (compressive)

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{12.814{,}37}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.037{,}8}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}29 \ \ \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{12.107{,}24}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 873{,}3}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}27 \ \ \text{mm}$$

Loading due to wind, test & new

Windward side (tensile)

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{13.131{,}02}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.040{,}8}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}2 \ \ \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{12.341{,}51}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 876{,}4}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}19 \ \ \text{mm}$$

Leeward side (compressive)

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{13.131{,}02}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.040{,}8}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}29 \ \ \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{12.341{,}51}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 876{,}4}{\pi \cdot 1.824^{\,2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}26 \quad \text{mm}$$

Loading due to wind, vacuum & corroded

Windward side (tensile)

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{10.027{,}72}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.372}{\pi \cdot 1.825{,}6^{\,2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}0938 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{9.320{,}59}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.714{,}2}{\pi \cdot 1.825{,}6^{\,2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}11 \quad \text{mm}$$

Leeward side (compressive)

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{10.027{,}72}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.372}{\pi \cdot 1.825{,}6^{\,2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}3 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{9.320{,}59}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.714{,}2}{\pi \cdot 1.825{,}6^{\,2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}25 \quad \text{mm}$$

Loading due to seismic, operating & corroded

Tensile side

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{10.027{,}72}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.127{,}6}{\pi \cdot 1.825{,}6^{\,2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}1 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{9.320{,}59}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.520{,}9}{\pi \cdot 1.825{,}6^{\,2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}12 \quad \text{mm}$$

Compressive side

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{10.027{,}72}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.127{,}6}{\pi \cdot 1.825{,}6^{\,2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}29 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{9.320{,}59}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.520{,}9}{\pi \cdot 1.825{,}6^{\,2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}25 \quad \text{mm}$$

Loading due to seismic, operating & new

Tensile side

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{10.344{,}88}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.169{,}3}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}1 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{9.555{,}38}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.548{,}7}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}11 \quad \text{mm}$$

Compressive side

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{10.344{,}88}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.169{,}3}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}28 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{9.555{,}38}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.548{,}7}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}24 \quad \text{mm}$$

Loading due to seismic, empty & corroded

Tensile side

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{7.975{,}37}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.893{,}3}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}0743 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{7.268{,}23}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.415{,}6}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}0809 \quad \text{mm}$$

Compressive side

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{7.975{,}37}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.893{,}3}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}24 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{7.268{,}23}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.415{,}6}{\pi \cdot 1.825{,}6^{\ 2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}2 \quad \text{mm}$$

Loading due to seismic, empty & new

Tensile side

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{8.292{,}67}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.936{,}1}{\pi \cdot 1.824^{\ 2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}0749 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{7.503{,}16}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.444{,}6}{\pi \cdot 1.824^{\;2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}0802 \quad \text{mm}$$

Compressive side

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{8.292{,}67}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.936{,}1}{\pi \cdot 1.824^{\;2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}23 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{7.503{,}16}{\pi \cdot 1.824 \cdot \frac{943{,}224}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.444{,}6}{\pi \cdot 1.824^{\;2} \cdot \frac{943{,}224}{100} \cdot 1} = 0{,}2 \quad \text{mm}$$

Loading due to seismic, vacuum & corroded

Tensile side

Required thickness, tensile stress at base:

$$t = -\frac{W}{\pi \cdot D \cdot S_t \cdot E} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_t \cdot E} = -\frac{10.027{,}72}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.127{,}6}{\pi \cdot 1.825{,}6^{\;2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}1 \quad \text{mm}$$

Required thickness, tensile stress at the top:

$$t = -\frac{W_t}{\pi \cdot D_t \cdot S_t \cdot E} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_t \cdot E} = -\frac{9.320{,}59}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.520{,}9}{\pi \cdot 1.825{,}6^{\;2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}12 \quad \text{mm}$$

Compressive side

Required thickness, compressive stress at base:

$$t = \frac{W}{\pi \cdot D \cdot S_c \cdot E_c} + \frac{4 \cdot M}{\pi \cdot D^2 \cdot S_c \cdot E_c} = \frac{10.027{,}72}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 2.127{,}6}{\pi \cdot 1.825{,}6^{\;2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}29 \quad \text{mm}$$

Required thickness, compressive stress at the top:

$$t = \frac{W_t}{\pi \cdot D_t \cdot S_c \cdot E_c} + \frac{4 \cdot M_t}{\pi \cdot D_t^2 \cdot S_c \cdot E_c} = \frac{9.320{,}59}{\pi \cdot 1.825{,}6 \cdot \frac{898{,}203}{100} \cdot 1} + \frac{4 \cdot 1e3 \cdot 1.520{,}9}{\pi \cdot 1.825{,}6^{\;2} \cdot \frac{898{,}203}{100} \cdot 1} = 0{,}25 \quad \text{mm}$$

Skirt Base Ring

Inputs	
Base configuration	single base plate
Base plate material	SA-516 Gr60
Base plate allowable stress, S_p	1.203,265 kg_f/cm^2
Foundation compressive strength	116,569 kg_f/cm^2
Concrete ultimate 28-day strength	210,921 kg_f/cm^2
Bolt circle, BC	1.934 mm
Base plate inner diameter, D_i	1.754 mm
Base plate outer diameter, D_o	2.014 mm
Base plate thickness, t_b	20 mm
Gusset separation, w	125 mm
Gusset height, h	200 mm
Gusset thickness, t_g	13 mm
Anchor Bolts	
Material	
Allowable stress, S_b	1.055 kg_f/cm^2
Bolt size and type	M24 x 3
Number of bolts, N	4
Corrosion allowance (applied to root radius)	0 mm
Anchor bolt clearance	12 mm
Bolt root area (corroded), A_b	3,13 cm^2
Diameter of anchor bolt holes, d_b	36 mm
Initial bolt preload	0% (0 kg_f/cm^2)
Bolt at 0°	No

Results Summary							
Load	**Vessel condition**	**Base V (kg_f)**	**Base M (kg_f-m)**	**W (kg)**	**Required bolt area (cm^2)**	**t_r Base (mm)**	**Foundation bearing stress (kg_f/cm^2)**
Wind	operating, corroded	652,9	2.372	10.155,2	0	6,3	2,0232
Wind	operating, new	652,9	2.375,1	10.472,3	0	6,37	2,0655
Wind	empty, corroded	652,9	2.372	8.102,8	0	5,87	1,7551
Wind	empty, new	652,9	2.375,1	8.420,1	0	5,94	1,7974
Wind	test, corroded	163,2	1.037,8	12.941,8	0	6,26	1,9956
Wind	test, new	163,2	1.040,8	13.258,5	0	6,32	2,0379
Wind	vacuum, corroded	652,9	2.372	10.155,2	0	6,3	2,0232
Seismic	operating, corroded	599,2	2.127,6	10.155,2	0	6,19	1,9515
Seismic	operating, new	617,9	2.169,3	10.472,3	0	6,27	2,0051
Seismic	empty, corroded	478,1	1.893,3	8.102,8	0	5,63	1,6145
Seismic	empty, new	496,8	1.936,1	8.420,1	0	5,72	1,6685
Seismic	vacuum, corroded	599,2	2.127,6	10.155,2	0	6,19	1,9515

Anchor bolt load (operating, corroded + Wind)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-10.155,18}{4} + \frac{4 \cdot 2.372}{4 \cdot 1,934} = -1.312,32 \ \ \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, corroded + Wind)

$$A_c = \frac{\pi \cdot (D_o^2 - D_i^2)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot (201{,}4^{\,2} - 175{,}4^{\,2})}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\,2}}{4} = 7.653{,}6737 \quad \text{cm}^2$$

$$I_c = \frac{\pi \cdot (D_o^4 - D_i^4)}{64} = \frac{\pi \cdot (201{,}4^{\,4} - 175{,}4^{\,4})}{64} = 3{,}4301\text{E}{+}07 \quad \text{cm}^4$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{10.155{,}18}{7.653{,}6737} + \frac{10 \cdot \frac{2.372}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 2{,}023 \quad \text{kg}_f/\text{cm}^2$$

As f_c <= 116,569 kg_f/cm^2 the base plate width is satisfactory.

Base plate required thickness (operating, corroded + Wind)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 2{,}023 \cdot 1.367{,}96^{\,2} = 58{,}3 \text{ kg}_f$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 2{,}023 \cdot 90^2 = -79{,}6 \text{ kg}_f$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 79{,}61}{1.203{,}265}} = 6{,}3 \quad \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, operating, corroded + Wind)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0 \text{ kg}_f$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \quad \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\,2} \cdot 200} = 0 \quad \text{kg}_f/\text{cm}^2$$

As S_r <= 1.804,898 kg_f/cm^2 the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (operating, new + Wind)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-10.472{,}34}{4} + \frac{4 \cdot 2.375{,}1}{4 \cdot 1{,}934} = -1.390{,}03 \quad \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, new + Wind)

$$A_c = \frac{\pi \cdot (D_o^2 - D_i^2)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot (201{,}4^{\,2} - 175{,}4^{\,2})}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\,2}}{4} = 7.653{,}6737 \quad \text{cm}^2$$

$$I_c = \frac{\pi \cdot (D_o^4 - D_i^4)}{64} = \frac{\pi \cdot (201{,}4^{\,4} - 175{,}4^{\,4})}{64} = 3{,}4301\text{E}{+}07 \quad \text{cm}^4$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{10.472{,}34}{7.653{,}6737} + \frac{10 \cdot \frac{2.375{,}1}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 2{,}066 \quad \text{kg}_f/\text{cm}^2$$

As f_c <= 116,569 kg_f/cm^2 the base plate width is satisfactory.

Base plate required thickness (operating, new + Wind)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 2{,}066 \cdot 1.367{,}96^{\ 2} = 59{,}5 \text{ kg}_\text{f}$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 2{,}066 \cdot 90^2 = -81{,}3 \text{ kg}_\text{f}$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 81{,}28}{1.203{,}265}} = 6{,}37 \ \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, operating, new + Wind)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0 \text{ kg}_\text{f}$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \ \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\ 2} \cdot 200} = 0 \ \text{kg}_f/\text{cm}^2$$

As S_r <= 1.804,898 $\text{kg}_\text{f}/\text{cm}^2$ the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (empty, corroded + Wind)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-8.102{,}83}{4} + \frac{4 \cdot 2.372}{4 \cdot 1{,}934} = -799{,}23 \ \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (empty, corroded + Wind)

$$A_c = \frac{\pi \cdot (D_o^2 - D_i^2)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot (201{,}4^{\ 2} - 175{,}4^{\ 2})}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\ 2}}{4} = 7.653{,}6737 \ \text{cm}^2$$

$$I_c = \frac{\pi \cdot (D_o^4 - D_i^4)}{64} = \frac{\pi \cdot (201{,}4^{\ 4} - 175{,}4^{\ 4})}{64} = 3{,}4301\text{E}{+}07 \ \text{cm}^4$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{8.102{,}83}{7.653{,}6737} + \frac{10 \cdot \frac{2.372}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 1{,}755 \ \text{kg}_f/\text{cm}^2$$

As f_c <= 116,569 $\text{kg}_\text{f}/\text{cm}^2$ the base plate width is satisfactory.

Base plate required thickness (empty, corroded + Wind)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 1{,}755 \cdot 1.367{,}96^{\ 2} = 50{,}6 \text{ kg}_\text{f}$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 1{,}755 \cdot 90^2 = -69{,}1 \text{ kg}_\text{f}$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 69{,}06}{1.203{,}265}} = 5{,}87 \ \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, empty, corroded + Wind)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0\ \text{kg}_\text{f}$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0\ \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^2 \cdot 200} = 0\ \ \text{kg}_f/\text{cm}^2$$

As S_r <= 1.804,898 $\text{kg}_\text{f}/\text{cm}^2$ the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (empty, new + Wind)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-8.420{,}13}{4} + \frac{4 \cdot 2.375{,}1}{4 \cdot 1{,}934} = -876{,}98\ \ \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (empty, new + Wind)

$$A_c = \frac{\pi \cdot \left(D_o^2 - D_i^2\right)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot \left(201{,}4^2 - 175{,}4^2\right)}{4} - \frac{4 \cdot \pi \cdot 3{,}6^2}{4} = 7.653{,}6737\ \ \text{cm}^2$$

$$I_c = \frac{\pi \cdot \left(D_o^4 - D_i^4\right)}{64} = \frac{\pi \cdot \left(201{,}4^4 - 175{,}4^4\right)}{64} = 3{,}4301\text{E}{+}07\ \ \text{cm}^4$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{8.420{,}13}{7.653{,}6737} + \frac{10 \cdot \frac{2.375{,}1}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 1{,}797\ \ \text{kg}_f/\text{cm}^2$$

As f_c <= 116,569 $\text{kg}_\text{f}/\text{cm}^2$ the base plate width is satisfactory.

Base plate required thickness (empty, new + Wind)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 1{,}797 \cdot 1.367{,}96^2 = 51{,}8\ \text{kg}_\text{f}$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 1{,}797 \cdot 90^2 = -70{,}7\ \text{kg}_\text{f}$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 70{,}73}{1.203{,}265}} = 5{,}94\ \ \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, empty, new + Wind)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0\ \text{kg}_\text{f}$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0\ \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\,2} \cdot 200} = 0 \ \text{kg}_f/\text{cm}^{\,2}$$

As S_r <= 1.804,898 kg_f/cm^2 the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (test, corroded + Wind)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-12.941{,}83}{4} + \frac{4 \cdot 1.037{,}8}{4 \cdot 1{,}934} = -2.698{,}87 \ \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (test, corroded + Wind)

$$A_c = \frac{\pi \cdot \left(D_o^2 - D_i^2\right)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot \left(201{,}4^{\,2} - 175{,}4^{\,2}\right)}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\,2}}{4} = 7.653{,}6737 \ \text{cm}^{\,2}$$

$$I_c = \frac{\pi \cdot \left(D_o^4 - D_i^4\right)}{64} = \frac{\pi \cdot \left(201{,}4^{\,4} - 175{,}4^{\,4}\right)}{64} = 3{,}4301\text{E}{+}07 \ \text{cm}^{\,4}$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{12.941{,}83}{7.653{,}6737} + \frac{10 \cdot \frac{1.037{,}8}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 1{,}996 \ \text{kg}_f/\text{cm}^{\,2}$$

As f_c <= 116,569 kg_f/cm^2 the base plate width is satisfactory.

Base plate required thickness (test, corroded + Wind)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 1{,}996 \cdot 1.367{,}96^{\ 2} = 57{,}5 \ \text{kg}_f$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 1{,}996 \cdot 90^{\,2} = -78{,}5 \ \text{kg}_f$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 78{,}52}{1.203{,}265}} = 6{,}26 \ \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, test, corroded + Wind)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0 \ \text{kg}_f$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \ \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\,2} \cdot 200} = 0 \ \text{kg}_f/\text{cm}^{\,2}$$

As S_r <= 1.804,898 kg_f/cm^2 the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (test, new + Wind)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-13.258{,}48}{4} + \frac{4 \cdot 1.040{,}8}{4 \cdot 1{,}934} = -2.776{,}45 \ \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (test, new + Wind)

$$A_c = \frac{\pi \cdot (D_o^2 - D_i^2)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot (201{,}4^{\,2} - 175{,}4^{\,2})}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\,2}}{4} = 7.653{,}6737 \ \ \mathrm{cm}^{\,2}$$

$$I_c = \frac{\pi \cdot (D_o^4 - D_i^4)}{64} = \frac{\pi \cdot (201{,}4^{\,4} - 175{,}4^{\,4})}{64} = 3{,}4301\mathrm{E}{+}07 \ \ \mathrm{cm}^{\,4}$$

$$f_c = \frac{N \cdot A_b \cdot \mathrm{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{13.258{,}48}{7.653{,}6737} + \frac{10 \cdot \frac{1.040{,}8}{2} \cdot 2.014}{3{,}4301\mathrm{E}{+}07} = 2{,}038 \ \ \mathrm{kg}_f/\mathrm{cm}^{\,2}$$

As f_c <= 116,569 kg_f/cm^2 the base plate width is satisfactory.

Base plate required thickness (test, new + Wind)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 2{,}038 \cdot 1.367{,}96^{\,2} = 58{,}7 \ \mathrm{kg_f}$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 2{,}038 \cdot 90^{2} = -80{,}2 \ \mathrm{kg_f}$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 80{,}19}{1.203{,}265}} = 6{,}32 \ \ \mathrm{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, test, new + Wind)

$$\mathrm{Bolt\ load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0 \ \mathrm{kg_f}$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \ \ \mathrm{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\mathrm{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\,2} \cdot 200} = 0 \ \ \mathrm{kg}_f/\mathrm{cm}^{\,2}$$

As S_r <= 1.804,898 kg_f/cm^2 the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (vacuum, corroded + Wind)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-10.155{,}18}{4} + \frac{4 \cdot 2.372}{4 \cdot 1{,}934} = -1.312{,}32 \ \ \mathrm{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (vacuum, corroded + Wind)

$$A_c = \frac{\pi \cdot (D_o^2 - D_i^2)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot (201{,}4^{\,2} - 175{,}4^{\,2})}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\,2}}{4} = 7.653{,}6737 \ \ \mathrm{cm}^{\,2}$$

$$I_c = \frac{\pi \cdot (D_o^4 - D_i^4)}{64} = \frac{\pi \cdot (201{,}4^{\,4} - 175{,}4^{\,4})}{64} = 3{,}4301\mathrm{E}{+}07 \ \ \mathrm{cm}^{\,4}$$

$$f_c = \frac{N \cdot A_b \cdot \mathrm{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{10.155{,}18}{7.653{,}6737} + \frac{10 \cdot \frac{2.372}{2} \cdot 2.014}{3{,}4301\mathrm{E}{+}07} = 2{,}023 \ \ \mathrm{kg}_f/\mathrm{cm}^{\,2}$$

As f_c <= 116,569 kg_f/cm^2 the base plate width is satisfactory.

Base plate required thickness (vacuum, corroded + Wind)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 2{,}023 \cdot 1.367{,}96^{\ 2} = 58{,}3 \text{ kg}_\text{f}$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 2{,}023 \cdot 90^2 = -79{,}6 \text{ kg}_\text{f}$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 79{,}61}{1.203{,}265}} = 6{,}3 \ \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, vacuum, corroded + Wind)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0 \text{ kg}_\text{f}$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \ \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\ 2} \cdot 200} = 0 \ \text{kg}_f/\text{cm}^{\ 2}$$

As S_r <= 1.804,898 $\text{kg}_\text{f}/\text{cm}^2$ the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (operating, corroded + Seismic)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-10.155{,}18}{4} + \frac{4 \cdot 2.127{,}6}{4 \cdot 1{,}934} = -1.438{,}68 \ \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, corroded + Seismic)

$$A_c = \frac{\pi \cdot (D_o^2 - D_i^2)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot \left(201{,}4^{\ 2} - 175{,}4^{\ 2}\right)}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\ 2}}{4} = 7.653{,}6737 \ \text{cm}^{\ 2}$$

$$I_c = \frac{\pi \cdot (D_o^4 - D_i^4)}{64} = \frac{\pi \cdot \left(201{,}4^{\ 4} - 175{,}4^{\ 4}\right)}{64} = 3{,}4301\text{E}{+}07 \ \text{cm}^{\ 4}$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{10.155{,}18}{7.653{,}6737} + \frac{10 \cdot \frac{2.127{,}6}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 1{,}951 \ \text{kg}_f/\text{cm}^{\ 2}$$

As f_c <= 116,569 $\text{kg}_\text{f}/\text{cm}^2$ the base plate width is satisfactory.

Base plate required thickness (operating, corroded + Seismic)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 1{,}951 \cdot 1.367{,}96^{\ 2} = 56{,}2 \text{ kg}_\text{f}$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 1{,}951 \cdot 90^2 = -76{,}8 \text{ kg}_\text{f}$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 76{,}79}{1.203{,}265}} = 6{,}19 \ \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, operating, corroded + Seismic)

$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0$ kg$_f$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \ \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^2 \cdot 200} = 0 \ \text{kg}_f/\text{cm}^2$$

As S_r <= 1.804,898 kg$_f$/cm^2 the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (operating, new + Seismic)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-10.472{,}34}{4} + \frac{4 \cdot 2.169{,}3}{4 \cdot 1{,}934} = -1.496{,}45 \ \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (operating, new + Seismic)

$$A_c = \frac{\pi \cdot \left(D_o^2 - D_i^2\right)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot \left(201{,}4^2 - 175{,}4^2\right)}{4} - \frac{4 \cdot \pi \cdot 3{,}6^2}{4} = 7.653{,}6737 \ \text{cm}^2$$

$$I_c = \frac{\pi \cdot \left(D_o^4 - D_i^4\right)}{64} = \frac{\pi \cdot \left(201{,}4^4 - 175{,}4^4\right)}{64} = 3{,}4301\text{E+}07 \ \text{cm}^4$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{10.472{,}34}{7.653{,}6737} + \frac{10 \cdot \frac{2.169{,}3}{2} \cdot 2.014}{3{,}4301\text{E+}07} = 2{,}005 \ \text{kg}_f/\text{cm}^2$$

As f_c <= 116,569 kg$_f$/cm^2 the base plate width is satisfactory.

Base plate required thickness (operating, new + Seismic)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 2{,}005 \cdot 1.367{,}96^2 = 57{,}8 \ \text{kg}_f$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 2{,}005 \cdot 90^2 = -78{,}9 \ \text{kg}_f$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 78{,}9}{1.203{,}265}} = 6{,}27 \ \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, operating, new + Seismic)

$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0$ kg$_f$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \ \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\,2} \cdot 200} = 0 \;\; \text{kg}_f/\text{cm}^{\,2}$$

As S_r <= 1.804,898 kg_f/cm^2 the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (empty, corroded + Seismic)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-8.102{,}83}{4} + \frac{4 \cdot 1.893{,}3}{4 \cdot 1{,}934} = -1.046{,}77 \;\; \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (empty, corroded + Seismic)

$$A_c = \frac{\pi \cdot \left(D_o^2 - D_i^2\right)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot \left(201{,}4^{\,2} - 175{,}4^{\,2}\right)}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\,2}}{4} = 7.653{,}6737 \;\; \text{cm}^{\,2}$$

$$I_c = \frac{\pi \cdot \left(D_o^4 - D_i^4\right)}{64} = \frac{\pi \cdot \left(201{,}4^{\,4} - 175{,}4^{\,4}\right)}{64} = 3{,}4301\text{E}{+}07 \;\; \text{cm}^{\,4}$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{8.102{,}83}{7.653{,}6737} + \frac{10 \cdot \frac{1.893{,}3}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 1{,}615 \;\; \text{kg}_f/\text{cm}^{\,2}$$

As f_c <= 116,569 kg_f/cm^2 the base plate width is satisfactory.

Base plate required thickness (empty, corroded + Seismic)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 1{,}615 \cdot 1.367{,}96^{\,2} = 46{,}5 \text{ kg}_f$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 1{,}615 \cdot 90^{\,2} = -63{,}5 \text{ kg}_f$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 63{,}53}{1.203{,}265}} = 5{,}63 \;\; \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, empty, corroded + Seismic)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0 \text{ kg}_f$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \;\; \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\,2} \cdot 200} = 0 \;\; \text{kg}_f/\text{cm}^{\,2}$$

As S_r <= 1.804,898 kg_f/cm^2 the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (empty, new + Seismic)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-8.420{,}13}{4} + \frac{4 \cdot 1.936{,}1}{4 \cdot 1{,}934} = -1.103{,}95 \;\; \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (empty, new + Seismic)

$$A_c = \frac{\pi \cdot (D_o^2 - D_i^2)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot (201{,}4^{\,2} - 175{,}4^{\,2})}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\,2}}{4} = 7.653{,}6737 \ \ \text{cm}^{\,2}$$

$$I_c = \frac{\pi \cdot (D_o^4 - D_i^4)}{64} = \frac{\pi \cdot (201{,}4^{\,4} - 175{,}4^{\,4})}{64} = 3{,}4301\text{E}{+}07 \ \ \text{cm}^{\,4}$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{8.420{,}13}{7.653{,}6737} + \frac{10 \cdot \frac{1.936{,}1}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 1{,}669 \ \ \text{kg}_f/\text{cm}^{\,2}$$

As f_c <= 116,569 kg_f/cm^2 the base plate width is satisfactory.

Base plate required thickness (empty, new + Seismic)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 1{,}669 \cdot 1.367{,}96^{\,2} = 48{,}1 \ \text{kg}_f$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 1{,}669 \cdot 90^{\,2} = -65{,}7 \ \text{kg}_f$$

$$t_r = \sqrt{\frac{6 \cdot M_{max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 65{,}66}{1.203{,}265}} = 5{,}72 \ \ \text{mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, empty, new + Seismic)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0 \ \text{kg}_f$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \ \ \text{mm}$$

The base plate thickness is satisfactory.

Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^{\,2} \cdot 200} = 0 \ \ \text{kg}_f/\text{cm}^{\,2}$$

As S_r <= 1.804,898 kg_f/cm^2 the skirt thickness is adequate to resist the gusset reaction.

Anchor bolt load (vacuum, corroded + Seismic)

$$P = \frac{-W}{N} + \frac{4 \cdot M}{N \cdot BC} = \frac{-10.155{,}18}{4} + \frac{4 \cdot 2.127{,}6}{4 \cdot 1{,}934} = -1.438{,}68 \ \ \text{kg}_f$$

The anchor bolts are satisfactory (no net uplift on anchor bolt)

Foundation bearing stress (vacuum, corroded + Seismic)

$$A_c = \frac{\pi \cdot (D_o^2 - D_i^2)}{4} - \frac{N \cdot \pi \cdot d_b^2}{4} = \frac{\pi \cdot (201{,}4^{\,2} - 175{,}4^{\,2})}{4} - \frac{4 \cdot \pi \cdot 3{,}6^{\,2}}{4} = 7.653{,}6737 \ \ \text{cm}^{\,2}$$

$$I_c = \frac{\pi \cdot (D_o^4 - D_i^4)}{64} = \frac{\pi \cdot (201{,}4^{\,4} - 175{,}4^{\,4})}{64} = 3{,}4301\text{E}{+}07 \ \ \text{cm}^{\,4}$$

$$f_c = \frac{N \cdot A_b \cdot \text{Preload}}{A_c} + \frac{W}{A_c} + \frac{\frac{M}{2} \cdot D_o}{I_c} = \frac{4 \cdot 3{,}1275 \cdot 0}{7.653{,}6737} + \frac{10.155{,}18}{7.653{,}6737} + \frac{10 \cdot \frac{2.127{,}6}{2} \cdot 2.014}{3{,}4301\text{E}{+}07} = 1{,}951 \ \ \text{kg}_f/\text{cm}^{\,2}$$

As f_c <= 116,569 kg_f/cm^2 the base plate width is satisfactory.

Base plate required thickness (vacuum, corroded + Seismic)

From Brownell & Young, Table 10.3:, $\frac{l}{b}$ = 0,0658

$$M_x = 0.01 \cdot 0{,}0015 \cdot 1{,}951 \cdot 1.367{,}96\ ^2 = 56{,}2 \text{ kg}_\text{f}$$

$$M_y = 0.01 \cdot -0{,}4858 \cdot 1{,}951 \cdot 90^2 = -76{,}8 \text{ kg}_\text{f}$$

$$t_r = \sqrt{\frac{6 \cdot M_{\max}}{S_p}} = \sqrt{\frac{100 \cdot 6 \cdot 76{,}79}{1.203{,}265}} = 6{,}19 \text{ mm}$$

The base plate thickness is satisfactory.

Base plate bolt load (Jawad & Farr eq. 12.13, vacuum, corroded + Seismic)

$$\text{Bolt load} = A_b \cdot f_s = 3{,}1275 \cdot 0 = 0 \text{ kg}_\text{f}$$

$$t_r = \left(3.91 \cdot \frac{F}{S_y \cdot \left(\frac{2 \cdot b}{w} + \frac{w}{2 \cdot l} - d_b \cdot \left(\frac{2}{w} + \frac{1}{2 \cdot l}\right)\right)}\right)^{0.5} = \left(3.91 \cdot 100 \cdot \frac{0}{2.202 \cdot \left(\frac{2 \cdot 90}{125} + \frac{125}{2 \cdot 50} - 36 \cdot \left(\frac{2}{125} + \frac{1}{2 \cdot 50}\right)\right)}\right)^{0.5} = 0 \text{ mm}$$

The base plate thickness is satisfactory.

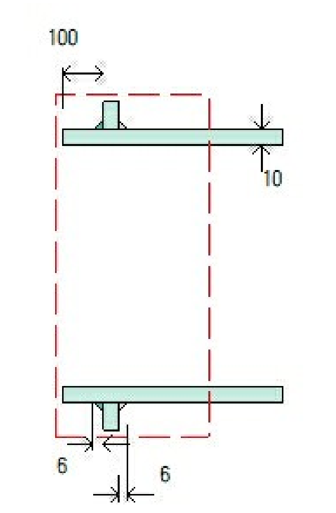
Check skirt for gusset reaction (Jawad & Farr eq. 12.14)

$$S_r = \frac{1{,}5 \cdot F \cdot b}{\text{gussets} \cdot \pi \cdot t_{sk}^2 \cdot h} = \frac{1{,}5 \cdot 100 \cdot 0 \cdot 90}{2 \cdot \pi \cdot 8{,}4^2 \cdot 200} = 0 \text{ kg}_f/\text{cm}^2$$

As S_r <= 1.804,898 $\text{kg}_\text{f}/\text{cm}^2$ the skirt thickness is adequate to resist the gusset reaction.

Skirt opening (SA1)

ASME Section VIII Division 1, 2021 Edition Metric		
Component		Skirt Opening
Description		Skirt opening
Drawing Mark		SA1
Sleeve Material		SA-516 60 (II-D Metric p. 16, ln. 3)
Location and Orientation		
Attached to		Support Skirt
Orientation		radial
Offset, L		650 mm
Angle, θ		45°
Distance, r		1.037 mm
Through a Category B Joint		No
Dimensions		
Inside Diameter		580 mm
Nominal Wall Thickness		10 mm
Skirt Thickness		10 mm
Leg_{41}		6 mm
Leg_{43}		6 mm
External Projection Available, L_{pr1}		120 mm
Internal Projection, L_{pr2}		100 mm
Corrosion	**Inner**	0 mm
	Outer	1,6 mm



Skirt Opening Reinforcement Summary			Required Thickness t_r (mm)	A_T (cm^2)	A_r (cm^2)	Ratio	Status
Operating Hot & Corroded	Wind	Tensile	0	32,951	0	N/A	OK
		Compressive	0,27	32,4376	1,5549	20,862	OK
	Seismic	Tensile	0	32,951	0	N/A	OK
		Compressive	0,26	32,455	1,5022	21,6046	OK
Operating Hot & New	Wind	Tensile	0	43,308	0	N/A	OK
		Compressive	0,26	42,7594	1,5117	28,2852	OK
	Seismic	Tensile	0	43,308	0	N/A	OK
		Compressive	0,25	42,775	1,4686	29,1262	OK
Empty Cold & Corroded	Wind	Tensile	0	32,951	0	N/A	OK
		Compressive	0,23	32,5139	1,3238	24,5612	OK
	Seismic	Tensile	0	32,951	0	N/A	OK
		Compressive	0,21	32,544	1,2327	26,4009	OK
Empty Cold & New	Wind	Tensile	0	43,308	0	N/A	OK
		Compressive	0,22	42,8393	1,2915	33,1702	OK
	Seismic	Tensile	0	43,308	0	N/A	OK
		Compressive	0,21	42,8682	1,212	35,3707	OK
Field Test Corr	Wind	Tensile	0	32,951	0	N/A	OK
		Compressive	0,28	32,4183	1,6134	20,0931	OK
Field Test New	Wind	Tensile	0	43,308	0	N/A	OK
		Compressive	0,27	42,7392	1,5672	27,2704	OK
External Pressure Hot & Corroded	Wind	Tensile	0	32,951	0	N/A	OK
		Compressive	0,27	32,4376	1,5549	20,862	OK
	Seismic	Tensile	0	32,951	0	N/A	OK
		Compressive	0,26	32,455	1,5022	21,6046	OK

Note: Skirt required thickness of zero on tensile side indicates load is compressive.

Skirt Opening Reinforcement Calculations	
Operating Hot & Corroded Wind Compressive	
$f_{r1} = \min\left[\frac{1.203,27}{1.203,27}, 1\right] =$	1
$f_{r2} = \min\left[\frac{1.203,27}{1.203,27}, 1\right] =$	1
$A_1 = \frac{2 \cdot 87,36 \cdot (1 \cdot 8,4 - 0,27)}{100} =$	14,2085 cm^2
$A_2 = 2 \cdot (57,76 - 0,27) \cdot 8,4 \cdot \frac{1}{100} =$	9,6579 cm^2
$A_3 = 2 \cdot 49,36 \cdot 8,4 \cdot \frac{1}{100} =$	8,2918 cm^2
$A_{41} = 3,74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_{43} = 3,74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_T = 14,2085 + 9,6579 + 8,2918 + 0,1397 + 0,1397 =$	32,4376 cm^2
$A_r = \frac{580 \cdot 0,27 + 2 \cdot 8,4 \cdot 0,27 \cdot (1 - 1)}{100} =$	1,5549 cm^2
$A_T = 32,4376 cm^2 \geq A_r = 1,5549 cm^2$	

Operating Hot & New Wind Compressive	
$f_{r1} = \min\left[\frac{1.203{,}27}{1.203{,}27},1\right] =$	1
$f_{r2} = \min\left[\frac{1.203{,}27}{1.203{,}27},1\right] =$	1
$A_1 = \frac{2 \cdot 95{,}24 \cdot (1 \cdot 10 - 0{,}26)}{100} =$	18,5509 cm^2
$A_2 = 2 \cdot (63{,}85 - 0{,}26) \cdot 10 \cdot \frac{1}{100} =$	12,7182 cm^2
$A_3 = 2 \cdot 53{,}85 \cdot 10 \cdot \frac{1}{100} =$	10,7703 cm^2
$A_{41} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_{43} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_T = 18{,}5509 + 12{,}7182 + 10{,}7703 + 0{,}36 + 0{,}36 =$	42,7594 cm^2
$A_r = \frac{580 \cdot 0{,}26 + 2 \cdot 10 \cdot 0{,}26 \cdot (1-1)}{100} =$	1,5117 cm^2
$A_T = 42{,}7594 cm^2 \geq A_r = 1{,}5117 cm^2$	
Empty Cold & Corroded Wind Compressive	
$f_{r1} = \min\left[\frac{1.203{,}27}{1.203{,}27},1\right] =$	1
$f_{r2} = \min\left[\frac{1.203{,}27}{1.203{,}27},1\right] =$	1
$A_1 = \frac{2 \cdot 87{,}36 \cdot (1 \cdot 8{,}4 - 0{,}23)}{100} =$	14,2781 cm^2
$A_2 = 2 \cdot (57{,}76 - 0{,}23) \cdot 8{,}4 \cdot \frac{1}{100} =$	9,6646 cm^2
$A_3 = 2 \cdot 49{,}36 \cdot 8{,}4 \cdot \frac{1}{100} =$	8,2918 cm^2
$A_{41} = 3{,}74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_{43} = 3{,}74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_T = 14{,}2781 + 9{,}6646 + 8{,}2918 + 0{,}1397 + 0{,}1397 =$	32,5139 cm^2
$A_r = \frac{580 \cdot 0{,}23 + 2 \cdot 8{,}4 \cdot 0{,}23 \cdot (1-1)}{100} =$	1,3238 cm^2
$A_T = 32{,}5139 cm^2 \geq A_r = 1{,}3238 cm^2$	
Empty Cold & New Wind Compressive	
$f_{r1} = \min\left[\frac{1.203{,}27}{1.203{,}27},1\right] =$	1
$f_{r2} = \min\left[\frac{1.203{,}27}{1.203{,}27},1\right] =$	1
$A_1 = \frac{2 \cdot 95{,}24 \cdot (1 \cdot 10 - 0{,}22)}{100} =$	18,6232 cm^2

$A_2 = 2 \cdot (63{,}85 - 0{,}22) \cdot 10 \cdot \frac{1}{100} =$	12,7258 cm^2
$A_3 = 2 \cdot 53{,}85 \cdot 10 \cdot \frac{1}{100} =$	10,7703 cm^2
$A_{41} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_{43} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_T = 18{,}6232 + 12{,}7258 + 10{,}7703 + 0{,}36 + 0{,}36 =$	42,8393 cm^2
$A_r = \frac{580 \cdot 0{,}22 + 2 \cdot 10 \cdot 0{,}22 \cdot (1-1)}{100} =$	1,2915 cm^2
$A_T = 42{,}8393 cm^2 \geq A_r = 1{,}2915 cm^2$	
Field Test Corr Wind Compressive	
$f_{r1} = \min\left[\frac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$f_{r2} = \min\left[\frac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$A_1 = \frac{2 \cdot 87{,}36 \cdot (1 \cdot 8{,}4 - 0{,}28)}{100} =$	14,1909 cm^2
$A_2 = 2 \cdot (57{,}76 - 0{,}28) \cdot 8{,}4 \cdot \frac{1}{100} =$	9,6563 cm^2
$A_3 = 2 \cdot 49{,}36 \cdot 8{,}4 \cdot \frac{1}{100} =$	8,2918 cm^2
$A_{41} = 3{,}74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_{43} = 3{,}74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_T = 14{,}1909 + 9{,}6563 + 8{,}2918 + 0{,}1397 + 0{,}1397 =$	32,4183 cm^2
$A_r = \frac{580 \cdot 0{,}28 + 2 \cdot 8{,}4 \cdot 0{,}28 \cdot (1-1)}{100} =$	1,6134 cm^2
$A_T = 32{,}4183 cm^2 \geq A_r = 1{,}6134 cm^2$	
Field Test New Wind Compressive	
$f_{r1} = \min\left[\frac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$f_{r2} = \min\left[\frac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$A_1 = \frac{2 \cdot 95{,}24 \cdot (1 \cdot 10 - 0{,}27)}{100} =$	18,5326 cm^2
$A_2 = 2 \cdot (63{,}85 - 0{,}27) \cdot 10 \cdot \frac{1}{100} =$	12,7163 cm^2
$A_3 = 2 \cdot 53{,}85 \cdot 10 \cdot \frac{1}{100} =$	10,7703 cm^2
$A_{41} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_{43} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2

$A_T = 18{,}5326 + 12{,}7163 + 10{,}7703 + 0{,}36 + 0{,}36 =$	42,7392 cm^2
$A_r = \dfrac{580 \cdot 0{,}27 + 2 \cdot 10 \cdot 0{,}27 \cdot (1-1)}{100} =$	1,5672 cm^2
$A_T = 42{,}7392 cm^2 \geq A_r = 1{,}5672 cm^2$	
External Pressure Hot & Corroded Wind Compressive	
$f_{r1} = \min\left[\dfrac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$f_{r2} = \min\left[\dfrac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$A_1 = \dfrac{2 \cdot 87{,}36 \cdot (1 \cdot 8{,}4 - 0{,}27)}{100} =$	14,2085 cm^2
$A_2 = 2 \cdot (57{,}76 - 0{,}27) \cdot 8{,}4 \cdot \dfrac{1}{100} =$	9,6579 cm^2
$A_3 = 2 \cdot 49{,}36 \cdot 8{,}4 \cdot \dfrac{1}{100} =$	8,2918 cm^2
$A_{41} = 3{,}74^{\,2} \cdot \dfrac{1}{100} =$	0,1397 cm^2
$A_{43} = 3{,}74^{\,2} \cdot \dfrac{1}{100} =$	0,1397 cm^2
$A_T = 14{,}2085 + 9{,}6579 + 8{,}2918 + 0{,}1397 + 0{,}1397 =$	32,4376 cm^2
$A_r = \dfrac{580 \cdot 0{,}27 + 2 \cdot 8{,}4 \cdot 0{,}27 \cdot (1-1)}{100} =$	1,5549 cm^2
$A_T = 32{,}4376 cm^2 \geq A_r = 1{,}5549 cm^2$	
Operating Hot & Corroded Seismic Compressive	
$f_{r1} = \min\left[\dfrac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$f_{r2} = \min\left[\dfrac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$A_1 = \dfrac{2 \cdot 87{,}36 \cdot (1 \cdot 8{,}4 - 0{,}26)}{100} =$	14,2244 cm^2
$A_2 = 2 \cdot (57{,}76 - 0{,}26) \cdot 8{,}4 \cdot \dfrac{1}{100} =$	9,6595 cm^2
$A_3 = 2 \cdot 49{,}36 \cdot 8{,}4 \cdot \dfrac{1}{100} =$	8,2918 cm^2
$A_{41} = 3{,}74^{\,2} \cdot \dfrac{1}{100} =$	0,1397 cm^2
$A_{43} = 3{,}74^{\,2} \cdot \dfrac{1}{100} =$	0,1397 cm^2
$A_T = 14{,}2244 + 9{,}6595 + 8{,}2918 + 0{,}1397 + 0{,}1397 =$	32,455 cm^2
$A_r = \dfrac{580 \cdot 0{,}26 + 2 \cdot 8{,}4 \cdot 0{,}26 \cdot (1-1)}{100} =$	1,5022 cm^2
$A_T = 32{,}455 cm^2 \geq A_r = 1{,}5022 cm^2$	
Operating Hot & New Seismic Compressive	

$f_{r1} = \min\left[\frac{1.203,27}{1.203,27},1\right] =$	1
$f_{r2} = \min\left[\frac{1.203,27}{1.203,27},1\right] =$	1
$A_1 = \frac{2 \cdot 95,24 \cdot (1 \cdot 10 - 0,25)}{100} =$	18,565 cm^2
$A_2 = 2 \cdot (63,85 - 0,25) \cdot 10 \cdot \frac{1}{100} =$	12,7197 cm^2
$A_3 = 2 \cdot 53,85 \cdot 10 \cdot \frac{1}{100} =$	10,7703 cm^2
$A_{41} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_{43} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_T = 18,565 + 12,7197 + 10,7703 + 0,36 + 0,36 =$	42,775 cm^2
$A_r = \frac{580 \cdot 0,25 + 2 \cdot 10 \cdot 0,25 \cdot (1-1)}{100} =$	1,4686 cm^2
$A_T = 42,775cm^2 \geq A_r = 1,4686cm^2$	
Empty Cold & Corroded Seismic Compressive	
$f_{r1} = \min\left[\frac{1.203,27}{1.203,27},1\right] =$	1
$f_{r2} = \min\left[\frac{1.203,27}{1.203,27},1\right] =$	1
$A_1 = \frac{2 \cdot 87,36 \cdot (1 \cdot 8,4 - 0,21)}{100} =$	14,3056 cm^2
$A_2 = 2 \cdot (57,76 - 0,21) \cdot 8,4 \cdot \frac{1}{100} =$	9,6673 cm^2
$A_3 = 2 \cdot 49,36 \cdot 8,4 \cdot \frac{1}{100} =$	8,2918 cm^2
$A_{41} = 3,74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_{43} = 3,74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_T = 14,3056 + 9,6673 + 8,2918 + 0,1397 + 0,1397 =$	32,544 cm^2
$A_r = \frac{580 \cdot 0,21 + 2 \cdot 8,4 \cdot 0,21 \cdot (1-1)}{100} =$	1,2327 cm^2
$A_T = 32,544cm^2 \geq A_r = 1,2327cm^2$	
Empty Cold & New Seismic Compressive	
$f_{r1} = \min\left[\frac{1.203,27}{1.203,27},1\right] =$	1
$f_{r2} = \min\left[\frac{1.203,27}{1.203,27},1\right] =$	1
$A_1 = \frac{2 \cdot 95,24 \cdot (1 \cdot 10 - 0,21)}{100} =$	18,6493 cm^2

$A_2 = 2 \cdot (63{,}85 - 0{,}21) \cdot 10 \cdot \frac{1}{100} =$	12,7285 cm^2
$A_3 = 2 \cdot 53{,}85 \cdot 10 \cdot \frac{1}{100} =$	10,7703 cm^2
$A_{41} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_{43} = 6^2 \cdot \frac{1}{100} =$	0,36 cm^2
$A_T = 18{,}6493 + 12{,}7285 + 10{,}7703 + 0{,}36 + 0{,}36 =$	42,8682 cm^2
$A_r = \frac{580 \cdot 0{,}21 + 2 \cdot 10 \cdot 0{,}21 \cdot (1-1)}{100} =$	1,212 cm^2
$A_T = 42{,}8682 cm^2 \geq A_r = 1{,}212 cm^2$	
External Pressure Hot & Corroded Seismic Compressive	
$f_{r1} = \min\left[\frac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$f_{r2} = \min\left[\frac{1.203{,}27}{1.203{,}27}, 1\right] =$	1
$A_1 = \frac{2 \cdot 87{,}36 \cdot (1 \cdot 8{,}4 - 0{,}26)}{100} =$	14,2244 cm^2
$A_2 = 2 \cdot (57{,}76 - 0{,}26) \cdot 8{,}4 \cdot \frac{1}{100} =$	9,6595 cm^2
$A_3 = 2 \cdot 49{,}36 \cdot 8{,}4 \cdot \frac{1}{100} =$	8,2918 cm^2
$A_{41} = 3{,}74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_{43} = 3{,}74^2 \cdot \frac{1}{100} =$	0,1397 cm^2
$A_T = 14{,}2244 + 9{,}6595 + 8{,}2918 + 0{,}1397 + 0{,}1397 =$	32,455 cm^2
$A_r = \frac{580 \cdot 0{,}26 + 2 \cdot 8{,}4 \cdot 0{,}26 \cdot (1-1)}{100} =$	1,5022 cm^2
$A_T = 32{,}455 cm^2 \geq A_r = 1{,}5022 cm^2$	

Seismic Code

Building Code: User-defined		
Base Shear Multiplier		0,0590
Portion at Top		0,0700
Vertical Accelerations Considered		No
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height		11,2992 ft (3,44 m)
Weight	Operating, Corroded	22.355 lb (10.140 kg)
	Empty, Corroded	17.830 lb (8.088 kg)
	Vacuum, Corroded	22.355 lb (10.140 kg)
Period of Vibration Calculation		
Fundamental Period, T	Operating, Corroded	0,019 sec (f = 52,2 Hz)
	Empty, Corroded	0,019 sec (f = 53,6 Hz)
	Vacuum, Corroded	0,019 sec (f = 52,3 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.

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Base Shear Calculations

Seismic Shear Report: Operating, Corroded					
Component	**Elevation of Bottom above Base (mm)**	**Elastic Modulus E (kg/cm²)**	**Inertia I (m^4)**	**Seismic Shear at Bottom (kg_f)**	**Bending Moment at Bottom (kg_f-m)**
Top Head	2.920	2.006.191,0	*	320,5	150
Shell V1	1.220	2.006.191,0	0,0459	532,6	1.446,2
Bottom Head (top)	1.070	2.006.191,0	*	551,3	1.527,6
Support Skirt	0	2.006.191,0	0,02383	599,2	2.127,6
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Empty, Corroded					
Component	**Elevation of Bottom above Base (mm)**	**Elastic Modulus E (kg/cm²)**	**Inertia I (m^4)**	**Seismic Shear at Bottom (kg_f)**	**Bending Moment at Bottom (kg_f-m)**
Top Head	2.920	2.063.397,1	*	288,2	134,8
Shell V1	1.220	2.063.397,1	0,0459	442,2	1.352,9
Bottom Head (top)	1.070	2.063.397,1	*	449	1.419,8
Support Skirt	0	2.063.397,1	0,02383	478,1	1.893,3
*Moment of Inertia I varies over the length of the component					

Seismic Shear Report: Vacuum, Corroded					
Component	Elevation of Bottom above Base (mm)	Elastic Modulus E (kg/cm²)	Inertia I (m^4)	Seismic Shear at Bottom (kg_f)	Bending Moment at Bottom (kg_f-m)
Top Head	2.920	2.061.255,7	*	320,5	150
Shell V1	1.220	2.061.255,7	0,0459	532,6	1.446,2
Bottom Head (top)	1.070	2.061.255,7	*	551,3	1.527,6
Support Skirt	0	2.006.191,0	0,02383	599,2	2.127,6
*Moment of Inertia I varies over the length of the component					

Base Shear Calculations

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Base Shear Calculations: Operating, Corroded

$$V = \text{Base Shear Multiplier} \cdot W = 0{,}0590 \cdot 22.355{,}1406 = 1.318{,}95 \ \ \text{lb}(598{,}27 \ \ \text{kg})$$

Base Shear Calculations: Empty, Corroded

$$V = \text{Base Shear Multiplier} \cdot W = 0{,}0590 \cdot 17.830{,}4785 = 1.052{,}00 \ \ \text{lb}(477{,}18 \ \ \text{kg})$$

Base Shear Calculations: Vacuum, Corroded

$$V = \text{Base Shear Multiplier} \cdot W = 0{,}0590 \cdot 22.355{,}1406 = 1.318{,}95 \ \ \text{lb}(598{,}27 \ \ \text{kg})$$

Wind Code

Building Code: User Defined		
Elevation of base above grade		0,98 ft (0,30 m)
Increase effective outer diameter by		1,51 ft (0,46 m)
Wind Force Coefficient, Cf		0,4700
Hazardous, toxic, or explosive contents		No
Vessel Characteristics		
Height, h		11,2992 ft (3,4440 m)
Effective Width	Operating, Corroded	6,0675 ft (1,8494 m)
	Empty, Corroded	6,0675 ft (1,8494 m)
	Hydrotest, New, Field	5,9985 ft (1,8283 m)
	Hydrotest, Corroded, Field	6,0675 ft (1,8494 m)
Fundamental Frequency, n_1	Operating, Corroded	52,2177 Hz
	Empty, Corroded	53,5642 Hz
	Hydrotest, New, Field	49,5162 Hz
	Hydrotest, Corroded, Field	49,7230 Hz
Damping coefficient, β	Operating, Corroded	0,0286
	Empty, Corroded	0,0238
	Hydrotest, New, Field	0,0288
	Hydrotest, Corroded, Field	0,0288

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Vacuum, Corroded
Hydrotest, New, field
Hydrotest, Corroded, field

Wind Pressure Table

Wind Deflection Report: Operating, Corroded

Component	Elevation of Bottom above Base (mm)	Effective OD (m)	Elastic Modulus E (kg/cm²)	Inertia I (m^4)	Platform Wind Shear at Bottom (kg_f)	Total Wind Shear at Bottom (kg_f)	Bending Moment at Bottom (kg_f-m)	Deflection at Top (mm)
Top Head	2.920	2,31	2.006.191,0	*	362,3	404,5	206	0,02
Shell V1	1.220	2,46	2.006.191,0	0,04589	362,3	565,2	1.619,9	0,01
Bottom Head (top)	1.070	2,47	2.006.191,0	*	362,3	576,6	1.714,2	0
Support Skirt	0	2,33	2.006.191,0	0,02007	362,3	652,9	2.372	0
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Empty, Corroded

Component	Elevation of Bottom above Base (mm)	Effective OD (m)	Elastic Modulus E (kg/cm²)	Inertia I (m^4)	Platform Wind Shear at Bottom (kg_f)	Total Wind Shear at Bottom (kg_f)	Bending Moment at Bottom (kg_f-m)	Deflection at Top (mm)
Top Head	2.920	2,31	2.063.397,1	*	362,3	404,5	206	0,02
Shell V1	1.220	2,46	2.063.397,1	0,04589	362,3	565,2	1.619,9	0,01
Bottom Head (top)	1.070	2,47	2.063.397,1	*	362,3	576,6	1.714,2	0
Support Skirt	0	2,33	2.063.397,1	0,02007	362,3	652,9	2.372	0
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Vacuum, Corroded								
Component	Elevation of Bottom above Base (mm)	Effective OD (m)	Elastic Modulus E (kg/cm²)	Inertia I (m^4)	Platform Wind Shear at Bottom (kg_f)	Total Wind Shear at Bottom (kg_f)	Bending Moment at Bottom (kg_f-m)	Deflection at Top (mm)
Top Head	2.920	2,31	2.061.255,7	*	362,3	404,5	206	0,02
Shell V1	1.220	2,46	2.061.255,7	0,04589	362,3	565,2	1.619,9	0,01
Bottom Head (top)	1.070	2,47	2.061.255,7	*	362,3	576,6	1.714,2	0
Support Skirt	0	2,33	2.006.191,0	0,02007	362,3	652,9	2.372	0
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Field Hydrotest, New								
Component	Elevation of Bottom above Base (mm)	Effective OD (m)	Elastic Modulus E (kg/cm²)	Inertia I (m^4)	Platform Wind Shear at Bottom (kg_f)	Total Wind Shear at Bottom (kg_f)	Bending Moment at Bottom (kg_f-m)	Deflection at Top (mm)
Top Head	2.920	2,31	2.072.676,5	*	90,6	101,1	53,3	0,01
Shell V1	1.220	2,46	2.072.676,5	0,0498	90,6	141,3	852,8	0,01
Bottom Head (top)	1.070	2,47	2.072.676,5	*	90,6	144,2	876,4	0
Support Skirt	0	2,33	2.072.676,5	0,02383	90,6	163,2	1.040,8	0
*Moment of Inertia I varies over the length of the component								

Wind Deflection Report: Field Hydrotest, Corroded								
Component	Elevation of Bottom above Base (mm)	Effective OD (m)	Elastic Modulus E (kg/cm²)	Inertia I (m^4)	Platform Wind Shear at Bottom (kg_f)	Total Wind Shear at Bottom (kg_f)	Bending Moment at Bottom (kg_f-m)	Deflection at Top (mm)
Top Head	2.920	2,31	2.072.676,5	*	90,6	101,1	53	0,01
Shell V1	1.220	2,46	2.072.676,5	0,04589	90,6	141,3	849,7	0,01
Bottom Head (top)	1.070	2,47	2.072.676,5	*	90,6	144,2	873,3	0
Support Skirt	0	2,33	2.072.676,5	0,02007	90,6	163,2	1.037,8	0
*Moment of Inertia I varies over the length of the component								

Wind Pressure (WP) table

Wind Force Coefficient, Cf: 0,4700

Design Wind Pressures		
To Height Z (m)	Wind Pressure (bar)	Adjusted by Cf (bar)
2,00	0,0065	0,0030
5,00	0,0086	0,0040
Design Wind Force determined from: F = Pressure * Af , where Af is the projected area.		

DEMISTER

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	900 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	250 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

EXTRA WEIGHT

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	900 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	274 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

EXTRA WEIGHT PARA LIFTING

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	900 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	595 kg
Loading Conditions	
Present When Operating	No
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	No
Present During Test	No

Extra weight para igualar pesos

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	600 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	52,3 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

Platform clips weight

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	900 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	50 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

Shell Insulation ring

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	1.200 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	53 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

Skirt insulation ring

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	-600 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	53 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

TRUNNION EXTRA WEIGHT

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	1.540 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	38,1 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

Tailing Lugs weight

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	1.800 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	50 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	Yes
Present When Vessel is Empty	Yes
Present During Test	Yes

Top head platform snow load

ASME Section VIII Division 1, 2021 Edition Metric	
Inputs	
Load Orientation	Vertical Load
Elevation Above Datum	2.286 mm
Direction Angle	0,00 deg
Distance from Center of Vessel	0 mm
Magnitude of Force	1.274 kg
Loading Conditions	
Present When Operating	Yes
Included in Vessel Lift Weight	No
Present When Vessel is Empty	Yes
Present During Test	No