Key Design Engineering

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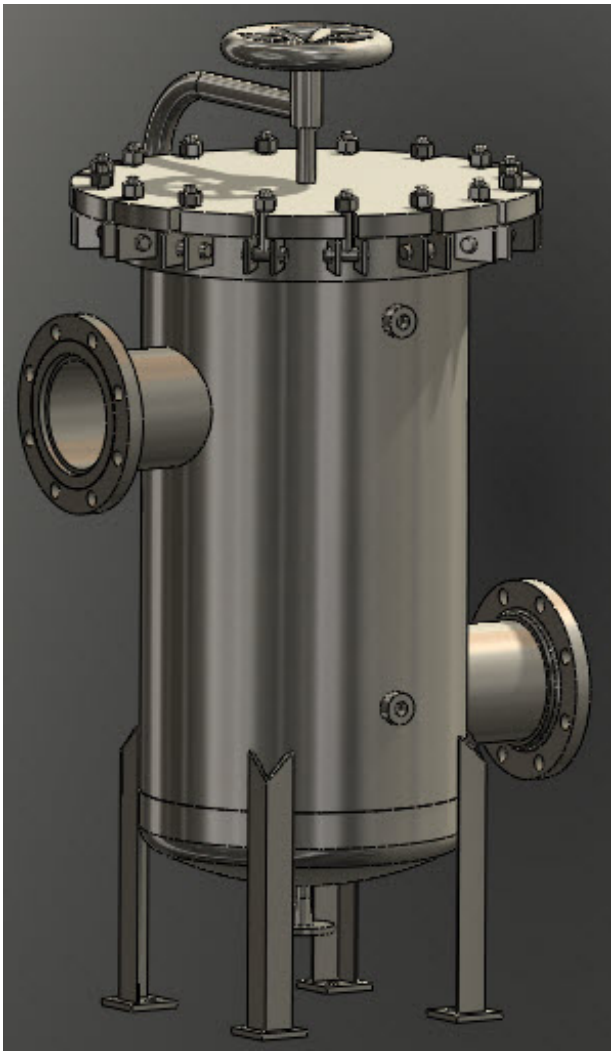

COMPRESS Pressure Vessel Design Calculations

Item: Sample Filter
Vessel No: KEY-026
Designer: David Burr
Date: March 31, 2011

www.keydesigneng.com

Note: This calculation booklet is a sample, and is intended for information purposes only.

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Settings Summary

COMPRESS Build 7110

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

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Design or Rating:	Get Pressure Rating and Calculate Required Thickness
Minimum thickness:	0.0625" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Find nozzle MAWP and MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	0.01"
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials > 1.25&#34 and <= 1.50" thick:	No
UG-37(a) shell tr calculation considers longitudinal stress:	No

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

Hydro/Pneumatic Test

Shop Hydrotest Pressure:	1.3 times design P
Test liquid specific gravity:	1.00
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116(e) Radiography:	RT4
UG-116(f) Postweld heat treatment:	None

Code Cases\Interpretations

Use Code Case 2547:	No
Apply interpretation VIII-1-83-66:	No
Apply interpretation VIII-1-86-175:	Yes
Apply interpretation VIII-1-83-115:	No
Apply interpretation VIII-1-01-37:	Yes
No UCS-66.1 MDMT reduction:	No
No UCS-68(c) MDMT reduction:	No
Disallow UG-20(f) exemptions:	No

UG-22 Loadings

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

Deficiencies Summary

No deficiencies found.

Pressure Summary

Pressure Summary for Chamber bounded by Item 2 - F&D Head and Item 6 - Bolted Cover

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T_e external (°F)	MDMT (°F)	MDMT Exemption	Impact Tested
Item 6 - Bolted Cover	150	250	175.42	179.91	253.91	250	-320	Note 1	No
Item 1 - Shell	150	250	266.28	273.11	93.73	250	-320	Note 1	No
Straight Flange on Item 2 - F&D Head	150	250	231.49	237.43	46.41	250	-320	Note 1	No
Item 2 - F&D Head	150	250	177.2	181.75	50.44	250	-320	Note 2	No
Item 13 - Legs	150	250	159.21	N/A	N/A	N/A	N/A	N/A	N/A
Item 5 - Flange (21")	150	250	159.21	165.35	494.68	250	-55	Note 3	No
Item 3 - Pipe (6") (Itm3)	150	250	245	N/I	68.55	250	-55	Note 4	No
Copy of Item 3 - Pipe (6") (Itm3b)	150	250	242.26	N/I	66.07	250	-55	Note 5	No
Item 7 - Half Coupling (1") (Itm7)	150	250	409.67	N/I	93.73	250	-55	Note 5	No
Item 9 - Pipe (3/4") (Itm9)	150	250	245	N/I	46.41	250	-55	Note 4	No

Chamber design MDMT is -20 °F
Chamber rated MDMT is -55 °F @ 159.21 psi
Chamber MAWP was used in the MDMT determination

Chamber MAWP hot & corroded is 159.21 psi @ 250 °F

Chamber MAP cold & new is 165.35 psi @ 70 °F

Chamber MAEP is 46.41 psi @ 250 °F
Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Rated MDMT per UHA-51(d)(1)(a) = -320 °F	
2.	Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F	
3.	Flange Rated MDMT per UHA-51(d)(1)(a) = -320 °F	Bolts rated MDMT per Fig UCS-66 note (c) = -55 °F
4.	Flange rating governs:	UCS-66(b)(1)(b)
5.	Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F Fig UCS-66.1 MDMT reduction = 116.1 °F, (coincident ratio = 0.38091) Rated MDMT is governed by UCS-66(b)(2)	UCS-66 governing thickness = 0.1875 in.

Design notes are available on the Settings Summary page.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Total Corrosion (in)	Joint E	Load
Item 6 - Bolted Cover	SA-240 304	21 OD	1.25	1.25*	1.1559	0	1.00	Internal
Item 1 - Shell	SA-240 304	18 OD	32	0.1875	0.1061	0	0.65	Internal
Straight Flange on Item 2 - F&D Head	SA-240 304	18 OD	2	0.125	0.0812	0	0.85	Internal
Item 2 - F&D Head	SA-240 304	18 OD	4.8285	0.125*	0.106	0	0.85	Internal

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

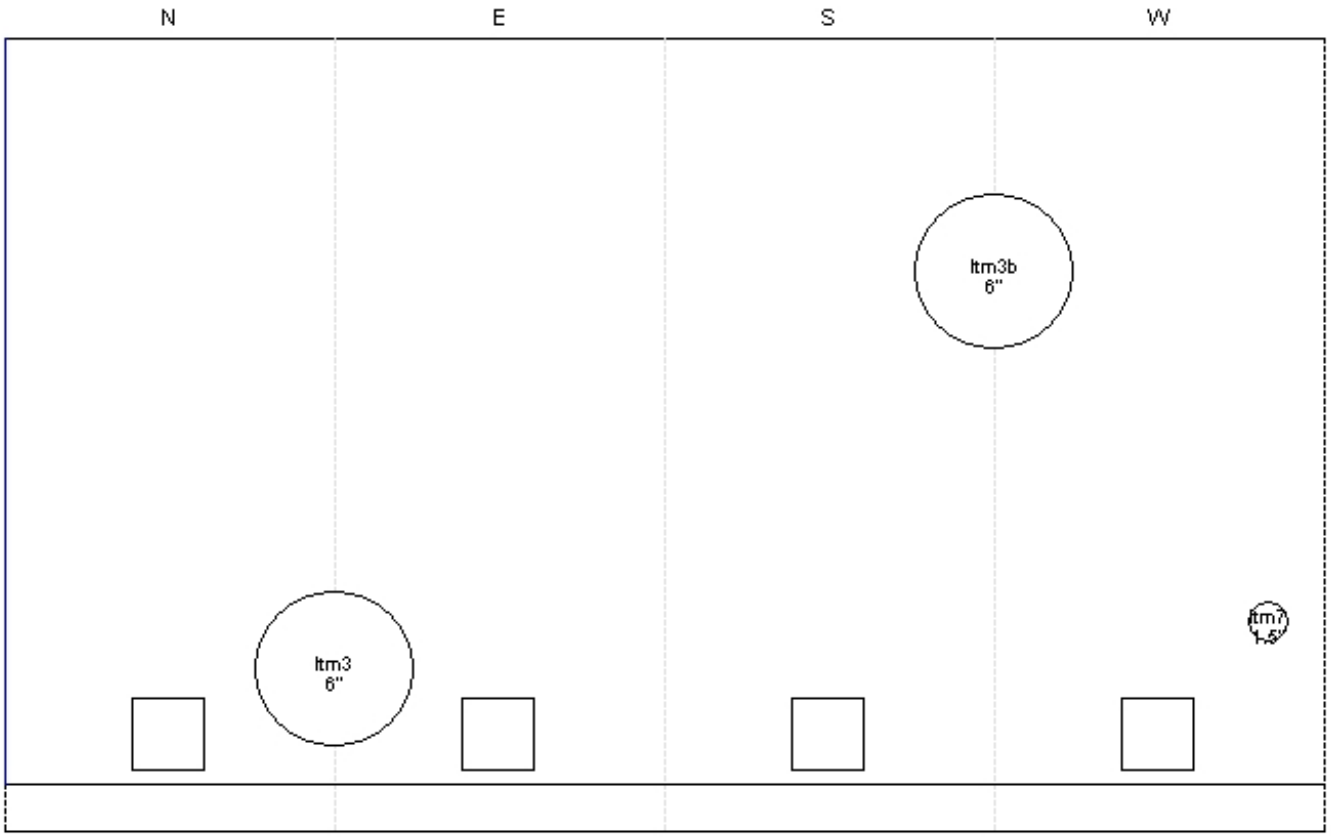
Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Long Seam Summary

Shell Long Seam Angles	
Component	**Seam 1**
Item 1 - Shell	315°

Shell Plate Lengths		
Component	**Starting Angle**	**Plate 1**
Item 1 - Shell	315°	55.9596"

*North is located at 0°
*Plate Lengths use the circumfrence of the vessel based on the mid diameter of the components



Shell Rollout

Shop test pressure determination for Chamber bounded by Item 2 - F&D Head and Item 6 - Bolted Cover based on design P per UG-99(b)

Shop hydrostatic test gauge pressure is 195 psi at 70 °F (the chamber design P = 150 psi)

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

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
Item 1 - Shell	195.778	0.778	1.0256	1.30	9,299	27,000	No
Straight Flange on Item 2 - F&D Head	195.781	0.781	1.0256	1.30	13,998	27,000	No
Item 2 - F&D Head	195.781	0.781	1.0256	1.30	14,096	27,000	No
Item 6 - Bolted Cover	195.778	0.778	1.0256	1.30	21,764	40,500	No
Item 5 - Flange (21")	195.787	0.787	1.0256	1.30	17,307	40,500	No
Copy of Item 3 - Pipe (6") (Itm3b) (1)	195.921	0.921	1	1.30	21,170	40,500	No
Item 3 - Pipe (6") (Itm3)	195.308	0.308	1.0256	1.30	21,103	40,500	No
Item 7 - Half Coupling (1") (Itm7)	195.318	0.318	1	1.30	9,180	40,500	No
Item 9 - Pipe (3/4") (Itm9)	195.475	0.475	1	1.30	18,105	40,500	No

Notes:
(1) Copy of Item 3 - Pipe (6") (Itm3b) limits the UG-99 stress ratio.
(2) P_L stresses at nozzle openings have been estimated using the method described in PVP-Vol. 399, pages 77-82.
(3) $1.5*0.9*S_y$ used as the basis for the maximum local primary membrane stress at the nozzle intersection P_L.
(4) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by Item 2 - F&D Head and Item 6 - Bolted Cover.

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

Nozzle Summary

Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
ltm3	6.625	0.28	0.1286	Yes	Yes	0.1875	0.1528		N/A	N/A	0	100.0
ltm3b	6.625	0.28	0.1272	Yes	Yes	0.1875	0.1113		N/A	N/A	0	100.0
ltm7	1.75	0.2175	0.0625	Yes	Yes	0.1875	N/A		N/A	N/A	0	Exempt
ltm9	1.05	0.113	0.113	Yes	Yes	0.125*	N/A		N/A	N/A	0	Exempt

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

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
Itm3	Item 3 - Pipe (6")	NPS 6 Sch 40S (Std)	SA-312 TP304 Wld & smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150
Itm3b	Copy of Item 3 - Pipe (6")	NPS 6 Sch 40 (Std)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 300
Itm7	Item 7 - Half Coupling (1")	NPS 1 Class 3000 - threaded	SA-105	No	No	No	N/A	N/A	N/A	N/A	N/A
Itm9	Item 9 - Pipe (3/4")	NPS 0.75 Sch 40 (Std)	SA-106 B Smls pipe	No	No	No	N/A	N/A	N/A	N/A	WN A105 Class 150

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements							Surface Area ft²
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid	
Item 6 - Bolted Cover	125.6	125.6	0	0	0	0	0	3
Item 1 - Shell	93.5	93.5	0	0	0	0	291.9	12
Item 2 - F&D Head	17.5	17.5	0	0	0	0	47.7	4
Item 13 - Legs	11.3	11.3	0	0	0	0	0	4
TOTAL:	**247.8**	**247.8**	**0**	**0**	**0**	**0**	**339.6**	**22**

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

Component	Weight (lb) Contributed by Attachments									Surface Area ft²
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads	
	New	Corroded	New	Corroded						
Item 6 - Bolted Cover	0	0	0	0	0	0	0	0	0	0
Item 1 - Shell	67.3	67.3	76.6	76.6	0	0	0	0	0	8
Item 2 - F&D Head	0	0	2	2	0	0	0	0	0	0
Item 13 - Legs	0	0	0	0	0	0	0	0	0	0
TOTAL:	**67.3**	**67.3**	**78.6**	**78.6**	**0**	**0**	**0**	**0**	**0**	**4**

Vessel operating weight, Corroded: 394 lb
Vessel operating weight, New: 394 lb
Vessel empty weight, Corroded: 394 lb
Vessel empty weight, New: 394 lb
Vessel test weight, New: 733 lb
Vessel surface area: 26 ft²

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 394 lb
Center of Gravity: 22.1308"

Vessel Capacity

Vessel Capacity** (New): 40 US gal
Vessel Capacity** (Corroded): 40 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

Item 1 - Shell

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Component: Cylinder
Material specification: SA-240 304 (II-D p. 86, ln. 25)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: P = 150 psi @ 250 °F
External design pressure: P_e = 15 psi @ 250 °F

Static liquid head:

P_{th} = 0.78 psi (SG = 1, H_s = 21.5634", Horizontal test head)

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

Design MDMT = -20 °F
Rated MDMT = -320 °F

No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Longitudinal joint - None UW-11(c) Type 2
Top circumferential joint - N/A
Bottom circumferential joint - None UW-11(c) Type 1

Estimated weight	New = 93.5 lb	corr = 93.5 lb
Capacity	New = 33.8 US gal	corr = 33.8 US gal

OD = 18"
Length L_c = 32"
t = 0.1875"

Design thickness, (at 250 °F) Appendix 1-1

t = $P*R_o$ / (S*E + 0.40*P) + Corrosion
= 150*9 / (19,500*0.65 + 0.40*150) + 0
= 0.1061"

Maximum allowable working pressure, (at 250 °F) Appendix 1-1

P = $S*E*t / (R_o - 0.40*t) - P_s$
= 19,500*0.65*0.1875 / (9 - 0.40*0.1875) - 0
= 266.28 psi

Maximum allowable pressure, (at 70 °F) Appendix 1-1

P = $S*E*t / (R_o - 0.40*t)$
= 20,000*0.65*0.1875 / (9 - 0.40*0.1875)
= 273.11 psi

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

L / D_o = 36.1178 / 18 = 2.0065

D_o / t = 18 / 0.0791 = 227.4320

From table G: A = 0.000191

From table HA-1: B = 2,558.6055 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,558.61 / (3*(18 / 0.0791))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.0791 + 0 = 0.0791"

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

L / D_o = 36.1178 / 18 = 2.0065

D_o / t = 18 / 0.1875 = 96.0000

From table G: A = 0.000689

From table HA-1: B = 6,748.7842 psi

P_a = 4*B / (3*(D_o / t))
= 4*6,748.78 / (3*(18 / 0.1875))
= 93.73 psi

% Forming strain - UHA-44(a)(2)(a)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*0.1875 / 8.9063)*(1 - 8.9063 / ∞)
= 1.0526%

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

P_v = W / (2*π*R_m) + M / (π*R_m^2)
= 359.9 / (2*π*8.9063) + 261 / (π*8.9063^2)
= 7.4778 lb/in

α = P_v / (P_e*D_o)
= 7.4778 / (15*18)
= 0.0277

n = 4

m = 1.23 / (L / D_o)^2
= 1.23 / (36.1178 / 18)^2
= 0.3055

Ratio P_e = (n^2 - 1 + m + m*α) / (n^2 - 1 + m)
= (4^2 - 1 + 0.3055 + 0.3055*0.0277) / (4^2 - 1 + 0.3055)
= 1.0006

Ratio P_e * P_e ≤ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight Check at Bottom Seam (Bergman, ASME paper 54-A-104)

P_v = $W / (2*\pi*R_m) + M / (\pi*R_m^2)$
= $-22.5 / (2*\pi*8.9063) + 0 / (\pi*8.9063^2)$
= -0.4023 lb/in

α = $P_v / (P_e*D_o)$
= -0.4023 / (15*18)
= -0.0015

n = 4

m = $1.23 / (L / D_o)^2$
= $1.23 / (36.1178 / 18)^2$
= 0.3055

Ratio P_e = $(n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
= $(4^2 - 1 + 0.3055 + 0.3055*-0.0015) / (4^2 - 1 + 0.3055)$
= 1.0000

Ratio P_e * P_e ≤ MAEP design cylinder thickness is satisfactory.

Design thickness = 0.1061"

The governing condition is due to internal pressure.

The cylinder thickness of 0.1875" is adequate.

The governing condition is due to pressure.

Thickness Required Due to Pressure + External Loads

Condition	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Location	Load	Pressure P (psi)	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
	S_t	S_c							
Operating, Hot & Corroded	19,500	10,322	250	0	Top	Weight	838.15	0.0336	0.0335
					Bottom	Weight	836.82	0.0339	0.0339
Operating, Hot & New	19,500	10,322	250	0	Top	Weight	838.15	0.0336	0.0335
					Bottom	Weight	836.82	0.0339	0.0339
Hot Shut Down, Corroded	19,500	10,322	250	0	Top	Weight	0	0.0005	0.0007
					Bottom	Weight	0	0	0
Hot Shut Down, New	19,500	10,322	250	0	Top	Weight	0	0.0005	0.0007
					Bottom	Weight	0	0	0
Empty, Corroded	20,000	12,142	70	0	Top	Weight	0	0.0004	0.0006
					Bottom	Weight	0	0	0
Empty, New	20,000	12,142	70	0	Top	Weight	0	0.0004	0.0006
					Bottom	Weight	0	0	0

Vacuum	19,500	10.322	250	0	Top	Weight	441.28	0.0069	0.0071
					Bottom	Weight	443.1	0.0064	0.0064
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	19,500	10.322	250	0	Top	Weight	0	0.0005	0.0007
					Bottom	Weight	0	0	0

Item 2 - F&D Head

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Component:	F&D Head
Material Specification:	SA-240 304 (II-D p.86, ln. 25)

Material Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: P = 150 psi @ 250 °F
External design pressure: P_e = 15 psi @ 250 °F

Static liquid head:

P_s= 0 psi (SG=1, H_s=0" Operating head)
P_{th}= 0.7806 psi (SG=1, H_s=21.6259" Horizontal test head)

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

Design MDMT = -20°F
Rated MDMT = -320°F

No impact test performed
Material is not normalized
Material is not produced to fine grain practice
PWHT is not performed
Do not Optimize MDMT / Find MAWP

Radiography:	Category A joints -	Spot UW-11(b) Type 1
	Head to shell seam -	None UW-11(c) Type 1

Estimated weight*:	new = 17.5 lb	corr = 17.5 lb
Capacity*:	new = 5.7 US gal	corr = 5.7 US gal

* includes straight flange

Outer diameter	=	18"
Crown radius L	=	18"
Knuckle radius r	=	3.75"
Minimum head thickness	=	0.125"
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.125"

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	=	0.106"
Design thickness due to external pressure (t_e)	=	0.0543"
Maximum allowable working pressure (MAWP)	=	177.2 psi
Maximum allowable pressure (MAP)	=	181.75 psi
Maximum allowable external pressure (MAEP)	=	50.44 psi

Note: Appendix 1-4 footnote 1 used to determine allowable stress.

M (Corroded)

$M=1/4*[3 + (L / r)^{1/2}]=1/4*[3 + (18 / 3.75)^{1/2}]=1.297723$

M (New)

$M=1/4*[3 + (L / r)^{1/2}]=1/4*[3 + (18 / 3.75)^{1/2}]=1.297723$

Design thickness for internal pressure, (Corroded at 250 °F) Appendix 1-4(d)

t = $P*L_o*M / (2*S*E + P*(M - 0.2)) + Corrosion$
= 150*18.125*1.2977 / (2*19,500*0.85 + 150*(1.2977 - 0.2)) + 0
= 0.1059"

The head internal pressure design thickness is 0.106".

Maximum allowable working pressure, (Corroded at 250 °F) Appendix 1-4(d)

P = $2*S*E*t / (M*L_o - t*(M - 0.2)) - P_s$
= 2*19,500*0.85*0.125 / (1.2977*18.125 - 0.125*(1.2977 - 0.2)) - 0
= 177.2 psi

The maximum allowable working pressure (MAWP) is 177.2 psi.

Maximum allowable pressure, (New at 70 °F) Appendix 1-4(d)

P = $2*S*E*t / (M*L_o - t*(M - 0.2)) - P_s$
= 2*20,000*0.85*0.125 / (1.2977*18.125 - 0.125*(1.2977 - 0.2)) - 0
= 181.75 psi

The maximum allowable pressure (MAP) is 181.75 psi.

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

Equivalent outside spherical radius (R_o)
= Outside crown radius
= 18.125 in

A = $0.125 / (R_o / t)$
= 0.125 / (18.125 / 0.054243)
= 0.000374

From Table HA-1: B = 5,012.2065 psi

P_a = $B / (R_o / t)$
= 5,012.207 / (18.125 / 0.0542)
= 15 psi

t = 0.0542" + Corrosion = 0.0542" + 0" = 0.0542"
Check the external pressure per UG-33(a)(1) Appendix 1-4(d)

t = $1.67*P_e*L_o*M / (2*S*E + 1.67*P_e*(M - 0.2)) + Corrosion$
= 1.67*15*18.125*1.2977 / (2*19,500*1 + 1.67*15*(1.2977 - 0.2)) + 0
= 0.0151"

The head external pressure design thickness (t_e) is 0.0542".

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

Equivalent outside spherical radius (R_o)

= Outside crown radius
= 18.125 in

A = $0.125 / (R_o / t)$
= 0.125 / (18.125 / 0.125)
= 0.000862

From Table HA-1: B = 7,313.6406 psi

P_a = $B / (R_o / t)$
= 7,313.641 / (18.125 / 0.125)
= 50.4389 psi

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(d)

P = $2*S*E*t / ((M*L_o - t*(M - 0.2))*1.67) - P_{s2}$
= 2*19,500*1*0.125 / ((1.2977*18.125 - 0.125*(1.2977 - 0.2))*1.67) - 0
= 124.84 psi

The maximum allowable external pressure (MAEP) is 50.44 psi.

% Forming strain - UHA-44(a)(2)(b)

EFE = $(75*t / R_f)*(1 - R_f / R_o)$
= $(75*0.125 / 3.8125)*(1 - 3.8125 / \infty)$
= 2.459%

Item 3 - Pipe (6") (Itm3)

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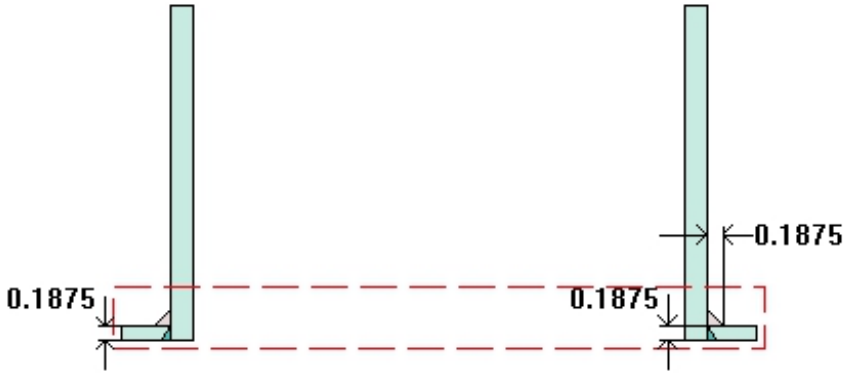
$t_{w(lower)}$ = 0.1875 in
Leg_{41} = 0.1875 in



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

Located on:	Item 1 - Shell
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld & smls pipe (II-D p. 86, ln. 36)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 6 Sch 40S (Std)
Flange description:	6 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT: (UCS-66(b)(1)(b))	-55°F
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	245 psi @ 250°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
Gasket Description:	Flexitallic Spiral Wound CGI 304 S.S.
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	45°
Local vessel minimum thickness:	0.1875 in
Nozzle center line offset to datum line:	5 in
End of nozzle to shell center:	15 in
Nozzle inside diameter, new:	6.065 in
Nozzle nominal wall thickness:	0.28 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	2.5 in
Projection available outside vessel to flange face, Lf:	6 in

Reinforcement Calculations for Internal Pressure

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2) For P = 245 psi @ 250 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
0.6824	0.7165	0.4548	0.2265	--	--	0.0352	0.1125	0.245

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1312	0.1312	weld size is adequate

Calculations for internal pressure 245 psi @ 250 °F

Nozzle rated MDMT per UHA-51(d)(1)(a) = -320 °F.

Parallel Limit of reinforcement per UG-40

L_R = MAX(d, R_n + (t_n - C_n) + (t - C))
= MAX(6.065, 3.0325 + (0.28 - 0) + (0.1875 - 0))
= 6.065 in

Outer Normal Limit of reinforcement per UG-40

L_H = MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)
= MIN(2.5*(0.1875 - 0), 2.5*(0.28 - 0) + 0)
= 0.4688 in

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

t_{rn} = P*R_n / (S_n*E - 0.6*P)
= 245*3.0325 / (19,500*1 - 0.6*245)
= 0.0384 in

Required thickness t_r from UG-37(a)

t_r = P*R_o / (S*E + 0.4*P)
= 245*9 / (19,500*1 + 0.4*245)
= 0.1125 in

Area required per UG-37(c)

Allowable stresses: S_n = 19,500, S_v = 19,500 psi

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

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

A = $d*t_r*F + 2*t_n*t_r*F*(1 - f_{r1})$
= $6.065*0.1125*1 + 2*0.28*0.1125*1*(1 - 1)$
= 0.6824 in^2

Area available from FIG. UG-37.1

A_1 = larger of the following= 0.4548 in^2

= $d*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $6.065*(1*0.1875 - 1*0.1125) - 2*0.28*(1*0.1875 - 1*0.1125)*(1 - 1)$
= 0.4548 in^2

= $2*(t + t_n)*(E_1*t - F*t_r) - 2*t_n*(E_1*t - F*t_r)*(1 - f_{r1})$
= $2*(0.1875 + 0.28)*(1*0.1875 - 1*0.1125) - 2*0.28*(1*0.1875 - 1*0.1125)*(1 - 1)$
= 0.0701 in^2

A_2 = smaller of the following= 0.2265 in^2

= $5*(t_n - t_{rn})*f_{r2}*t$
= $5*(0.28 - 0.0384)*1*0.1875$
= 0.2265 in^2

= $5*(t_n - t_{rn})*f_{r2}*t_n$
= $5*(0.28 - 0.0384)*1*0.28$
= 0.3382 in^2

A_{41} = Leg^2*f_{r2}
= 0.1875^2*1
= 0.0352 in^2

Area = $A_1 + A_2 + A_{41}$
= 0.4548 + 0.2265 + 0.0352
= 0.7165 in^2

As Area >= A the reinforcement is adequate.

UW-16(c) Weld Check

Fillet weld: t_{min} = lesser of 0.75 or t_n or t_R = 0.1875 in
$t_{c(min)}$ = lesser of 0.25 or 0.7*t_{min} = 0.1312 in
$t_{c(actual)}$ = 0.7*Leg = 0.7*0.1875 = 0.1313 in

The fillet weld size is satisfactory.

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

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG\text{-}27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 245*3.0325 / (19,500*1 - 0.6*245) + 0
= 0.0384 in

t_a = max[$t_{a\ UG\text{-}27}$, $t_{a\ UG\text{-}22}$]
= max[0.0384 , 0]
= 0.0384 in

t_{b1} = $P*R_o$ / (S*E + 0.4*P) + Corrosion
= 245*9 / (19,500*1 + 0.4*245) + 0
= 0.1125 in

t_{b1} = max[t_{b1} , $t_{b\ UG16}$]
= max[0.1125 , 0.0625]
= 0.1125 in

t_b = min[t_{b3} , t_{b1}]
= min[0.245 , 0.1125]
= 0.1125 in

$t_{UG\text{-}45}$ = max[t_a , t_b]
= max[0.0384 , 0.1125]
= 0.1125 in

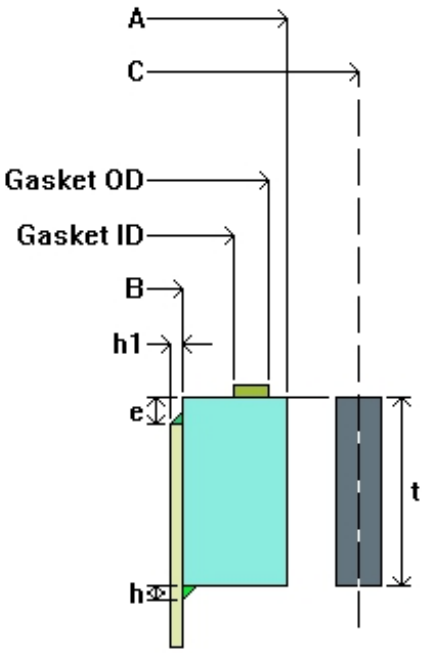
Available nozzle wall thickness new, t = 0.875*0.28 = 0.245 in

The nozzle neck thickness is adequate.

ASME VIII-1, 2010 Edition, Appendix 2 Flange Calculations

Flange is attached to:	Item 1 - Shell (Top)	
Flange type:	Ring type loose	
Flange material specification:	SA-240 304 (II-D p. 86, ln. 25)	
Bolt material specification:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)	
Bolt Description:	0.625 in Coarse Thread	
Internal design pressure, P:	150 psi @ 250 °F	
Required flange thickness: t_r=	2.5734 in	
Maximum allowable working pressure, MAWP:	159.21 psi @ 250 °F	
Maximum allowable pressure, MAP:	165.35 psi @ 70 °F	
External design pressure, P_e	15 psi @ 250 °F	
Maximum allowable external pressure, MAEP:	494.68 psi @ 250 °F	
Corrosion allowance:	Bore = 0 in	Flange = 0 in
Bolt corrosion (root), C_{bolt}:	0 in	
Design MDMT:	-20 °F	No impact test performed
Rated MDMT:	-55 °F	Flange material is not normalized Material is produced to fine grain practice PWHT is not performed
Estimated weight:	New = 67.3 lb	corroded = 67.3 lb

Flange dimensions, new



flange OD	A	= 21 in
bolt circle	C	= 23 in
gasket OD		= 20.5 in
gasket ID		= 19.5 in
flange ID	B	= 18.125 in
thickness	t	= 2.625 in
bolting		= 16- 0.625 in dia
lower fillet weld	h	= 0.1875 in
upper fillet weld	h1	= 0.1875 in
length	e	= 0.375 in
gasket factor	m	= 2
seating stress	y	= 2,500 psi
Gasket thickness	T	= 0.175 in

Item 6 - Bolted Cover

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Component:	Bolted Cover
Attached to:	Item 5 - Flange (21")
Material specification:	SA-240 304 (II-D p. 86, ln. 25)

Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: P = 150 psi @ 250 °F
External design pressure: P_e = 15 psi @ 250 °F

Static liquid head:

P_{th} = 0.79 psi_{head} (SG = 1, H_s = 21.8134", Horizontal test

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

Design MDMT = -20 °F	No impact test performed
Rated MDMT = -320 °F	Material is not normalized
	Material is not produced to Fine Grain Practice
	PWHT is not performed

Radiography: Category A joints - Seamless No RT

Estimated weight: New = 125.6 lb corr = 125.6 lb

Head diameter, d = 20"
Cover thickness, t = 1.25"

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

$t = d*Sqr(C*P / (S*E) + 1.9*W*h_G / (S*E*d^3)) + Corrosion$
$= 20*Sqr(0.3*150 / (19,500*1) + 1.9*56,520*1.5 / (19,500*1*20^3)) + 0$
= 1.1559 in

Design thickness, (at 70 °F) UG-34 (c)(2), gasket seating

$t = d*Sqr(1.9*W*h_G / (S*E*d^3)) + Corrosion$
$= 20*Sqr(1.9*68,660*1.5 / (20,000*1*20^3)) + 0$
= 0.6994 in

Maximum allowable working pressure, (at 250 °F)

$P = (S*E / C)*((t / d)^2 - (1.9*W*h_G / (S*E*d^3))) - P_s$
$= (19,500*1 / 0.3)*((1.25 / 20)^2 - (1.9*66,096.93*1.5 / (19,500*1*20^3))) - 0$
= 175.42 psi

Maximum allowable pressure, (At 70 °F)

$P = (S*E / C)*((t / d)^2 - (1.9*W*h_G / (S*E*d^3)))$
$= (20,000*1 / 0.3)*((1.25 / 20)^2 - (1.9*67,791.69*1.5 / (20,000*1*20^3)))$
= 179.91 psi

Design thickness for external pressure, (at 250 °F) U-2(g)

$t = d*Sqr(C*P_a / (S*E)) + Corrosion$

= 20*Sqr(0.3*15 / (19,500*1)) + 0
= 0.3038 in

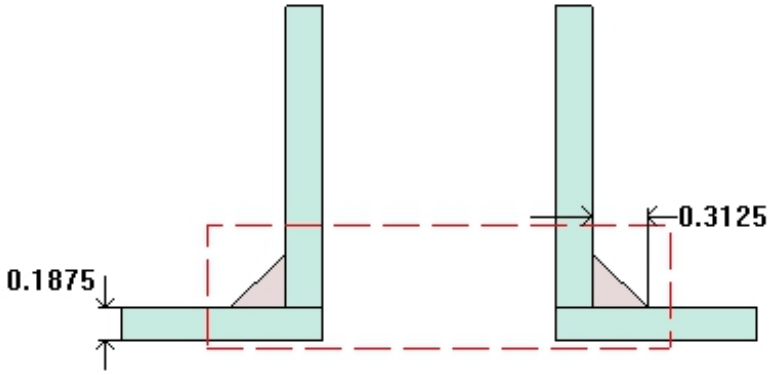
Maximum allowable external pressure, (At 250 °F) U-2(g)

P_a = (S*E / C)*(t / d)^2
= (19,500*1 / 0.3)*(1.25 / 20)^2
= 253.91 psi

Item 7 - Half Coupling (1") (Itm7)

ASME Section VIII Division 1, 2010 Edition

$t_{w(lower)}$ = 0 in
Leg_{41} = 0.3125 in



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

Located on:	Item 1 - Shell
Liquid static head included:	0 psi
Nozzle material specification:	SA-105 (II-D p. 18, ln. 5)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 1 Class 3000 - threaded
Nozzle orientation:	300°
Local vessel minimum thickness:	0.1875 in
Nozzle center line offset to datum line:	7 in
End of nozzle to shell center:	11 in
Nozzle inside diameter, new:	1.315 in
Nozzle nominal wall thickness:	0.2175 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	2 in

Reinforcement Calculations for Internal Pressure

The vessel wall thickness governs the MAWP of this nozzle.

UG-37 Area Calculation Summary (in^2) For P = 409.67 psi @ 250 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.2175

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

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.1268	0.2188	weld size is adequate

Calculations for internal pressure 409.67 psi @ 250 °F

Nozzle impact test exemption temperature from Fig UCS-66 Curve B = -20 °F
Fig UCS-66.1 MDMT reduction = 116.1 °F, (coincident ratio = 0.38091)
Rated MDMT is governed by UCS-66(b)(2).

Nozzle UCS-66 governing thk: 0.1875 in
Nozzle rated MDMT: -55 °F

Parallel Limit of reinforcement per UG-40

L_R = $MAX(d, R_n + (t_n - C_n) + (t - C))$
= $MAX(1.315, 0.6575 + (0.2175 - 0) + (0.1875 - 0))$
= 1.315 in

Outer Normal Limit of reinforcement per UG-40

L_H = $MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$
= $MIN(2.5*(0.1875 - 0), 2.5*(0.2175 - 0) + 0)$
= 0.4688 in

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$
= $409.6698*0.6575 / (20{,}000*1 - 0.6*409.6698)$
= 0.0136 in

Required thickness t_r from UG-37(a) $_n$

t_r = $P*R_o$ / (S*E + 0.4*P)
= 409.6698*9 / (19,500*1 + 0.4*409.6698)
= 0.1875 in

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

Check the weld - From UW-16(f)(3)(a)(3)(a)

Wall thickness per UG-45(a):	t_{r1} = 0.0178 in (E =1)
Wall thickness per UG-45(b)(1):	t_{r2} = 0.1875 in
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in
Standard wall pipe per UG-45(b)(4):	t_{r4} = 0.1269 in
The greater of t_{r2} or t_{r3}:	t_{r5} = 0.1875 in
The lesser of t_{r4} or t_{r5}:	t_{r6} = 0.1269 in

Required per UG-45 is the larger of t_{r1} or t_{r6} = 0.1269 in

$t_{w(actual)}$ = 0.7*Leg = 0.7*0.3125 = 0.2188 in

The fillet weld size is satisfactory.

ASME B16.11 Coupling Wall Thickness Check

Wall thickness req'd per ASME B16.11 2.1.1:	t_{r1} = 0.0178 in (E =1)
Wall thickness per UG-16(b):	t_{r3} = 0.0625 in

Available nozzle wall thickness new, t = 0.2175 in

The nozzle neck thickness is adequate.

Straight Flange on Item 2 - F&D Head

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Component:	Straight Flange
Material specification:	SA-240 304 (II-D p. 86, ln. 25)

Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: P = 150 psi @ 250 °F
External design pressure: P_e = 15 psi @ 250 °F

Static liquid head:

P_{th} = 0.78 psi (SG = 1, H_s = 21.6259", Horizontal test head)

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

Design MDMT = -20 °F
Rated MDMT = -320 °F

No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Longitudinal joint - Spot UW-11(b) Type 1
Circumferential joint - None UW-11(c) Type 1

Estimated weight	New = 4.1 lb	corr = 4.1 lb
Capacity	New = 2.14 US gal	corr = 2.14 US gal

OD = 18"
Length L_c = 2"
t = 0.125"

Design thickness, (at 250 °F) Appendix 1-1

t = $P*R_o$ / (S*E + 0.40*P) + Corrosion
= 150*9 / (19,500*0.85 + 0.40*150) + 0
= 0.0812"

Maximum allowable working pressure, (at 250 °F) Appendix 1-1

P = $S*E*t$ / (R_o - 0.40*t) - P_s
= 19,500*0.85*0.125 / (9 - 0.40*0.125) - 0
= 231.49 psi

Maximum allowable pressure, (at 70 °F) Appendix 1-1

P = $S*E*t$ / (R_o - 0.40*t)
= 20,000*0.85*0.125 / (9 - 0.40*0.125)
= 237.43 psi

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

L / D_o = 36.1178 / 18 = 2.0065
= = 227.4320

D_o / t = 18 / 0.0791

From table G: A = 0.000191

From table HA-1: B = 2,558.6055 psi

P_a = 4*B / (3*(D_o / t))
= 4*2,558.61 / (3*(18 / 0.0791))
= 15 psi

Design thickness for external pressure P_a = 15 psi

t_a = t + Corrosion = 0.0791 + 0 = 0.0791"

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

L / D_o = 36.1178 / 18 = 2.0065

D_o / t = 18 / 0.125 = 144.0000

From table G: A = 0.000374

From table HA-1: B = 5,012.4644 psi

P_a = 4*B / (3*(D_o / t))
= 4*5,012.46 / (3*(18 / 0.125))
= 46.41 psi

% Forming strain - UHA-44(a)(2)(a)

EFE = (50*t / R_f)*(1 - R_f / R_o)
= (50*0.125 / 8.9375)*(1 - 8.9375 / ∞)
= 0.6993%

Design thickness = 0.0812"

The governing condition is due to internal pressure.

The cylinder thickness of 0.125" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Load	Pressure P (psi)	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
	S_t	S_c						
Operating, Hot & Corroded	19,500	9.316	250	0	Weight	386.61	0.0487	0.0487
Operating, Hot & New	19,500	9.316	250	0	Weight	386.61	0.0487	0.0487
Hot Shut Down, Corroded	19,500	9.316	250	0	Weight	0	0	0
Hot Shut Down, New	19,500	9.316	250	0	Weight	0	0	0
Empty, Corroded	20,000	11.048	70	0	Weight	0	0	0

Empty, New	20,000	11,048	70	0	Weight	0	0	0
Vacuum	19,500	9,316	250	0	Weight	263.99	0.0071	0.0071
Hot Shut Down, Corroded, Weight & Eccentric Moments Only	19,500	9,316	250	0	Weight	0	0	0

Item 9 - Pipe (3/4") (Itm9)

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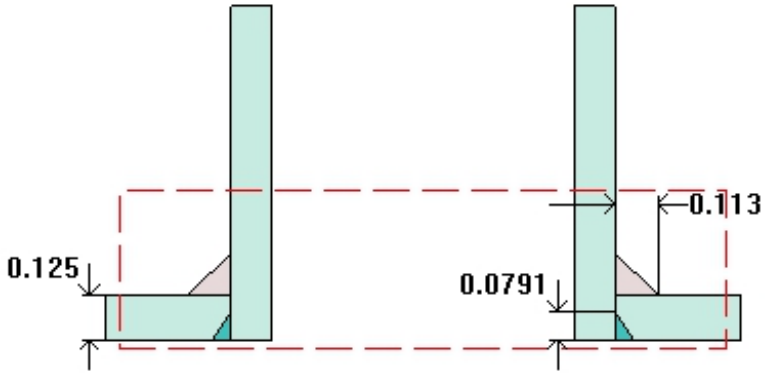
$t_{w(lower)}$ = 0.0791 in
Leg_{41} = 0.113 in



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

Located on:	Item 2 - F&D Head
Liquid static head included:	0 psi
Nozzle material specification:	SA-106 B Smls pipe (II-D p. 10, ln. 40)
Nozzle longitudinal joint efficiency:	1
Nozzle description:	NPS 0.75 Sch 40 (Std)
Flange description:	0.75 inch Class 150 WN A105
Bolt Material:	SA-193 B7 Bolt <= 2 1/2 (II-D p. 334, ln. 32)
Flange rated MDMT: (UCS-66(b)(1)(b))	-55°F
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	245 psi @ 250°F
ASME B16.5 flange rating MAP:	285 psi @ 70°F
ASME B16.5 flange hydro test:	450 psi @ 70°F
PWHT performed:	No
Circumferential joint radiography:	None UW-11(c) Type 1
Nozzle orientation:	0°
Calculated as hillside:	No
Local vessel minimum thickness:	0.125 in
End of nozzle to datum line:	-8.9 in
Nozzle inside diameter, new:	0.824 in
Nozzle nominal wall thickness:	0.113 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	0.0191 in
Projection available outside vessel to flange face, Lf:	2.0791 in
Distance to head center, R:	0 in

Reinforcement Calculations for Internal Pressure

The attached ASME B16.5 flange limits the nozzle MAWP.

UG-37 Area Calculation Summary (in^2) For P = 245 psi @ 250 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0989	0.0989

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 size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0791	0.0791	weld size is adequate
Nozzle to shell groove (Lower)	0.0791	0.0791	weld size is adequate

Calculations for internal pressure 245 psi @ 250 °F

Fig UCS-66.2 general note (1) applies.

Nozzle is impact test exempt per UCS-66(d) (NPS 4 or smaller pipe).

Nozzle UCS-66 governing thk: 0.0989 in

Nozzle rated MDMT: -155 °F

Parallel Limit of reinforcement per UG-40

L_R = $MAX(d, R_n + (t_n - C_n) + (t - C))$

= $MAX(0.824, 0.412 + (0.113 - 0) + (0.125 - 0))$

= 0.824 in

Outer Normal Limit of reinforcement per UG-40

L_H = $MIN(2.5*(t - C), 2.5*(t_n - C_n) + t_e)$

= $MIN(2.5*(0.125 - 0), 2.5*(0.113 - 0) + 0)$

= 0.2825 in

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

t_{rn} = $P*R_n / (S_n*E - 0.6*P)$

= $245*0.412 / (17{,}100*1 - 0.6*245)$

= 0.006 in

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

t_r = $P*L_o*M / (2*S*E + P*(M - 0.2))$
= 245*18.125*1 / (2*19,500*1 + 245*(1 - 0.2))
= 0.1133 in

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

UW-16(d) Weld Check

t_{min} = lesser of 0.75 or t_n or t = 0.113 in
$t_{1(min)}$ or $t_{2(min)}$ = lesser of 0.25 or $0.7*t_{min}$ = 0.0791 in
$t_{1(actual)}$ = 0.7*Leg = 0.7*0.113 = 0.0791 in
The weld size t_1 is satisfactory.
$t_{2(actual)}$ = 0.0791 in
The weld size t_2 is satisfactory.

$t_1 + t_2 = 0.1582 >= 1.25*t_{min}$

The combined weld sizes for t_1 and t_2 are satisfactory.

UG-45 Nozzle Neck Thickness Check

$t_{a\ UG-27}$ = P*R / (S*E - 0.6*P) + Corrosion
= 245*0.412 / (17,100*1 - 0.6*245) + 0
= 0.006 in

t_a = $max[t_{a\ UG-27} , t_{a\ UG-22}]$
= max[0.006 , 0]
= 0.006 in

t_{b1} = 0.1133 in

t_{b1} = $max[t_{b1} , t_{b\ UG16}]$
= max[0.1133 , 0.0625]
= 0.1133 in

t_b = $min[t_{b3} , t_{b1}]$
= min[0.0989 , 0.1133]
= 0.0989 in

t_{UG-45} = $max[t_a , t_b]$
= max[0.006 , 0.0989]
= 0.0989 in

Available nozzle wall thickness new, t_n = 0.875*0.113 = 0.0989 in

The nozzle neck thickness is adequate.

Reinforcement Calculations for External Pressure

UG-37 Area Calculation Summary (in^2) For Pe = 46.41 psi @ 250 °F							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
This nozzle is exempt from area calculations per UG-36(c)(3)(a)							0.0625	0.0989

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

UW-16 Weld Sizing Summary			
Weld description	Required weld size (in)	Actual weld size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.0791	0.0791	weld size is adequate
Nozzle to shell groove (Lower)	0.0791	0.0791	weld size is adequate

Item 13 - Legs

Leg material:			
Leg description:			2x2x1/8 Equal Angle (Leg in)
Number of legs:	N =	4	
Overall length:		16	in
Base to girth seam length:		12.38	in
Bolt circle:		17	in
Anchor bolt size:		0.375	inch series 8 threaded
Anchor bolt material:			
Anchor bolts/leg:		1	
Anchor bolt allowable stress:	S_b =	20,000	psi
Anchor bolt corrosion allowance:		0	in
Anchor bolt hole clearance:		0.375	in
Base plate width:		3	in
Base plate length:		3	in
Base plate thickness:		0.25	in (0.0487 in required)
Base plate allowable stress:		24,000	psi
Foundation allowable bearing stress:		1,658	psi
Effective length coefficient:	K =	1.2	
Coefficient:	C_m =	0.85	
Leg yield stress:	F_y =	36,000	psi
Leg elastic modulus:	E =	29,000,000	psi
Leg to shell fillet weld:		0.125	in (0.0012 in required)
Legs braced:		No	

Note: The support attachment point is assumed to be 1 in up from the cylinder circumferential seam.

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Governing Condition **Weight operating corroded** **Moment = 21.7 lb_f-ft**	**0**	0	83.9	0.0	173	452	0	0.0305	0.0318
		90	98.4	0.0	203	530	0	0.0358	0.0373
		180	112.9	0.0	233	608	0	0.0410	0.0427
		270	98.4	0.0	203	530	0	0.0358	0.0373

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Weight empty corroded **Moment = 21.7 lb_f-ft**	**0**	0	83.9	0.0	173	452	0	0.0305	0.0318
		90	98.4	0.0	203	530	0	0.0358	0.0373
		180	112.9	0.0	233	608	0	0.0410	0.0427
		270	98.4	0.0	203	530	0	0.0358	0.0373

Loading	Force attack angle °	Leg position °	Axial end load lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Weight vacuum corroded **Moment = 21.7 lb_f-ft**	**0**	0	83.9	0.0	173	452	0	0.0305	0.0318
		90	98.4	0.0	203	530	0	0.0358	0.0373
		180	112.9	0.0	233	608	0	0.0410	0.0427
		270	98.4	0.0	203	530	0	0.0358	0.0373