

Coil RE-RATE



Premier Boiler & COMBUSTION

Pressure Vessel Design Calculations

Item: C9000 Coil

Drawing No.: 1-151-A

Alteration Code: NBIC Part 3 - 2023 Edition

Alteration Design Code: ASME Section VIII, Div. 1 - 2023 Edition

Alteration Calculations Revision A
Scope Of Work
Re-rate Coil to 90psi @ 335°F

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Deficiencies Summary

No deficiencies found.

Warnings Summary

Warnings for [Flange #1](#)

This body flange is being counted as a line of support for external pressure. (warning)

Warnings for Vessel

The vessel does not have a right closure (head or cover). (warning)

The vessel does not have a left closure (head or cover). (warning)

ASME B16.5 / B16.47 Flange Warnings Summary

Flange	Applicable Warnings
Flange #1	1

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.

Revision History

Revisions			
No.	Date	Operator	Notes
A	6/11/2024	J Lowry, LLC	New vessel created ASME Section VIII Division 1 [COMPRESS 2024 Build 8400]

Settings Summary

COMPRESS 2024 Build 8400	
ASME Section VIII Division 1, 2023 Edition	
Units	U.S. Customary
Datum Line Location	0.00" from right seam
Vessel Design Mode	Design Mode
Minimum thickness	0.0625" per UG-16(b)
Design for cold shut down only	No
Design for lethal service (full radiography required)	No
Design nozzles for	Design P only
Corrosion weight loss	100% of theoretical loss
UG-23 Stress Increase	1.20
Skirt/legs stress increase	1.0
Minimum nozzle projection	0.25"
Juncture calculations for $\alpha > 30$ only	Yes
Preheat P-No 1 Materials $> 1.25"$ and $\leq 1.50"$ 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	No
ASME B16.9 fittings are entered as minimum thickness	No
Butt welds	Tapered per Figure UCS-66.3(a)
Disallow Appendix 1-5, 1-8 calculations under 15 psi	No
Hydro/Pneumatic Test	
Shop Hydrotest Pressure	1.3 times vessel MAWP [UG-99(b)]
Test liquid specific gravity	1.00
Maximum stress during test	90% of yield
Required Marking - UG-116	
UG-116(e) Radiography	None
UG-116(f) Postweld heat treatment	None
Code Cases/Interpretations	
Use Appendix 46	No
Use UG-44(b)	Yes
Use Code Case 3035	No
Apply interpretation VIII-1-83-66	Yes
Apply interpretation VIII-1-86-175	Yes
Apply interpretation VIII-1-01-37	No
Apply interpretation VIII-1-01-150	Yes
Apply interpretation VIII-1-07-50	Yes
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	No
UG-22 Loadings	
UG-22(a) Internal or External Design Pressure	Yes
UG-22(b) Weight of the vessel and normal contents under operating or test conditions	No
UG-22(c) Superimposed static reactions from weight of attached equipment (external loads)	No
UG-22(d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs	No
UG-22(f) Wind reactions	No
UG-22(f) Seismic reactions	No
UG-22(j) Test pressure and coincident static head acting during the test:	No

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

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

License Information	
Company Name	J Lowry
License	Commercial
License Key ID	33620
Support Expires	May 03, 2025
Account Number	415386935659501

Pressure Summary

Component Summary									
Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T _e external (°F)	MDMT (°F)	MDMT Exemption	Impact Tested
Cylinder #1	90	335	1,922.06	2,055.68	770.44	335	-320	Note 1	No
B16.9 Tee #1	90	335	1,889.42	2,020.77	770.44	335	-320	Note 2	No
Flange #1	90	335	199.75	275	N/A	335	-55	Note 3	No
B16.9 Elbow #1	90	335	1,889.42	2,020.77	809.74	335	-320	Note 2	No

Chamber Summary	
Design MDMT	-20 °F
Rated MDMT	-20 °F @ 199.75 psi
MAWP hot & corroded	199.75 psi @ 335 °F
MAP cold & new	275 psi @ 70 °F
MAEP	770.44 psi @ 335 °F
(1) The rated MDMT is limited to the design MDMT based on the setting in the Calculations tab of the Set Mode dialog.	

Notes for MDMT Rating		
Note #	Exemption	Details
1.	Impact test exempt per UHA-51(g) (coincident ratio = 0.0772)	
2.	Impact test exempt per UHA-51(g) (coincident ratio = 0.0876)	
3.	Flange rated MDMT per UHA-51(d)(1)(a) = -320°F	Bolts rated MDMT per Fig UCS-66 note (c) = -55°F

Radiography Summary

UG-116 Radiography							
Component	Longitudinal Seam		Left Circumferential Seam		Right Circumferential Seam		Mark
	Category (Fig UW-3)	Radiography / Joint Type	Category (Fig UW-3)	Radiography / Joint Type	Category (Fig UW-3)	Radiography / Joint Type	
Cylinder #1	N/A	Seamless No RT	C	N/A	B	None UW-11(c) / Type 1	None
Flange #1	N/A	Seamless No RT	N/A	N/A / Gasketed	C	N/A	N/A
B16.9 Tee #1	N/A	Seamless No RT	B	None UW-11(c) / Type 1	B	None UW-11(c) / Type 1	None
B16.9 Elbow #1	N/A	Seamless No RT	B	UW-11(a)(4) exempt / Type 1	B	UW-11(a)(4) exempt / Type 1	N/A
UG-116(e) Required Marking: None							

Thickness Summary

Component Data								
Component Identifier	Material	Diameter (In)	Length (In)	Nominal t (In)	Design t (In)	Total Corrosion (In)	Joint E	Load
Cylinder #1	SA-312 TP304 Wld & smls pipe	2.067 ID	96	0.154	0.0283	0	0.85	External
B16.9 Tee #1	SA-403 304	2.375 OD	5	0.154	0.0283	0	0.85	External

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

Weight Summary

Weight (lb) Contributed by Vessel Elements											
Component	Metal New*	Metal Corroded	Insulation	Insulation Supports	Lining	Piping + Liquid	Operating Liquid		Test Liquid		Surface Area ft ²
							New	Corroded	New	Corroded	
Cylinder #1	29.9	29.9	0	0	0	0	0	0	11.6	11.6	5
B16.9 Tee #1	1.8	1.8	0	0	0	0	0	0	1.4	1.4	1
TOTAL:	31.7	31.7	0	0	0	0	0	0	13	13	6
*Shells with attached nozzles have weight reduced by material cut out for opening.											

Weight (lb) Contributed by Attachments										
Component	Body Flanges		Nozzles & Flanges		Packed Beds	Trays	Tray Supports	Rings & Clips	Vertical Loads	Surface Area ft ²
	New	Corroded	New	Corroded						
Cylinder #1	5	5	0	0	0	0	0	0	0	0
B16.9 Tee #1	0	0	1.5	1.5	0	0	0	0	0	0
TOTAL:	5	5	1.5	1.5	0	0	0	0	0	0

Vessel Totals		
	New	Corroded
Operating Weight (lb)	38	38
Empty Weight (lb)	38	38
Test Weight (lb)	52	52
Surface Area (ft ²)	6	-
Capacity** (US gal)	1	1
**The vessel capacity does not include volume of nozzle, piping or other attachments.		

Vessel Lift Condition	
Vessel Lift Weight, New (lb)	38
Center of Gravity from Datum (In)	55.0174

Hydrostatic Test

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

$$\begin{aligned} \text{Gauge pressure at } 70^{\circ}\text{F} &= 1.3 \cdot \text{MAWP} \cdot \text{LSR} \\ &= 1.3 \cdot 199.75 \cdot 1.0695 \\ &= 277.72 \text{ psi} \end{aligned}$$

Horizontal shop hydrostatic test				
Identifier	Local test pressure (psi)	Test liquid static head (psi)	UG-99(b) stress ratio	UG-99(b) pressure factor
Flange #1	278.002	0.28	N/A	1.30
Cylinder #1 (1)	277.996	0.273	1.0695	1.30
B16.9 Tee #1	277.996	0.273	1.0695	1.30
B16.9 Elbow #1	277.868	0.146	1.0695	1.30
(1) Cylinder #1 limits the UG-99(b) stress ratio. (2) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.				

The field test condition has not been investigated.

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

Horizontal shop hydrostatic test - Minimum test temperature		
Identifier	Rated MDMT (°F)	Minimum Test Temperature (°F)
Flange #1	-320	-290
Cylinder #1	-320	-290
B16.9 Tee #1	-320	-290
B16.9 Elbow #1	-320	-290
Chamber Rated MDMT	-20	10
Limit chamber rated MDMT to Design MDMT option is active.		

Vacuum Summary

Largest Unsupported Length Le			
Component	Line of Support	Elevation above Datum (In)	Length l.e (In)
-	Flange #1	101.094	N/A
-	Flange #1	101.094	N/A
Cylinder #1 Left	-	101	101.094
Cylinder #1 Right	-	5	101.094
B16.9 Tee #1 Left	-	5	101.094
-	B16.9 Tee #1 Right	0	N/A
B16.9 Tee #1 Right	-	0	101.094

Bill of Materials

Shells							
Item #	Type	Material	Thk [In]	Dia. [In]	Length [In]	Wt. [lb] (ea.)	Qty
S1	Cylinder	SA-312 TP304 Wld & smls pipe; NPS 2 Sch 40S (Std)	0.154	2.067 ID	96	29.9	1

ASME B16.9 Fittings				
Item #	Type	Material	Size [In]	Qty
EB1	B16.9 Elbow Long Radius	SA-403 304	NPS 2 Sch 40S (Std)	1
T1	B16.9 Tee	SA-403 304	NPS 2 Sch 40S (Std)	1

Flanges						
Item #	Type	Material	NPS	Dia. [In]	Wt. [lb] (ea.)	Qty
AF1	ASME B16.5 Slip On - Class 150	A182 F304	2	6 x 2.44	5	1

Fasteners				
Item #	Description	Material	Length [In]	Qty
FB1	5/8" coarse bolt	SA-193 B7 Bolt <= 2 1/2	2.8	4

All listed flange bolts require associated nuts and washers in accordance with Division 1, UCS-11.

Cylinder #1

ASME Section VIII Division 1, 2023 Edition				
Component		Cylinder		
Material		SA-312 TP304 Wld & smls pipe (II-D p. 92, ln. 25)		
Pipe NPS and Schedule		NPS 2 Sch 40S (Std)		
Impact Tested	Normalized	Fine Grain Practice	PWHT	Maximize MDMT/ No MAWP
No	No	No	No	No
		Design Pressure (psi)	Design Temperature (°F)	Design MDMT (°F)
Internal		90	335	-20
External		33	335	
Static Liquid Head				
Condition		P _s (psi)	H _s (in)	SG
Test horizontal		0.27	7.567	1
Dimensions				
Inner Diameter		2.067"		
Length		96"		
Pipe Nominal Thickness		0.154"		
Pipe Minimum Thickness ¹		0.1348"		
Corrosion	Inner	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		Capacity (US gal)
New		29.92		1.39
Corroded		29.92		1.39
Radiography				
Longitudinal seam		Seamless No RT		
Right Circumferential seam		None UW-11(c) Type 1		

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

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	<u>0.0059"</u>
Design thickness due to external pressure (t _e)	<u>0.0283"</u>
Maximum allowable working pressure (MAWP)	<u>1,922.06 psi</u>
Maximum allowable pressure (MAP)	<u>2,055.68 psi</u>
Maximum allowable external pressure (MAEP)	<u>770.44 psi</u>
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \frac{199.75 \cdot 1.0335}{20,000 \cdot 0.85 - 0.6 \cdot 199.75} =$	0.0122"
Stress ratio = $\frac{t_r \cdot E^*}{t_n - c} = \frac{0.0122 \cdot 0.85}{0.1348 - 0} =$	0.0771
Impact test exempt per UHA-51(g) (coincident ratio = 0.0772)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 335 °F) UG-27(c)(1)

$$t = \frac{P \cdot R}{S \cdot E - 0.60 \cdot P} + \text{Corrosion} = \frac{90 \cdot 1.0335}{18,700 \cdot 0.85 - 0.60 \cdot 90} + 0 = \underline{0.0059"}$$

Maximum allowable working pressure, (at 335 °F) UG-27(c)(1)

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} - P_s = \frac{18,700 \cdot 0.85 \cdot (0.154 \cdot 0.875)}{1.0335 + 0.60 \cdot (0.154 \cdot 0.875)} - 0 = \underline{1,922.06} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R + 0.60 \cdot t} = \frac{20,000 \cdot 0.85 \cdot (0.154 \cdot 0.875)}{1.0335 + 0.60 \cdot (0.154 \cdot 0.875)} = \underline{2,055.68} \text{ psi}$$

External Pressure, (Corroded & at 335 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{101.094}{2.375} = 42.5659$$

$$\frac{D_o}{t} = \frac{2.375}{0.0283} = 83.9469$$

From table G: $A = 0.000160$

From table HA-1: $B = 2,077.7015 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2,077.7}{3 \cdot (2.375/0.0283)} = 33 \text{ psi}$$

Design thickness for external pressure $P_a = 33 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.0283 + 0 = \underline{0.0283"}$$

Maximum Allowable External Pressure, (Corroded & at 335 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{101.094}{2.375} = 42.5659$$

$$\frac{D_o}{t} = \frac{2.375}{0.154 \cdot 0.875} = 17.6252$$

From table G: $A = 0.003771$

From table HA-1: $B = 10,184.3609 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 10,184.36}{3 \cdot (2.375/(0.154 \cdot 0.875))} = \underline{770.44} \text{ psi}$$

Flange #1

ASME B16.5-2020 Flange	
Description	NPS 2 Class 150 SO A182 F304
Attached to	Left end of Cylinder #1
Bolt Material	SA-193 B7 Bolt $\leq 2 \frac{1}{2}$ (II-D p. 418, ln. 32)
Blind included	No
Rated MDMT	-55°F
Liquid static head	0 psi
MAWP rating	199.75 psi @ 335°F
MAP rating	275 psi @ 70°F
Hydrotest rating	425 psi @ 70°F
External fillet weld leg (UW-21)	0.2156" (0.2156" min)
Internal fillet weld leg (UW-21)	0.154" (0.154" min)
PWHT performed	No
Produced to Fine Grain Practice and Supplied in Heat Treated Condition	No
Impact Tested	No
UW-21 Flange Welds	
$X_{\min} = \min [1.4 \cdot t_n, g_0] = [1.4 \cdot 0.154, 0.31] =$	0.2156"
External Leg $\min = X_{\min} + \frac{C_o}{0.7} = 0.2156 + \frac{0}{0.7} =$	0.2156"
Internal Leg $\min = \min \left[t_n, 0.25" + \frac{C_i}{0.7} \right] = \min \left[0.154, 0.25 + \frac{0}{0.7} \right] =$	0.154"
Notes	
Flange rated MDMT per UHA-51(d)(1)(a) = -320°F Bolts rated MDMT per Fig UCS-66 note (c) = -55°F	

B16.9 Tee #1

ASME Section VIII Division 1, 2023 Edition				
Component		ASME B16.9 Tee		
Material		SA-403 304 (II-D p. 92, ln. 40)		
Pipe NPS and Schedule		NPS 2 Sch 40S (Std)		
Impact Tested	Normalized	Fine Grain Practice	PWHT	Maximize MDMT/No MAWP
No	No	No	No	No
		Design Pressure (psi)	Design Temperature (°F)	Design MDMT (°F)
Internal		90	335	-20
External		33	335	
Static Liquid Head				
Condition		P _s (psi)	H _s (in)	SG
Test horizontal		0.27	7.567	1
Dimensions				
Outer Diameter		2.375"		
Nominal Thickness		0.154"		
Minimum Thickness ¹		0.1348"		
Center-to-End Run, C		2.5"		
Center-to-End Outlet, M		2.5"		
Corrosion	Inner	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		Capacity (US gal)
New		1.77		0.1
Corroded		1.77		0.1
Radiography				
Longitudinal seam		Seamless No RT		
Left Circumferential seam		None UW-11(c) Type 1		
Right Circumferential seam		None UW-11(c) Type 1		

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

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	<u>0.0068"</u>
Design thickness due to external pressure (t _e)	<u>0.0283"</u>
Maximum allowable working pressure (MAWP)	<u>1,889.42 psi</u>
Maximum allowable pressure (MAP)	<u>2,020.77 psi</u>
Maximum allowable external pressure (MAEP)	<u>770.44 psi</u>
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \frac{199.75 \cdot 1.1875}{20,000 \cdot 0.85 + 0.4 \cdot 199.75} =$	0.0139"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0139 \cdot 0.85}{0.1348 - 0} =$	0.0876
Impact test exempt per UHA-51(g) (coincident ratio = 0.0876)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 335 °F) Appendix 1-1

$$t = \frac{P \cdot R_o}{S \cdot E + 0.40 \cdot P} + \text{Corrosion} = \frac{90 \cdot 1.1875}{18,700 \cdot 0.85 + 0.40 \cdot 90} + 0 = \underline{0.0068"}$$

Maximum allowable working pressure, (at 335 °F) Appendix 1-1

$$P = \frac{S \cdot E \cdot t}{R_o - 0.40 \cdot t} - P_a = \frac{18,700 \cdot 0.85 \cdot (0.154 \cdot 0.875)}{1.1875 - 0.40 \cdot (0.154 \cdot 0.875)} - 0 = \underline{1.889.42} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R_o - 0.40 \cdot t} = \frac{20,000 \cdot 0.85 \cdot (0.154 \cdot 0.875)}{1.1875 - 0.40 \cdot (0.154 \cdot 0.875)} = \underline{2.020.77} \text{ psi}$$

External Pressure, (Corroded & at 335 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{101.094}{2.375} = 42.5659$$

$$\frac{D_o}{t} = \frac{2.375}{0.0283} = 83.9469$$

From table G: $A = 0.000160$

From table HA-1: $B = 2,077.7015 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 2,077.7}{3 \cdot (2.375/0.0283)} = 33 \text{ psi}$$

Design thickness for external pressure $P_a = 33 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.0283 + 0 = \underline{0.0283"}$$

Maximum Allowable External Pressure, (Corroded & at 335 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{101.094}{2.375} = 42.5659$$

$$\frac{D_o}{t} = \frac{2.375}{0.154 \cdot 0.875} = 17.6252$$

From table G: $A = 0.003771$

From table HA-1: $B = 10,184.3609 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 10,184.36}{3 \cdot (2.375/(0.154 \cdot 0.875))} = \underline{770.44} \text{ psi}$$

B16.9 Elbow #1

ASME Section VIII Division 1, 2023 Edition				
Component		ASME B16.9 Elbow		
Type		Long Radius 90-deg		
Material		SA-403 304 (II-D p. 92, ln. 40)		
Pipe NPS and Schedule		NPS 2 Sch 40S (Std)		
Attached To		B16.9 Tee #1		
Impact Tested	Normalized	Fine Grain Practice	PWHT	Maximize MDMT/ No MAWP
No	No	No	No	No
		Design Pressure (psi)	Design Temperature (°F)	Design MDMT (°F)
Internal		90	335	-20
External		33	335	
Static Liquid Head				
Condition		P _s (psi)	H _s (in)	SG
Test horizontal		0.15	4.0335	1
Dimensions				
Outer Diameter		2.375"		
Nominal Thickness		0.154"		
Minimum Thickness ¹		0.1348"		
Center-to-End, A		3"		
Corrosion	Inner	0"		
	Outer	0"		
Weight and Capacity				
		Weight (lb)		Capacity (US gal)
New		1.47		0.07
Corroded		1.47		0.07
Radiography				
Longitudinal seam		Seamless No RT		
Left Circumferential seam		None UW-11(c) Type 1		
Right Circumferential seam		None UW-11(c) Type 1		

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

Results Summary	
Governing condition	UG-16
Minimum thickness per UG-16	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	<u>0.0068"</u>
Design thickness due to external pressure (t _e)	<u>0.0173"</u>
Maximum allowable working pressure (MAWP)	<u>1,889.42 psi</u>
Maximum allowable pressure (MAP)	<u>2,020.77 psi</u>
Maximum allowable external pressure (MAEP)	<u>809.74 psi</u>
Rated MDMT	-320 °F

UHA-51 Material Toughness Requirements	
$t_r = \frac{199.75 \cdot 1.1875}{20,000 \cdot 0.85 + 0.4 \cdot 199.75} =$	0.0139"
Stress ratio $= \frac{t_r \cdot E^*}{t_n - c} = \frac{0.0139 \cdot 0.85}{0.1348 - 0} =$	0.0876
Impact test exempt per UHA-51(g) (coincident ratio = 0.0876)	
Rated MDMT =	-320°F
Material is exempt from impact testing at the Design MDMT of -20°F.	

Design thickness, (at 335 °F) Appendix 1-1

$$t = \frac{P \cdot R_o}{S \cdot E + 0.40 \cdot P} + \text{Corrosion} = \frac{90 \cdot 1.1875}{18,700 \cdot 0.85 + 0.40 \cdot 90} + 0 = \underline{0.0068"}$$

Maximum allowable working pressure, (at 335 °F) Appendix 1-1

$$P = \frac{S \cdot E \cdot t}{R_o - 0.40 \cdot t} - P_a = \frac{18,700 \cdot 0.85 \cdot (0.154 \cdot 0.875)}{1.1875 - 0.40 \cdot (0.154 \cdot 0.875)} - 0 = \underline{1.889.42} \text{ psi}$$

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

$$P = \frac{S \cdot E \cdot t}{R_o - 0.40 \cdot t} = \frac{20,000 \cdot 0.85 \cdot (0.154 \cdot 0.875)}{1.1875 - 0.40 \cdot (0.154 \cdot 0.875)} = \underline{2.020.77} \text{ psi}$$

External Pressure, (Corroded & at 335 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{7.2124}{2.375} = 3.0368$$

$$\frac{D_o}{t} = \frac{2.375}{0.0173} = 137.1750$$

From table G: $A = 0.000261$

From table HA-1: $B = 3,395.1397 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 3,395.14}{3 \cdot (2.375/0.0173)} = 33 \text{ psi}$$

Design thickness for external pressure $P_a = 33 \text{ psi}$

$$t_a = t + \text{Corrosion} = 0.0173 + 0 = \underline{0.0173"}$$

Maximum Allowable External Pressure, (Corroded & at 335 °F) UG-28(c)

$$\frac{L}{D_o} = \frac{7.2124}{2.375} = 3.0368$$

$$\frac{D_o}{t} = \frac{2.375}{0.154 \cdot 0.875} = 17.6252$$

From table G: $A = 0.005566$

From table HA-1: $B = 10,703.8329 \text{ psi}$

$$P_a = \frac{4 \cdot B}{3 \cdot (D_o/t)} = \frac{4 \cdot 10,703.83}{3 \cdot (2.375/(0.154 \cdot 0.875))} = \underline{809.74} \text{ psi}$$