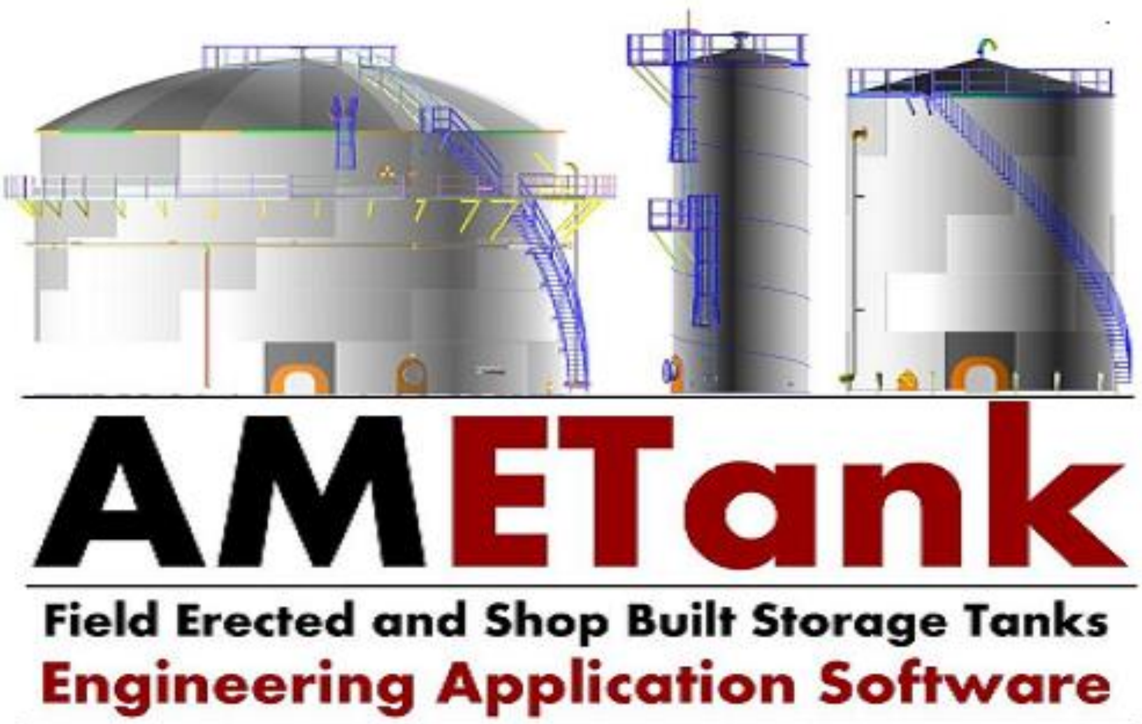
AMETANK REPORT



The following report is subject to the disclaimer statement as stated in the Disclaimer and Special Notes section at the end.

Table of Contents

No Warnings!!

Project Design Data and Summary

Back

Project Data

Job : 2025-03-27-23-50
Date of Calcs. : 03-Apr-2025
Mfg. or Insp. Date :
Designer : Melior
Project :
Tag ID : Q9192 GAL 20,000
Plant :
Plant Location :
Site :
Design Basis : API-650 13th Edition Errata 1, 2021
Annexes Used : E, J

Design Parameters and Operating Conditions

Design Parameters

Design Internal Pressure = 0 psi or 0 inh2o
Design External Pressure = -0 psi or -0 inh2o

D of Tank = 12 ft
OD of Tank = 12 ft
ID of Tank = 11.9583 ft
CL of Tank = 11.9792 ft
Shell Height = 24 ft
S.G of Contents = 1
S.G of Hydrotest = 1
Hydrotest Liquid Level = 24 ft
Max Design Liq. Level = 24 ft
Max Operating Liq. Level = 24 ft
Min Liq. Level = 1 ft
Design Temperature = 120 ºF
MDMT (Minimum Design Metal Temperature) = 20 ºF
Tank Joint Efficiency = 0.7
Ground Snow Load = 0 psf
Roof Live Load = 20 psf
Additional Roof Dead Load = 0 psf

Wind Load Basis: ASCE 7-05
3 Second Gust Wind Speed (entered), Vg = 105 mph
Wind Importance Factor, Iw = 1
Design Wind Speed, V = Vg * SQRT(Iw) = 105 mph

Seismic Method: API-650 - ASCE7 Mapped(Ss & S1)
Seismic Use Group = II

Site Class = C
T_L (sec) = 12
Ss (g) = 0.24
S1 (g) = 0.093
Av (g) = 0.0896
Q = 0.6667
Importance Factor = 1.25

Design Remarks

Summary Results

Shell

Shell #	Width (in)	Material	CA (in)	JE	Min Yield Strength (psi)	Tensile Strength (psi)	Sd (psi)	St (psi)	Weight (lbf)
1	96	A36	0	0.7000	36,000	58,000	21,000	21,000	3,070
2	96	A36	0	0.7000	36,000	58,000	21,000	21,000	3,070
3	95.75	A36	0	0.7000	36,000	58,000	21,000	21,000	3,062

(continued)

Shell #	Weight CA (lbf)	t-min Erection (in)	t-Des (in)	t-Test (in)	t-min Seismic (in)	t-min Ext-Pe (in)	t-min (in)	t-Actual (in)	Status
1	3,070	0.236	0.0488	0.0488	0.0343	NA	0.236	0.25	OK
2	3,070	0.236	0.0318	0.0318	0.023	NA	0.236	0.25	OK
3	3,062	0.236	0.0149	0.0149	0.0117	NA	0.236	0.25	OK

Total Weight of Shell = 9,203.6403 lbf

Roof

Type = Self Supported Conical Roof
Plates Material = A36
t.required = 0.1875 in
t.actual = 0.25 in
Roof corrosion allowance = 0 in
Roof Joint Efficiency = 0.7
Plates Overlap Weight = 17.2234 lbf
Plates Weight = 1,198.2583 lbf

Bottom

Type : Flat Bottom Non Annular
Bottom Material = A36
t.required = 0.236 in
t.actual = 0.25 in
Bottom corrosion allowance = 0 in
Bottom Joint Efficiency = 0.7
Total Weight of Bottom = 1,185.72 lbf

Top Member

Type = Detail B
Size = L3x3x3/8
Material = A36
Weight = 270.7586 lbf

Anchors

Quantity = 4
Size = 1 in
Material = A36
Bolt Hole Circle Radius = 6.177 ft

Nameplate Information

Pressure Combination Factor	0.4
Design Standard	API-650 13th Edition Errata 1, 2021
Appendices Used	E, J
Roof	A36 : 0.25 in
Shell (1)	A36 : 0.25 in
Shell (2)	A36 : 0.25 in
Shell (3)	A36 : 0.25 in
Bottom	A36 : 0.25 in

Roof Design Details Back

Roof Type = Cone
Structure Support Type = None (Self Supported)

Material Properties

Material = A36
Minimum Tensile Strength (Sut) = 58,000 psi
Minimum Yield Strength (Sy) = 36,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd) = 21,000 psi
Density (d) = 0.2833 lb/in^3
Modulus of Elasticity at Design Temperature (E) = 28,800,000 psi

Geometry

Rh = Horizontal Radius (in)
slope = Slope (Rise / Run)

Rh = 72.884 in
slope = 0.1667

Description	Variable	Equation	Value	Unit
Slope Angle	Theta	ARCTAN(slope)	9.4623	deg
Angle With Vertical Line	Alpha	90 - Theta	80.5377	deg
Height	h	Rh * TAN(Theta)	12.1473	in
Surface Area	A	(pi * (Rh^2)) / COS(Theta)	16,918.579	in^2
Center of Gravity from Base	CG	h / 3	4.0491	in
Vertical Projected Area	Av	Rh * h	885.3462	in^2
Horizontal Projected Area	Ah	pi * (Rh^2)	16,688.3835	in^2
Volume	V	(pi * (Rh^2) * h) / 3	67,573.1191	in^3

Weights

d-ins = Insulation Density (lbf/ft^3)
DL-add = Added dead load (psf)
t = Plates Thickness (in)
t-ins = Insulation Thickness (in)
Wr-pl-add = Additional Weight (lb)

d-ins = 8 lbf/ft^3
DL-add = 0.0 psf
t = 0.25 in
t-ins = 0 in
Wr-pl-add = 0 lb

Description	Variable	Equation	Value	Unit
Plates Nominal Weight	Wr-pl	(A * d * t) + Wr-pl-add	1,198.2584	lb

Plates Corroded Weight	Wr-pl-corr	(A * d * (t - CA)) + Wr-pl-add	1,198.2584	lb
New Plates Dead Load Pressure	DL-pl	Wr-pl / Ah	10.3395	psf
Corroded Plates Dead Load Pressure	DL-pl-corr	Wr-pl-corr / Ah	10.3395	psf
Insulation Weight	Wr-ins	t-ins * d-ins * A	0.0	lb
Insulation Dead Load Pressure	DL-ins	Wr-ins / Ah	0.0	psf
Dead Load	DL	DL-pl + DL-ins + DL-add	10.3395	psf
Total Nominal Dead Weight	Wr-DL	DL * Ah	1,198.2584	lb
Additional Dead Weight	Wr-DL-add	DL-add * Ah	0.0	lb

Loads

B = Maximum Gravity Load Combination Based on Balanced Snow Load (psf)
e.1b = Gravity Loads Combination 1 Based on Balanced Snow Load per *API 650 Section 5.2.2* (psf)
e.1u = Gravity Loads Combination 1 Based on Unbalanced Snow Load per *API 650 Section 5.2.2* (psf)
e.2b = Gravity Loads Combination 2 Based on Balanced Snow Load per *API 650 Section 5.2.2* (psf)
e.2u = Gravity Loads Combination 2 Based on Unbalanced Snow Load per *API 650 Section 5.2.2* (psf)
Fpe = External Pressure Combination Factor
Lr = Minimum Roof Live Load (psf)
max-gravity-load = Maximum Gravity Load (psf)
Pe = Design External Pressure (psf)
S = Ground Snow Load (psf)
Sb = Balanced Snow load per *API 650 Section 5.2.1 (h)* (psf)
Su = Unbalanced Snow load per *API 650 Section 5.2.1 (h)* (psf)
U = Maximum Gravity Load Combination Based on Unbalanced Snow Load (psf)
W-max-gravity-load = Maximum Gravity Load Weight (lb)

Fpe = 0.4
Lr = 20.0 psf
Pe = 0.0 psf
S = 0.0 psf

Sb = 0.84 * S
Sb = 0.84 * 0.0
Sb = 0.0 psf

Su = Sb
Su = 0.0
Su = 0.0 psf

e.1b = DL + MAX(Lr , Sb) + (Fpe * Pe)
e.1b = 10.3395 + MAX(20.0 , 0.0) + (0.4 * 0.0)
e.1b = 30.3395 psf

e.2b = DL + Pe + (0.4 * MAX(Lr , Sb))
e.2b = 10.3395 + 0.0 + (0.4 * MAX(20.0 , 0.0))
e.2b = 18.3395 psf

B = MAX(e.1b , e.2b)
B = MAX(30.3395 , 18.3395)
B = 30.3395 psf

e.1u = DL + MAX(Lr , Su) + (Fpe * Pe)

e.1u = 10.3395 + MAX(20.0 , 0.0) + (0.4 * 0.0)
e.1u = 30.3395 psf

e.2u = DL + Pe + (0.4 * MAX(Lr , Su))
e.2u = 10.3395 + 0.0 + (0.4 * MAX(20.0 , 0.0))
e.2u = 18.3395 psf

U = MAX(e.1u , e.2u)
U = MAX(30.3395 , 18.3395)
U = 30.3395 psf

max-gravity-load = MAX(B , U)
max-gravity-load = MAX(30.3395 , 30.3395)
max-gravity-load = 30.3395 psf

W-max-gravity-load = max-gravity-load * Ah
W-max-gravity-load = 30.3395 * 115.8916
W-max-gravity-load = 3,516.0894 lb

Erection Requirements

t-erec-req = Minimum Erection Thickness Including Corrosion Allowance (in)

As per API-650 5.10.2.2, Minimum Erection Thickness (t-erec) = 0.1875 in

t-erec-req = t-erec + CA
t-erec-req = 0.1875 + 0
t-erec-req = 0.1875 in

Gravity Loads Thickness Calculation

B-max = Max Gravity Load Based on Roof Actual Thickness (Balanced Snow Load) (psf)
Pe-max-1 = MAWV Based on Gravity Loads Combination 1 per *API 650 Section 5.2.2* (psf)
t-calc-1 = Calculated Thickness Based on Balanced Snow Load (in)

t-calc-1 = (((2 * 12 * D) / SIN(Theta)) * SQRT((B / (144 * E)))) + CA
t-calc-1 = (((2 * 12 * 12.0) / SIN(9.4623)) * SQRT((30.3395 / (144 * 28,800,000)))) + 0
t-calc-1 = 0.1498 in

B-max = (((t-actual - CA) * (SIN(Theta) / (2 * 12 * D)))^2) * 144 * E
B-max = (((0.25 - 0) * (SIN(9.4623) / (2 * 12 * 12.0)))^2) * 144 * 28,800,000
B-max = 84.4595 psf

Pe-max-1 = MAX(((L_max - DL - MAX(Lr , S)) / Fpe) , 0)
Pe-max-1 = MAX(((84.4595 - 10.3395 - MAX(20.0 , 0.0)) / 0.4) , 0)
Pe-max-1 = 135.2999 psf

Pe-max-2 = MAWV Based on Gravity Loads Combination 1 per *API 650 Section 5.2.2* (psf)
t-calc-2 = Calculated Thickness Based on Unbalanced Snow Load (in)
U-max = Max Gravity Load Based on Roof Actual Thickness (Unbalanced Snow Load) (psf)

t-calc-2 = (((2 * 12 * D) / SIN(Theta)) * SQRT((U / (1.33 * 144 * E)))) + CA
t-calc-2 = (((2 * 12 * 12.0) / SIN(9.4623)) * SQRT((30.3395 / (1.33 * 144 * 28,800,000)))) + 0
t-calc-2 = 0.1299 in

U-max = (((t-actual - CA) * (SIN(Theta) / (2 * 12 * D)))^2) * 1.33 * 144 * E
U-max = (((0.25 - 0) * (SIN(9.4623) / (2 * 12 * 12.0)))^2) * 1.33 * 144 * 28,800,000

U-max = 112.3311 psf

Pe-max-2 = MAX(((L_max - DL - MAX(Lr , S)) / Fpe) , 0)
Pe-max-2 = MAX(((112.3311 - 10.3395 - MAX(20.0 , 0.0)) / 0.4) , 0)
Pe-max-2 = 204.979 psf

Required Thickness

MAWV-Roof = Maximum Allowable Working Vacuum (psf)
t-act = Installed Thickness (in)
t-req = Required Thickness (in)

t-act = 0.25 in

t-req = MAX(t-erec-req , t-calc-1 , t-calc-2)
t-req = MAX(0.1875 , 0.1498 , 0.1299)
t-req = 0.1875 in

t >= t-req ==> PASS

MAWV-Roof = MIN(Pe-max-1 , Pe-max-2)
MAWV-Roof = MIN(135.2999 , 204.979)
MAWV-Roof = 135.2999 psf

Top Member Detail B Design Back

DLR = Nominal Weight of Roof Plates and Attached Structural (lbf)
DLS = Nominal Weight of Shell Plates and Framing (lbf)

DLS = Ws + W_framing
DLS = 9,203.6404 + 269.7491
DLS = 9,473.3895 lbf

DLR = Wr + W_structural
DLR = 1,198.2584 + 149.4112
DLR = 1,347.6695 lbf

Material Properties
Material = A36
Minimum Tensile Strength (Sut) = 58,000 psi
Minimum Yield Strength (Sy) = 36,000 psi

Compression Ring Detail b Properties
A_detail = Detail Total Area (in^2)
A_roof = Contributing Roof Area (in^2)
A_shell = Contributing Shell Area (in^2)
A_sum = Total area (in^2)
c_combined = Combined centroid (in)
d_shell = Shell centroid (in)
d_stiff = Stiffener centroid (in)
e1 = Distance from neutral axis to edge 1 (inside) (in)
e2 = Distance from neutral axis to edge 2 (outside) (in)
I_1 = moment of inertia of first body (in^4)
I_2 = moment of inertia of second body (in^4)
I_combined = Combined moment of inertia (in^4)
I_shell = Contributing Shell Moment Of Inertia (in^4)
I_sum = Sum of moments of inertia's (in^4)
R2 = Length of Normal to Head (in)
S = Combined stiffener shell section modulus (in^3)
Wc = Maximum Width of Participating Shell per *API-650 Figure F-2* (in)
Wh = Maximum Width of Participating Head per *API-650 Figure F-2* (in)

R2 = (ID / 2) / SIN(Theta)
R2 = (143.5 / 2) / SIN(9.4623)
R2 = 436.4382 in

Wh = 0.3 * SQRT((R2 * (th - CA-head)))
Wh = 0.3 * SQRT((436.4382 * (0.25 - 0)))
Wh = 3.1337 in

Wc = 0.6 * SQRT(((ID / 2) * (tc-nominal - CA-shell)))
Wc = 0.6 * SQRT(((143.5 / 2) * (0.25 - 0)))
Wc = 2.5412 in

Angle Size L3X3X3/8 Section Properties

Description	Variable	New	Corroded	Unit

Weight	W	7.2	7.2	lbf/ft
Cross Sectional Area	A	2.11	2.11	in^2
Moment Of Inertia About X Axis	Ix	1.75	1.75	in^4
Moment Of Inertia About Y Axis	Iy	1.75	1.75	in^4
Section Modulus About X Axis	Sx	0.825	0.825	in^3
Section Modulus About Y Axis	Sy	0.825	0.825	in^3
Centroid X Coords	cx	0.884	0.884	in
Centroid Y Coords	cy	0.884	0.884	in
Angle Long Leg Length	L1-angle	3.0	3.0	in
Angle Short Leg Length	L2-angle	3.0	3.0	in
Angle Thickness	t-angle	0.375	0.375	in

I_shell = ((Wc - h) * ((tc-nominal - CA-shell)^3)) / 12
I_shell = ((2.5412 - 0.375) * ((0.25 - 0)^3)) / 12
I_shell = 0.0028 in^4

A_shell = (Wc - h) * (tc-nominal - CA-shell)
A_shell = (2.5412 - 0.375) * (0.25 - 0)
A_shell = 0.5415 in^2

A_roof = Wh * (th - CA-head)
A_roof = 3.1337 * (0.25 - 0)
A_roof = 0.7834 in^2

A_detail = A_shell + A_roof + A-corr
A_detail = 0.5415 + 0.7834 + 2.11
A_detail = 3.435 in^2

Stiffener and Shell Combined Section Properties

Description	Variable	Equation	Value	Unit
Shell centroid	d_shell	(tc-nominal - CA-shell) / 2	0.125	in
Stiffener centroid	d_stiff	cy + (tc-nominal - CA-shell)	1.134	in
moment of inertia of first body	I_1	Ic + (Area * (Distance^2))	4.4634	in^4
moment of inertia of second body	I_2	Ic + (Area * (Distance^2))	0.0113	in^4
Total area	A_sum	A_1 + A_2	2.6515	in^2
Sum of moments of inertia's	I_sum	I_1 + I_2	4.4746	in^4
Combined centroid	c_combined	((Centroid-1 * Area-1) + (Centroid-2 * Area-2)) / (Area-1 + Area-2)	0.9279	in
Combined moment of inertia	I_combined	Ic - (Area * (Distance^2))	2.1916	in^4
Distance from neutral axis to edge 1 (inside)	e1	c_combined	0.9279	in
Distance from neutral axis to edge 2 (outside)	e2	((tc-nominal - CA-shell) + L1-angle) - e1	2.3221	in

Combined stiffener shell section modulus	S	I / MAX(d-1 , d-2)	0.9438	in^3

d_shell = (tc-nominal - CA-shell) / 2
d_shell = (0.25 - 0) / 2
d_shell = 0.125 in

d_stiff = cy + (tc-nominal - CA-shell)
d_stiff = 0.884 + (0.25 - 0)
d_stiff = 1.134 in

I_1 = Ic + (Area * (Distance^2))
I_1 = 1.75 + (2.11 * (1.134^2))
I_1 = 4.4634 in^4

I_2 = Ic + (Area * (Distance^2))
I_2 = 0.0028 + (0.5415 * (0.125^2))
I_2 = 0.0113 in^4

A_sum = A_1 + A_2
A_sum = 2.11 + 0.5415
A_sum = 2.6515 in^2

I_sum = I_1 + I_2
I_sum = 4.4634 + 0.0113
I_sum = 4.4746 in^4

c_combined = ((Centroid-1 * Area-1) + (Centroid-2 * Area-2)) / (Area-1 + Area-2)
c_combined = ((1.134 * 2.11) + (0.125 * 0.5415)) / (2.11 + 0.5415)
c_combined = 0.9279 in

I_combined = Ic - (Area * (Distance^2))
I_combined = 4.4746 - (2.6515 * (0.9279^2))
I_combined = 2.1916 in^4

e1 = c_combined
e1 = 0.9279
e1 = 0.9279 in

e2 = ((tc-nominal - CA-shell) + L1-angle) - e1
e2 = ((0.25 - 0) + 3.0) - 0.9279
e2 = 2.3221 in

S = I / MAX(d-1 , d-2)
S = 2.1916 / MAX(0.9279 , 2.3221)
S = 0.9438 in^3

Design Requirements per API-650 Section 5
A_roof = Compression Region Required Area for Self Supported Cone Roof per *API-650 5.10.5.2* (in^2)
Fa = Least Allowable Tensile Stress for the Materials in the Roof-To-Shell Joint (psi)
Fy = Minimum Specified Yield Strength (psi)
Max-p = Maximum Allowable Load for the Actual Resisting Area per *API-650 5.10.5.2* (psf)
p = Max Gravity Load per *API-650 5.2.2 e)* (psf)

Fy = 36,000 psi
p = 30.3395 psf

Fa = 0.6 * Fy
Fa = 0.6 * 36,000
Fa = 21,600 psi

A_roof = (p * (D^2)) / (8 * Fa * TAN(theta))
A_roof = (30.3395 * (12.0^2)) / (8 * 21,600 * TAN(9.4623))
A_roof = 0.1517 in^2

A_detail >= A_roof ==> PASS

Max-p = (A_detail / (D^2)) * 8 * Fa * TAN(theta)
Max-p = (3.435 / (12.0^2)) * 8 * 21,600 * TAN(9.4623)
Max-p = 686.9913 psf

Internal Pressure - Appendix F Requirements
A_actual = Area resisting compressive force (in^2)
D = Tank nominal diameter (ft)
DLR = Nominal weight of roof plates and attached structural (lbf)
DLS = Nominal weight of shell plates and framing (lbf)
Fp = Internal Pressure Combination Factor
Fy = Minimum specified yield-strength of the materials in the roof-to-shell junction (psi)
ID = Tank inside diameter (ft)
MDL = Moment About the Shell-to-Bottom Joint from the Nominal Weight of the Shell and Roof Structural Supported by the Shell that is not Attached to the Roof Plate (ft.lbf)
MDLR = Moment About the Shell-to-Bottom Joint from the Nominal Weight of the Roof Plate Plus any Structural Components Attached to the Roof (ft.lbf)
MF = Moment About the Shell-to-Bottom Joint from Liquid Weight (ft.lbf)
Mw = Wind Moment From Horizontal Plus Vertical Wind Pressures (ft.lbf)
Mws = Wind Moment From Horizontal Wind Pressure (ft.lbf)
P = Design pressure (psi)
P_uplift = Uplift due to internal pressure per *API-650 F.1.2* (lbf)
Theta angle = Angle between the roof and a horizontal plane at the roof-to-shell junction (deg)
W_add_DL = Additional dead load weight (lbf)
W_framing = Weight of framing supported by the shell and roof (lbf)
Wr = Roof plates weight (lbf)
Ws = Shell plates weight (lbf)
W_structural = Weight of roof attached structural (lbf)

A_actual = 3.435 in^2
D = 12.0 ft
DLR = 1,347.6695 lbf
DLS = 9,473.3895 lbf
Fp = 0.4
Fy = 36,000 psi
ID = 11.9583 ft
MDL = 56,840.3371 ft.lbf
MDLR = 8,086.0171 ft.lbf
MF = 29,314.8294 ft.lbf
Mw = 65,719.2813 ft.lbf
Mws = 49,215.6 ft.lbf
P = 0.0 psi
Theta angle = 9.4623 deg
W_add_DL = 0.0 lbf

W_framing = 269.7491 lbf
Wr = 1,198.2584 lbf
Ws = 9,203.6404 lbf
W_structural = 149.4112 lbf

P_uplift = P * pi * ((ID^2) / 4)
P_uplift = 0.0 * pi * ((143.5^2) / 4)
P_uplift = 0.0 lbf

P_uplift <= Wr , Tank design does not need to meet App. F requirements.

P_F51 = Maximum allowable internal pressure for the actual resisting area per *API 650 F.5.1* (inH2O)
P_max_internal = Maximum allowable internal pressure (psi)

P_std = 2.5 psi

P_F51 = ((0.962 * Fy * TAN(Theta angle) * A_actual) / (D^2)) + ((0.245 * DLR) / (D^2))
P_F51 = ((0.962 * 36,000 * TAN(9.4623) * 3.435) / (12.0^2)) + ((0.245 * 1,347.6695) / (12.0^2))
P_F51 = 139.9774 inH2O

P_max_internal = MIN(P_std , P_F51)
P_max_internal = MIN(2.5 , 5.0569)
P_max_internal = 2.5 psi

Shell Design Back

Ac = Convective Design Response Spectrum Acceleration Coefficient
Ai = Impulsive Design Response Spectrum Acceleration Coefficient
Av = Vertical ground acceleration coefficient description
CG-shell = Shell center of gravity (ft)
D = Tank Nominal Diameter per *API-650 5.6.1.1 Note 1* (ft)
d-ins = Insulation Density (lbf/ft^3)
G = Product Design Specific Gravity
Gt = Hydrotest Specific Gravity
H = Shell height (ft)
H-Hydrotest-L = Max Hydrotest Liquid Level (ft)
HL = Max Liquid Level (ft)
h-min = Minimum Shell Course Height per *API-650 5.6.1.2* (in)
Pe = Design External Pressure (psf)
Pi = Design Internal Pressure (psi)
Rwi = Impulsive Force Reduction Factor
t-ins = Insulation Thickness (in)
V = Wind velocity (mile/hr)
W-ins = Shell Insulation Weight (lbf)
W-shell = Shell Nominal Weight (lb)
W-shell-add = Shell Additional Weight (lb)
W-shell-corr = Shell Corroded Weight (lb)

Ac = 0.0494
Ai = 0.06
Av = 0.0896
D = 12.0 ft
d-ins = 8 lbf/ft^3
G = 1
Gt = 1
H = 24 ft
H-Hydrotest-L = 24.0 ft
HL = 24.0 ft
h-min = 72 in
Pe = 0.0 psf
Pi = 0.0 psi
Rwi = 4
t-ins = 0 in
V = 105.0 mile/hr
W-shell-add = 0 lb

API-650 Design Method: One Foot (1ft)

Rwi = Impulsive Force Reduction Factor

Rwi = 4

Course # 1 (bottom course) Design

CA = Corrosion allowance per *API-650 5.3.2* (in)
D1 = Shell Course Centerline Diameter (in)
H = Design Liquid Level per *API-650 5.6.3.2* (ft)
H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)
h1 = Course Height (ft)

H-Hydrotest = Hydrotest Liquid Level per *API-650 5.6.3.2* (ft)
H-max = Maximum Liquid Level for the Installed Thickness (ft)
H-max-@-Pi = Maximum Liquid Level for the Installed Thickness @ Design Internal Pressure (ft)
Ht' = Effective Hydrostatic Test Liquid Level per *API-650 F.2* (ft)
JE = Joint efficiency
loc = Course Location (ft)
Ma = Course Material
Pi-max-@-H = Maximum Allowable Internal Pressure for the Installed Thickness @ Design Liquid Level (inH2O)
Rwi = Impulsive Force Reduction Factor
t = Installed Thickness (in)
t_d = Course Design Thickness per *API-650 Sections J.3.3 and A.4.1* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *J.3.3 and A.4.1* (in)
W-1 = Shell Course Nominal Weight (lb)
W-1-corr = Shell Course Nominal Weight (lb)

CA = 0 in
H = 24.0 ft
h1 = 8.0 ft
H-Hydrotest = 24.0 ft
JE = 0.7
loc = 0 ft
Ma = A36
Rwi = 4
t = 0.25 in

Shell Course Center of Gravity (CG-1) = 4.0 ft

D1 = OD - t
D1 = 144.0 - 0.25
D1 = 143.75 in

W-1 = pi * Dc * t * h1 * d
W-1 = pi * 143.75 * 0.25 * 96.0 * 0.2833
W-1 = 3,070.5455 lb

W-1-corr = pi * Dc * (t - CA) * h1 * d
W-1-corr = pi * 143.75 * (0.25 - 0) * 96.0 * 0.2833
W-1-corr = 3,070.5455 lb

Material Properties
Material = A36
Minimum Tensile Strength (Sut) = 58,000 psi
Minimum Yield Strength (Sy) = 36,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd) = 21,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Hydrostatic Test Stress (St) = 21,000 psi
Permissible Design Metal Temperature (MDMT-permissible) = -20 °F

Thickness Required by Erection
As per API-650 J.3.3.b, Thickness Required by Erection (t_erec) = 0.236 in

Thickness Required by Design
H' = H
H' = 24.0
H' = 24.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 12.0 * (24.0 - 1) * 1) / (0.7 * 21,000)) + 0
t_d = 0.0488 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 24.0
Ht' = 24.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 12.0 * (24.0 - 1) * 1) / (0.7 * 21,000)
t_t = 0.0488 in

Seismic Design Required Thickness
Nc = Convective Hoop Membrane Unit Force per *API 650 Section E.6.1.4* (lbf/in)
Nh = Product Hydrostatic Membrane Force per *API 650 Section E.6.1.4 and Section 5.6.3.2* (lbf/in)
Ni = Impulsive Hoop Membrane Unit Force per *API 650 Section E.6.1.4* (lbf/in)
Sd-seismic = Maximum Allowable Hoop Tension Membrane Stress per *API-650 E.6.2.4* (psi)
ts = Seismic Minimum Thickness per *API 650 Section E.6.2.4* (in)

As per API 650 Section E.6.1.4, Shell Course Liquid Surface to Analysis Point Distance (Y) = 24.0 ft

Ni = 1.39 * Ai * G * (D^2)
Ni = 1.39 * 0.06 * 1 * (12.0^2)
Ni = 12.0096 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.0494 * 1 * (12.0^2) * COSH(((3.68 * (24.0 - 24.0)) / 12.0))) / COSH(((3.68 * 24.0) / 12.0))
Nc = 0.0089 lbf/in

Nh = 2.6 * (H - H_offset) * D * G
Nh = 2.6 * (24.0 - 0) * 12.0 * 1
Nh = 748.8 lbf/in

sigma_T- = Total Combined Hoop Stress per *API 650 Eq E.6.1.4-6, Sections E.6.1.4, EC.6.1.3* (psi)
sigma_T+ = Total Combined Hoop Stress per *API 650 Eq E.6.1.4-6, Sections E.6.1.4, EC.6.1.3* (psi)

sigma_T+ = (Nh + SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T+ = (748.8 + SQRT(((12.0096^2) + (0.0089^2) + (((0.0896 * 748.8) / 2.5)^2)))) / MAX((0.25 - 0) , 0.0001)
sigma_T+ = 3,112.8064 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (748.8 - SQRT(((12.0096^2) + (0.0089^2) + (((0.0896 * 748.8) / 2.5)^2)))) / MAX((0.25 - 0) , 0.0001)
sigma_T- = 2,877.5936 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 21,000) , (0.9 * 36,000 * 0.7))
Sd-seismic = 22,680 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA
ts = ((3,112.8064 * (0.25 - 0)) / 22,680.0) + 0
ts = 0.0343 in

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts)
t-min = MAX(0.236 , 0.0488 , 0.0488 , 0.0343)
t-min = 0.236 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.25 - 0) * 21,000 * 0.7) / (2.6 * 12.0 * 1)) + 1) + 0
H-max = 118.7885 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(118.7885 , 0)
H-max-@-Pi = 118.7885 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((118.7885 - (24.0 + 0)) * (12 * 1)) + 0.0) , 0)
Pi-max-@-H = 1,137.4615 inH2O

Course # 2 Design
CA = Corrosion allowance per *API-650 5.3.2* (in)
D2 = Shell Course Centerline Diameter (in)
H = Design Liquid Level per *API-650 5.6.3.2* (ft)
H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)
h2 = Course Height (ft)
H-Hydrotest = Hydrotest Liquid Level per *API-650 5.6.3.2* (ft)
H-max = Maximum Liquid Level for the Installed Thickness (ft)
H-max-@-Pi = Maximum Liquid Level for the Installed Thickness @ Design Internal Pressure (ft)
Ht' = Effective Hydrostatic Test Liquid Level per *API-650 F.2* (ft)
JE = Joint efficiency
loc = Course Location (ft)
Ma = Course Material
Pi-max-@-H = Maximum Allowable Internal Pressure for the Installed Thickness @ Design Liquid Level (inH2O)
Rwi = Impulsive Force Reduction Factor
t = Installed Thickness (in)
t_d = Course Design Thickness per *API-650 Sections J.3.3 and A.4.1* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *J.3.3 and A.4.1* (in)
W-2 = Shell Course Nominal Weight (lb)
W-2-corr = Shell Course Nominal Weight (lb)

CA = 0 in
H = 16.0 ft
h2 = 8.0 ft
H-Hydrotest = 16.0 ft
JE = 0.7
loc = 8.0 ft
Ma = A36
Rwi = 4
t = 0.25 in

Shell Course Center of Gravity (CG-2) = 12.0 ft

D2 = OD - t
D2 = 144.0 - 0.25
D2 = 143.75 in

W-2 = pi * Dc * t * h2 * d
W-2 = pi * 143.75 * 0.25 * 96.0 * 0.2833
W-2 = 3,070.5455 lb

W-2-corr = pi * Dc * (t - CA) * h2 * d
W-2-corr = pi * 143.75 * (0.25 - 0) * 96.0 * 0.2833
W-2-corr = 3,070.5455 lb

Material Properties
Material = A36
Minimum Tensile Strength (Sut) = 58,000 psi
Minimum Yield Strength (Sy) = 36,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd) = 21,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Hydrostatic Test Stress (St) = 21,000 psi
Permissible Design Metal Temperature (MDMT-permissible) = -20 °F

Thickness Required by Erection
As per API-650 J.3.3.b, Thickness Required by Erection (t_erec) = 0.236 in

Thickness Required by Design
H' = H
H' = 16.0
H' = 16.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 12.0 * (16.0 - 1) * 1) / (0.7 * 21,000)) + 0
t_d = 0.0318 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 16.0
Ht' = 16.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 12.0 * (16.0 - 1) * 1) / (0.7 * 21,000)
t_t = 0.0318 in

Seismic Design Required Thickness
Nc = Convective Hoop Membrane Unit Force per *API 650 Section E.6.1.4* (lbf/in)
Nh = Product Hydrostatic Membrane Force per *API 650 Section E.6.1.4 and Section 5.6.3.2* (lbf/in)
Ni = Impulsive Hoop Membrane Unit Force per *API 650 Section E.6.1.4* (lbf/in)
Sd-seismic = Maximum Allowable Hoop Tension Membrane Stress per *API-650 E.6.2.4* (psi)
ts = Seismic Minimum Thickness per *API 650 Section E.6.2.4* (in)

As per API 650 Section E.6.1.4, Shell Course Liquid Surface to Analysis Point Distance (Y) = 16.0 ft

Ni = 1.39 * Ai * G * (D^2)
Ni = 1.39 * 0.06 * 1 * (12.0^2)
Ni = 12.0096 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.0494 * 1 * (12.0^2) * COSH(((3.68 * (24.0 - 16.0)) / 12.0))) / COSH(((3.68 * 24.0) / 12.0))
Nc = 0.0519 lbf/in

Nh = 2.6 * (H - H_offset) * D * G

Nh = 2.6 * (16.0 - 0) * 12.0 * 1
Nh = 499.2 lbf/in

sigma_T- = Total Combined Hoop Stress per *API 650 Eq E.6.1.4-6, Sections E.6.1.4, EC.6.1.3* (psi)
sigma_T+ = Total Combined Hoop Stress per *API 650 Eq E.6.1.4-6, Sections E.6.1.4, EC.6.1.3* (psi)

sigma_T+ = (Nh + SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T+ = (499.2 + SQRT(((12.0096^2) + (0.0519^2) + (((0.0896 * 499.2) / 2.5)^2)))) / MAX((0.25 - 0) , 0.0001)
sigma_T+ = 2,082.9935 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (499.2 - SQRT(((12.0096^2) + (0.0519^2) + (((0.0896 * 499.2) / 2.5)^2)))) / MAX((0.25 - 0) , 0.0001)
sigma_T- = 1,910.6065 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 21,000) , (0.9 * 36,000 * 0.7))
Sd-seismic = 22,680 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA
ts = ((2,082.9935 * (0.25 - 0)) / 22,680.0) + 0
ts = 0.023 in

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts)
t-min = MAX(0.236 , 0.0318 , 0.0318 , 0.023)
t-min = 0.236 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.25 - 0) * 21,000 * 0.7) / (2.6 * 12.0 * 1)) + 1) + 8.0
H-max = 126.7885 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(126.7885 , 0)
H-max-@-Pi = 126.7885 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((126.7885 - (16.0 + 8.0)) * (12 * 1)) + 0.0) , 0)
Pi-max-@-H = 1,233.4615 inH2O

Course # 3 Design
CA = Corrosion allowance per *API-650 5.3.2* (in)
D3 = Shell Course Centerline Diameter (in)
H = Design Liquid Level per *API-650 5.6.3.2* (ft)
H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)
h3 = Course Height (ft)
H-Hydrotest = Hydrotest Liquid Level per *API-650 5.6.3.2* (ft)
H-max = Maximum Liquid Level for the Installed Thickness (ft)
H-max-@-Pi = Maximum Liquid Level for the Installed Thickness @ Design Internal Pressure (ft)
Ht' = Effective Hydrostatic Test Liquid Level per *API-650 F.2* (ft)
JE = Joint efficiency
loc = Course Location (ft)
Ma = Course Material
Pi-max-@-H = Maximum Allowable Internal Pressure for the Installed Thickness @ Design Liquid Level

(inH2O)
Rwi = Impulsive Force Reduction Factor
t = Installed Thickness (in)
t_d = Course Design Thickness per *API-650 Sections J.3.3 and A.4.1* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *J.3.3 and A.4.1* (in)
W-3 = Shell Course Nominal Weight (lb)
W-3-corr = Shell Course Nominal Weight (lb)

CA = 0 in
H = 8.0 ft
h3 = 7.9792 ft
H-Hydrotest = 8.0 ft
JE = 0.7
loc = 16.0 ft
Ma = A36
Rwi = 4
t = 0.25 in

Shell Course Center of Gravity (CG-3) = 19.9896 ft

D3 = OD - t
D3 = 144.0 - 0.25
D3 = 143.75 in

W-3 = pi * Dc * t * h3 * d
W-3 = pi * 143.75 * 0.25 * 95.75 * 0.2833
W-3 = 3,062.5493 lb

W-3-corr = pi * Dc * (t - CA) * h3 * d
W-3-corr = pi * 143.75 * (0.25 - 0) * 95.75 * 0.2833
W-3-corr = 3,062.5493 lb

Material Properties
Material = A36
Minimum Tensile Strength (Sut) = 58,000 psi
Minimum Yield Strength (Sy) = 36,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd) = 21,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Hydrostatic Test Stress (St) = 21,000 psi
Permissible Design Metal Temperature (MDMT-permissible) = -20 °F

Thickness Required by Erection
As per API-650 J.3.3.b, Thickness Required by Erection (t_erec) = 0.236 in

Thickness Required by Design
H' = H
H' = 8.0
H' = 8.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 12.0 * (8.0 - 1) * 1) / (0.7 * 21,000)) + 0
t_d = 0.0149 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 8.0

Ht' = 8.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 12.0 * (8.0 - 1) * 1) / (0.7 * 21,000)
t_t = 0.0149 in

Seismic Design Required Thickness
Nc = Convective Hoop Membrane Unit Force per *API 650 Section E.6.1.4* (lbf/in)
Nh = Product Hydrostatic Membrane Force per *API 650 Section E.6.1.4 and Section 5.6.3.2* (lbf/in)
Ni = Impulsive Hoop Membrane Unit Force per *API 650 Section E.6.1.4* (lbf/in)
Sd-seismic = Maximum Allowable Hoop Tension Membrane Stress per *API-650 E.6.2.4* (psi)
ts = Seismic Minimum Thickness per *API 650 Section E.6.2.4* (in)

As per API 650 Section E.6.1.4, Shell Course Liquid Surface to Analysis Point Distance (Y) = 8.0 ft

Ni = 2.77 * Ai * G * (D^2) * ((Y / (0.75 * D)) - (0.5 * ((Y / (0.75 * D))^2)))
Ni = 2.77 * 0.06 * 1 * (12.0^2) * ((8.0 / (0.75 * 12.0)) - (0.5 * ((8.0 / (0.75 * 12.0))^2)))
Ni = 11.8187 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.0494 * 1 * (12.0^2) * COSH(((3.68 * (24.0 - 8.0)) / 12.0))) / COSH(((3.68 * 24.0) / 12.0))
Nc = 0.5996 lbf/in

Nh = 2.6 * (H - H_offset) * D * G
Nh = 2.6 * (8.0 - 0) * 12.0 * 1
Nh = 249.6 lbf/in

sigma_T- = Total Combined Hoop Stress per *API 650 Eq E.6.1.4-6, Sections E.6.1.4, EC.6.1.3* (psi)
sigma_T+ = Total Combined Hoop Stress per *API 650 Eq E.6.1.4-6, Sections E.6.1.4, EC.6.1.3* (psi)

sigma_T+ = (Nh + SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T+ = (249.6 + SQRT(((11.8187^2) + (0.5996^2) + (((0.0896 * 249.6) / 2.5)^2)))) / MAX((0.25 - 0) , 0.0001)
sigma_T+ = 1,057.7384 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (249.6 - SQRT(((11.8187^2) + (0.5996^2) + (((0.0896 * 249.6) / 2.5)^2)))) / MAX((0.25 - 0) , 0.0001)
sigma_T- = 939.0616 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 21,000) , (0.9 * 36,000 * 0.7))
Sd-seismic = 22,680 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA
ts = ((1,057.7384 * (0.25 - 0)) / 22,680.0) + 0
ts = 0.0117 in

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts)
t-min = MAX(0.236 , 0.0149 , 0.0149 , 0.0117)
t-min = 0.236 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.25 - 0) * 21,000 * 0.7) / (2.6 * 12.0 * 1)) + 1) + 16.0

H-max = 134.7885 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(134.7885 , 0)
H-max-@-Pi = 134.7885 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((134.7885 - (8.0 + 16.0)) * (12 * 1)) + 0.0) , 0)
Pi-max-@-H = 1,329.4615 inH2O

Shell Design Summary Results

W-ins = t-ins * d-ins * pi * (OD + t-ins) * H
W-ins = 0.0 * 8 * pi * (12.0 + 0.0) * 24
W-ins = 0.0 lbf

W-shell-corr = (W-1-corr + W-2-corr + W-3-corr) + W-shell-add
W-shell-corr = (3,070.5455 + 3,070.5455 + 3,062.5493) + 0
W-shell-corr = 9,203.6404 lb

W-shell = (W-1 + W-2 + W-3) + W-shell-add
W-shell = (3,070.5455 + 3,070.5455 + 3,062.5493) + 0
W-shell = 9,203.6404 lb

CG-shell = ((CG-1 * W-1) + (CG-2 * W-2) + (CG-3 * W-3)) / W-shell
CG-shell = ((4.0 * 3,070.5455) + (12.0 * 3,070.5455) + (19.9896 * 3,062.5493)) / 9,203.6404
CG-shell = 11.9896 ft

Shell Design Summary

Course	Height (ft)	Material	CA (in)	JE	Sy (psi)	Sut (psi)	Sd (psi)	St (psi)	t_erec (in)
3	7.9792	A36	0	0.7	36,000	58,000	21,000	21,000	0.236
2	8.0	A36	0	0.7	36,000	58,000	21,000	21,000	0.236
1	8.0	A36	0	0.7	36,000	58,000	21,000	21,000	0.236

Shell Design Summary (continued)

Course	t-design (in)	t-test (in)	t-seismic (in)	t-ext (in)	t-min (in)	t-installed (in)	Status	H-max-@-Pi (ft)	Pi-max-@-H (psi)
3	0.0149	0.0149	0.0117	N/A	0.236	0.25	PASS	134.7885	48.0285
2	0.0318	0.0318	0.023	N/A	0.236	0.25	PASS	126.7885	44.5604
1	0.0488	0.0488	0.0343	N/A	0.236	0.25	PASS	118.7885	41.0923

Intermediate Stiffeners Design

Stiffeners Design For Wind Loading

D = Nominal Tank Diameter (ft)
H1 = Maximum Unstiffened Transformed Shell Height per *API-650 5.9.6.1* (ft)
N = Actual Wind Girders Quantity
Ns = Required Number of Girders per *API 650 5.9.6.3 and 5.9.6.4*
Pwd = Design Wind Pressure Including Inward Drag per *API-650 5.9.6.1* (psf)
Pwv = Wind Pressure where Design Wind Speed V is Used per *API-650 5.9.6.1* (psf)
ts_min = Thickness of the Thinnest Shell Course (in)
V = Wind velocity (mile/hr)

D = 12.0 ft
N = 0
V = 105.0 mile/hr

Shell Courses Heights (W) = [8.0 8.0 7.9792] ft

ts_min = MIN(ts_1 , ts_2 , ts_3)
ts_min = MIN(0.25 , 0.25 , 0.25)
ts_min = 0.25 in

Stiffeners Required Quantity

HTS = Height of Transformed Shell per *API 650 5.9.6.2* (ft)

Transformed shell courses heights

Variable	Equation	Value	Unit		
Wtr_1	W_1 * SQRT(((t_min / ts_1)^5))	8.0000	ft	N/A	N/A
Wtr_2	W_2 * SQRT(((t_min / ts_2)^5))	8.0000	ft	N/A	N/A
Wtr_3	W_3 * SQRT(((t_min / ts_3)^5))	7.9792	ft	N/A	N/A

HTS = Wtr_1 + Wtr_2 + Wtr_3
HTS = 8.0 + 8.0 + 7.9792
HTS = 23.9792 ft

Pwv = 31 * ((V / 120)^2)
Pwv = 31 * ((105.0 / 120)^2)
Pwv = 23.7344 psf

Pwd = Pwv + 5
Pwd = 23.7344 + 5
Pwd = 28.7344 psf

H1 = 600000 * ts_min * SQRT(((ts_min / D)^3)) * (36 / Pwd)
H1 = 600000 * 0.25 * SQRT(((0.25 / 12.0)^3)) * (36 / 28.7344)
H1 = 565.1063 ft

Ns = CEILING(((HTS / Hsafe) - 1))
Ns = CEILING(((23.9792 / 565.1063) - 1))
Ns = 0

N >= Ns ==> PASS

Flat Bottom: non Annular Plate Design [Back]

Bottom Type = Flat
Bottom Support Type = Continuously Supported on Foundation

CA = Corrosion allowance (in)
CA_1 = Bottom Shell Course Corrosion Allowance (in)
chime = Outside Projection (Chime Distance) (in)
E = Joint efficiency
Ma_1 = Bottom Shell Course Material
Ma-bottom = Material
S = Bottom Shell Course Maximum Stress (psi)
S1 = Bottom Shell Course Product Stress per *API-650 Table 5.1b Note b* (psi)
S2 = Bottom Shell Course Hydrostatic Stress per *API-650 Table 5.1b Note b* (psi)
Sd_1 = Bottom Shell Course Allowable Design Stress (psi)
St_1 = Bottom Shell Course Allowable Hydrostatic Test Stress (psi)
tb = Installed Thickness (in)
tb-req = Bottom Required Thickness (in)
td_1 = Bottom Shell Course Design Thickness (in)
ts_1 = Bottom Shell Course Nominal Thickness (in)
tt_1 = Bottom Shell Course Hydrotest Thickness (in)

CA = 0 in
CA_1 = 0 in
chime = 1 in
E = 0.7
Ma_1 = A36
Ma-bottom = A36
Sd_1 = 21,000 psi
St_1 = 21,000 psi
tb = 0.25 in
td_1 = 0.0488 in
ts_1 = 0.25 in
tt_1 = 0.0488 in

Bottom Plates Material Properties
Material = A36
Minimum Tensile Strength (Sut-btm) = 58,000 psi
Minimum Yield Strength (Sy-btm) = 36,000 psi
Density (d-btm) = 0.2833 lb/in^3
Permissible Design Metal Temperature (MDMT-permissible-btm) = -20 °F

Calculation of Hydrostatic Test Stress & Product Stress per API-650 Section 5.5.1
S1 = ((td_1 - CA_1) / (ts_1 - CA_1)) * Sd_1
S1 = ((0.0488 - 0) / (0.25 - 0)) * 21,000
S1 = 4,100.5714 psi

As per API-650 5.5.1, first shell course material, A36, is in Group I; therefore, butt welded annular plates are not required

S2 = (tt_1 / ts_1) * St_1
S2 = (0.0488 / 0.25) * 21,000
S2 = 4,100.5714 psi

As per API-650 5.5.1, first shell course material, A36, is in Group I; therefore, butt welded annular plates are not required

S = MAX(S1 , S2)
S = MAX(4,100.5714 , 4,100.5714)
S = 4,100.5714 psi

Bottom Weight
A-btm = Bottom Surface Area (ft^2)
CA = Corrosion allowance (in)
chime = Outside Projection (Chime Distance) (in)
OD-btm = Bottom Outer Diameter (ft)
tb = Installed Thickness (in)
Wb-pl = Bottom Plates Weight (lb)
Wb-pl-add = Bottom Additional Weight (lb)
Wb-pl-corr = Bottom Corroded Plates Weight (lb)
Wb-pl-corroded-overlap = Bottom Weight Corroded Overlap (lb)
Wb-pl-overlap = Bottom Overlap Weight (lb)

CA = 0 in
chime = 1 in
tb = 0.25 in
Wb-pl-add = 0 lb
Wb-pl-corroded-overlap = 0.5378 lb
Wb-pl-overlap = 0.5378 lb

OD-btm = OD + (chime * 2)
OD-btm = 12.0 + (0.0833 * 2)
OD-btm = 12.1667 ft

A-btm = pi * ((OD-btm / 2)^2)
A-btm = pi * ((12.1667 / 2)^2)
A-btm = 116.2607 ft^2

Wb-pl = (A-btm * tb * d-btm) + Wb-pl-overlap + Wb-pl-add
Wb-pl = (16,741.5473 * 0.25 * 0.2833) + 0.5378 + 0
Wb-pl = 1,186.2579 lb

Wb-pl-corr = (A-btm * (tb - CA) * d-btm) + Wb-pl-corroded-overlap + Wb-pl-add
Wb-pl-corr = (16,741.5473 * (0.25 - 0) * 0.2833) + 0.5378 + 0
Wb-pl-corr = 1,186.2579 lb

Bottom Design due to External Pressure
P-btm = Downward Pressure (psi)

Liquid Height to Pressure Conversion Factor (f) = 0.4335

P-btm = (d-btm * (tb - CA-btm)) + (Lmin * f * SG)
P-btm = (0.2833 * (0.25 - 0)) + (1.0 * 0.4335 * 1)
P-btm = 0.5043 psi

P-btm >= Pv ==> There is no uplift due to external pressure

Bottom Required Thickness
As per API-650 J.3.2.1, Required Thickness by Erection (tb-erec) = 0.236 in

tb-req = tb-erec
tb-req = 0.236
tb-req = 0.236 in

tb >= tb-req ==> PASS

Bottom Outside Projection
As per API-650 J.3.2.3, Minimum Required Outside Projection (chime) = 1 in

chime >= chime ==> PASS

Wind Moment (Per API-650 Section 5.11)

Back

Wind Pressures per API-650 & ASCE7-05

I = Wind Importance Factor per *ASCE 7-05 Table 6-1*
P_WR = Roof Design Wind Pressure per *API-650 5.2.1.k* (psf)
P_WS = Shell Design Wind Pressure per *API-650 5.2.1.k* (psf)
V = Design Wind Velocity (3-sec gust) per *ASCE 7-05* (mph)
V_s = Adjusted Design Wind Velocity per *API 650 Section 5.2.1.k* (mph)

I = 1
V = 105.0 mph

Wind Velocity per API-650 and ASCE7-05

V_s = V * SQRT(I)
V_s = 105.0 * SQRT(1)
V_s = 105.0 mph

Roof Wind Pressure
P_WR = 31 * ((V_s / 120)^2)
P_WR = 31 * ((105.0 / 120)^2)
P_WR = 23.7344 psf

Shell Wind Pressure
P_WS = 18.6 * ((V_s / 120)^2)
P_WS = 18.6 * ((105.0 / 120)^2)
P_WS = 14.2406 psf

Wind Overturning and Sliding Stability

Ah = Roof Horizontal Projected Area (ft^2)
Ah-total = Roof Horizontal Projected Area Including Insulation (ft^2)
As = Shell Total Vertical Projected Area (ft^2)
Av-roof = Roof Vertical Projected Area (ft^2)
CA_1 = Bottom Shell Course Corrosion Allowance (in)
CA-btm = Corrosion Allowance of Bottom Plates Under the Shell (in)
CG-roof = Roof Center of Gravity (ft)
COF = Maximum Allowable Sliding Friction Coefficient per *API 650, Section 5.11.4*
DLR = Nominal Weight of Roof Plates and Attached Structural (lbf)
DLS = Nominal Weight of Shell Plates and Framing (lbf)
D-outer = Tank Max Outer Diameter (ft)
Fby = Yield Strength of Bottom Plates Under the Shell (psi)
F-friction = Friction Force per *API 650, Section 5.11.4* (lbf)
F-wind = Sliding Force (lbf)
M_DL = Moment About the Shell-To-Bottom Joint from the Nominal Weight of the Shell (ft.lbf)
M_DLR = Moment About the Shell-To-Bottom Joint from the Nominal Weight of the Roof Plate Plus any Attached Structural (ft.lbf)
M_F = Moment About the Shell-To-Bottom Joint From Liquid Weight (ft.lbf)
M_Pi = Moment About the Shell-To-Bottom Joint From Design Internal Pressure per *API-650 5.11.2.2* (ft.lbf)
M_w = Overturning Moment About the Shell-To-Bottom Joint from Wind Pressures per *API-650 5.11.2.2*

(ft.lbf)
M_WR = Roof Wind Overturning Moment per *API-650 5.11.2.2* (ft.lbf)
M_WS = Shell Wind Overturning Moment per *API-650 5.11.2.2* (ft.lbf)
Rh = Roof Horizontal Radius (ft)
tb = Thickness of Bottom Plates Under the Shell (in)
tr-ins = Roof Insulation Thickness (in)
ts_1 = Bottom Shell Course Nominal Thickness (in)
ts-ins = Shell Insulation Thickness (in)
W-access-corr = Access Corroded Weight (lbf)
W-app-corr = Appurtenances Corroded Weight (lbf)
Wb-pl-corr = Bottom Corroded Plates Weight (lbf)
wind-uplift = Wind Uplift per *API-650 5.2.1.k* (psf)
wL = Tank Content Resisting Weight per *API-650 5.11.2.3* (lbf/ft)
Wr-pl = Roof New Plates Weight (lbf)
Wr-pl-corr = Roof Corroded Plates Weight (lbf)
Ws-framing = Shell New Framing Weight (lbf)
Ws-framing-corr = Shell Corroded Framing Weight (lbf)
Ws-pl = Shell New Plates Weight (lbf)
Ws-pl-corr = Shell Corroded Plates Weight (lbf)
Ws-struct-corr = Roof Corroded Structure Weight Supported by Shell (lbf)
W-stairs-corr = Stairways Corroded Weight (lbf)
W-struct = Roof New Structure Weight (lbf)
W-struct-corr = Roof Corroded Structure Weight (lbf)
W-windgirder-corr = Wind Girder Corroded Weight (lbf)
Xs = Moment Arm of Wind Force on Shell (ft)
Xw = Moment Arm of Wind Force on Roof (ft)

Ah = 115.8916 ft^2
Av-roof = 6.1482 ft^2
CA_1 = 0 in
CA-btm = 0 in
CG-roof = 0.3374 ft
COF = 0.4
DLR = 1,347.6695 lbf
DLS = 9,473.3895 lbf
Fby = 36,000 psi
Rh = 6.0737 ft
tb = 0.25 in
tr-ins = 0 in
ts_1 = 0.25 in
ts-ins = 0 in
W-access-corr = 0 lbf
W-app-corr = 340.3158 lbf
Wb-pl-corr = 1,186.2579 lbf
Wr-pl = 1,198.2584 lbf
Wr-pl-corr = 1,198.2584 lbf
Ws-framing = 269.7491 lbf
Ws-framing-corr = 270.7586 lbf
Ws-pl = 9,203.6404 lbf
Ws-pl-corr = 9,203.6404 lbf
Ws-struct-corr = 0.0 lbf
W-stairs-corr = 0 lbf
W-struct = 0.0 lbf
W-struct-corr = 0.0 lbf
W-windgirder-corr = 0 lbf

Design Uplift Pressure per API-650 5.2.1.k

The internal pressure uplift force does not exceed the weight of roof plates, Annex F Section F.4.1 is not applicable. Therefore the wind uplift is not limited per API-650 Section 5.2.1.k.2.

wind-uplift = P_WR
wind-uplift = 23.7344
wind-uplift = 23.7344 psf

Overturning Moments

Xw = D / 2
Xw = 12.0 / 2
Xw = 6.0 ft

Ah-total = pi * ((Rh + tr-ins)^2)
Ah-total = pi * ((6.0737 + 0.0)^2)
Ah-total = 115.8916 ft^2

M_Pi = Pg * Ah * Xw
M_Pi = 0.0 * 115.8916 * 6.0
M_Pi = 0.0 ft.lbf

M_WR = wind-uplift * Ah-total * Xw
M_WR = 23.7344 * 115.8916 * 6.0
M_WR = 16,503.6813 ft.lbf

D-outer = OD + (2 * (ts-ins / 12))
D-outer = 12.0 + (2 * (0 / 12))
D-outer = 12.0 ft

As = D-outer * H
As = 12.0 * 24
As = 288.0 ft^2

Xs = H / 2
Xs = 24 / 2
Xs = 12 ft

M_WS = P_WS * As * Xs
M_WS = 14.2406 * 288.0 * 12
M_WS = 49,215.6 ft.lbf

M_w = M_WR + M_WS
M_w = 16,503.6813 + 49,215.6
M_w = 65,719.2813 ft.lbf

Resistance to Overturning per API-650 5.11.2

M_DL = (D / 2) * DLS
M_DL = (12.0 / 2) * 9,473.3895
M_DL = 56,840.3371 ft.lbf

M_DLR = (D / 2) * DLR
M_DLR = (12.0 / 2) * 1,347.6695
M_DLR = 8,086.0171 ft.lbf

wL = MIN((0.45 * Lmax * D) , (4.67 * (tb-req - CA-btm) * SQRT((Fby * Lmax))))

wL = MIN((0.45 * 24.0 * 12.0) , (4.67 * (0.236 - 0) * SQRT((36,000 * 24.0))))
wL = 129.6 lbf/ft

M_F = (D / 2) * wL * pi * D
M_F = (12.0 / 2) * 129.6 * pi * 12.0
M_F = 29,314.8294 ft.lbf

An unanchored tank must meet the criteria from API-650 5.11.2.1
Criterion 1
((0.6 * M_w) + M_Pi) < ((M_DL / 1.5) + M_DLR)
((0.6 * 65,719.2813) + 0.0) < ((56,840.3371 / 1.5) + 8,086.0171)
39,431.5688 < 45,979.5752 ==> Tank is stable

Criterion 2
(M_w + (Fp * M_Pi)) < (((M_DL + M_F) / 2) + M_DLR)
(65,719.2813 + (0.4 * 0.0)) < (((56,840.3371 + 29,314.8294) / 2) + 8,086.0171)
Since 65,719.2813 >= 51,163.6004 ==> Tank must be anchored

Criterion 3
(M_WS + (Fp * M_Pi)) < ((M_DL / 1.5) + M_DLR)
(49,215.6 + (0.4 * 0.0)) < ((56,840.3371 / 1.5) + 8,086.0171)
Since 49,215.6 >= 45,979.5752 ==> Tank must be anchored

Resistance to Sliding per API-650 5.11.4
F-wind = P_WS * As
F-wind = 14.2406 * 288.0
F-wind = 4,101.3 lbf

F-friction = COF * (Wr-pl-corr + W-struct-corr + Ws-pl-corr + Ws-framing-corr + Wb-pl-corr + W-stairs-corr + W-access-corr + W-app-corr + W-windgirder-corr)
F-friction = 0.4 * (1,198.2584 + 0.0 + 9,203.6404 + 270.7586 + 1,186.2579 + 0 + 0 + 340.3158 + 0)
F-friction = 4,879.6924 lbf

F-friction >= F-wind ==> Tank is stable

Anchorage Requirement
Tank must be anchored per API-650 5.11 by Criterion 2 and Criterion 3

Seismic Design Back

Site Ground Motion Design

Seismic Method = ASCE7-MAPPED-SS-AND-S1

Ac = Convective Design Response Spectrum Acceleration Coefficient per *API 650 Sections E.4.6.1*
Ac-min = Adjusted Convective Design Response Spectrum Acceleration Coefficient
Af = Acceleration Coefficient for Sloshing Wave Height per *API 650 Sections E.7.2*
Ai = per *API 650 Sections E.4.6.1*
Ai = Impulsive Design Response Spectrum Acceleration Coefficient per *API 650 Sections E.4.6.1*
Anchorage_System = Anchorage System
Av = Vertical Ground Acceleration Coefficient per *API 650 Sections E.6.1.3 and E.2.2*
D = Nominal Tank Diameter (ft)
Fa = Site Acceleration Coefficient
Fv = Site Velocity Coefficient
H = Maximum Design Product Level (ft)
I = Importance Factor
K = Spectral Acceleration Adjustment Coefficient
Ks = Sloshing Coefficient per *API 650 Section E.4.5.2*
Q = MCE to Design Level Scale Factor
rho_product = Product Mass Density (lbf/ft^3)
Rwc = Convective Force Reduction Factor
Rwi = Impulsive Force Reduction Factor
S1 = Spectral Response Acceleration at a Period of One Second
SD1 = Design Spectral Response Acceleration at a Period of One Second per *API 650 Sections E.4.6.1 and E.2.2*
SDS = Design Spectral Response Acceleration at Short Period per *API 650 Sections E.4.6.1 and E.2.2*
Seismic_Site_Class = Seismic Site Class
Seismic_Use_Group = Seismic Use Group
shell-course-modulus-of-elasticity-information-list = Shell Course Modulus of Elasticity Information List (psi)
shell-course-thickness-information-list = Shell Course Thickness Information List (in)
Ss = Spectral Response Acceleration Short Period
Tc = Convective Natural Period per *API 650 Section E.4.5.2* (sec)
TL = Regional Dependent Transistion Period for Longer Period Ground Motion (sec)

Anchorage_System = MECHANICALLY-ANCHORED
D = 12.0 ft
Fa = 1.2
Fv = 1.7
H = 24.0 ft
I = 1.25
K = 1.5
Q = 0.6667
rho_product = 62.4279 lbf/ft^3
Rwc = 2
Rwi = 4
S1 = 0.093
Seismic_Site_Class = SEISMIC-SITE-CLASS-C
Seismic_Use_Group = SEISMIC-USE-GROUP-II
shell-course-modulus-of-elasticity-information-list = [28,800,000 28,800,000 28,800,000.0] psi
shell-course-thickness-information-list = [0.25 0.25 0.25] in
Ss = 0.24
TL = 12 sec

SDS = Q * Fa * Ss
SDS = 0.6667 * 1.2 * 0.24
SDS = 0.192

SD1 = Q * Fv * S1
SD1 = 0.6667 * 1.7 * 0.093
SD1 = 0.1054

Ks = 0.578 / SQRT(TANH(((3.68 * H) / D)))
Ks = 0.578 / SQRT(TANH(((3.68 * 24.0) / 12.0)))
Ks = 0.578

Tc = Ks * SQRT(D)
Tc = 0.578 * SQRT(12.0)
Tc = 2.0023 sec

Ai = SDS * (I / Rwi)
Ai = 0.192 * (1.25 / 4)
Ai = 0.06

Ai = MAX(Ai , 0.007)
Ai = MAX(0.06 , 0.007)
Ai = 0.06

Tc <= TL

Ac = K * SD1 * (1 / Tc) * (I / Rwc)
Ac = 1.5 * 0.1054 * (1 / 2.0023) * (1.25 / 2)
Ac = 0.0494

Ac-min = MIN(Ac , Ai)
Ac-min = MIN(0.0494 , 0.06)
Ac-min = 0.0494

Av = (2 / 3) * 0.7 * SDS
Av = (2 / 3) * 0.7 * 0.192
Av = 0.0896

Af = K * SD1 * I * (1 / Tc)
Af = 1.5 * 0.1054 * 1.25 * (1 / 2.0023)
Af = 0.0987

Seismic Design

h_bottom = Bottom Elevation (ft)
h_bottom-ground = Bottom Elevation from Ground (ft)

h_bottom = 0.0 ft
h_bottom-ground = 0.0 ft

A = Roof Surface Area (ft^2)
Ac = Convective Design Response Spectrum Acceleration Coefficient
Af = Acceleration Coefficient for Sloshing Wave Height
Ah-shell = Roof Horizontal Projected Area Supported by The Shell (ft^2)
Ai = Impulsive Design Response Spectrum Acceleration Coefficient

Anchorage_System = Anchorage System
A-rs = Roof Area Supported by The Shell (ft^2)
Av = Vertical Ground Acceleration Coefficient
ca1 = Bottom Shell Course Corrosion Allowance (in)
ca_bottom = Bottom Corrosion Allowance (in)
D = Nominal Tank Diameter (ft)
DELTAs = Sloshing Wave Height Above Product Design Height per *API 650 Section E.7.2* (ft)
Event_Type = Event Type
Fa = Site Acceleration Coefficient
F_c = Allowable Longitudinal Shell Compression Stress per *API 650 Section E.6.2.2.3, Eq E.6.2.2.3-2b* (lbf/in^2)
Freeboard = Actual Freeboard (ft)
Freeboard_recommended = Minimum Recommended Freeboard per *API-650 Table E.7* (ft)
Fv = Site Velocity Coefficient
Fy = Yield Strength (lb/in^2)
G = Specific Gravity
Ge = Effective Specific Gravity per *API 650 Section E.2.2*
H = Maximum Design Product Level (ft)
Hrcg = Top of Shell to Roof and roof appurtenances Center of Gravity (ft)
hs = Additional Shell Height Required Above Sloshing Height (ft)
H_shell = Shell height (ft)
I = Importance Factor
J = Anchorage Ratio per *API 650 Section E.6.2.1.1.1*
K = Spectral Acceleration Adjustment Coefficient
Ks = Sloshing Coefficient
Min_Anchor_Quantity = Minimum Anchor Quantity per *API-650 5.12.2*
Min_Anchor_Spacing = Minimum Anchor Spacing per *API-650 5.12.3* (ft)
Mrw = Ringwall Overturning Moment per *API 650 Section E.6.1.5* (ft.lb)
Ms = Slab Overturning Moment per *API 650 Section E.6.1.5* (ft.lb)
mu = Friction Coefficient per *API 650, Section E.7.6*
Overturn_Stability_Ratio = Overturning Stability Ratio per *API 650 Section E.6.2.3*
P = Design Pressure (lbf/in^2)
Q = MCE to Design Level Scale Factor
S1 = Spectral Response Acceleration at a Period of One Second
Sb = Roof Balanced Snow Load (psf)
SD1 = Design Spectral Response Acceleration at a Period of 1 Second
SDS = Design Spectral Response Acceleration at Short Period
Seismic_Site_Class = Seismic Site Class
Seismic_Use_Group = Seismic Use Group
sigma_c = Mechanically Anchored Maximum Longitudinal Shell Compression Stress per *API 650 Section E.6.2.2.2, Eq E.6.2.2.2-1b* (lbf/in^2)
Ss = Spectral Response Acceleration Short Period
ta = Thickness, excluding corrosion allowance, of the bottom annulus under the shell required to provide the resisting force for self anchorage per *API-650 E.2.2* (in)
tb-corr = Bottom Plates Corroded Thickness (in)
t_bottom = Bottom Plate Thickness (in)
Tc = Convective Natural Period (sec)
TL = Regional Dependent Transistion Period for Longer Period Ground Motion (sec)
ts1 = Bottom Shell Course Thickness (in)
ts1_c = Shell Course 1 Corroded Thickness (in)
V = Total Design Base Shear per *API 650 Section E.6.1* (lbf)
Vc = Design Base Shear for Convective Component per *API 650 Section E.6.1* (lbf)
Vi = Design Base Shear for Impulsive Component per *API 650 Section E.6.1* (lbf)
Vmax = Local Shear Transfer per *API 650 Section E.7.7* (lbf/ft)
Vs = Self Anchored Sliding Resistance Maximum Allowable Base Shear per *API 650 Section E.7.6* (lbf)
w_a = Force Resisting Uplift - Self Anchored per *API 650 Section E.6.2.1.1* (lbf/ft)

w_a = (lbf/ft)
wa_limit = Self Anchored Force Resisting Uplift Max Limit per *API 650 Section E.6.2.1.1, Eq E.6.2.1.1-1b* (lbf/ft)
w_a_self-anchored = Self Anchored Force Resisting Uplift per *API 650 Section E.6.2.1.1, Eq E.6.2.1.1-1b* (lbf/ft)
Wb-attachments = Bottom Attachments Weight (lb)
Wb-pl = Bottom Plates Weight (lb)
Wc = Convective Effective Weight per *API 650 Section E.6.1.1* (lbf)
Weff = Total Effective Weight per *API 650 Section E.6.1.1* (lbf)
Wf = Tank Bottom Total Weight (lbf)
Wfd = Tank Foundation Weight (lbf)
Wg = Soil Weight (lbf)
Wi = Impulsive Effective Weight per *API 650 Section E.6.1.1* (lbf)
wint = Calculated Design Uplift Due to Product Pressure (lbf/ft)
Wp = Tank Contents Total Weight (lbf)
Wr = Total Weight of Fixed Tank Roof including Framing, Knuckles, any Permanent Attachments and 10 % of the Roof Balanced Design Snow Load (lbf)
Wr-attachments = Roof Attachments Weight (lb)
Wr-DL-add = Roof Additional Dead Weight (lb)
Wr-pl = Roof Plates Nominal Weight (lb)
wrs = Specified Tank Roof Load Acting on Tank Shell (lbf/ft)
Wrs = Roof Load Acting on The Tank Shell Including 10 % of the Roof Balanced Design Snow Load (lbf)
Ws = Total Weight of Tank Shell and Appurtenances (lbf)
Ws-attachments = Shell Attachments Weight (lb)
Ws-framing = Shell Framing Weight (lb)
Ws-pl = Shell Plates Nominal Weight (lb)
Wss = Roof Structure Weight Supported by The Tank Shell (lb)
W-struct = Roof Structure Weight (lb)
W_T = Total Weight of Tank Shell, Roof, Framing, Knuckles, Product, Bottom, Attachments, Appurtenances, Participating Balanced Snow Load per *API-650 Eq E.6.2.3-1* (lbf)
wt = Tank and Roof Weight Acting at base of Shell per *API 650 Section E.6.2.1.1.1* (lbf/ft)
Xc = Height from tank shell bottom to the center of action of convective lateral force for computing ringwall overturning moment per *API 650 Section E.6.1.2.1* (ft)
Xcs = Height from tank shell bottom to the center of action of convective lateral force for computing slab overturning moment per *API 650 Section E.6.1.2.2* (ft)
Xi = Height from tank shell bottom to the center of action of impulsive lateral force for computing ringwall overturning moment per *API 650 Section E.6.1.2.1* (ft)
Xis = Height from tank shell bottom to the center of action of impulsive lateral force for computing slab overturning moment per *API 650 Section E.6.1.2.2* (ft)
Xr = Height from tank shell bottom to the center of gravity of roof and roof appurtenances per *API 650 Section E.6.1.2* (ft)
Xs = Height from tank shell bottom to shell's center of gravity (ft)

A = 117.4901 ft^2
Ac = 0.0494
Af = 0.0987
Ah-shell = 115.8916 ft^2
Ai = 0.06
Anchorage_System = MECHANICALLY-ANCHORED
A-rs = 117.4901 ft^2
Av = 0.0896
ca1 = 0 in
ca_bottom = 0 in
D = 12.0 ft
Event_Type = MAXIMUM-CONSIDERED-EARTHQUAKE-MCE
Fa = 1.2

Fv = 1.7
Fy = 36,000.0 lb/in^2
G = 1
H = 24.0 ft
Hrcg = 0.3374 ft
hs = 0 ft
H_shell = 24 ft
I = 1.25
K = 1.5
Ks = 0.578
Min_Anchor_Quantity = 4
Min_Anchor_Spacing = 10 ft
mu = 0.4
P = 0.0 lbf/in^2
Q = 0.6667
S1 = 0.093
Sb = 0.0 psf
SD1 = 0.1054
SDS = 0.192
Seismic_Site_Class = SEISMIC-SITE-CLASS-C
Seismic_Use_Group = SEISMIC-USE-GROUP-II
Ss = 0.24
t_bottom = 0.25 in
Tc = 2.0023 sec
TL = 12 sec
ts1 = 0.25 in
Wb-attachments = 0 lb
Wb-pl = 1,186.2579 lb
Wfd = 0 lbf
Wg = 0 lbf
Wp = 168,275.6044 lbf
Wr-attachments = 149.4112 lb
Wr-DL-add = 0.0 lb
Wr-pl = 1,198.2584 lb
Ws-attachments = 281.9047 lb
Ws-framing = 269.7491 lb
Ws-pl = 9,203.6404 lb
Wss = 0 lb
W-struct = 0 lb
Xs = 11.9896 ft

Seismic Method (seismic-method) = ASCE7-MAPPED-SS-AND-S1

Weights
Wf = Wb-pl
Wf = 1,186.2579
Wf = 1,186.2579 lbf

Wr = (Wr-pl + Wr-attachments + W-struct + Wr-DL-add) + (0.1 * Sb * Ah)
Wr = (1,198.2584 + 149.4112 + 0.0 + 0.0) + (0.1 * 0.0 * 115.8916)
Wr = 1,347.6695 lbf

Wrs = ((Wr-pl + Wr-attachments + Wr-DL-add) * (A-rs / A)) + Wss + (0.1 * Sb * Ah-shell)
Wrs = ((1,198.2584 + 149.4112 + 0.0) * (117.4901 / 117.4901)) + 0.0 + (0.1 * 0.0 * 115.8916)
Wrs = 1,347.6695 lbf

Ws = Ws-pl + Ws-framing + Ws-attachments
Ws = 9,203.6404 + 269.7491 + 281.9047
Ws = 9,755.2942 lbf

W_T = Ws + Wr + Wp + Wf
W_T = 9,755.2942 + 1,347.6695 + 168,275.6044 + 1,186.2579
W_T = 180,564.826 lbf

Effective Weight of Product
Wi = (1.0 - (0.218 * (D / H))) * Wp
Wi = (1.0 - (0.218 * (12.0 / 24.0))) * 168,275.6044
Wi = 149,933.5635 lbf

Wc = 0.23 * (D / H) * TANH(((3.67 * H) / D)) * Wp
Wc = 0.23 * (12.0 / 24.0) * TANH(((3.67 * 24.0) / 12.0)) * 168,275.6044
Wc = 19,351.6782 lbf

Weff = Wi + Wc
Weff = 149,933.5635 + 19,351.6782
Weff = 169,285.2417 lbf

Design Loads
Vi = Ai * (Ws + Wr + Wf + Wi)
Vi = 0.06 * (9,755.2942 + 1,347.6695 + 1,186.2579 + 149,933.5635)
Vi = 9,733.3671 lbf

Vc = Ac * Wc
Vc = 0.0494 * 19,351.6782
Vc = 955.9729 lbf

V = SQRT(((Vi^2) + (Vc^2)))
V = SQRT(((9,733.3671^2) + (955.9729^2)))
V = 9,780.2004 lbf

Center of Action for Effective Lateral Forces
Xr = H_shell + Hrcg
Xr = 24 + 0.3374
Xr = 24.3374 ft

Xi = (0.5 - (0.094 * (D / H))) * H
Xi = (0.5 - (0.094 * (12.0 / 24.0))) * 24.0
Xi = 10.872 ft

Xc = (1.0 - ((COSH(((3.67 * H) / D)) - 1) / (((3.67 * H) / D) * SINH(((3.67 * H) / D))))) * H
Xc = (1.0 - ((COSH(((3.67 * 24.0) / 12.0)) - 1) / (((3.67 * 24.0) / 12.0) * SINH(((3.67 * 24.0) / 12.0))))) * 24.0
Xc = 20.7345 ft

Xis = (0.5 + (0.06 * (D / H))) * H
Xis = (0.5 + (0.06 * (12.0 / 24.0))) * 24.0
Xis = 12.72 ft

Xcs = (1.0 - ((COSH(((3.67 * H) / D)) - 1.937) / (((3.67 * H) / D) * SINH(((3.67 * H) / D))))) * H
Xcs = (1.0 - ((COSH(((3.67 * 24.0) / 12.0)) - 1.937) / (((3.67 * 24.0) / 12.0) * SINH(((3.67 * 24.0) / 12.0))))) * 24.0
Xcs = 20.7385 ft

Overturning Moment
Mrw = SQRT((((Ai * ((Wi * Xi) + (Ws * Xs) + (Wr * Xr)))^2) + ((Ac * (Wc * Xc))^2)))
Mrw = SQRT((((0.06 * ((149,933.5635 * 10.872) + (9,755.2942 * 11.9896) + (1,347.6695 * 24.3374)))^2) + ((0.0494 * (19,351.6782 * 20.7345))^2)))
Mrw = 108,614.2967 ft.lb

Ms = SQRT((((Ai * ((Wi * Xis) + (Ws * Xs) + (Wr * Xr)))^2) + ((Ac * (Wc * Xcs))^2)))
Ms = SQRT((((0.06 * ((149,933.5635 * 12.72) + (9,755.2942 * 11.9896) + (1,347.6695 * 24.3374)))^2) + ((0.0494 * (19,351.6782 * 20.7385))^2)))
Ms = 124,997.176 ft.lb

Resistance to Design Loads
Ge = G * (1 - (0.4 * Av))
Ge = 1 * (1 - (0.4 * 0.0896))
Ge = 0.9642

wrs = Wrs / (pi * D)
wrs = 1,347.6695 / (pi * 12.0)
wrs = 35.748 lbf/ft

wt = (Ws / (pi * D)) + wrs
wt = (9,755.2942 / (pi * 12.0)) + 35.748
wt = 294.5153 lbf/ft

wint = P * 144 * ((pi * ((D^2) / 4)) / (pi * D))
wint = 0.0 * 144 * ((pi * ((12.0^2) / 4)) / (pi * 12.0))
wint = 0.0 lbf/ft

Bottom Annular Plates Requirements
tb-corr = t_bottom - ca_bottom
tb-corr = 0.25 - 0
tb-corr = 0.25 in

ts1_c = ts1 - ca1
ts1_c = 0.25 - 0
ts1_c = 0.25 in

ta = MIN(tb-corr , ts1_c)
ta = MIN(0.25 , 0.25)
ta = 0.25 in

wa_limit = 1.28 * H * D * Ge
wa_limit = 1.28 * 24.0 * 12.0 * 0.9642
wa_limit = 355.4279 lbf/ft

w_a_self-anchored = 7.9 * ta * SQRT((Fy * H * Ge))
w_a_self-anchored = 7.9 * 0.25 * SQRT((36,000.0 * 24.0 * 0.9642))
w_a_self-anchored = 1,802.5965 lbf/ft

w_a = MIN(w_a_self-anchored , wa_limit)
w_a = MIN(1,802.5965 , 355.4279)
w_a = 355.4279 lbf/ft

w_a = w_a
w_a = 355.4279

w_a = 355.4279 lbf/ft

Tank Stability
J = Mrw / ((D^2) * (((wt * (1 - (0.4 * Av))) + wa) - (Fp * wint)))
J = 108,614.2967 / ((12.0^2) * (((294.5153 * (1 - (0.4 * 0.0896))) + 355.4279) - (0.4 * 0.0)))
J = 1.1797

J <= 1.54 ==> Tank is stable, anchoring is not required

Seismic Method (seismic-method) = ASCE7-MAPPED-SS-AND-S1

sigma_c = ((wt * (1 + (0.4 * Av))) + ((1.273 * Mrw) / (D^2))) * (1 / (12 * ts))
sigma_c = ((294.5153 * (1 + (0.4 * 0.0896))) + ((1.273 * 108,614.2967) / (12.0^2))) * (1 / (12 * 0.25))
sigma_c = 421.7504 lbf/in^2

F_c = (1.0E6 * (ts / (2.5 * D))) + (600 * SQRT((G * H)))
F_c = (1.0E6 * (0.25 / (2.5 * 12.0))) + (600 * SQRT((1 * 24.0)))
F_c = 11,272.721 lbf/in^2

sigma_c < F_c

Overturn_Stability_Ratio = (0.5 * D * (W_T + Wfd + Wg)) / Ms
Overturn_Stability_Ratio = (0.5 * 12.0 * (180,564.826 + 0 + 0)) / 124,997.176
Overturn_Stability_Ratio = 8.6673

Overturn_Stability_Ratio >= 2.0 ==> PASS

Freeboard
DELTAs = 0.42 * D * Af
DELTAs = 0.42 * 12.0 * 0.0987
DELTAs = 0.4974 ft

Freeboard = H_shell - Lmax-operating
Freeboard = 24 - 24.0
Freeboard = 0.0 ft [0.0 in]

Freeboard_recommended = 0.7 * DELTAs
Freeboard_recommended = 0.7 * 0.4974
Freeboard_recommended = 0.3482 ft [4.1786 in]

As per API-650 E.7.2 and Table E.7, freeboard is recommended but not required

Sliding Resistance
Vs = MU * (Ws + Wr + Wf + Wp) * (1.0 - (0.4 * Av))
Vs = 0.4 * (9,755.2942 + 1,347.6695 + 1,186.2579 + 168,275.6044) * (1.0 - (0.4 * 0.0896))
Vs = 69,637.3531 lbf

V <= Vs

Local Shear Transfer
Vmax = (2 * V) / (pi * D)
Vmax = (2 * 9,780.2004) / (pi * 12.0)
Vmax = 518.8557 lbf/ft

Anchor Bolt Design Back

A-s = Installed Bolt Nominal Root Area (in^2)
A-s-r = Anchor Required Root Area (in^2)
Av = Seismic Vertical Earthquake Acceleration Coefficient (g)
Ca-anchor = Anchor Corrosion Allowance (in)
d = Anchor Bolt Diameter (in)
D = Tank nominal diameter (ft)
Dac = Bolt Circle Diameter (ft)
d-req = Bolt Required Diameter per *ANSI B1.1* (in)
Fp = Design Pressure Operating Ratio
Fty = Minimum Yield Strength of the Bottom Shell Course (psi)
Fy = Anchor Yield Strength per *API-650 Table 5.21b* (psi)
Fy-ambient = Anchor Yield Strength at Ambient Temperature per *API-650 Table 5.21b* (psi)
H = Tank Height (ft)
Ma-anchor = Anchor Material
Mrw = Seismic Overturning Moment (ft.lbf)
MWS = Shell Wind Overturning Moment (ft.lbf)
N = Anchors Quantity
n = Number of threads per unit length (in)
N-min = Minimum Required Number of Anchors per *API-650 5.12.3*
OD = Tank Outer diameter (ft)
P = Internal Pressure (inH2O)
p = Bolt Thread Pitch
P_attachment = Anchor Attachment Design Load per *API-650 Section 5.12.13 and Steel Plate Engineering Data-Volume 2 Part V* (lbf)
position_angles = Anchors Position Angles (deg)
Pt = Test Pressure (inH2O)
PWR = Roof Wind Pressure (inH2O)
S_d = Allowable Anchor Stress per *API-650 Table 5.20b* (psi)
S_d_shell = Allowable Shell Stress at Anchor Attachment per *API-650 Table 5.20b* (psi)
T_b = Load per Anchor per *API-650 5.12.2* (lbf)
U = Net Uplift Load per *API-650 Section 5.12.2 and Table 5.20b* (lbf)
W1 = Corroded Weight of the Roof Plates Plus the Corroded Weight of the Shell and any Other Corroded Permanent Attachments Acting on the Shell (lbf)
W2 = Corroded Weight of the Shell and any Corroded Permanent Attachments Acting on the Shell Including the Portion of the Roof Plates and Framing Acting on The Shell (lbf)
W3 = Nominal Weight of the Roof Plates Plus the Nominal Weight of the Shell and any Other Permanent Attachments Acting on the Shell (lbf)
Wr-pl = Roof Plates Nominal Weight (lb)
Wr-pl-corr = Roof Corroded Plates Weight (lb)
Wrs-pl-corr = Roof Plates Corroded Weight Acting on The Shell (lb)
Ws-framing = Shell New Framing Weight (stiffeners) (lbf)
Ws-framing-corr = Shell Corroded Framing Weight (stiffeners) (lbf)
Ws-pl = Shell Plates Nominal Weight (lb)
Ws-pl-corr = Shell Corroded Plates Weight (lb)
Wss = Roof Structure Nominal Weight Acting on The Shell (lb)
Wss-corr = Roof Structure Corroded Weight Acting on The Shell (lb)
Y-bolt = Anchor Yield Load (lbf)

Av = 0.0896 g
Ca-anchor = 0 in
D = 12.0 ft
d = 1 in

Dac = 12.3542 ft
Fp = 0.4
Fty = 36,000 psi
H = 24 ft
Ma-anchor = A36
Mrw = 108,614.2967 ft.lbf
MWS = 49,215.6 ft.lbf
n = 8 in
N = 4
OD = 12.0 ft
p = 0.13
P = 0.0 inH2O
position_angles = [45 135 225 315] deg
Pt = 0.0 inH2O
PWR = 4.5624 inH2O
Wr-pl = 1,198.2584 lb
Wr-pl-corr = 1,198.2584 lb
Wrs-pl-corr = 1,198.2584 lb
Ws-framing = 269.7491 lbf
Ws-framing-corr = 270.7586 lbf
Ws-pl = 9,203.6404 lb
Ws-pl-corr = 9,203.6404 lb
Wss = 0 lb
Wss-corr = 0 lb

Anchors Spacing Requirements

Max Allowable Spacing Between Anchors at Shell Outer Diameter per API-650 5.12.3
Max Allowable Spacing (max_allowable_spacing) = 10 ft
Actual Spacing (actual_spacing) = 9.4248 ft

actual_spacing <= max_allowable_spacing ==> PASS

N-min = CEILING(((pi * OD) / 10))
N-min = CEILING(((pi * 12.0) / 10))
N-min = 4

N >= N-min ==> PASS

Anchors meet spacing requirements.

Anchors Average Spacing (half the span on each side of the anchor) at Bolt Circle
Anchors are equally spaced.
Average Spacing (average_spacing) = 9.7 ft
Bolt loads will be based on equally spaced anchors.

Anchor Material Properties

Material = A36
Minimum Tensile Strength (Sut-anchor) = 58,000 psi
Minimum Yield Strength at Ambient Temperature (Sy-ambient-anchor) = 36,000 psi
Minimum Yield Strength (Sy-anchor) = 36,000 psi

Fy = MIN(Sy-anchor , 55000)
Fy = MIN(36,000 , 55000)
Fy = 36,000 psi

Fy-ambient = MIN(Sy-ambient-anchor , 55000)
Fy-ambient = MIN(36,000 , 55000)
Fy-ambient = 36,000 psi

Uplift Load Cases per API-650 Table 5.20b

W1 = Ws-pl-corr + Ws-framing-corr + Wr-pl-corr
W1 = 9,203.6404 + 270.7586 + 1,198.2584
W1 = 10,672.6574 lbf

W2 = Ws-pl-corr + Ws-framing-corr + Wrs-pl-corr + Wss-corr
W2 = 9,203.6404 + 270.7586 + 1,198.2584 + 0
W2 = 10,672.6574 lbf

W3 = Ws-pl + Ws-framing + Wr-pl + Wss
W3 = 9,203.6404 + 269.7491 + 1,198.2584 + 0
W3 = 10,671.6479 lbf

As per API-650 Section 5.12.13, Seismic Attachment Load Multiplier (f_seismic) = 1.5
Seismic anchoring is not required and API-650 Section 5.12.13 does not apply.

Uplift Case 1: Design Pressure Only
U = (P * (D^2) * 4.08) - W1
U = (0.0 * (12.0^2) * 4.08) - 10,672.6574
U = -10,672.6574 (Set to 0 lbf since it cannot be less than 0)

T_b = U / N
T_b = 0 / 4
T_b = 0 lbf

S_d = (5 / 12) * Fy
S_d = (5 / 12) * 36,000
S_d = 15,000 psi

A-s-r = T_b / S_d
A-s-r = 0 / 15,000
A-s-r = 0.0 in^2

P_attachment = 1.5 * T_b
P_attachment = 1.5 * 0
P_attachment = 0.0 lbf

S_d_shell = (2 / 3) * Fty
S_d_shell = (2 / 3) * 36,000
S_d_shell = 24,000 psi

Uplift Case 2: Test Pressure Only
U = (Pt * (D^2) * 4.08) - W3
U = (0.0 * (12.0^2) * 4.08) - 10,671.6479
U = -10,671.6479 (Set to 0 lbf since it cannot be less than 0)

T_b = U / N
T_b = 0 / 4
T_b = 0 lbf

S_d = (5 / 9) * Fy-ambient
S_d = (5 / 9) * 36,000

S_d = 20,000 psi

A-s-r = T_b / S_d
A-s-r = 0 / 20,000
A-s-r = 0.0 in^2

P_attachment = 1.5 * T_b
P_attachment = 1.5 * 0
P_attachment = 0.0 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 36,000
S_d_shell = 30,000 psi

Uplift Case 3: Wind Load Only
U = ((PWR * (D^2) * 4.08) + ((4 * MWS) / D)) - W2
U = ((4.5624 * (12.0^2) * 4.08) + ((4 * 49,215.6) / 12.0)) - 10,672.6574
U = 8,413.0352 lbf

T_b = U / N
T_b = 8,413.0352 / 4
T_b = 2,103.2588 lbf

S_d = 0.8 * Fy
S_d = 0.8 * 36,000
S_d = 28,800 psi

A-s-r = T_b / S_d
A-s-r = 2,103.2588 / 28,800
A-s-r = 0.073 in^2

P_attachment = 1.5 * T_b
P_attachment = 1.5 * 2,103.2588
P_attachment = 3,154.8882 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 36,000
S_d_shell = 30,000 psi

Uplift Case 4: Seismic Load Only
U = ((4 * Mrw) / D) - (W2 * (1 - (0.4 * Av)))
U = ((4 * 108,614.2967) / 12.0) - (10,672.6574 * (1 - (0.4 * 0.0896)))
U = 25,914.6163 lbf

T_b = U / N
T_b = 25,914.6163 / 4
T_b = 6,478.6541 lbf

S_d = 0.8 * Fy
S_d = 0.8 * 36,000
S_d = 28,800 psi

A-s-r = T_b / S_d
A-s-r = 6,478.6541 / 28,800
A-s-r = 0.225 in^2

P_attachment = f_seismic * T_b
P_attachment = 1.5 * 6,478.6541
P_attachment = 9,717.9811 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 36,000
S_d_shell = 30,000 psi

Uplift Case 5: Design Pressure + Wind Load
U = ((((Fp * P) + PWR) * (D^2) * 4.08) + ((4 * MWS) / D)) - W1
U = ((((0.4 * 0.0) + 4.5624) * (12.0^2) * 4.08) + ((4 * 49,215.6) / 12.0)) - 10,672.6574
U = 8,413.0352 lbf

T_b = U / N
T_b = 8,413.0352 / 4
T_b = 2,103.2588 lbf

S_d = (5 / 9) * Fy
S_d = (5 / 9) * 36,000
S_d = 20,000 psi

A-s-r = T_b / S_d
A-s-r = 2,103.2588 / 20,000
A-s-r = 0.1052 in^2

P_attachment = 1.5 * T_b
P_attachment = 1.5 * 2,103.2588
P_attachment = 3,154.8882 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 36,000
S_d_shell = 30,000 psi

Uplift Case 6: Design Pressure + Seismic Load
U = ((Fp * P * (D^2) * 4.08) + ((4 * Mrw) / D)) - (W1 * (1 - (0.4 * Av)))
U = ((0.4 * 0.0 * (12.0^2) * 4.08) + ((4 * 108,614.2967) / 12.0)) - (10,672.6574 * (1 - (0.4 * 0.0896)))
U = 25,914.6163 lbf

T_b = U / N
T_b = 25,914.6163 / 4
T_b = 6,478.6541 lbf

S_d = 0.8 * Fy
S_d = 0.8 * 36,000
S_d = 28,800 psi

A-s-r = T_b / S_d
A-s-r = 6,478.6541 / 28,800
A-s-r = 0.225 in^2

P_attachment = f_seismic * T_b
P_attachment = 1.5 * 6,478.6541
P_attachment = 9,717.9811 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 36,000

S_d_shell = 30,000 psi

Uplift Case 7: Frangibility Pressure
Not applicable. It is applied if the roof to shell joint is frangible.

Summary of Uplift Cases

Uplift Cases	Total Uplift Load (lbf)	Load per Anchor (lbf)	Anchor Allowable Stress (psi)	Anchor Required Area (in^2)	Anchor Bolt Required Diameter (in)	Attachment Design Load (lbf)	Allowable Shell Stress at Anchor Attachment (psi)
Design Pressure	0	0	15,000	0.0	0.1625	0.0	24,000
Test Pressure	0	0	20,000	0.0	0.1625	0.0	30,000
Wind Load	8,413.0352	2,103.2588	28,800	0.073	0.4674	3,154.8882	30,000
Seismic Load	25,914.6163	6,478.6541	28,800	0.225	0.6977	9,717.9811	30,000
Design Pressure + Wind	8,413.0352	2,103.2588	20,000	0.1052	0.5284	3,154.8882	30,000
Design Pressure + Seismic	25,914.6163	6,478.6541	28,800	0.225	0.6977	9,717.9811	30,000

- Anchor Bolt Required Diameter = SQRT((A-s-r * (4 / pi))) + (1.3 / n) + (Ca-anchor * 2)
- Governing Uplift Case = Seismic Load
- Anchor Bolt Minimum Required Area = 0.225 in^2

Bolt Required Diameter per ANSI B1.1

d-req = SQRT((A * (4 / pi))) + (1.3 / n) + (Ca * 2)
d-req = SQRT((0.225 * (4 / pi))) + (1.3 / 8) + (0 * 2)
d-req = 0.6977 in

d >= d-req ==> PASS

A-s = (pi / 4) * ((d - (1.3 / n))^2)
A-s = (pi / 4) * ((1 - (1.3 / 8))^2)
A-s = 0.5509 in^2

Y-bolt = A-s * Sy-ambient-anchor
Y-bolt = 0.5509 * 36,000
Y-bolt = 19,831.7945 lbf

Anchorage Summary

Required Number of Anchors = 4
Actual Number of Anchors = 4
Bolt Hole Circle Radius = 6.1771 ft

Required Bolt Diameter = 0.6977 in
Actual Bolt Diameter = 1 in
Bolt Thread Pitch = 0.13

Anchor Chair Design Back

Anchor Chair Design per AISI T-192 Part V

a = Top Plate Width Along Shell (in)
b = Top Plate Length (in)
bmin = Top Plate Minimum Length (in)
c = Top Plate Thickness (in)
CA = Chair Corrosion Allowance (in)
c_corr = Top Plate Corroded Thickness (in)
D = Tank Nominal Diameter (ft)
d = Anchor Bolt Diameter (in)
e = Anchor Bolt Eccentricity (in)
Earthquakes-Considered = Earthquakes Considered
emin = Minimum Calculated Eccentricity (in)
emin-btm = Minimum Eccentricity Based on Bolt Clearance From Bottom Plates per *API-650 5.12.4* (in)
emin-req = Minimum Required Eccentricity (in)
Et = Bottom Plates Thermal Expansion Coefficient per *API-650 Table P.1b* (in/in.fdeg)
f = Top Plate Outside To Hole Edge Distance (in)
f_min = Distance from Outside of Top Plate to Edge of Hole per *AISI T-192 Part V, Notation* (in)
g = Vertical Plates Distance (in)
g_min = Minimum Distance Between Vertical Plates per *AISI T-192, PartV, Notation* (in)
h = Chair Height (in)
h-eff = Effective Chair Height (in)
hmax = Chair Maximum Height (in)
j = Vertical Plate Thickness (in)
j_corr = Vertical Plate Corroded Thickness (in)
j_min = Vertical Plate Minimum Thickness per *AISI T-192 Part V, Vertical Side Plates* (in)
k = Vertical Plates Average Width (in)
m = Base or Bottom Plate Thickness (in)
Ma-chair = Chair Material
outside-projection = Bottom Outside Projection (in)
R = Nominal Shell Radius (in)
Ssw-chair = Chair Allowable Stress for Seismic or Wind Design per *API-650 5.12.9* (psi)
T = Difference between ambient and design temperature per *API 650 5.12.4* (°F)
t = Shell Thickness (in)
T_ambient = Ambient Temperature (°F)
T_design = Design Temperature (°F)
V = Wind Velocity (mph)
Y-bolt = Anchor Bolt Yield Load (lbf)

a = 8 in
b = 8 in
c = 0.5 in

CA = 0 in
d = 1 in
D = 12.0 ft
e = 2.125 in
Earthquakes-Considered = ASCE7-MAPPED-SS-AND-S1
Et = 6.67E-6 in/in.fdeg
f = 3.875 in
g = 4.5 in
h = 12 in
j = 0.5 in
k = 4.4306 in
m = 0.25 in
Ma-chair = A36
outside-projection = 1 in
R = 72.0 in
t = 0.25 in
T_ambient = 70 °F
T_design = 120 °F
V = 105.0 mph
Y-bolt = 19,831.7945 lbf

Anchor Chair Material Properties
Material = A36
Minimum Tensile Strength (Sut-chair) = 58,000 psi
Minimum Yield Strength (Sy-chair) = 36,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd-chair) = 21,000 psi
As per API-650 J.3.3 and A.4.1, Allowable Hydrostatic Test Stress (St-chair) = 21,000 psi

Ssw-chair = 1.33 * Sd-chair
Ssw-chair = 1.33 * 21,000
Ssw-chair = 27,930 psi

Size Requirements
c_corr = c - (2 * CA)
c_corr = 0.5 - (2 * 0)
c_corr = 0.5 in

j_corr = j - (2 * CA)
j_corr = 0.5 - (2 * 0)
j_corr = 0.5 in

Chair Minimum Height (hmin) = 12 in

h >= hmin ==> PASS

hmax = 3 * a
hmax = 3 * 8
hmax = 24 in

h-eff = MIN(hmax , h)
h-eff = MIN(24 , 12)
h-eff = 12 in

emin = (0.886 * d) + 0.572
emin = (0.886 * 1) + 0.572
emin = 1.458 in

T = T_design - T_ambient
T = 120 - 70
T = 50 °F

emin-btm = (d / 2) + outside-projection + 0.125 + (6 * Et * D * T)
emin-btm = (1 / 2) + 1 + 0.125 + (6 * 6.67E-6 * 12.0 * 50)
emin-btm = 1.649 in

emin-req = MAX(emin , emin-btm)
emin-req = MAX(1.458 , 1.649)
emin-req = 1.649 in

e >= emin-req ==> PASS

g_min = d + 1
g_min = 1 + 1
g_min = 2 in

g >= g_min ==> PASS

f_min = (d / 2) + 0.125
f_min = (1 / 2) + 0.125
f_min = 0.625 in

f >= f_min ==> PASS

j_min = MAX(0.5 , (0.04 * (h-eff - c_corr)) , ((P-design / (25000 * k)) + (2 * CA)))
j_min = MAX(0.5 , (0.04 * (12 - 0.5)) , ((9,717.9811 / (25000 * 4.4306)) + (2 * 0)))
j_min = 0.5 in

j >= j_min ==> PASS

bmin = emin + d + 0.25
bmin = 1.458 + 1 + 0.25
bmin = 2.708 in

b >= bmin ==> PASS

Top Plate Minimum Required Thickness

Uplift Cases	P-chair (lbf)	P-design (lbf)	Sd-chair (psi)	c_min (in)	Status

Design Pressure	0.0	0.0	21,000	0.0	PASS
Test Pressure	0.0	0.0	21,000	0.0	PASS
Wind Load	3,154.8882	3,154.8882	27,930	0.2068	PASS
Seismic Load	9,717.9811	9,717.9811	27,930	0.363	PASS
Design Pressure + Wind	3,154.8882	3,154.8882	27,930	0.2068	PASS
Design Pressure + Seismic	9,717.9811	9,717.9811	27,930	0.363	PASS

- P-chair = Anchor Chair Uplift Load
- P-design = Anchor Chair Design Load = min(P-chair, Y-bolt)
- Sd-chair = Anchor Chair Allowable Stress
- c_min = Top Plate Minimum Required Thickness
- c_min = SQRT(((P-design / (Sd-chair * f)) * ((0.375 * g) - (0.22 * d)))) + (2 * CA)
- Governing Uplift Case = Seismic Load
- Governing Thickness (c_min) = 0.363 in

Top Plate Stress

Uplift Cases	P-chair (lbf)	P-design (lbf)	S_top-plate (psi)	Sd-chair (psi)	Stress Ratio	Status
Design Pressure	0.0	0.0	0.0	21,000	0.0%	PASS
Test Pressure	0.0	0.0	0.0	21,000	0.0%	PASS
Wind Load	3,154.8882	3,154.8882	4,779.1468	27,930	17.11%	PASS
Seismic Load	9,717.9811	9,717.9811	14,721.1739	27,930	52.71%	PASS
Design Pressure + Wind	3,154.8882	3,154.8882	4,779.1468	27,930	17.11%	PASS
Design Pressure + Seismic	9,717.9811	9,717.9811	14,721.1739	27,930	52.71%	PASS

- P-chair = Anchor Chair Uplift Load
- P-design = Anchor Chair Design Load = min(P-chair, Y-bolt)
- S_top-plate = Top Plate Stress
- S_top-plate = (P-design / (f * (c_corr^2))) * ((0.375 * g) - (0.22 * d))
- Sd-chair = Anchor Chair Allowable Stress
- Governing Uplift Case = Seismic Load
- Governing Stress (S_top-plate) = 14,721.1739 psi

Z = Chair Reduction Factor per *AISI T-192 Part V, Eq 5-4*

Shell Stress at Anchor Attachment
Z = 1 / ((((0.177 * a * m) / SQRT((R * t))) * ((m / t)^2)) + 1)
Z = 1 / ((((0.177 * 8 * 0.25) / SQRT((72.0 * 0.25))) * ((0.25 / 0.25)^2)) + 1)
Z = 0.923

Uplift Cases	P-chair (lbf)	P-design (lbf)	S_Shell (psi)	Sd-shell (psi)	Stress Ratio	Status
Design Pressure	0.0	0.0	0.0	24,000	0.0%	PASS

Test Pressure	0.0	0.0	0.0	30,000	0.0%	PASS
Wind Load	3,154.8882	3,154.8882	1,992.5593	30,000	6.64%	PASS
Seismic Load	9,717.9811	9,717.9811	6,137.6671	30,000	20.46%	PASS
Design Pressure + Wind	3,154.8882	3,154.8882	1,992.5593	30,000	6.64%	PASS
Design Pressure + Seismic	9,717.9811	9,717.9811	6,137.6671	30,000	20.46%	PASS

- P-chair = Anchor Chair Uplift Load
- P-design = Anchor Chair Design Load = min(P-chair, Y-bolt)
- S_Shell = Stress at Attachment
- S_Shell = ((P-design * e) / (t^2)) * (((1.32 * Z) / (((1.43 * a * (h^2)) / (R * t)) + ((4 * a * (h^2))^0.333))) + (0.031 / SQRT((R * t))))
- Sd-shell = Allowable Stress at Anchor Attachment
- Governing Uplift Case = Seismic Load
- Governing Stress (S_Shell) = 6,137.6671 psi
- Governing Allowable Stress (Sd-Shell) = 30,000 psi

Appuntenances Design Back

Plan View

LABEL	MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (in)	INSIDE PROJ (in)	ORIENT	RADIUS (in)	REMARKS	REF DWG
Circular-Manway-0001	RM01A		24" ROOF MANWAY	10"	1"	180 '	2'-6"		
Coupling-0001	RCP01A		2" 3000# ROOF HALF-THR COUPLING	--	0"	0 '	4'-2"		
Coupling-0002	RCP01A		2" 3000# ROOF HALF-THR COUPLING	--	0"	90 '	4'-2"		

Elevation View

LABEL	MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (in)	INSIDE PROJ (in)	ORIENT	ELEVATION (in)	REMARKS	REF DWG
A	SN01A		4" SHELL NOZZLE	7"	1"	0 '	10 1/4"		
Anchor-Chair-Bolts	AC01A		ANCHOR CHAIRS	--	--	SEE TABLE	--		
B	SN01A		4" SHELL NOZZLE	7"	1"	90 '	10 1/4"		
C	SN01A		4" SHELL NOZZLE	7"	1"	180 '	10 1/4"		
D	SN01A		4" SHELL NOZZLE	7"	1"	270 '	10 1/4"		
E	SN01A		4" SHELL NOZZLE	7"	1"	0 '	22'-11"		
F	SN02A		4" SHELL NOZZLE	7"	1"	45 '	22'-11"	W/ BLIND	
G	SN02A		4" SHELL NOZZLE	7"	1"	75 '	11"	W/ BLIND	
Name-Plate	NP01A		STD API	--	--	0 '	3'-4"		

Shell Nozzle: A

Repad Design

NOZZLE Description : 4 in SCH 80 TYPE RFSO
Material: A53-B

t_rpr = (Repad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 1 : Elevation = 0.8542 ft

COURSE PARAMETERS:
t-calc = 0.0488 in
t_cr = 0.0488 in (Course t-calc less C.A)
t_c = 0.25 in (Course t less C.A.)
t_Basis = 0.0488 in

(SHELL NOZZLE REF. API-650 TABLE 5.6B, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0488 * 4.5
Required Area = 0.2197 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.25 - 0.0488) * 4.5
Available Shell Area = 0.9053 in2

Available Nozzle Neck Area = 2 * [(4 * (t_n - CA)) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = 2 * [(4 * (0.337 - 0)) + 0.25] * (0.337 - 0) * MIN((15,000/21,000) 1)
Available Nozzle Neck Area = 0.7693 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2197 - 0.9053 - 0.7693
A-rpr = 0 in2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

t_shell_PWHT = Thickness of the shell plate, insert plate, or thickened insert plate for PWHT (in)

Nozzle Neck Material Properties
Material = A53-B
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd-neck) = 21,000 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.25
t_shell_PWHT = 0.25 in

Thermal Stress Relief (PWHT) Requirements
D = Nozzle Nominal Diameter (NPS) (in)
Group = Shell Material Group
t_shell = Shell Plate Thickness (in)

D = 4 in
Group = I
t_shell = 0.25 in

As per API 650, 13th Ed, Section 5.7.4.2, Lower Plate Thickness Limit for PWHT (t_PWHT) = 1 in
As per API 650, 13th Ed, Section 5.7.4.2, Lower Nozzle Diameter Limit for PWHT (D_PWHT) = 12 in
As per API 650, 13th Ed, Section 5.7.4.2, Time Required for PWHT for incremental thickness (T_ratio_PWHT) = 1 in/hr
Shell thickness (0.25 in) is less than or equal to specified lower limit (1 in).
Diameter (4 in) is less than specified lower limit (12 in).
As per API 650, 13th Ed, Section 5.7.4.2, Thermal Stress Relief (PWHT) is not required.

Shell Nozzle: B

Repad Design

NOZZLE Description : 4 in SCH 80 TYPE RFSO
Material: A53-B

t_rpr = (Repad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 1 : Elevation = 0.8542 ft

COURSE PARAMETERS:
t-calc = 0.0488 in
t_cr = 0.0488 in (Course t-calc less C.A)
t_c = 0.25 in (Course t less C.A.)
t_Basis = 0.0488 in

(SHELL NOZZLE REF. API-650 TABLE 5.6B, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0488 * 4.5
Required Area = 0.2197 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.25 - 0.0488) * 4.5

Available Shell Area = 0.9053 in2

Available Nozzle Neck Area = 2 * [(4 * (t_n - CA)) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = 2 * [(4 * (0.337 - 0)) + 0.25] * (0.337 - 0) * MIN((15,000/21,000) 1)
Available Nozzle Neck Area = 0.7693 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2197 - 0.9053 - 0.7693
A-rpr = 0 in2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

t_shell_PWHT = Thickness of the shell plate, insert plate, or thickened insert plate for PWHT (in)

Nozzle Neck Material Properties
Material = A53-B
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd-neck) = 21,000 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.25
t_shell_PWHT = 0.25 in

Thermal Stress Relief (PWHT) Requirements
D = Nozzle Nominal Diameter (NPS) (in)
Group = Shell Material Group
t_shell = Shell Plate Thickness (in)

D = 4 in
Group = I
t_shell = 0.25 in

As per API 650, 13th Ed, Section 5.7.4.2, Lower Plate Thickness Limit for PWHT (t_PWHT) = 1 in
As per API 650, 13th Ed, Section 5.7.4.2, Lower Nozzle Diameter Limit for PWHT (D_PWHT) = 12 in
As per API 650, 13th Ed, Section 5.7.4.2, Time Required for PWHT for incremental thickness (T_ratio_PWHT) = 1 in/hr
Shell thickness (0.25 in) is less than or equal to specified lower limit (1 in).
Diameter (4 in) is less than specified lower limit (12 in).
As per API 650, 13th Ed, Section 5.7.4.2, Thermal Stress Relief (PWHT) is not required.

Shell Nozzle: C

Repad Design

NOZZLE Description : 4 in SCH 80 TYPE RFSO
Material: A53-B

t_rpr = (Repad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)

Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 1 : Elevation = 0.8542 ft

COURSE PARAMETERS:
t-calc = 0.0488 in
t_cr = 0.0488 in (Course t-calc less C.A)
t_c = 0.25 in (Course t less C.A.)
t_Basis = 0.0488 in

(SHELL NOZZLE REF. API-650 TABLE 5.6B, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0488 * 4.5
Required Area = 0.2197 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.25 - 0.0488) * 4.5
Available Shell Area = 0.9053 in2

Available Nozzle Neck Area = 2 * [(4 * (t_n - CA)) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = 2 * [(4 * (0.337 - 0)) + 0.25] * (0.337 - 0) * MIN((15,000/21,000) 1)
Available Nozzle Neck Area = 0.7693 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2197 - 0.9053 - 0.7693
A-rpr = 0 in2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

t_shell_PWHT = Thickness of the shell plate, insert plate, or thickened insert plate for PWHT (in)

Nozzle Neck Material Properties
Material = A53-B
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd-neck) = 21,000 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.25
t_shell_PWHT = 0.25 in

Thermal Stress Relief (PWHT) Requirements
D = Nozzle Nominal Diameter (NPS) (in)
Group = Shell Material Group
t_shell = Shell Plate Thickness (in)

D = 4 in
Group = I
t_shell = 0.25 in

As per API 650, 13th Ed, Section 5.7.4.2, Lower Plate Thickness Limit for PWHT (t_PWHT) = 1 in
As per API 650, 13th Ed, Section 5.7.4.2, Lower Nozzle Diameter Limit for PWHT (D_PWHT) = 12 in

As per API 650, 13th Ed, Section 5.7.4.2, Time Required for PWHT for incremental thickness (T_ratio_PWHT) = 1 in/hr
Shell thickness (0.25 in) is less than or equal to specified lower limit (1 in).
Diameter (4 in) is less than specified lower limit (12 in).
As per API 650, 13th Ed, Section 5.7.4.2, Thermal Stress Relief (PWHT) is not required.

Shell Nozzle: D

Repad Design

NOZZLE Description : 4 in SCH 80 TYPE RFSO
Material: A53-B

t_rpr = (Repad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 1 : Elevation = 0.8542 ft

COURSE PARAMETERS:
t-calc = 0.0488 in
t_cr = 0.0488 in (Course t-calc less C.A)
t_c = 0.25 in (Course t less C.A.)
t_Basis = 0.0488 in

(SHELL NOZZLE REF. API-650 TABLE 5.6B, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0488 * 4.5
Required Area = 0.2197 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.25 - 0.0488) * 4.5
Available Shell Area = 0.9053 in2

Available Nozzle Neck Area = 2 * [(4 * (t_n - CA)) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = 2 * [(4 * (0.337 - 0)) + 0.25] * (0.337 - 0) * MIN((15,000/21,000) 1)
Available Nozzle Neck Area = 0.7693 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2197 - 0.9053 - 0.7693
A-rpr = 0 in2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

t_shell_PWHT = Thickness of the shell plate, insert plate, or thickened insert plate for PWHT (in)

Nozzle Neck Material Properties
Material = A53-B
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd-neck) = 21,000 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.25
t_shell_PWHT = 0.25 in

Thermal Stress Relief (PWHT) Requirements
D = Nozzle Nominal Diameter (NPS) (in)
Group = Shell Material Group
t_shell = Shell Plate Thickness (in)

D = 4 in
Group = I
t_shell = 0.25 in

As per API 650, 13th Ed, Section 5.7.4.2, Lower Plate Thickness Limit for PWHT (t_PWHT) = 1 in
As per API 650, 13th Ed, Section 5.7.4.2, Lower Nozzle Diameter Limit for PWHT (D_PWHT) = 12 in
As per API 650, 13th Ed, Section 5.7.4.2, Time Required for PWHT for incremental thickness (T_ratio_PWHT) = 1 in/hr
Shell thickness (0.25 in) is less than or equal to specified lower limit (1 in).
Diameter (4 in) is less than specified lower limit (12 in).
As per API 650, 13th Ed, Section 5.7.4.2, Thermal Stress Relief (PWHT) is not required.

Shell Nozzle: E

Repad Design

NOZZLE Description : 4 in SCH 80 TYPE RFSO
Material: A53-B

t_rpr = (Repad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 3 : Elevation = 22.9167 ft

COURSE PARAMETERS:
t-calc = 0.0149 in
t_cr = 0.0149 in (Course t-calc less C.A)
t_c = 0.25 in (Course t less C.A.)
t_Basis = 0.0149 in

(SHELL NOZZLE REF. API-650 TABLE 5.6B, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0149 * 4.5

Required Area = 0.0669 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.25 - 0.0149) * 4.5
Available Shell Area = 1.0581 in2

Available Nozzle Neck Area = 2 * [(4 * (t_n - CA)) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = 2 * [(4 * (0.337 - 0)) + 0.25] * (0.337 - 0) * MIN((15,000/21,000) 1)
Available Nozzle Neck Area = 0.7693 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.0669 - 1.0581 - 0.7693
A-rpr = 0 in2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

t_shell_PWHT = Thickness of the shell plate, insert plate, or thickened insert plate for PWHT (in)

Nozzle Neck Material Properties
Material = A53-B
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd-neck) = 21,000 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.25
t_shell_PWHT = 0.25 in

Thermal Stress Relief (PWHT) Requirements
D = Nozzle Nominal Diameter (NPS) (in)
Group = Shell Material Group
t_shell = Shell Plate Thickness (in)

D = 4 in
Group = I
t_shell = 0.25 in

As per API 650, 13th Ed, Section 5.7.4.2, Lower Plate Thickness Limit for PWHT (t_PWHT) = 1 in
As per API 650, 13th Ed, Section 5.7.4.2, Lower Nozzle Diameter Limit for PWHT (D_PWHT) = 12 in
As per API 650, 13th Ed, Section 5.7.4.2, Time Required for PWHT for incremental thickness (T_ratio_PWHT) = 1 in/hr
Shell thickness (0.25 in) is less than or equal to specified lower limit (1 in).
Diameter (4 in) is less than specified lower limit (12 in).
As per API 650, 13th Ed, Section 5.7.4.2, Thermal Stress Relief (PWHT) is not required.

Shell Nozzle: F

Repad Design

NOZZLE Description : 4 in SCH 80 TYPE RFSO
Material: A53-B

t_rpr = (Repad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 3 : Elevation = 22.9167 ft

COURSE PARAMETERS:
t-calc = 0.0149 in
t_cr = 0.0149 in (Course t-calc less C.A)
t_c = 0.25 in (Course t less C.A.)
t_Basis = 0.0149 in

(SHELL NOZZLE REF. API-650 TABLE 5.6B, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0149 * 4.5
Required Area = 0.0669 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.25 - 0.0149) * 4.5
Available Shell Area = 1.0581 in2

Available Nozzle Neck Area = 2 * [(4 * (t_n - CA)) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = 2 * [(4 * (0.337 - 0)) + 0.25] * (0.337 - 0) * MIN((15,000/21,000) 1)
Available Nozzle Neck Area = 0.7693 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.0669 - 1.0581 - 0.7693
A-rpr = 0 in2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

t_shell_PWHT = Thickness of the shell plate, insert plate, or thickened insert plate for PWHT (in)

Nozzle Neck Material Properties
Material = A53-B
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd-neck) = 21,000 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.25
t_shell_PWHT = 0.25 in

Thermal Stress Relief (PWHT) Requirements
D = Nozzle Nominal Diameter (NPS) (in)
Group = Shell Material Group
t_shell = Shell Plate Thickness (in)

D = 4 in
Group = I

t_shell = 0.25 in

As per API 650, 13th Ed, Section 5.7.4.2, Lower Plate Thickness Limit for PWHT (t_PWHT) = 1 in
As per API 650, 13th Ed, Section 5.7.4.2, Lower Nozzle Diameter Limit for PWHT (D_PWHT) = 12 in
As per API 650, 13th Ed, Section 5.7.4.2, Time Required for PWHT for incremental thickness (T_ratio_PWHT) = 1 in/hr
Shell thickness (0.25 in) is less than or equal to specified lower limit (1 in).
Diameter (4 in) is less than specified lower limit (12 in).
As per API 650, 13th Ed, Section 5.7.4.2, Thermal Stress Relief (PWHT) is not required.

Shell Nozzle: G

Repad Design

NOZZLE Description : 4 in SCH 80 TYPE RFSO
Material: A53-B

t_rpr = (Repad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 1 : Elevation = 0.9167 ft

COURSE PARAMETERS:
t-calc = 0.0488 in
t_cr = 0.0488 in (Course t-calc less C.A)
t_c = 0.25 in (Course t less C.A.)
t_Basis = 0.0488 in

(SHELL NOZZLE REF. API-650 TABLE 5.6B, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0488 * 4.5
Required Area = 0.2197 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.25 - 0.0488) * 4.5
Available Shell Area = 0.9053 in2

Available Nozzle Neck Area = 2 * [(4 * (t_n - CA)) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = 2 * [(4 * (0.337 - 0)) + 0.25] * (0.337 - 0) * MIN((15,000/21,000) 1)
Available Nozzle Neck Area = 0.7693 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2197 - 0.9053 - 0.7693
A-rpr = 0 in2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

t_shell_PWHT = Thickness of the shell plate, insert plate, or thickened insert plate for PWHT (in)

Nozzle Neck Material Properties
Material = A53-B
As per API-650 J.3.3 and A.4.1, Allowable Design Stress (Sd-neck) = 21,000 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.25
t_shell_PWHT = 0.25 in

Thermal Stress Relief (PWHT) Requirements
D = Nozzle Nominal Diameter (NPS) (in)
Group = Shell Material Group
t_shell = Shell Plate Thickness (in)

D = 4 in
Group = I
t_shell = 0.25 in

As per API 650, 13th Ed, Section 5.7.4.2, Lower Plate Thickness Limit for PWHT (t_PWHT) = 1 in
As per API 650, 13th Ed, Section 5.7.4.2, Lower Nozzle Diameter Limit for PWHT (D_PWHT) = 12 in
As per API 650, 13th Ed, Section 5.7.4.2, Time Required for PWHT for incremental thickness (T_ratio_PWHT) = 1 in/hr
Shell thickness (0.25 in) is less than or equal to specified lower limit (1 in).
Diameter (4 in) is less than specified lower limit (12 in).
As per API 650, 13th Ed, Section 5.7.4.2, Thermal Stress Relief (PWHT) is not required.

Roof Manway: Circular-Manway-0001

Repad Design

(Per API-650 Section 5.8.4 and other references below)
MANWAY Description : 24 in Neck Thickness 0.25
Material: A36

t_rpr = (Repad Required Thickness)
MOUNTED ON ROOF: Elevation = 24.648 ft

ROOF PARAMETERS:
t-calc = 0.1875 in
t_cr = 0.25 in (Roof t-act less C.A)
t_c = 0.25 in
t_Basis = 0.1875 in

(FOR ROOF MANWAY,REF. API-650 FIG 5-16, TABLE 5-13)

Required Area = t_Basis * D
Required Area = 0.1875 * 24
Required Area = 4.5 in2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (0.25 - 0.1875) * 24
Available Roof Area = 1.5 in2

Available Manway Neck Area = 2 * [(4 * (t_n - CA)) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)
Available Manway Neck Area = 2 * [(4 * (0.25 - 0)) + 0.25] * (0.25 - 0) * MIN((23,200/21,000) 1)
Available Manway Neck Area = 0.625 in2

A-rpr = (Required Area - Available Roof Area - Available Manway Neck Area)
A-rpr = 4.5 - 1.5 - 0.625
A-rpr = 2.375 in2

As per API-650 J.3.6.3, since roof loads does not exceed 25 psf, t_rpr = 0

No Reinforcement Pad required.

Normal and Emergency Venting (API-2000 7th Edition) Back

Normal Venting

insulation_type = Insulation type
latitude = Latitude zone
R_i = Reduction factor for insulation per *API-2000 Sections 3.3.2.3.2 and 3.3.2.3.3*
T = Product storage temperature (°F)
vapor-pressure-type = Vapor pressure type
Vi = Total required in-breathing volumetric flow rate (ft^3/hr)
V_ip = Required in-breathing flow rate due to liquid movement per *API-2000 Section 3.3.2.2, Eq 6* (ft^3/hr)
V_IT = Required in-breathing flow rate due to thermal effects per *API-2000 Section 3.3.2.3.3, Eq 10* (ft^3/hr)
Vo = Total required out-breathing volumetric flow rate (ft^3/hr)
V_op = Required out-breathing flow rate due to liquid movement per *API-2000 Section 3.3.2.2.1-a, Eq 2* (ft^3/hr)
V_OT = Required out-breathing flow rate due to thermal effects per *API-2000 Section 3.3.2.3.2, Eq 8* (ft^3/hr)
V_pe = Maximum emptying rate (gpm)
V_pf = Maximum filling rate (gpm)
V_tk = Tank capacity (gal)

insulation_type = NO-INSULATION
latitude = BETWEEN-42-AND-58
T = 100 °F
vapor-pressure-type = HEXANE-OR-SIMILAR
V_pe = 100 gpm
V_pf = 100 gpm
V_tk = 20,456.4083 gal

R_i = 1
R_i = 1
R_i = 1

In-breathing
V_ip = 8.02 * V_pe
V_ip = 8.02 * 100
V_ip = 802.0 ft^3/hr

V_ip = 802 ft^3/hr of air

As per API-2000 Section 3.3.2.3.3, Table 2, Vapor Pressure Factor (C) = 5

V_IT = 3.08 * C * (V_tk^0.7) * R_i
V_IT = 3.08 * 5 * (2,734.624^0.7) * 1
V_IT = 3,920.5686 ft^3/hr

V_IT = 3,920.5686 ft^3/hr of air

Vi = V_ip + V_IT
Vi = 802.0 + 3,920.5686
Vi = 4,722.5686 ft^3/hr

Vi = 4,722.5686 ft^3/hr of air

Out-breathing
V_op = 8.02 * V_pf
V_op = 8.02 * 100
V_op = 802.0 ft^3/hr

V_op = 802 ft^3/hr of air

As per API-2000 Section 3.3.2.3.2, Table 1, Latitude Factor (Y) = 0.25

V_OT = 1.51 * Y * (V_tk^0.9) * R_i
V_OT = 1.51 * 0.25 * (2,734.624^0.9) * 1
V_OT = 467.8696 ft^3/hr

V_OT = 467.8695 ft^3/hr of air

Vo = V_op + V_OT
Vo = 802.0 + 467.8696
Vo = 1,269.8696 ft^3/hr

Vo = 1,269.8695 ft^3/hr of air

Emergency Venting
ATWS = Wetted surface area (ft^2)
D = Tank diameter (ft)
F = Environmental factor per *API-2000 Section 3.3.3.3.4*
H = Tank height (ft)
insulation_type = Insulation type
P_g = Design pressure (psi)
q = Required emergency venting capacity per *API-2000 Section 3.3.3.3.4, Table 6* (ft^3/hr)
vapor-pressure-type = Vapor pressure type

D = 12.0 ft
H = 24 ft
insulation_type = NO-INSULATION
P_g = 0.0 psi
vapor-pressure-type = HEXANE-OR-SIMILAR

As per API-2000 Table 9, Environmental factor for insulation (F_ins) = 1.0
As per API-2000 Table 9, Environmental factor for drainage (F_drain) = 1.0

F = MIN(F_ins , F_drain)
F = MIN(1.0 , 1.0)
F = 1.0

ATWS = pi * D * MIN(H , 30)
ATWS = pi * 12.0 * MIN(24 , 30)
ATWS = 904.7787 ft^2

q = 494481.3921 * F
q = 494481.3921 * 1.0
q = 494,481.3921 ft^3/hr

Capacities and Weights Back

Capacity to Top of Shell (to Tank Height) : 20,163 gal
Capacity to Design Liquid Level : 20,163 gal
Capacity to Maximum Liquid Level : 20,163 gal
Working Capacity (to Normal Working Level) : 0 gal
Net working Capacity (Working Capacity - Min Capacity) : -840 gal
Minimum Capacity (to Min Liq Level) : 840 gal

Component	New Condition (lbf)	Corroded (lbf)
SHELL	9,204	9,204
ROOF	1,216	1,216
RAFTERS	0	0
GIRDERS	0	0
FRAMING	0	0
COLUMNS	0	0
TRUSS	0	0
STRUCTURE COMPONENTS	0	0
BOTTOM	1,187	1,187
STAIRWAYS	0	0
ACCESS	0	0
STIFFENERS	271	271
WIND GIRDERS	0	0
ANCHOR CHAIRS	91	91
SHELL APPURTENANCES	190	190
ROOF APPURTENANCES	149	149
BOTTOM APPURTENANCES	0	0
INSULATION	0	0
FLOATING ROOF	0	0
TOTAL	12,309.3158	12,309.3158

Weight of Tank, Empty : 12,309.3158 lbf
Weight of Tank, Full of Product (Design SG = 1) : 181,759.3158 lbf
Weight of Tank, Full of Water : 181,759.6155 lbf
Net Working Weight, Full of Product (Design SG = 1) : 174,699.1863 lbf
Net Working Weight Full of Water : 174,699.1863 lbf

Foundation Area Req'd : 116.2607 ft2
Foundation Loading, Empty : 105.8768 lbf/ft2
Foundation Loading, Full of Product Design : 1,563.3764 lbf/ft2
Foundation Loading, Full of Water : 1,563.379 lbf/ft2

SURFACE AREAS
Roof : 117.4901 ft2
Shell : 901.637 ft2
Bottom : 116.2607 ft2

Internal Pressure Moment : 0 lbf-ft
Wind Moment : 65,719.2813 lbf-ft
Seismic Moment (Ringwall) : 108,614.2967 lbf-ft
Seismic Moment (Slab) : 124,997.176 lbf-ft

MISCELLANEOUS ATTACHED ROOF ITEMS
MISCELLANEOUS ATTACHED SHELL ITEMS

Reactions on Foundation [Back]

A_rss = Area of Tank Roof Supported by the Tank Shell (ft^2)
A_v = Vertical Earthquake Acceleration Coefficient (g)
D = Tank Nominal Diameter (ft)
F-wind = Wind Horizontal Force (lbf)
gamma_b = Bottom Plate Density (lbf/in^3)
gamma_w = Water Density (lb/ft^3)
Hs = Tank Height (Shell Only) (ft)
L_dead_bottom = Dead Load on Bottom per *API 650, Section 5.13, Table 5.21* (psf)
L_dead_shell = Dead Load on Shell per *API 650, Section 5.13, Table 5.21* (lbf/ft)
L_hydrostatic_bottom = Hydrostatic Load on Bottom per *API 650, Section 5.13, Table 5.21* (psf)
L_internal-pressure_bottom = Internal Pressure Load on Bottom per *API 650, Section 5.13, Table 5.21* (psf)
Lmax = Maximum Liquid Level (ft)
L_minimum-roof-live-load_shell = Minimum Roof Live Load on Shell per *API 650, Section 5.13, Table 5.21* (lbf/ft)
L_pressure-test_bottom = Pressure Test Load on Bottom per *API 650, Section 5.13, Table 5.21* (psf)
Lr = Minimum Roof Live Load (psf)
L_seismic_bottom = Seismic Load on Bottom per *API 650, Section 5.13, Table 5.21* (psf)
L_seismic_shell = Seismic Load on Shell per *API 650, Section 5.13, Table 5.21* (lbf/ft)
L_snow_shell = Snow Load on Shell per *API 650, Section 5.13, Table 5.21* (lbf/ft)
L_stored-liquid_bottom = Stored Liquid Load on Shell per *API 650, Section 5.13, Table 5.21* (psf)
L_vacuum_shell = Vacuum Load on Shell per *API 650, Section 5.13, Table 5.21* (lbf/ft)
L_wind_shell = Wind Load on Shell per *API 650, Section 5.13, Table 5.21* (lbf/ft)
M_rw = Ringwall Foundation Seismic Overturning Moment (ft.lbf)
M_s = Slab Foundation Seismic Overturning Moment (ft.lbf)
P = Design Internal Pressure (psi)
Pt = Test pressure (psi)
Pv = Design External Pressure (psi)
P_WS = Shell Wind Pressure (psi)
S = Design Snow Load (psf)
SG = Product Specific Gravity
tb = Bottom Plate Thickness (in)
Wr-attachments = Roof Attachments Weight (lb)
Wr-ins = Roof Insulation Weight (lb)
Wr-pl = Roof Plates Nominal Weight (lb)
Ws-attachments = Shell Attachments Weight (lb)
Ws-framing = Shell Framing Weight (lb)
Ws-ins = Shell Insulation Weight (lb)
Ws-pl = Shell Plates Nominal Weight (lb)
W-wind = Wind Overturning Moment (ft.lbf)

A_rss = 117.4901 ft^2
A_v = 0.0896 g
D = 12.0 ft
F-wind = 4,101.3 lbf
gamma_b = 0.2833 lbf/in^3 [489.5424 lbf/ft^3]
gamma_w = 62.4279 lb/ft^3
Hs = 24 ft
Lmax = 24.0 ft
Lr = 20.0 psf
M_rw = 108,614.2967 ft.lbf
M_s = 124,997.176 ft.lbf

P = 0.0 psi
Pt = 0.0 psi
Pv = 0.0 psi
P_WS = 0.0989 psi
S = 0.0 psf
SG = 1
tb = 0.25 in [0.0208 ft]
Wr-attachments = 149.4112 lb
Wr-ins = 0.0 lb
Wr-pl = 1,198.2584 lb
Ws-attachments = 281.9047 lb
Ws-framing = 269.7491 lb
Ws-ins = 0.0 lb
Ws-pl = 9,203.6404 lb
W-wind = 65,719.2813 ft.lbf

W_rss = Wr-pl + Wr-ins + Wr-attachments
W_rss = 1,198.2584 + 0.0 + 149.4112
W_rss = 1,347.6695 lbf

Ws = Ws-pl + Ws-ins + Ws-attachments + Ws-framing
Ws = 9,203.6404 + 0.0 + 281.9047 + 269.7491
Ws = 9,755.2942 lbf

Unfactored (Working Stress) Downward Reactions on Foundations

Load Case	Location	Equation	Value	Unit
Dead Load	Shell	(Ws + W_rss) / (pi * D)	294.5153	lbf/ft
Dead Load	Bottom	tb * gamma_b	10.1988	psf
Internal Pressure	Bottom	P	0.0	psf
Vacuum	Shell	(Pv * A_rss) / (pi * D)	0.0	lbf/ft
Hydrostatic Test	bottom	Lmax * gamma_w	1,498.2696	psf
Minimum Roof Live Load	Shell	(Lr * A_rss) / (pi * D)	62.3305	lbf/ft
Seismic	Shell	((4 * (M_rw / D)) + (0.4 * (Ws + W_rss) * A_v)) / (pi * D)	970.9167	lbf/ft
Seismic	Bottom	(32 * M_s) / (pi * (D^3))	736.8118	psf
Snow	Shell	(S * A_rss) / (pi * D)	0.0	lbf/ft
Stored Liquid	Bottom	SG * Lmax * gamma_w	1,498.2696	psf
Pressure Test	Bottom	Pt	0.0	psf
Wind	Shell	(2 * (Hs^2) * P_WS) / (pi * D)	435.1614	lbf/ft

- Seismic bottom reaction varies linearly from 32*Ms/(PI*D^3) at the tank shell to zero at the center of the tank
- API 650, Section 5.13, Table 5.21

L_dead_shell = (Ws + W_rss) / (pi * D)
L_dead_shell = (9,755.2942 + 1,347.6695) / (pi * 12.0)
L_dead_shell = 294.5153 lbf/ft

L_dead_bottom = tb * gamma_b
L_dead_bottom = 0.0208 * 489.5424
L_dead_bottom = 10.1988 psf

L_internal-pressure_bottom = P
L_internal-pressure_bottom = 0.0
L_internal-pressure_bottom = 0.0 psf

L_vacuum_shell = (Pv * A_rss) / (pi * D)
L_vacuum_shell = (0.0 * 117.4901) / (pi * 12.0)
L_vacuum_shell = 0.0 lbf/ft

L_hydrostatic_bottom = Lmax * gamma_w
L_hydrostatic_bottom = 24.0 * 62.4279
L_hydrostatic_bottom = 1,498.2696 psf

L_minimum-roof-live-load_shell = (Lr * A_rss) / (pi * D)
L_minimum-roof-live-load_shell = (20.0 * 117.4901) / (pi * 12.0)
L_minimum-roof-live-load_shell = 62.3305 lbf/ft

L_seismic_shell = ((4 * (M_rw / D)) + (0.4 * (Ws + W_rss) * A_v)) / (pi * D)
L_seismic_shell = ((4 * (108,614.2967 / 12.0)) + (0.4 * (9,755.2942 + 1,347.6695) * 0.0896)) / (pi * 12.0)
L_seismic_shell = 970.9167 lbf/ft

L_seismic_bottom = (32 * M_s) / (pi * (D^3))
L_seismic_bottom = (32 * 124,997.176) / (pi * (12.0^3))
L_seismic_bottom = 736.8118 psf

L_snow_shell = (S * A_rss) / (pi * D)
L_snow_shell = (0.0 * 117.4901) / (pi * 12.0)
L_snow_shell = 0.0 lbf/ft

L_stored-liquid_bottom = SG * Lmax * gamma_w
L_stored-liquid_bottom = 1 * 24.0 * 62.4279
L_stored-liquid_bottom = 1,498.2696 psf

L_pressure-test_bottom = Pt
L_pressure-test_bottom = 0.0
L_pressure-test_bottom = 0.0 psf

L_wind_shell = (2 * (Hs^2) * P_WS) / (pi * D)
L_wind_shell = (2 * (24^2) * 14.2406) / (pi * 12.0)
L_wind_shell = 435.1614 lbf/ft

Disclaimer and Special Notes Back

AMETank is a general-purpose software for storage tank design and detailing. AMETank employs a number of procedures and processes following API, AWWA, EN, and other related standards.

Neither employees, contractors, committees, and assignees of these standards nor TechnoSoft make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information generated by or contained within the application software, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in the application or its outputs.

Neither TechnoSoft nor any of TechnoSoft employees, subcontractors, consultants, or other assignees represent that the use of this software application would not infringe upon privately owned rights as related to any of the standards, algorithms, procedures, outputs, incorporated within, or generated by, the software.

TechnoSoft has made its best effort to assure the accuracy and reliability of the algorithms, procedures, and data employed within and generated by the software. However, TechnoSoft makes no representation, warranty, or guarantee in connection with the use of the software, outputs, or procedures and recommendations as incorporated within the documentation, manuals, training, or any other materials exchanged as part of any communications with TechnoSoft as related to the use of the software. TechnoSoft hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of the software application and information or for the violation of any authorities having jurisdiction with which this use may conflict.

AMETank facilitates the use of sound engineering practices and algorithms. The software is not intended to eliminate the need for having expertise and knowledge in deploying these sound engineering practices and algorithms. No part of the software as related to its use or the use of its outputs should be interpreted as the sole or only requirement that must be satisfied for a design. Additional requirements or alternative procedures may be used in addition to or in lieu of the software and its outputs.

The procedures, algorithms, and reports used and generated by TechnoSoft and the software should not be interpreted by anyone as the only practice or software to inhibit the use of additional or alternative procedures or applications for conducting a design.

TechnoSoft does not represent, warrant, or guarantee the accuracy or conformance to the applicable standard, of any data, equations, schematics, or other information incorporated within the data tables, references, or materials that has been made part of, used by, or generated by, the software application.