TANK CALCULATIONS

Filtrate Drum
DR0002
IGCC Coal Gasification Project

PROJECT ENGINEER

Southern Company

DESIGN ENGINEER

Chattanooga Boiler and Tank, Inc.
1011 E. Main St.
Chattanooga, TN 37408

Customer:
Southern Company
Job Number:
2084-01
Date: 05-26-2011 Rev.: 1

Comments

Comments

Shell

Joint efficiency for all shell courses = 85%. X-rays are required. Quantity of x-rays shall be per A.5.3.

Roof

Roof is butt welded

Wind

Anchorage of the tank for wind is required

Per 5.2.1 (k)(1), wind loads are based on ASCE 7.

Shell External Pressure

Per 5.2.5, vacuum calculations are not required.

Seismic

Tank is mechanically anchored

Importance factor used is as required based on the Seismic Use Group.

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Design Data

Tank Diameter	10'- 0.0000" (Inside)
Tank Height	25'- 6.0000"
High Liquid Level	24'- 9.0000"
Low Liquid Level	0'- 0.0000"
Total Capacity	14,540 gallons
	346 barrels
Working Capacity	14,540 gallons
	346 barrels
Design Standard..	API-650 11th Edition, Add. 2, App. J
Design Metal Temperature	20 °F
Operating Temperature	132 °F
Design Temperature	160 °F
Roof Live Load	20.00 psf
Roof Snow Load	5.00 psf
Additional Roof Loads	0.00 psf
Wind:	
Velocity	100 mph
Importance Factor	1.15
Exposure	C
Seismic:	
Site Class	C
Importance Factor	1.25
Use Group	III
Ss Value	20.40 %
S_1 Value	8.70 %
Vertical Acceleration	0.00 g
Transitional Period (T_L)	8
Specific Gravity	0.99

Quality Record

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Internal Pressure (Design).............................	Atmospheric
(Operating).............................	Atmospheric
External Pressure (Design).............................	1.00 inches of water
(Operating).............................	Atmospheric

Corrosion Allowance:

Bottom	0.1250 in
Shell Courses 1 - 1	0.1250 in
Courses 2 - 2	0.1250 in
Courses 3 - 4	0.1250 in
Roof	0.1250 in
Compression Ring	0.1250 in
Anchor Bolts	0.0000 in
Anchor Chairs	0.0000 in

Summary

Total Weight of Tank: 10,852 lbs
Total Operating Weight: 130,936 lbs
Total Testing Weight: 132,149 lbs

Bottom

Flat Bottom:
0.3750 in (A36) PL (weight: 1,284 lbs)

Outside projection = 2.0000 in

Tank bottom is butt welded.

Shell

Shell Course 01: 0.2500 in (A36) PL x 94.0000 in wide (weight: 2,513 lbs)

Shell Course 02: 0.2500 in (A36) PL x 94.0000 in wide (weight: 2,513 lbs)

Shell Course 03: 0.2500 in (A36) PL x 70.7500 in wide (weight: 1,891 lbs)

Shell Course 04: 0.2500 in (A36) PL x 47.0000 in wide (weight: 1,256 lbs)

Self-Supporting Cone Roof

0.3125 in (A36) PL (weight: 1,016 lbs)

Roof Slope: 2.0000 in 12 ⌀: 9.4623° Roof Rise: 0.8333 ft

Roof is butt welded

Compression Ring

L2 x2 x3/8 per Detail b (A36)
Weight: 148 lbs

2 inches Vertical leg of rim angle is lap welded to the outside of the shell with the horizontal leg turned out

Rim Angle is attached 0.2500 inches above the top of shell

Anchor Bolt

(8) 1 inch (A307-B) Bolts on 10.5417 ft BC (Equal spaced)

Quality Record

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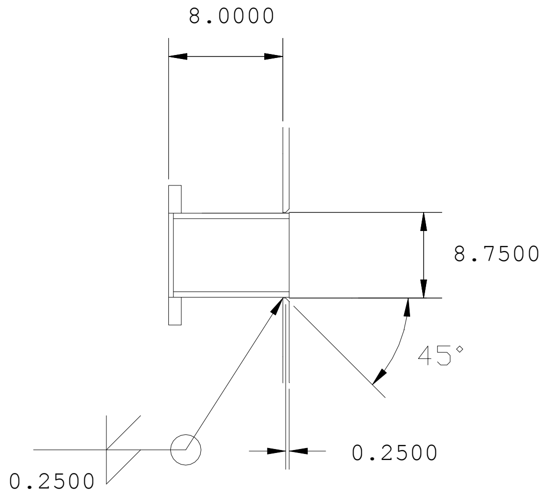
Shell Nozzles

Filtrate Inlet (A)

8" 150# SO Flanged Nozzle
Elevation: 294.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.5000 in

Flange Material:
A105

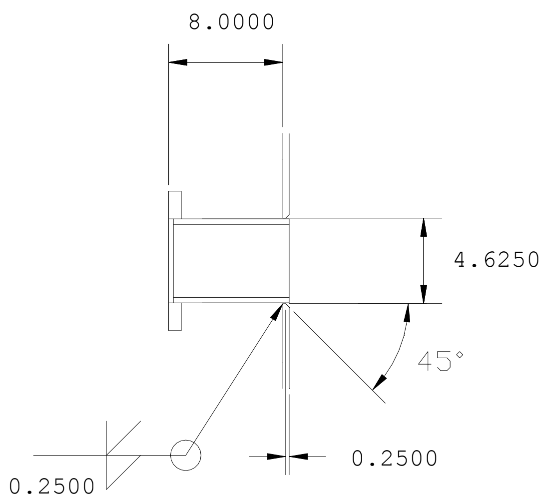


Pump Recirculation (B)

4" 150# SO Flanged Nozzle
Elevation: 294.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.3370 in

Flange Material:
A105



Customer:
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2084-01
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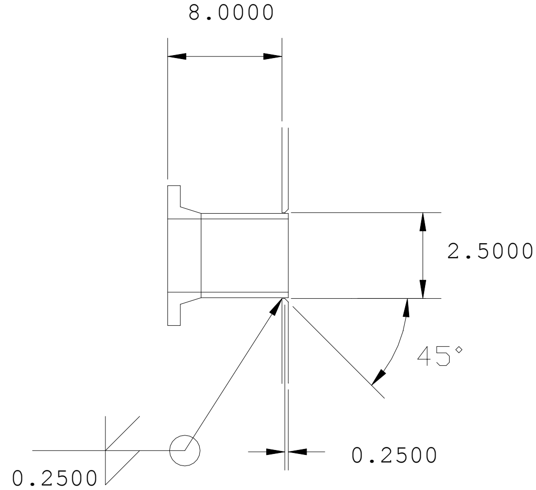
Inlet from DR0004 (C)

2" 150# WN Flanged Nozzle
Elevation: 282.0000 in
Orientation: 0.0000°

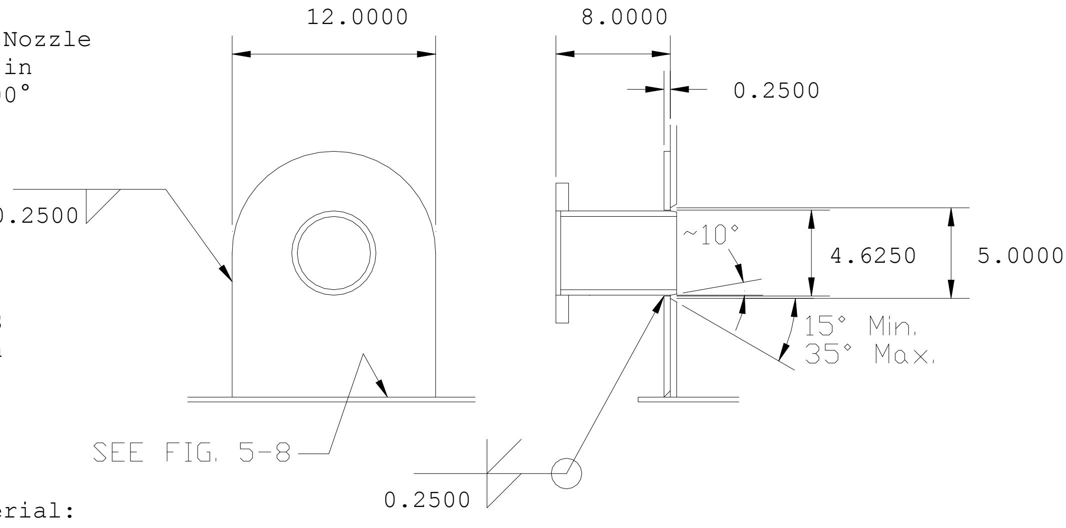
Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.2180 in

Flange Material:
A105



Drain (D)

4" 150# SO Flanged Nozzle
Elevation: 2.2500 in
Orientation: 0.0000°



Nozzle Neck:
SCH80 Pipe
Material: A53-B SMLS
Thickness: 0.3370 in

Flange Material:
A105

Reinforcing Pad Material:
A36

Nozzle is too close to bottom. Minimum distance is 6 in.

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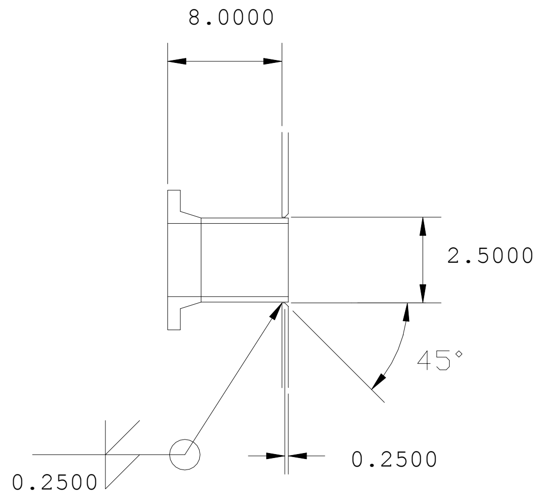
Level Glass (K1)

2" 150# WN Flanged Nozzle
Elevation: 12.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.2180 in

Flange Material:
A105

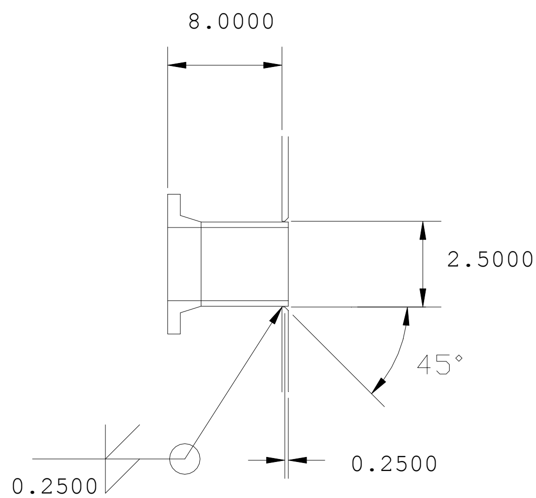


Level Glass (K2)

2" 150# WN Flanged Nozzle
Elevation: 297.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.2180 in

Flange Material:
A105



Quality Record

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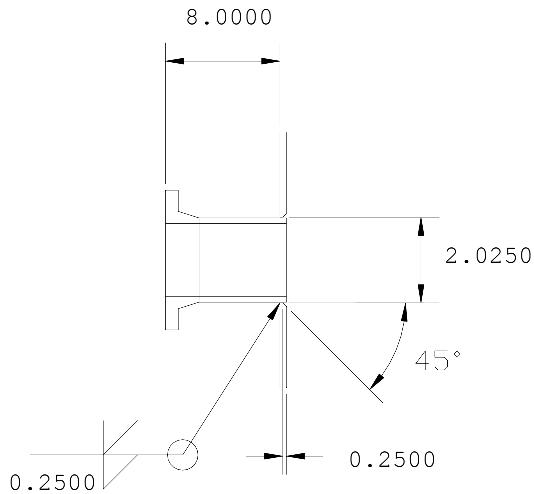
Level (L1)

1 1/2" 150# WN Flanged Nozzle
Elevation: 12.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.2000 in

Flange Material:
A105

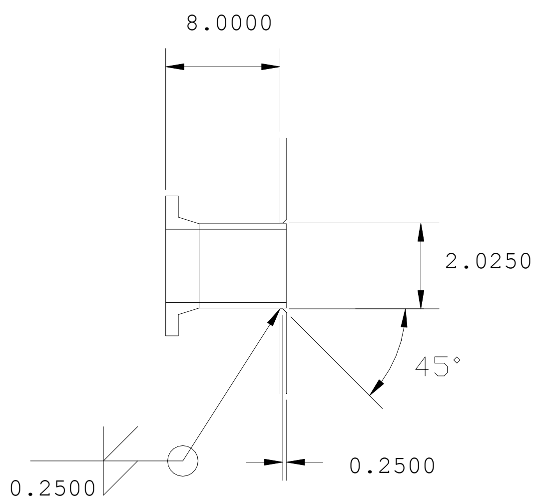


Level (L2)

1 1/2" 150# WN Flanged Nozzle
Elevation: 297.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.2000 in

Flange Material:
A105

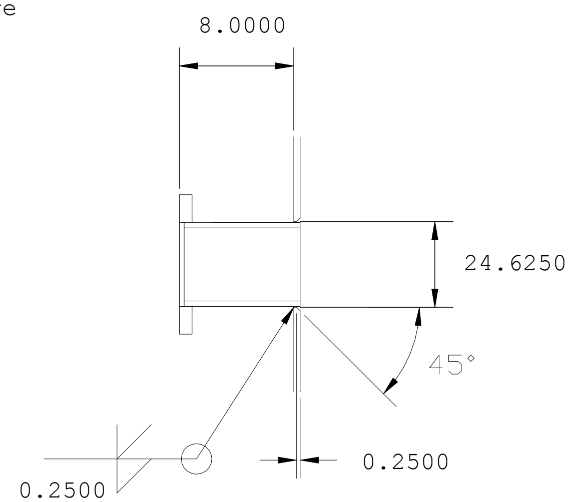


Shell Manway (M)

24" API-650 Shell Manhole w/Blind Flange
Elevation: 30.0000 in
Orientation: 0.0000°

Nozzle Neck: Plate
Material Grade: A36
Wall Thickness: 0.2500 in

Flange Material:
A36



Flange Thickness: 0.5000 in
Machining Allowance: 0.1875 in

Blind Flange Material Grade: A36

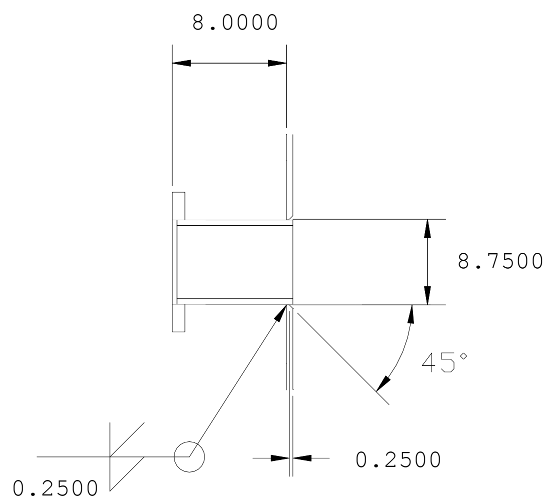
Thickness: 0.5625 in

Overflow (O)

8" 150# SO Flanged Nozzle
Elevation: 297.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.5000 in

Flange Material:
A105



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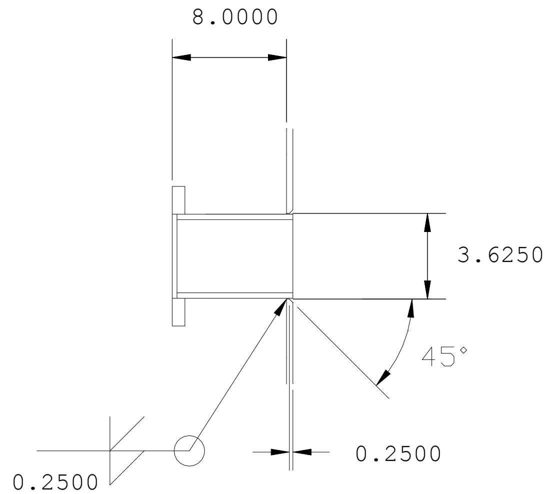
Customer: Southern Company Job Number: 2084-01 Date: 05-26-2011 Rev.: 1

Level Transmitter (L3)

3" 150# SO Flanged Nozzle
Elevation: 12.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.3000 in

Flange Material:
A105

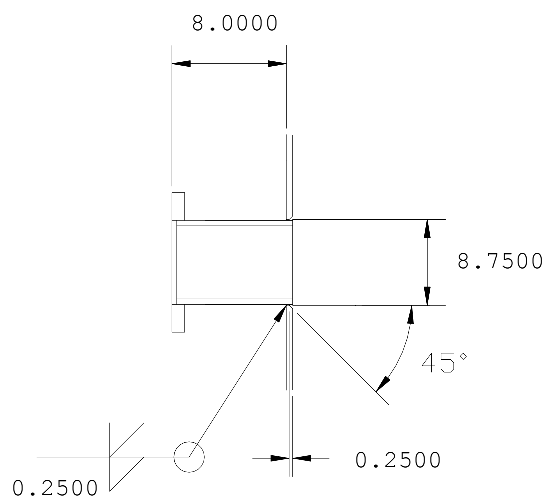


Pump Suction (E)

8" 150# SO Flanged Nozzle
Elevation: 14.0000 in
Orientation: 0.0000°

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Wall Thickness: 0.5000 in

Flange Material:
A105



Bottom Design

Flat Bottom

Material Grade: A36

Thickness (t_b): 0.3750 in

Corrosion Allowance (CA): 0.1250 in

Minimum required outside projection per J.3.2.3 = 1.2500 in

Actual outside projection (p) = 2.0000 in

Minimum thickness per J.3.2.1 = 0.2360 in

Minimum thickness + corrosion allowance = 0.2360 + 0.1250 = 0.3610 in

Tank bottom is butt welded.

Shell Design

Per A.4.1

$$t = \frac{2.6\ (H - 1.0) D\ G}{SE} + CA$$

where
Diameter (D) = 10.0000 ft
Design Specific Gravity (G) = 1.00
Joint Efficiency (E) = 0.85

Shell Course 01

Material Grade: A36

Shell Height: 7.8333 ft

Allowable Stress per A.4.1 (S) = 21000.0000 psi

H = 24.7500 ft

Corrosion Allowance (CA): 0.1250 in

$$t = \frac{(2.6)(24.7500 - 1.0)(10.0000)(1.0000)}{(21000.0000)(0.8500)} + 0.1250 = 0.1596 \text{ in}$$

(Per J.3.3 - min. t = 0.1875 in)
Actual t = 0.2500 in

Shell Course 02

Material Grade: A36

Shell Height: 7.8333 ft

Allowable Stress per A.4.1 (S) = 21000.0000 psi

H = 16.9167 ft

Corrosion Allowance (CA): 0.1250 in

$$t = \frac{(2.6)(16.9167 - 1.0)(10.0000)(1.0000)}{(21000.0000)(0.8500)} + 0.1250 = 0.1482 \text{ in}$$

(Per J.3.3 - min. t = 0.1875 in)
Actual t = 0.2500 in

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Shell Course 03

Material Grade: A36

Shell Height: 5.8958 ft

Allowable Stress per A.4.1 (S) = 21000.0000 psi

H = 9.0833 ft

Corrosion Allowance (CA): 0.1250 in

$$t = \frac{(2.6)(9.0833 - 1.0)(10.0000)(1.0000)}{(21000.0000)(0.8500)} + 0.1250 = 0.1368 \text{ in}$$

(Per J.3.3 - min. t = 0.1875 in)
Actual t = 0.2500 in

Shell Course 04

Material Grade: A36

Shell Height: 3.9167 ft

Allowable Stress per A.4.1 (S) = 21000.0000 psi

H = 3.1875 ft

Corrosion Allowance (CA): 0.1250 in

$$t = \frac{(2.6)(3.1875 - 1.0)(10.0000)(1.0000)}{(21000.0000)(0.8500)} + 0.1250 = 0.1282 \text{ in}$$

(Per J.3.3 - min. t = 0.1875 in)
Actual t = 0.2500 in

Self-Supporting Cone Roof per API-650

Material Grade: A36
Roof Thickness (t_r): 0.3125 in
Corrosion Allowance (CA): 0.1250 in
Tank Diameter (D): 10.0000 ft

Roof is butt welded

Roof Slope: 2.0000 in 12
θ: 9.4623°
Roof Rise: 0.8333 ft

Live Load (L_v): 20.0000 lbf/ft²
Snow Load (Sb): 5.0000 lbf/ft²
Dead Load (D_L): 12.7625 lbf/ft²
Ext. Pressure (P_e): 5.1960 lbf/ft²

Per R.1(e)(1), $T = D_L + (L_v \text{ or } Sb) + 0.40P_e =$
$12.7625 + 20.0000 + (0.40)(5.1960) = 34.8409$ lbf/ft²

Per R.1(e)(2), $T = D_L + 0.4(L_v \text{ or } Sb) + P_e =$
$12.7625 + (0.4)(20.0000) + 5.1960 = 25.9585$ lbf/ft²

Use greater of (1) or (2), T = 34.8409 lbf/ft²

Minimum thickness + corrosion allowance = 0.1875 + 0.1250 = 0.3125 in

Per 5.10.5.1:

$$t_r = \frac{D}{400.0000 \sin\theta} \sqrt{\left\{ \frac{T}{45.0000} \right\}} + CA =$$

$$\frac{10.0000}{400.0000 \sin(9.4623)} \sqrt{\left\{ \frac{34.8409}{45.0000} \right\}} + 0.1250 = 0.2588 \text{ in}$$

For Unbalanced Snow Load: Su = 1.0 Sb = 1.0 * 5.0000 = 5.0000 lbf/ft²

Per R.1(e)(1), $U = D_L + Su + 0.40P_e =$
$12.7625 + 5.0000 + (0.40)(5.1960) = 19.8409$ lbf/ft²

Per R.1(e)(2), $U = D_L + 0.4(Su) + P_e =$
$12.7625 + (0.4)(5.0000) + 5.1960 = 19.9585$ lbf/ft²

Use greater of (1) or (2), U = 19.9585 lbf/ft²

Per 5.10.5.1:

$$t_r = \frac{D}{460.0 \sin\theta} \sqrt{\left\{ \frac{U}{45.0000} \right\}} + CA =$$

$$\frac{10.0000}{460.0 \sin(9.4623)} \sqrt{\left\{ \frac{19.9585}{45.0000} \right\}} + 0.1250 = 0.2131 \text{ in}$$

Per 5.10.5.2:

p = Greater of T or U = 34.8409 lbf/ft^2

For Shell, Fy = 36000.0000 psi
For Roof, Fy = 36000.0000 psi
For Compression Ring, Fy = 36000.0000 psi
Least Fy = 36000.0000 psi
Fa = 0.6Fy = 0.6 * 36000.0000 = 21600.0000 psi

$$A_r = \frac{pD^2}{8F_a \tan\theta} = \frac{(34.8409)(10.0000)^2}{8 * 21600.0000 * \tan(9.4623)} = 0.1210 \text{ in}^2$$

Compression Ring

L2 x2 x3/8 per Detail b

2 inches Vertical leg of rim angle is lap welded to the outside of the shell with the horizontal leg turned out

Rim Angle is attached 0.2500 inches above the top of shell

Material: A36

API-650 Figure F-2

R_c = 60.0000 in

Roof Angle (ø) = 9.4623°

$R_2 = R_c/(\sin ø)$ = 60.0000/(sin 9.4623) = 364.9658 in

t_h = 0.3125 in

$w_h = 0.3\sqrt{(R_2 t_h)} = 0.3\sqrt{(364.9658 * 0.3125)}$ = 3.2039 in
not to exceed 12.0000 in
therefore w_h = 3.2039 in

Available area from roof (A_r) = $t_h w_h$ = 0.3125 * 3.2039 = 1.0012 in²

t_c = 0.2500 in

$w_c = 0.6\sqrt{(R_c t_c)} = 0.6\sqrt{(60.0000 * 0.2500)}$ = 2.3238 in

Distance from top of angle to top of shell (b) = 0.2500 in
Available area from shell (A_s) = $(w_c - b)t_c$ = (2.3238 - 0.2500) * 0.2500 = 0.5184 in²

Yield strength (F_y) = 36000.0000 psi

t_a = 0.3750 in
Horizontal projection of angle (a_1) = 1.6250 in
Maximum horizontal projection = $t_a * 3000/\sqrt{(F_y)}$ = 0.3750 * 3000/√(36000.0000) = 5.9293 in
therefore a_1 = 1.6250 in
Vertical projection of angle (a_2) = 2.0000 in
Maximum vertical projection = w_c = 2.3238 in
therefore a_2 = 2.0000 in
Available area from compression ring (A_c) = $(a_1 + a_2)t_a$ = (1.6250 + 2.0000)0.3750 = 1.3594 in²

Total available area (A_t) = $A_r + A_s + A_c$ = 1.0012 + 0.5184 + 1.3594 = 2.8790 in²

Check in Corroded Condition

Quality Record

Approved

Roof corrosion allowance = 0.1250 in
t_h = Roof thickness - CA = 0.3125 - 0.1250 = 0.1875 in

$w_h = 0.3 \sqrt{(R_2 t_h)} = 0.3 \sqrt{(364.9658 * 0.1875)} = 2.4817$ in
not to exceed 12.0000 in
therefore w_h = 2.4817 in

Available area from roof (A_r) = $t_h w_h$ = 0.1875 * 2.4817 = 0.4653 in²

Shell corrosiona allowance = 0.1250 in
t_c = shell thickness - CA = 0.2500 - 0.1250 = 0.1250 in

$w_c = 0.6 \sqrt{(R_c t_c)} = 0.6 \sqrt{(60.0000 * 0.1250)} = 1.6432$ in

Distance from top of angle to top of shell (b) = 0.2500 in
Available area from shell (A_s) = (w_c - b)t_c = (1.6432 - 0.2500) * 0.1250 = 0.1741 in²

Angle corrosion allowance = 0.1250 in
t_a = Angle thickness - CA = 0.3750 - 0.1250 = 0.2500 in
Horizontal projection of angle (a_1) = 1.6250 in
Maximum horizontal projection = $t_a * 3000/\sqrt{(F_y)}$ = 0.2500 * 3000/$\sqrt{(36000.0000)}$
= 3.9528 in
therefore a_1 = 1.6250 in
Vertical projection of angle (a_2) = 2.0000 in
Maximum vertical projection = w_c = 1.6432 in
therefore a_2 = 1.6432 in
Available area from compression ring (A_c) = (a_1 + a_2)t_a =
(1.6250 + 1.6432)0.2500 = 0.8170 in²

Total available area (A_t) = A_r + A_s + A_c = 0.4653 + 0.1741 + 0.8170 = 1.4565 in²

Quality Record

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Wind Calculations

Wind velocity (V) = 100 mph
Tank diameter (D) = 10.0000 ft
Thinnest shell course thickness (t) = 0.2500 in

Importance factor (I) = 1.15
Exposure C

Per 5.2.1 (k)(1), wind loads are based on ASCE 7.

For Shell:

Centroid of shell C_s = 12.7500 ft

z = C_s but not less than 15.00 ft

z = 15.0000 ft from bottom of tank

Per ASCE7, zg = 900.00 ft

$\alpha = 9.50$

$K_z = 2.01(15.00/900.00)^{(2/9.50)} = 0.85$

$K_d = 0.95$

$K_{zt} = 1.00$

V = 100.00 mph

$q_z = 0.00256 K_z K_{zt} K_d V^2 I =$
$(0.00256)(0.85)(1.00)(0.95)(100.00)^2(1.15) = 23.74$ lbf/ft²

$h/D = 25.50/10.00 = 2.55$

$C_f = 0.50 + [(0.60 - 0.50)/(7.00 - 1.00)](2.55 - 1.00) = 0.5258$

$G = 0.85$

$P_w = q_z G C_f = (23.74)(0.85)(0.5258) = 10.6115$ lbf/ft²
but not less than 10.0000 lbf/ft²
= 10.6115 lbf/ft²

For Roof:

Top of roof C_s = 26.33 ft

z = C_s but not less than 15.00 ft

z = 26.33 ft from bottom of tank

Per ASCE7, zg = 900.00 ft

$\alpha = 9.50$

$K_z = 2.01(26.33/900.00)^{(2/9.50)} = 0.96$

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$K_d = 0.85$
$K_{zt} = 1.00$
$V = 100.00$ mph

$q_z = 0.00256 K_z K_{zt} K_d V^2 I =$
$(0.00256)(0.96)(1.00)(0.85)(100.00)^2(1.15) = 23.9145$ lbf/ft²

$GC_p = 0.90$
$U_w = q_z GC_p = (23.9145)(0.90) = 21.5230$ lbf/ft²

Per 5.9.7.1:

Per ASCE7, $K_z = 0.85$
$K_d = 0.95$
$K_{zt} = 1.00$
$V = 120.00$ mph
$G = 0.85$
$P = 5.00$ lbf/ft²
$P_w = 0.00256 K_z K_{zt} K_d V^2 IG + P =$
$(0.00256)(0.85)(1.00)(0.95)(120.00)^2(1.15)(0.85) + 5.00 = 34.0597$ lbf/ft²

Multiplier (m) = $P_w/36.00 = 34.0597/36.00 = 0.9461$
not less than 1.0, therefore m = 1.0000

Per 5.9.7.1: $H_1 = 600000.00t[\sqrt{(t/D)^3}](120/V)^2 =$
$(600000.00)(0.2500)[\sqrt{(0.2500 / 10.0000)^3}](120/100)^2 = 853.8150$ ft

Per 5.9.7.2: $t_{uniform} = t = 0.2500$ in

For each shell course, $W_{tr} = W \sqrt{\left(\frac{t_{uniform}}{t_{actual}}\right)^5}$

(Shell courses are numbered from bottom to top)

Shell Course	W (ft)	T_{actual} (in)	W_{tr} (ft)
4	3.9167	0.2500	3.9167
3	5.8958	0.2500	5.8958
2	7.8333	0.2500	7.8333
1	7.8333	0.2500	7.8333
		Total Transposed Width:	25.4792

Overturning moment:
Total vertical height (H) = 25.5000 ft

Overturning Moment (M_w) = $P_w DH^2/2 + U_w \pi D^3/8 =$
$= (10.6115)(10.0000)(25.5000)^2/2 + (21.5230)(\pi)(10.0000)^3/8 = 42952.7204$ ft-lbs

Quality Record

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Tank does not contain internal pressure. Therefore, MPi = 0

Check for tank stability without anchors per 5.11.2

Weight of shell and roof supported by shell (DL) = 9336.4568 lbs

M_{DL} = DL * D/2 = 9336.4568 * 10.0000 / 2 = 46682.2838 ft-lbs

Bottom thickness used (t_b) = 0.1250 in

Bottom material yield strength (F_{by}) = 36000.0000 psi

$w_L = 4.6700 t_b \sqrt{(F_{by} H)} = (4.6700)(0.1250)\sqrt{(36000.0000 * 24.7500)} = 551.0179$ lbf/ft

not to exceed 0.900HD = 0.900 * 24.7500 * 10.0000 = 222.7500 lbf/ft

therefore, w_L = 222.7500 lbf/ft

$M_F = w_L(\pi)D^2/2 = (222.7500)(\pi)(10.0000)^2/2 = 34989.4882$ ft-lbs

For tank to be stable: $0.6M_w + M_{pi} < M_{DL}/1.5$ and $M_w + 0.40M_{pi} < (M_{DL} + M_F)/2$

$0.6M_w + M_{pi}$ = (0.6)(42952.7204) + (0.0000) = 25771.6322 ft-lbs

$M_{DL}/1.5$ = 46682.2838/1.5 = 31121.5225 ft-lbs

$M_w + 0.40M_{pi}$ = 42952.7204 + (0.40)(0.0000) = 42952.7204 ft-lbs

$(M_{DL} + M_F)/2$ = (46682.2838 + 34989.4882)/2 = 40835.8860 ft-lbs

Anchorage of the tank for wind is required

Quality Record

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Weights

	New (lbf)	Corroded (lbf)
Product:	120083.9234	120083.9234
Total Shell Plates:	8172.6111	4086.3056
Total Bottom Plates:	1284.3629	856.2420
Total Roof Plates:	1016.1908	609.7145
Total Live Load:	1570.7963	1570.7963
Total Snow Load:	392.6991	392.6991
Total Additional Dead Load:	0.0000	0.0000
Shell Insulation:	0.0000	0.0000
Roof Insulation:	0.0000	0.0000
Total Rafters:	0.0000	0.0000
Total Roof and Framing:	1016.1908	1016.1908
Total Shell Appurtenances:	0.0000	0.0000
Total Roof Appurtenances:	0.0000	0.0000
Total Roof Appurtenances acting on Shell	0.0000	0.0000
Live Load acting on Shell:	1570.7963	1570.7963
Snow Load acting on Shell:	392.6991	392.6991
Total of Roof acting on Shell:	1016.1908	609.7145
Total of Roof Structural acting on Shell:	0.0000	0.0000
Total Compression Ring and Shell Stiffener	147.6549	98.4366

Seismic Calculations

Tank diameter (D): 10.0000 ft
Product Height (H): 24.7500 ft
Specific Gravity (G): 0.9900

Tank is mechanically anchored

Mapped spectral response acceleration (S_S): 0.2040 g
Mapped spectral response acceleration (S_1): 0.0870 g
Mapped spectral response acceleration (S_0) = $0.4S_S$ = (0.4)(0.2040) = 0.0816 g
Mapped spectral response acceleration (S_P) = $0.8S_1$ = (0.8)(0.0870) = 0.0696 g

Vertical earthquake acceleration coefficient (A_V): 0.0000 g

Site Class per E.4.4 : C
Seismic Use Group per E.3.1 : III

From Table E-1, F_a = 1.2000
From Table E-2, F_v = 1.7000
From Table E-5, I = 1.5000
From Table E-4, R_{wi} = 4.0000
From Table E-4, R_{wc} = 2.0000

Scaling factor per E.2, Q = 2/3

$S_{DS} = QF_aS_S$ = (2/3)(1.2000)(0.2040) = 0.1632
$S_{D1} = QF_vS_1$ = (2/3)(1.7000)(0.0870) = 0.0986

E.4.5.2 Convective (Sloshing) Period

E.4.5.2-c:

$$K_s = \frac{0.578}{\sqrt{\tanh\left(\frac{3.68H}{D}\right)}} = \frac{0.578}{\sqrt{\tanh\left(\frac{(3.68)(24.7500)}{10.0000}\right)}} = 0.5780$$

Per E4.5.2-b: $T_c = 1.0K_s\sqrt{D} = (1.0)(0.5780)\sqrt{10.0000} = 1.8278$

E.4.6.1 Spectral Acceleration Coefficients

Impulsive spectral acceleration parameter:

Per E.4.6.1-1:

$$A_i = S_{DS}\left(\frac{I}{R_{wi}}\right) = 0.1632\left(\frac{1.50}{4.0000}\right) = 0.0612$$

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However, per E.4.6.1-2, $A_i \geq 0.0070$
Therefore, $A_i = 0.0612$

Convective spectral acceleration parameter:

$T_L = 8.0000$
$K = 1.5$

$T_c \leq T_L$, Per E.4.6.1-4

$$A_c = KS_{D1} \left(\frac{1}{T_c} \right) \left(\frac{I}{R_{wc}} \right) = (1.5)(0.0986) \left(\frac{1}{1.8278} \right) \left(\frac{1.50}{2.0000} \right) = 0.0607$$

However, $A_c \leq A_i$
Therefore, $A_c = 0.0607$

Per E.6.1.1

$D/H = 10.0000/24.7500 = 0.4040$

Weights:
W_s = 8320 lbs
W_f = 1284 lbs
W_r = Roof weight + 10% of snow = 1055 lbs
W_P = 120084 lbs

$D/H < 1.333$

Per E.6.1.1-2, $W_i = (1.0 - 0.218D/H)W_P = (1.0 - 0.218 * 0.4040)(120084)$
$= 109507$ lbs

Per E.6.1.1-3, $W_c = 0.230D/H \tanh(3.67H/D)W_P =$
$(0.230)(0.4040)[\tanh(3.67/0.4040)](120084) = 11159$ lbs

Per E.6.1-2, $V_i = A_i(W_s + W_r + W_f + W_i) =$
$(0.0612)(8320 + 1055 + 1284 + 109507) = 7354$ lbs
Per E.6.1-3, $V_c = A_cW_c = (0.0607)(11159) = 677$ lbs
Per E.6.1-1, $V = \sqrt{(V_i^2 + V_c^2)} = \sqrt{[(7354)^2 + (677)^2]} = 7385$ lbs

Per E.6.1.2.1

$D/H < 1.333$

Per E.6.1.2.1-2, $X_i = [0.5 - 0.094D/H]H = [0.5 - (0.094)(0.4040)](24.7500)$
$= 11.4350$ ft

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Per E.6.1.2.1-3,

$$X_c = \left[1.0 - \frac{\cosh(3.67H/D) - 1}{3.67H/D \sinh(3.67H/D)} \right] H =$$

$$\left[1.0 - \frac{\cosh(3.67/0.4040) - 1}{(3.67/0.4040)\sinh(3.67/0.4040)} \right] (24.7500) = 22.0258 \text{ ft}$$

Per E.6.1.2.2

D/H < 1.333

Per E6.1.2.2-2, $X_{is} = [0.500 + 0.060D/H]H = [0.500 + (0.060)(0.4040)](24.7500)$
$= 12.9750$ ft

Per E.6.1.2.2-3,

$$X_{cs} = \left[1.0 - \frac{\cosh(3.67H/D) -1.937}{3.67H/D \sinh(3.67H/D)} \right] H =$$

$$\left[1.0 - \frac{\cosh(3.67/0.4040) - 1.937}{(3.67/0.4040)\sinh(3.67/0.4040)} \right](24.7500) = 22.0264 \text{ ft}$$

Per E.6.1.5

Per E.6.1.5-1, $M_{rw} = \sqrt{\{[A_i(W_iX_i + W_sX_s + W_rX_r)]^2 + [A_c(W_cX_c)]^2\}} =$
$\sqrt{\{[0.0612(109507*11.4350 + 8320*12.2144 + 1055*25.7778)]^2 + [0.0607(11159*22.0258)]^2\}} = 85826$ ft-lbs

Per E.6.1.5-2, $M_s = \sqrt{\{[A_i(W_iX_{is} + W_sX_s + W_rX_r)]^2 + [A_c(W_cX_{cs})]^2\}} =$
$\sqrt{\{[0.0612(109507*12.9750 + 8320*12.2144 + 1055*25.7778)]^2 + [0.0607(11159*22.0264)]^2\}} = 96007$ ft-lbs

Mechanically-anchored tank (new condition)

Per E.6.2.1.1.1

$W_s = 8320$ lbs
$w_{rs} = 33.5964$ lbf/ft
$t_s = 0.0346$ in
Per E.6.2.1.1.1-2, $w_t = W_s/(\pi D) + w_{rs} = 8320/(\pi * 10.0000) + 33.5964$
$= 298.4386$ lbf/ft

Shell compression per E.6.2.2.2-1b

$\sigma_c = [w_t(1 + 0.4A_v) + 1.273M_{rw}/D^2]/(12t_s) =$
$[298.4386(1 + (0.4)(0.0000)) + (1.273)(85826)/(10.0000)^2]/(12 * 0.0346) =$
3351 psi

Mechanically-anchored tank (corroded condition)

Per E.6.2.1.1.1

W_s = 4225 lbs
w_{rs} = 20.6578 lbf/ft
t_s = 0.0346 in
Per E.6.2.1.1.1-2, $w_t = W_s/(\pi D) + w_{rs} = 4225/(\pi * 10.0000) + 20.6578$
$= 155.1352$ lbf/ft

Shell compression per E.6.2.2.2-1b

$\sigma_c = [w_t(1 + 0.4A_v) + 1.273M_{rw}/D^2]/(12t_s) =$
$[155.1352(1 + (0.4)(0.0000)) + (1.273)(85826)/(10.0000)^2]/(12 * 0.0346) =$
3006 psi

Allowable Compression Stresses in Shell per E.6.2.2.3

For new condition:
$GHD^2/t^2 = (0.9900)(24.7500)(10.0000)^2/(0.0346)^2 = 2047448$

For $GHD^2/t^2 \geq 1000000$
Per E.6.2.2.3-1b, $F_c = 1000000t_s/D = (1000000)(0.0346)/10.0000 = 3459$ psi

Freeboard requirements per E.7.2

$T_c \leq T_L$
Per E.7.2-3, $A_f = KS_{D1}/T_c = (1.5)(0.0986)/1.8278 = 0.0809$

Wave Height Per E.7.2-1: $\delta_s = 0.5DA_f = (0.5)(10.0000)(0.0809) = 0.4046$ ft
Per Table E-7, minimum freeboard = $1.0\delta_s = (1.0)(0.4046) = 0.4046$ ft

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Hoop Stress per E.6.1.4

$G =$ 0.99
$D =$ 10.0000 ft
$H =$ 24.7500 ft
$A_i =$ 0.0612
$A_c =$ 0.0607
$A_v =$ 0.0000
$D/H =$ 0.4040

Shell Course 01

$Y =$ 24.7500 ft

$D/H < 1.333$ and $Y \geq 0.75D$

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2 = 8.4217$ lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 24.7500)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

$= 0.0013$ lbf/in

$N_h = 2.60D(Y-1)G = (2.60)(10.0000)((24.7500)-1)(0.99) = 611.3250$ lbf/in

Shell thickness (t) = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2\}}]/t =$
$[611.3250 + \sqrt{\{(8.4217)^2 + (0.0013)^2\}}]/0.1250 = 4957.9739$ psi

Allowable stress per E.6.2.4
Lesser of:
1.33SE = (1.33)(21000.0000)(0.8500) = 23740.5000 psi
or
0.90FyE = (0.90)(36000.0000)(0.8500) = 27540.0000 psi
Therefore, Allowable stress = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa =$
(4957.9739 * 0.1250)/23740.5000 = 0.0261 in

Shell Course 02

$Y = 16.9167$ ft

$D/H < 1.333$ and $Y \geq 0.75D$

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2 = 8.4217$ lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 16.9167)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

$= 0.0117$ lbf/in

$N_h = 2.60D(Y-1)G = (2.60)(10.0000)((16.9167)-1)(0.99) = 409.6950$ lbf/in

Shell thickness (t) = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2\}}]/t =$
$[409.6950 + \sqrt{\{(8.4217)^2 + (0.0117)^2\}}]/0.1250 = 3344.9339$ psi

Allowable stress per E.6.2.4
Lesser of:
1.33SE = (1.33)(21000.0000)(0.8500) = 23740.5000 psi
or
0.90FyE = (0.90)(36000.0000)(0.8500) = 27540.0000 psi
Therefore, Allowable stress = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(3344.9339 * 0.1250)/23740.5000 = 0.0176 in

Shell Course 03

Y = 9.0833 ft

D/H < 1.333 and Y ≥ 0.75D

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2 = 8.4217$ lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 9.0833)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 0.2081 lbf/in

$N_h = 2.60D(Y-1)G = (2.60)(10.0000)((9.0833)-1)(0.99) = 208.0650$ lbf/in

Shell thickness (t) = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2\}}]/t =$
$[208.0650 + \sqrt{\{(8.4217)^2 + (0.2081)^2\}}]/0.1250 = 1731.9144$ psi

Allowable stress per E.6.2.4
Lesser of:
1.33SE = (1.33)(21000.0000)(0.8500) = 23740.5000 psi
or
0.90FyE = (0.90)(36000.0000)(0.8500) = 27540.0000 psi
Therefore, Allowable stress = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(1731.9144 * 0.1250)/23740.5000 = 0.0091 in

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Shell Course 04

Y = 3.1875 ft

D/H < 1.333 and Y < 0.75D

Per E.6.1.4-2b, $N_i = 2.77A_iGD^2 \left[\frac{Y}{0.75D} - 0.5 \left(\frac{Y}{0.75D} \right)^2 \right] =$

$$(2.77)(0.0612)(0.99)(10.0000)^2 \left[\frac{3.1875}{(0.75)(10.0000)} - 0.5 \left(\frac{3.1875}{(0.75)(10.0000)} \right)^2 \right]$$

= 5.6170 lbf/in

Per E.6.1.4-4b, $N_c = \frac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 3.1875)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 1.8219 lbf/in

$N_h = 2.60D(Y\text{-}1)G = (2.60)(10.0000)((3.1875)\text{-}1)(0.99) = 56.3063$ lbf/in

Shell thickness (t) = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2\}}]/t =$
$[56.3063 + \sqrt{\{(5.6170)^2 + (1.8219)^2\}}]/0.1250 = 497.6909$ psi

Allowable stress per E.6.2.4
Lesser of:
1.33SE = (1.33)(21000.0000)(0.8500) = 23740.5000 psi
or
0.90FyE = (0.90)(36000.0000)(0.8500) = 27540.0000 psi
Therefore, Allowable stress = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(497.6909 * 0.1250)/23740.5000 = 0.0026 in

Quality Record

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Shell Nozzles Reinforcement Calculations

Filtrate Inlet (A)

Description: 8" 150# SO Flanged Nozzle
Elevation: 294.0000 in
Orientation: 0.0000°
Corrosion Allowance: C_n = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 8.6250 in
Wall Thickness: t_n = 0.5000 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (0.2500 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0004 in

Hoop Stress at Nozzle

Y = 0.2500 ft

D/H < 1.333 and Y < 0.75D

Per E.6.1.4-2b, $N_i = 2.77 A_i G D^2 \left[\frac{Y}{0.75D} - 0.5 \left(\frac{Y}{0.75D} \right)^2 \right] =$

$$(2.77)(0.0612)(0.99)(10.0000)^2 \left[\frac{0.2500}{(0.75)(10.0000)} - 0.5 \left(\frac{0.2500}{(0.75)(10.0000)} \right)^2 \right]$$

= 0.5501 lbf/in

Per E.6.1.4-4b, $N_c = \frac{0.98 A_c G D^2 \cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2 \cosh[3.68(24.7500 - 0.2500)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 5.3704 lbf/in

N_h = 2.60DYG = (2.60)(10.0000)(0.2500)(0.99) = 6.4350 lbf/in

Shell thickness: t = 0.1250 in

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Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{N_i^2 + N_c^2}]/t$ =
$[6.4350 + \sqrt{(0.5501)^2 + (5.3704)^2}]/0.1250$ = 94.6681 psi

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(94.6681 * 0.1250)/23740.5000 = 0.0005 in

Required shell thickness for Nozzle Calculations: t_r = 0.0005 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 8.7500 in
Required Area: $A_r = t_r D_s$ = 0.0005 * 8.7500 = 0.0044 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 8.7500 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (8.7500 - 8.7500/2)* (0.2500 - 0.1250 - 0.0005) = 1.0894 in²

Available Reinforcement from nozzle neck per 5.7.2.4:

Shell allowable stress: S_s = 21000.0000 psi
Nozzle neck allowable stress: S_n = 21000.0000 psi
Reduction factor: $F_n = S_n/S_s$ = 21000.0000/21000.0000 but no greater than 1
therefore, F_n = 1.0000

Available Reinforcement from outside projection:
Projection: L_o = lesser of P_o or $4t_n$ = 2.0000 in
Available Area: $A_{ano} = 2F_nL_o(t_n - C_n)$ =
2 * 1.0000 * 2.0000 * (0.5000 - 0.0000) = 2.0000 in²

Available Reinforcement from portion in shell:
Available Area: $A_{an} = 2F_n(t - C_s)(t_n - C_n)$ =
2 * 1.0000 * (0.2500 - 0.1250) * (0.5000 - 0.0000) = 0.1250 in²

Total available area of reinforcement: A_{at} = 3.2144 in²

Check nozzle attachment strength paths:
Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.0044 - 1.0894) * 21000.0000 = -22785.5687 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

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Check attachment strength: Outside fillet weld, Groove weld

$$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) + 0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$$

$$\{0.60 * 21000.0000 * \pi * 8.6250 * 0.707(0.2500) + 0.875 * 0.70 * 21000.0000 * \pi * 8.6250 * (0.2500 - 0.1250)\}/2 =$$

$$36869.0024 \text{ lbs}$$

Check attachment strength: Nozzle neck, Outside fillet weld

$$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) + 0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$$

$$\{0.80 * 0.875 * 21000.0000 * \pi * (0.5000 - 0.0000) * (8.6250 - 0.5000 - 0.0000) + 0.60 * 21000.0000 * \pi * 8.6250 * 0.707(0.2500)\}/2 =$$

$$123978.3300 \text{ lbs}$$

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Pump Recirculation (B)

Description: 4" 150# SO Flanged Nozzle
Elevation: 294.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 4.5000 in
Wall Thickness: t_n = 0.3370 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (0.2500 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0004 in

Hoop Stress at Nozzle

Y = 0.2500 ft

D/H < 1.333 and Y < 0.75D

Per E.6.1.4-2b, $N_i = 2.77A_iGD^2 \left[\frac{Y}{0.75D} - 0.5 \left(\frac{Y}{0.75D} \right)^2 \right] =$

$$(2.77)(0.0612)(0.99)(10.0000)^2 \left[\frac{0.2500}{(0.75)(10.0000)} - 0.5 \left(\frac{0.2500}{(0.75)(10.0000)} \right)^2 \right]$$

= 0.5501 lbf/in

Per E.6.1.4-4b, $N_c = \frac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 0.2500)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 5.3704 lbf/in

$N_h = 2.60DYG = (2.60)(10.0000)(0.2500)(0.99) = 6.4350$ lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{N_i^2 + N_c^2}]/t =$
$[6.4350 + \sqrt{(0.5501)^2 + (5.3704)^2}]/0.1250 = 94.6681$ psi

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Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(94.6681 * 0.1250)/23740.5000 = 0.0005 in

Required shell thickness for Nozzle Calculations: t_r = 0.0005 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 4.6250 in
Required Area: $A_r = t_rD_s$ = 0.0005 * 4.6250 = 0.0023 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 4.6250 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (4.6250 - 4.6250/2)* (0.2500 - 0.1250 - 0.0005) = 0.5758 in²

Available Reinforcement from nozzle neck per 5.7.2.4:

Shell allowable stress: S_s = 21000.0000 psi
Nozzle neck allowable stress: S_n = 21000.0000 psi
Reduction factor: $F_n = S_n/S_s$ = 21000.0000/21000.0000 but no greater than 1
therefore, F_n = 1.0000

Available Reinforcement from outside projection:
Projection: L_o = lesser of P_o or $4t_n$ = 1.3480 in
Available Area: $A_{ano} = 2F_nL_o(t_n - C_n)$ =
2 * 1.0000 * 1.3480 * (0.3370 - 0.0000) = 0.9086 in²

Available Reinforcement from portion in shell:
Available Area: $A_{an} = 2F_n(t - C_s)(t_n - C_n)$ =
2 * 1.0000 * (0.2500 - 0.1250) * (0.3370 - 0.0000) = 0.0843 in²

Total available area of reinforcement: A_{at} = 1.5686 in²

Check nozzle attachment strength paths:
Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.0023 - 0.5758) * 21000.0000 = -12043.8006 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

Check attachment strength: Outside fillet weld, Groove weld

$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) +$
$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$
$\{0.60 * 21000.0000 * \pi * 4.5000 * 0.707(0.2500) +$
$0.875 * 0.70 * 21000.0000 * \pi * 4.5000 * (0.2500 - 0.1250)\}/2 =$
19236.0013 lbs

Check attachment strength: Nozzle neck, Outside fillet weld

$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$
$0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.3370 - 0.0000) * (4.5000 - 0.3370 - 0.0000) +$
$0.60 * 21000.0000 * \pi * 4.5000 * 0.707(0.2500)\}/2 =$
48136.7561 lbs

Inlet from DR0004 (C)

Description: 2" 150# WN Flanged Nozzle
Elevation: 282.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 2.3750 in
Wall Thickness: t_n = 0.2180 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (1.2500 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0018 in

Hoop Stress at Nozzle

Y = 1.2500 ft

D/H < 1.333 and Y < 0.75D

Per E.6.1.4-2b, $N_i = 2.77A_iGD^2 \left[\frac{Y}{0.75D} - 0.5 \left(\frac{Y}{0.75D} \right)^2 \right] =$

$$(2.77)(0.0612)(0.99)(10.0000)^2 \left[\frac{1.2500}{(0.75)(10.0000)} - 0.5 \left(\frac{1.2500}{(0.75)(10.0000)} \right)^2 \right]$$

= 2.5641 lbf/in

Per E.6.1.4-4b, $N_c = \frac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 1.2500)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 3.7170 lbf/in

N_h = 2.60DYG = (2.60)(10.0000)(1.2500)(0.99) = 32.1750 lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2\}}]/t$ =
$[32.1750 + \sqrt{\{(2.5641)^2 + (3.7170)^2\}}]/0.1250$ = 293.5243 psi

Quality Record

Approved

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(293.5243 * 0.1250)/23740.5000 = 0.0015 in

Required shell thickness for Nozzle Calculations: t_r = 0.0018 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 2.5000 in
Required Area: $A_r = t_r D_s$ = 0.0018 * 2.5000 = 0.0046 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 2.5000 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (2.5000 - 2.5000/2)* (0.2500 - 0.1250 - 0.0018) = 0.3079 in²

Check nozzle attachment strength paths:
Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.0046 - 0.3079) * 21000.0000 = -6371.3235 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

Check attachment strength: Outside fillet weld, Groove weld
$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) +$
$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$
$\{0.60 * 21000.0000 * \pi * 2.3750 * 0.707(0.2500) +$
$0.875 * 0.70 * 21000.0000 * \pi * 2.3750 * (0.2500 - 0.1250)\}/2 =$
10152.3340 lbs

Check attachment strength: Nozzle neck, Outside fillet weld
$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$
$0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.2180 - 0.0000) * (2.3750 - 0.2180 - 0.0000) +$
$0.60 * 21000.0000 * \pi * 2.3750 * 0.707(0.2500)\}/2 =$
19166.1750 lbs

Nozzle reinforcement calculations are not required.

Drain (D)

Description: 4" 150# SO Flanged Nozzle
Elevation: 2.2500 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle is too close to bottom. Minimum distance is 6 in.

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 4.5000 in
Wall Thickness: t_n = 0.3370 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Reinforcing Pad:
Material Grade: A36
Thickness: tp = 0.2500 in
Outside Diameter: Dp = 12.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (24.5625 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0358 in

Hoop Stress at Nozzle

Y = 24.5625 ft

D/H < 1.333 and Y ≥ 0.75D

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2 = 8.4217$ lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 24.5625)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 0.0013 lbf/in

$N_h = 2.60DYG = (2.60)(10.0000)(24.5625)(0.99) = 632.2388$ lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{N_i^2 + N_c^2}]/t =$
$[632.2388 + \sqrt{(8.4217)^2 + (0.0013)^2}]/0.1250 = 5125.2839$ psi

Quality Record

Approved

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/S_a$ =
(5125.2839 * 0.1250)/23740.5000 = 0.0270 in

Required shell thickness for Nozzle Calculations: t_r = 0.0358 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 5.0000 in
Required Area: $A_r = t_r D_s$ = 0.0358 * 5.0000 = 0.1789 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 5.0000 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (5.0000 - 5.0000/2)* (0.2500 - 0.1250 - 0.0358) = 0.4461 in²

Available Reinforcement from shell (below nozzle):
Diameter of Shell available: D_{sb} = 2.5000 in
Available Area: $A_{as} = 2(D_{sb} - D_1/2)(t - C_s - t_r)$ =
2 * (2.5000 - 5.0000/2)* (0.2500 - 0.1250 - 0.0358) = 0.0000 in²

Area available from shell is the lesser of:
Area above nozzle: 0.4461 in²
and Area below nozzle: 0.0000 in²

Available Reinforcement from nozzle neck per 5.7.2.4:

Shell allowable stress: S_s = 21000.0000 psi
Nozzle neck allowable stress: S_n = 21000.0000 psi
Reduction factor: $F_n = S_n/S_s$ = 21000.0000/21000.0000 but no greater than 1
therefore, F_n = 1.0000

Available Reinforcement from outside projection:
Projection: L_o = lesser of P_o or $4t_n$ = 1.3480 in
Available Area: $A_{ano} = 2F_nL_o(t_n - C_n)$ =
2 * 1.0000 * 1.3480 * (0.3370 - 0.0000) = 0.9086 in²

Available Reinforcement from portion in shell:
Available Area: $A_{an} = 2F_n(t - C_s)(t_n - C_n)$ =
2 * 1.0000 * (0.2500 - 0.1250) * (0.3370 - 0.0000) = 0.0843 in²

Available Reinforcement from reinforcing pad:

Reinforcing pad allowable stress: S_p = 21000.0000 psi
Reduction factor: $F_p = S_p/S_s$ = 21000.0000/21000.0000 but no greater than 1
therefore, F_p = 1.0000

Reinforcing pad outside limit: L_{po} = 5.0000 in
Reinforcing pad inside diameter: L_{pi} = 4.6250 in
Available Area: $A_{arp} = F_p(L_{po} - L_{pi})(t_p)$ =
1.0000 * (5.0000 - 4.6250) * 0.2500 = 0.0938 in²

Total available area of reinforcement: A_{at} = 1.0866 in²

Check nozzle attachment strength paths:

Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.1789 - 0.0000) * 21000.0000 = 3756.6176 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

Reinforcing pad fillet weld:
Weld size: W_p = 0.2500 in
Allowable stress: S_p = 21000.0000 psi

Check attachment strength: Outside fillet weld, Groove weld

$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) +$
$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$
$\{0.60 * 21000.0000 * \pi * 4.5000 * 0.707(0.2500) +$
$0.875 * 0.70 * 21000.0000 * \pi * 4.5000 * (0.2500 - 0.1250)\}/2 =$
19236.0013 lbs

Check attachment strength: Nozzle neck, Outside fillet weld

$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$
$0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.3370 - 0.0000) * (4.5000 - 0.3370 - 0.0000) +$
$0.60 * 21000.0000 * \pi * 4.5000 * 0.707(0.2500)\}/2 =$
48136.7561 lbs

Check attachment strength: Repad fillet weld, Groove weld

$W_a = \{0.60 * S_p * RFL * 0.707(W_p) +$
$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$
$\{0.60 * 21000.0000 * 18.1923 * 0.707(0.2500) +$
$0.875 * 0.70 * 21000.0000 * \pi * 4.5000 * (0.2500 - 0.1250)\}/2 =$
23751.4385 lbs

Check attachment strength: Nozzle neck, Repad fillet weld

$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$
$0.60 * S_p * RFL * 0.707(W_p)\}/2 =$
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.3370 - 0.0000) * (4.5000 - 0.3370 - 0.0000) +$
$0.60 * 21000.0000 * 18.1923 * 0.707(0.2500)\}/2 =$
52652.1933 lbs

Level Glass (K1)

Description: 2" 150# WN Flanged Nozzle
Elevation: 12.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 2.3750 in
Wall Thickness: t_n = 0.2180 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (23.7500 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0346 in

Hoop Stress at Nozzle

Y = 23.7500 ft

D/H < 1.333 and Y ≥ 0.75D

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2 = 8.4217$ lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 23.7500)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 0.0014 lbf/in

$N_h = 2.60DYG = (2.60)(10.0000)(23.7500)(0.99) = 611.3250$ lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2]}/t =$
$[611.3250 + \sqrt{\{(8.4217)^2 + (0.0014)^2\}}]/0.1250 = 4957.9739$ psi

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = (σ_T * t)/Sa =
(4957.9739 * 0.1250)/23740.5000 = 0.0261 in

Quality Record

Approved

Required shell thickness for Nozzle Calculations: t_r = 0.0346 in

Reinforcement of Nozzle for Design:

Diameter of Hole in Shell: D_1 = 2.5000 in

Required Area: $A_r = t_r D_s$ = 0.0346 * 2.5000 = 0.0865 in²

Available Reinforcement from shell:

Diameter of Shell available: D_s = 2.5000 in

Shell corrosion allowance: C_s = 0.1250 in

Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =

2 * (2.5000 - 2.5000/2)* (0.2500 - 0.1250 - 0.0346) = 0.2260 in²

Check nozzle attachment strength paths:

Required strength: $W_r = (A_r - A_{as})S_a$ =

(0.0865 - 0.2260) * 21000.0000 = -2930.1471 lbs

Nozzle neck:

Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:

Weld size: W_o = 0.2500 in

Allowable stress: S_o = 21000.0000 psi

Groove weld:

Weld size: W_g = 0.2500 in

Allowable stress: S_g = 21000.0000 psi

Check attachment strength: Outside fillet weld, Groove weld

$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) +$

$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$

$\{0.60 * 21000.0000 * \pi * 2.3750 * 0.707(0.2500) +$

$0.875 * 0.70 * 21000.0000 * \pi * 2.3750 * (0.2500 - 0.1250)\}/2 =$

10152.3340 lbs

Check attachment strength: Nozzle neck, Outside fillet weld

$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$

$0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$

$\{0.80 * 0.875 * 21000.0000 * \pi * (0.2180 - 0.0000) * (2.3750 - 0.2180 - 0.0000) +$

$0.60 * 21000.0000 * \pi * 2.3750 * 0.707(0.2500)\}/2 =$

19166.1750 lbs

Nozzle reinforcement calculations are not required.

Quality Record

Approved

Level Glass (K2)

Description: 2" 150# WN Flanged Nozzle
Elevation: 297.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 2.3750 in
Wall Thickness: t_n = 0.2180 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (0.0000 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0000 in

Hoop Stress at Nozzle

Y = 0.0000 ft

D/H < 1.333 and Y < 0.75D

Per E.6.1.4-2b, $N_i = 2.77A_iGD^2 \left[\frac{Y}{0.75D} - 0.5 \left(\frac{Y}{0.75D} \right)^2 \right] =$

$$(2.77)(0.0612)(0.99)(10.0000)^2 \left[\frac{0.0000}{(0.75)(10.0000)} - 0.5 \left(\frac{0.0000}{(0.75)(10.0000)} \right)^2 \right]$$

= 0.0000 lbf/in

Per E.6.1.4-4b, $N_c = \frac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 0.0000)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 5.8879 lbf/in

N_h = 2.60DYG = (2.60)(10.0000)(0.0000)(0.99) = 0.0000 lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2\}}]/t =$
$[0.0000 + \sqrt{\{(0.0000)^2 + (5.8879)^2\}}]/0.1250 = 47.1035$ psi

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(47.1035 * 0.1250)/23740.5000 = 0.0002 in

Required shell thickness for Nozzle Calculations: t_r = 0.0002 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 2.5000 in
Required Area: $A_r = t_r D_s$ = 0.0002 * 2.5000 = 0.0006 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 2.5000 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (2.5000 - 2.5000/2)* (0.2500 - 0.1250 - 0.0002) = 0.3119 in²

Check nozzle attachment strength paths:
Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.0006 - 0.3119) * 21000.0000 = -6536.4587 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

Check attachment strength: Outside fillet weld, Groove weld
$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) + 0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2$ =
$\{0.60 * 21000.0000 * \pi * 2.3750 * 0.707(0.2500) + 0.875 * 0.70 * 21000.0000 * \pi * 2.3750 * (0.2500 - 0.1250)\}/2$ =
10152.3340 lbs

Check attachment strength: Nozzle neck, Outside fillet weld
$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) + 0.60 * S_o * \pi * d * 0.707(W_o)\}/2$ =
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.2180 - 0.0000) * (2.3750 - 0.2180 - 0.0000) + 0.60 * 21000.0000 * \pi * 2.3750 * 0.707(0.2500)\}/2$ =
19166.1750 lbs

Nozzle reinforcement calculations are not required.

Quality Record

Approved

Level (L1)

Description: 1 1/2" 150# WN Flanged Nozzle
Elevation: 12.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 1.9000 in
Wall Thickness: t_n = 0.2000 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (23.7500 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0346 in

Hoop Stress at Nozzle

Y = 23.7500 ft

D/H < 1.333 and Y ≥ 0.75D

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2 = 8.4217$ lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 23.7500)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 0.0014 lbf/in

$N_h = 2.60DYG = (2.60)(10.0000)(23.7500)(0.99) = 611.3250$ lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{N_i^2 + N_c^2}]/t =$
$[611.3250 + \sqrt{(8.4217)^2 + (0.0014)^2}]/0.1250 = 4957.9739$ psi

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa =$
(4957.9739 * 0.1250)/23740.5000 = 0.0261 in

Quality Record

Approved

Required shell thickness for Nozzle Calculations: t_r = 0.0346 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 2.0250 in
Required Area: $A_r = t_r D_s$ = 0.0346 * 2.0250 = 0.0701 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 2.0250 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (2.0250 - 2.0250/2)* (0.2500 - 0.1250 - 0.0346) = 0.1831 in²

Check nozzle attachment strength paths:
Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.0701 - 0.1831) * 21000.0000 = -2373.4191 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

Check attachment strength: Outside fillet weld, Groove weld
$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) +$
$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$
$\{0.60 * 21000.0000 * \pi * 1.9000 * 0.707(0.2500) +$
$0.875 * 0.70 * 21000.0000 * \pi * 1.9000 * (0.2500 - 0.1250)\}/2 =$
8121.8672 lbs

Check attachment strength: Nozzle neck, Outside fillet weld
$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$
$0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.2000 - 0.0000) * (1.9000 - 0.2000 - 0.0000) +$
$0.60 * 21000.0000 * \pi * 1.9000 * 0.707(0.2500)\}/2 =$
14497.4998 lbs

Nozzle reinforcement calculations are not required.

Level (L2)

Description: 1 1/2" 150# WN Flanged Nozzle
Elevation: 297.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 1.9000 in
Wall Thickness: t_n = 0.2000 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (0.0000 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0000 in

Hoop Stress at Nozzle

Y = 0.0000 ft

D/H < 1.333 and Y < 0.75D

Per E.6.1.4-2b, $N_i = 2.77 A_i G D^2 \left[\frac{Y}{0.75D} - 0.5 \left(\frac{Y}{0.75D} \right)^2 \right] =$

$$(2.77)(0.0612)(0.99)(10.0000)^2 \left[\frac{0.0000}{(0.75)(10.0000)} - 0.5 \left(\frac{0.0000}{(0.75)(10.0000)} \right)^2 \right]$$

= 0.0000 lbf/in

Per E.6.1.4-4b, $N_c = \frac{0.98 A_c G D^2 \cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2 \cosh[3.68(24.7500 - 0.0000)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 5.8879 lbf/in

$N_h = 2.60DYG = (2.60)(10.0000)(0.0000)(0.99) = 0.0000$ lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2\}}]/t =$
$[0.0000 + \sqrt{\{(0.0000)^2 + (5.8879)^2\}}]/0.1250 = 47.1035$ psi

Quality Record

Approved

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(47.1035 * 0.1250)/23740.5000 = 0.0002 in

Required shell thickness for Nozzle Calculations: t_r = 0.0002 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 2.0250 in
Required Area: $A_r = t_r D_s$ = 0.0002 * 2.0250 = 0.0005 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 2.0250 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (2.0250 - 2.0250/2)* (0.2500 - 0.1250 - 0.0002) = 0.2526 in²

Check nozzle attachment strength paths:
Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.0005 - 0.2526) * 21000.0000 = -5294.5316 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

Check attachment strength: Outside fillet weld, Groove weld
$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) +$
$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$
$\{0.60 * 21000.0000 * \pi * 1.9000 * 0.707(0.2500) +$
$0.875 * 0.70 * 21000.0000 * \pi * 1.9000 * (0.2500 - 0.1250)\}/2 =$
8121.8672 lbs

Check attachment strength: Nozzle neck, Outside fillet weld
$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$
$0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.2000 - 0.0000) * (1.9000 - 0.2000 - 0.0000) +$
$0.60 * 21000.0000 * \pi * 1.9000 * 0.707(0.2500)\}/2 =$
14497.4998 lbs

Nozzle reinforcement calculations are not required.

Shell Manway (M)

Description: 24" API-650 Shell Manhole w/Blind Flange

Elevation: 30.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: Plate
Material Grade: A36
Outside Diameter: d = 24.5000 in
Wall Thickness: t_n = 0.2500 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A36

Thickness: 0.5000 in
Machining Allowance: 0.1875 in

Blind Flange Material Grade: A36

Thickness: 0.5625 in

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (22.2500 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0324 in

Hoop Stress at Nozzle

Y = 22.2500 ft

D/H < 1.333 and Y ≥ 0.75D

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2$ = 8.4217 lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]}$ =

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 22.2500)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 0.0019 lbf/in

$N_h = 2.60DYG = (2.60)(10.0000)(22.2500)(0.99)$ = 572.7150 lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2\}}]/t$ =
$[572.7150 + \sqrt{\{(8.4217)^2 + (0.0019)^2\}}]/0.1250$ = 4649.0939 psi

Quality Record

Approved

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/S_a$ =
(4649.0939 * 0.1250)/23740.5000 = 0.0245 in

Required shell thickness for Nozzle Calculations: t_r = 0.0324 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 24.6250 in
Required Area: $A_r = t_r D_s$ = 0.0324 * 24.6250 = 0.7981 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 24.6250 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (24.6250 - 24.6250/2)* (0.2500 - 0.1250 - 0.0324) = 2.2801 in²

Available Reinforcement from nozzle neck per 5.7.2.4:

Shell allowable stress: S_s = 21000.0000 psi
Nozzle neck allowable stress: S_n = 21000.0000 psi
Reduction factor: $F_n = S_n/S_s$ = 21000.0000/21000.0000 but no greater than 1
therefore, F_n = 1.0000

Available Reinforcement from outside projection:
Projection: L_o = lesser of P_o or $4t_n$ = 1.0000 in
Available Area: $A_{ano} = 2F_nL_o(t_n - C_n)$ =
2 * 1.0000 * 1.0000 * (0.2500 - 0.0000) = 0.5000 in²

Available Reinforcement from portion in shell:
Available Area: $A_{an} = 2F_n(t - C_s)(t_n - C_n)$ =
2 * 1.0000 * (0.2500 - 0.1250) * (0.2500 - 0.0000) = 0.0625 in²

Total available area of reinforcement: A_{at} = 2.8426 in²

Check nozzle attachment strength paths:
Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.7981 - 2.2801) * 21000.0000 = -31121.6544 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

Quality Record

Approved

Check attachment strength: Outside fillet weld, Groove weld

$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) +$
$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$
$\{0.60 * 21000.0000 * \pi * 24.5000 * 0.707(0.2500) +$
$0.875 * 0.70 * 21000.0000 * \pi * 24.5000 * (0.2500 - 0.1250)\}/2 =$
104729.3402 lbs

Check attachment strength: Nozzle neck, Outside fillet weld

$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$
$0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.2500 - 0.0000) * (24.5000 - 0.2500 - 0.0000) +$
$0.60 * 21000.0000 * \pi * 24.5000 * 0.707(0.2500)\}/2 =$
225694.3332 lbs

Overflow (O)

Description: 8" 150# SO Flanged Nozzle
Elevation: 297.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 8.6250 in
Wall Thickness: t_n = 0.5000 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (0.0000 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0000 in

Hoop Stress at Nozzle

Y = 0.0000 ft

D/H < 1.333 and Y < 0.75D

Per E.6.1.4-2b, $N_i = 2.77A_iGD^2 \left[\frac{Y}{0.75D} - 0.5 \left(\frac{Y}{0.75D} \right)^2 \right] =$

$$(2.77)(0.0612)(0.99)(10.0000)^2 \left[\frac{0.0000}{(0.75)(10.0000)} - 0.5 \left(\frac{0.0000}{(0.75)(10.0000)} \right)^2 \right]$$

= 0.0000 lbf/in

Per E.6.1.4-4b, $N_c = \frac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 0.0000)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 5.8879 lbf/in

N_h = 2.60DYG = (2.60)(10.0000)(0.0000)(0.99) = 0.0000 lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{\{N_i^2 + N_c^2}]/t =$
$[0.0000 + \sqrt{\{(0.0000)^2 + (5.8879)^2\}}]/0.1250 = 47.1035$ psi

Quality Record

Approved

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(47.1035 * 0.1250)/23740.5000 = 0.0002 in

Required shell thickness for Nozzle Calculations: t_r = 0.0002 in

Reinforcement of Nozzle for Design:
Diameter of Hole in Shell: D_1 = 8.7500 in
Required Area: $A_r = t_r D_s$ = 0.0002 * 8.7500 = 0.0022 in²

Available Reinforcement from shell:
Diameter of Shell available: D_s = 8.7500 in
Shell corrosion allowance: C_s = 0.1250 in
Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =
2 * (8.7500 - 8.7500/2)* (0.2500 - 0.1250 - 0.0002) = 1.0916 in²

Available Reinforcement from nozzle neck per 5.7.2.4:

Shell allowable stress: S_s = 21000.0000 psi
Nozzle neck allowable stress: S_n = 21000.0000 psi
Reduction factor: $F_n = S_n/S_s$ = 21000.0000/21000.0000 but no greater than 1
therefore, F_n = 1.0000

Available Reinforcement from outside projection:
Projection: L_o = lesser of P_o or $4t_n$ = 2.0000 in
Available Area: $A_{ano} = 2F_nL_o(t_n - C_n)$ =
2 * 1.0000 * 2.0000 * (0.5000 - 0.0000) = 2.0000 in²

Available Reinforcement from portion in shell:
Available Area: $A_{an} = 2F_n(t - C_s)(t_n - C_n)$ =
2 * 1.0000 * (0.2500 - 0.1250) * (0.5000 - 0.0000) = 0.1250 in²

Total available area of reinforcement: A_{at} = 3.2166 in²

Check nozzle attachment strength paths:
Required strength: $W_r = (A_r - A_{as})S_a$ =
(0.0022 - 1.0916) * 21000.0000 = -22877.6055 lbs

Nozzle neck:
Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:
Weld size: W_o = 0.2500 in
Allowable stress: S_o = 21000.0000 psi

Groove weld:
Weld size: W_g = 0.2500 in
Allowable stress: S_g = 21000.0000 psi

Quality Record

Approved

Check attachment strength: Outside fillet weld, Groove weld

$$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) + 0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$$

$$\{0.60 * 21000.0000 * \pi * 8.6250 * 0.707(0.2500) + 0.875 * 0.70 * 21000.0000 * \pi * 8.6250 * (0.2500 - 0.1250)\}/2 =$$

$$36869.0024 \text{ lbs}$$

Check attachment strength: Nozzle neck, Outside fillet weld

$$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) + 0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$$

$$\{0.80 * 0.875 * 21000.0000 * \pi * (0.5000 - 0.0000) * (8.6250 - 0.5000 - 0.0000) + 0.60 * 21000.0000 * \pi * 8.6250 * 0.707(0.2500)\}/2 =$$

$$123978.3300 \text{ lbs}$$

Level Transmitter (L3)

Description: 3" 150# SO Flanged Nozzle
Elevation: 12.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 3.5000 in
Wall Thickness: t_n = 0.3000 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (23.7500 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0346 in

Hoop Stress at Nozzle

Y = 23.7500 ft

D/H < 1.333 and Y ≥ 0.75D

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2 = 8.4217$ lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 23.7500)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 0.0014 lbf/in

$N_h = 2.60DYG = (2.60)(10.0000)(23.7500)(0.99) = 611.3250$ lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{N_i^2 + N_c^2}]/t =$
$[611.3250 + \sqrt{(8.4217)^2 + (0.0014)^2}]/0.1250 = 4957.9739$ psi

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(4957.9739 * 0.1250)/23740.5000 = 0.0261 in

Quality Record

Approved

Required shell thickness for Nozzle Calculations: t_r = 0.0346 in

Reinforcement of Nozzle for Design:

Diameter of Hole in Shell: D_1 = 3.6250 in

Required Area: $A_r = t_r D_s$ = 0.0346 * 3.6250 = 0.1254 in²

Available Reinforcement from shell:

Diameter of Shell available: D_s = 3.6250 in

Shell corrosion allowance: C_s = 0.1250 in

Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =

2 * (3.6250 - 3.6250/2)* (0.2500 - 0.1250 - 0.0346) = 0.3277 in²

Available Reinforcement from nozzle neck per 5.7.2.4:

Shell allowable stress: S_s = 21000.0000 psi

Nozzle neck allowable stress: S_n = 21000.0000 psi

Reduction factor: $F_n = S_n/S_s$ = 21000.0000/21000.0000 but no greater than 1

therefore, F_n = 1.0000

Available Reinforcement from outside projection:

Projection: L_o = lesser of P_o or $4t_n$ = 1.2000 in

Available Area: $A_{ano} = 2F_nL_o(t_n - C_n)$ =

2 * 1.0000 * 1.2000 * (0.3000 - 0.0000) = 0.7200 in²

Available Reinforcement from portion in shell:

Available Area: $A_{an} = 2F_n(t - C_s)(t_n - C_n)$ =

2 * 1.0000 * (0.2500 - 0.1250) * (0.3000 - 0.0000) = 0.0750 in²

Total available area of reinforcement: A_{at} = 1.1227 in²

Check nozzle attachment strength paths:

Required strength: $W_r = (A_r - A_{as})S_a$ =

(0.1254 - 0.3277) * 21000.0000 = -4248.7132 lbs

Nozzle neck:

Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:

Weld size: W_o = 0.2500 in

Allowable stress: S_o = 21000.0000 psi

Groove weld:

Weld size: W_g = 0.2500 in

Allowable stress: S_g = 21000.0000 psi

Quality Record

Approved

Check attachment strength: Outside fillet weld, Groove weld

$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) +$
$0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$
$\{0.60 * 21000.0000 * \pi * 3.5000 * 0.707(0.2500) +$
$0.875 * 0.70 * 21000.0000 * \pi * 3.5000 * (0.2500 - 0.1250)\}/2 =$
14961.3343 lbs

Check attachment strength: Nozzle neck, Outside fillet weld

$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) +$
$0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$
$\{0.80 * 0.875 * 21000.0000 * \pi * (0.3000 - 0.0000) * (3.5000 - 0.3000 - 0.0000) +$
$0.60 * 21000.0000 * \pi * 3.5000 * 0.707(0.2500)\}/2 =$
34410.9246 lbs

Pump Suction (E)

Description: 8" 150# SO Flanged Nozzle
Elevation: 14.0000 in
Orientation: 0.0000°
Corrosion Allowance: Cn = 0.0000 in

Nozzle Neck: SCH80 Pipe
Material Grade: A53-B SMLS
Outside Diameter: d = 8.6250 in
Wall Thickness: t_n = 0.5000 in
Outside Projection: Po = 8.0000 in
Inside Projection: Pi = 0.0000 in

Flange Material Grade: A105

Calculate Required Shell Thickness at Nozzle

For Design: tr = 2.6000 * (23.5833 + 0.0000) * 10.0000 * 1.0000/[0.8500 * 21000.0000]
= 0.0344 in

Hoop Stress at Nozzle

Y = 23.5833 ft

D/H < 1.333 and Y ≥ 0.75D

Per E.6.1.4-3b, $N_i = 1.39A_iGD^2 = (1.39)(0.0612)(0.99)(10.0000)^2 = 8.4217$ lbf/in

Per E.6.1.4-4b, $N_c = \dfrac{0.98A_cGD^2\cosh[3.68(H - Y)/D]}{\cosh[3.68H/D]} =$

$$\frac{(0.98)(0.0607)(0.9900)(10.0000)^2\cosh[3.68(24.7500 - 23.5833)/10.0000]}{\cosh[(3.68)(24.7500/10.0000)]}$$

= 0.0014 lbf/in

$N_h = 2.60DYG = (2.60)(10.0000)(23.5833)(0.99) = 607.0350$ lbf/in

Shell thickness: t = 0.1250 in

Per E.6.1.4-5, $\sigma_T = [N_h + \sqrt{N_i^2 + N_c^2}]/t =$
$[607.0350 + \sqrt{(8.4217)^2 + (0.0014)^2}]/0.1250 = 4923.6539$ psi

Allowable stress per E.6.2.4 = 23740.5000 psi

Minimum required thickness = $(\sigma_T * t)/Sa$ =
(4923.6539 * 0.1250)/23740.5000 = 0.0259 in

Quality Record

Approved

Required shell thickness for Nozzle Calculations: t_r = 0.0344 in

Reinforcement of Nozzle for Design:

Diameter of Hole in Shell: D_1 = 8.7500 in

Required Area: $A_r = t_r D_s$ = 0.0344 * 8.7500 = 0.3006 in²

Available Reinforcement from shell:

Diameter of Shell available: D_s = 8.7500 in

Shell corrosion allowance: C_s = 0.1250 in

Available Area: $A_{as} = 2(D_s - D_1/2)(t - C_s - t_r)$ =

2 * (8.7500 - 8.7500/2)* (0.2500 - 0.1250 - 0.0344) = 0.7932 in²

Available Reinforcement from nozzle neck per 5.7.2.4:

Shell allowable stress: S_s = 21000.0000 psi

Nozzle neck allowable stress: S_n = 21000.0000 psi

Reduction factor: $F_n = S_n/S_s$ = 21000.0000/21000.0000 but no greater than 1

therefore, F_n = 1.0000

Available Reinforcement from outside projection:

Projection: L_o = lesser of P_o or $4t_n$ = 2.0000 in

Available Area: $A_{ano} = 2F_nL_o(t_n - C_n)$ =

2 * 1.0000 * 2.0000 * (0.5000 - 0.0000) = 2.0000 in²

Available Reinforcement from portion in shell:

Available Area: $A_{an} = 2F_n(t - C_s)(t_n - C_n)$ =

2 * 1.0000 * (0.2500 - 0.1250) * (0.5000 - 0.0000) = 0.1250 in²

Total available area of reinforcement: A_{at} = 2.9182 in²

Check nozzle attachment strength paths:

Required strength: $W_r = (A_r - A_{as})S_a$ =

(0.3006 - 0.7932) * 21000.0000 = -10344.7304 lbs

Nozzle neck:

Allowable stress: S_n = 21000.0000 psi

Outside fillet weld:

Weld size: W_o = 0.2500 in

Allowable stress: S_o = 21000.0000 psi

Groove weld:

Weld size: W_g = 0.2500 in

Allowable stress: S_g = 21000.0000 psi

Quality Record

Approved

Check attachment strength: Outside fillet weld, Groove weld

$$W_a = \{0.60 * S_o * \pi * d * 0.707(W_o) + 0.875 * 0.70 * S_g * \pi * d * (W_g - C_s)\}/2 =$$
$$\{0.60 * 21000.0000 * \pi * 8.6250 * 0.707(0.2500) + 0.875 * 0.70 * 21000.0000 * \pi * 8.6250 * (0.2500 - 0.1250)\}/2 =$$
$$36869.0024 \text{ lbs}$$

Check attachment strength: Nozzle neck, Outside fillet weld

$$W_a = \{0.80 * 0.875 * S_n * \pi * (t_n - C_n) * (d - t_n - C_n) + 0.60 * S_o * \pi * d * 0.707(W_o)\}/2 =$$
$$\{0.80 * 0.875 * 21000.0000 * \pi * (0.5000 - 0.0000) * (8.6250 - 0.5000 - 0.0000) + 0.60 * 21000.0000 * \pi * 8.6250 * 0.707(0.2500)\}/2 =$$
$$123978.3300 \text{ lbs}$$

Approved

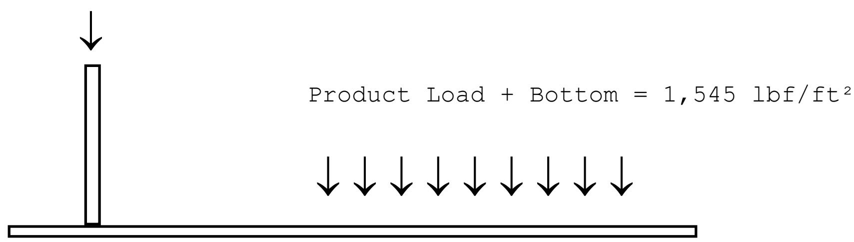
Customer:
Southern Company
Job Number:
2084-01
Date: 05-26-2011 Rev.: 1

Foundation Loads

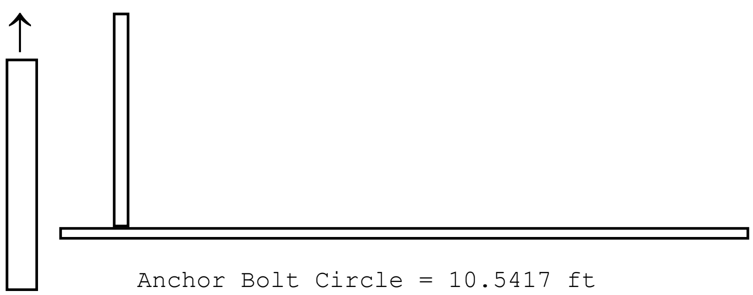
Dead Load = 297 lbf/ft
Dead Load + Live Load = 347 lbf/ft
Dead Load + Snow Load = 310 lbf/ft
Wind Load + Dead Load = 844 lbf/ft

(Wind Overturning Moment = 42,953 ft-lbs)

Seismic Values needed for E.6.2.3
- WP = 120,084 lbs
- Wf = 1,284 lbs
- WT = 131,097 lbs
- Ms = 96,007 ft-lbs



Anchor Bolt Load:
- Wind = 1,329 lbs
- Seismic = 3,681 lbs
- Bolt Area x Yield Strength = 19,836 lbs



Total Weight of Tank: 10,852 lbs
Total Operating Weight: 130,936 lbs
Total Testing Weight: 132,149 lbs

Quality Record

Approved

Anchor Chair Design per SG11.4S

Nomenclature

L'	Anchor Bolt Dia	1.0000	in
B_l	Max Bolt Load (S_y * A_{root})	19,836	lbs
BB	Radial dimension (width) of gusset	6.0000	in
S_5	Allowable chair plate stress (S_y * 0.8)	28,800	psi
CA	Corrosion Allowance	0.0000	in
P_t	Total internal pressure of tank at bottom (int press + static head)	0.91	psi
D	Outside diameter of tank	10.0000	ft
t_6	Actual thickness of shell (corroded)	0.1250	in
t_{13}	Thickness of shell + repad (equal to t_6 if no repad used)	0.3750	in
S_y	Allowable yield stress of shell	36000	psi
w_p	Length of chair top plate	6.0000	in
t_B	Bottom plate thickness (corroded)	0.2500	in
e	Radial distance to anchor bolt circle	3.0000	in
H	Gusset height	12.0000	in
DD	Average radial width of gusset	3.0000	in

Thickness of chair plate (min)

t_{11}	$= 1.23*[3*L'*B_l/(BB*S_5)]^{0.5} + CA$	0.7218	in

Hoop stress in shell due to internal pressure

S_8	$= P_t*(12*D-2*t_6)/(2*t_6)$	436	psi

Calculate allowable shell stress used to resist anchor load

S_{14}	$= 0.8*S_y-S_8$	28,364	psi

Height of gussets

Correction factor

CF	$= 1 / [0.177*w_p*t_B/(6*D*t_6)^{0.5}*(t_B/t_6)^2 + 1]$	0.7206	

Load per bolt

P	$= U_n/N_B$ (or greater of wind/seismic load)	12,228	lbs

Stress in the shell

Shell Only

S_{14}	$= P*e/t_6^2\ [1.32*CF/(1.43*w_p*H_1^2/(6*D*t_6)+(4*w_p*H_1^2)^{0.333})+0.031/(6*D*t_6)^{0.5})]$	38,995	psi
	Stress in the shell exceeds allowable, use a repad.		

Shell w/Repad

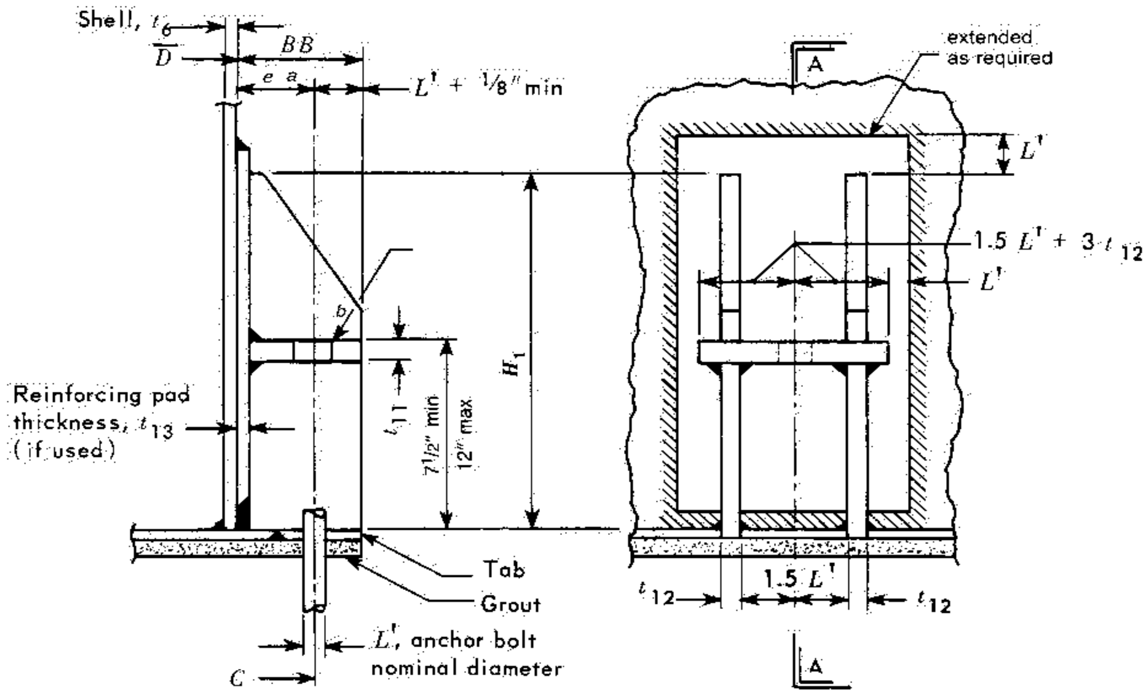
$S_{(14)}$	$= P*e/t_{13}^2\ [1.32*CF/(1.43*w_p*H_1^2/(6*D*t_{13})+(4*w_p*H_1^2)^{0.333})+0.031/(6*D*t_{13})^{0.5})]$	5,250	psi
	Stress in the shell + repad is OK.		

Minimum thickness of gusset (use the larger of)

t_{12}	$= B_l/(72{,}000*DD)*[1 + (1 + 96*DD*H_1^2/B_l)^{0.5}] + CA$	0.2533	in
or			
t_{12}	$= 0.063*BB + CA$	0.3780	in

Shell!, t_6

Approved



Section A–A

Approved