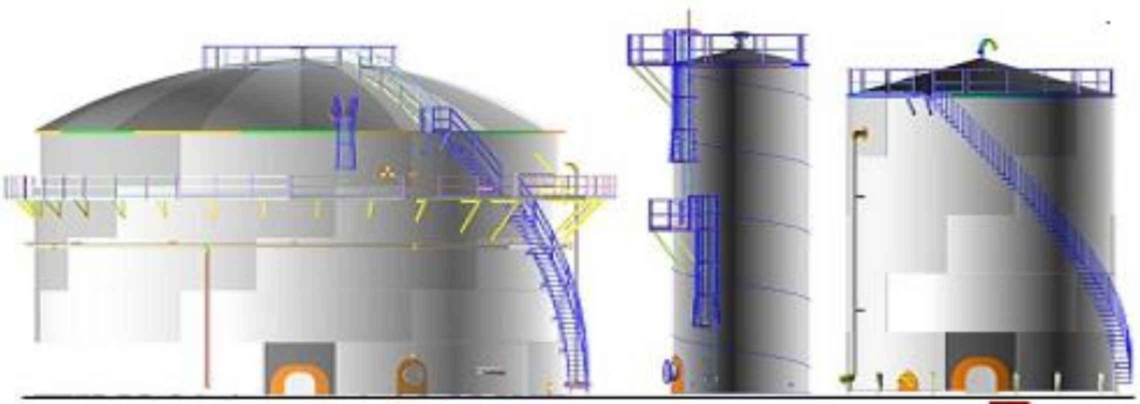
AMETANK REPORT



AMETank

Field Erected and Shop Built Storage Tanks
Engineering Application Software

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

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No Warnings!!

Project Design Data and Summary

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Project Data

Job : 2025-06-19-00-40
Date of Calcs. : 20-Jun-2025
Mfg. or Insp. Date :
Designer : Melior
Project :
Tag ID : Q9270 API
Plant :
Plant Location :
Site :
Design Basis : API-650 13th Edition Errata 1, 2021
Annexes Used : E, F, J, M, S

Design Parameters and Operating Conditions

Design Parameters

Design Internal Pressure = 0.1084 psi or 3 inh2o
Design External Pressure = -0.0361 psi or -1 inh2o

D of Tank = 10 ft
OD of Tank = 10.0313 ft
ID of Tank = 10 ft
CL of Tank = 10.0156 ft
Shell Height = 30 ft
S.G of Contents = 1.1
S.G of Hydrotest = 1
Hydrotest Liquid Level = 30 ft
Max Design Liq. Level = 30 ft
Max Operating Liq. Level = 30 ft
Min Liq. Level = 1 ft
Design Temperature = 375 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

Appendix F Data

Failure pressure (Pf) = 3.6067 psi
Maximum design pressure (P_max) = 2.2841 psi

Wind Load Basis: ASCE 7-16
3 Second Gust Wind Speed (entered), Vg = 105 mph

Design Wind Speed, V = Vg = 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)	Reduction Factor	Sd (psi)	St (psi)
1	60	A240-316	0	0.7000	21,875	75,000	0.8575	19,725	27,000
2	60	A240-316	0	0.7000	21,875	75,000	0.8575	19,725	27,000
3	60	A240-316	0	0.7000	21,875	75,000	0.8575	19,725	27,000
4	60	A240-316	0	0.7000	21,875	75,000	0.8575	19,725	27,000
5	60	A240-316	0	0.7000	21,875	75,000	0.8575	19,725	27,000
6	59.375	A240-316	0	0.7000	21,875	75,000	0.8575	19,725	27,000

(continued)

Shell #	Weight (lbf)	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)
1	1,228	1,228	0.1875	0.0601	0.0399	0.0646	NA	0.1875	0.1875
2	1,228	1,228	0.1875	0.0497	0.033	0.0539	NA	0.1875	0.1875
3	1,228	1,228	0.1875	0.0394	0.0261	0.0431	NA	0.1875	0.1875
4	1,228	1,228	0.1875	0.029	0.0193	0.0324	NA	0.1875	0.1875
5	1,228	1,228	0.1875	0.0186	0.0124	0.0218	NA	0.1875	0.1875
6	1,215	1,215	0.1875	0.0083	0.0055	0.0111	NA	0.1875	0.1875

(continued)

Shell #	Status
1	OK

2	OK
3	OK
4	OK
5	OK
6	OK

Total Weight of Shell = 7,378.2999 lbf

Roof

Type = Self Supported Conical Roof
Plates Material = A240-316
t.required = 0.1875 in
t.actual = 0.1875 in
Roof corrosion allowance = 0 in
Roof Joint Efficiency = 0.7
Plates Overlap Weight = 0 lbf
Plates Weight = 639.6276 lbf

Bottom

Type : Flat Bottom Non Annular
Bottom Material = A240-316
t.required = 0.1875 in
t.actual = 0.1875 in
Bottom corrosion allowance = 0 in
Bottom Joint Efficiency = 0.7
Total Weight of Bottom = 639.55 lbf

Top Member

Type = Detail B
Size = L2x2x1/4
Material = A240-316
Weight = 100.397 lbf

Anchors

Quantity = 4
Size = 1 in
Material = A36
Bolt Hole Circle Radius = 5.1822 ft

Nameplate Information

Pressure Combination Factor	0.4
Design Standard	API-650 13th Edition Errata 1, 2021
Appendices Used	E, F, J, M, S
Roof	A240-316 : 0.1875 in
Shell (1)	A240-316 : 0.1875 in
Shell (2)	A240-316 : 0.1875 in
Shell (3)	A240-316 : 0.1875 in

Shell (4)	A240-316 : 0.1875 in
Shell (5)	A240-316 : 0.1875 in
Shell (6)	A240-316 : 0.1875 in
Bottom	A240-316 : 0.1875 in

Roof Design Details Back

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

Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
As per API-650 S.2b, Allowable Design Stress (Sd) = 19.7250e3 psi
Density (d) = 0.290 lb/in^3
Modulus of Elasticity at Design Temperature (E) = 26.550e6 psi

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

Rh = 60.7735 in
slope = 0.166667

Description	Variable	Equation	Value	Unit
Slope Angle	Theta	ARCTAN(slope)	9.46232	deg
Angle With Vertical Line	Alpha	90 - Theta	80.5377	deg
Height	h	Rh * TAN(Theta)	10.1289	in
Surface Area	A	(pi * (Rh^2)) / COS(Theta)	11.7633e3	in^2
Center of Gravity from Base	CG	h / 3	3.37631	in
Vertical Projected Area	Av	Rh * h	615.570	in^2
Horizontal Projected Area	Ah	pi * (Rh^2)	11.6032e3	in^2
Volume	V	(pi * (Rh^2) * h) / 3	39.1760e3	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 = 8.0 lbf/ft^3
DL-add = 0.0 psf
t = 0.18750 in
t-ins = 0.0 in
Wr-pl-add = 0.0 lb

Description	Variable	Equation	Value	Unit
Plates Nominal Weight	Wr-pl	(A * d * t) + Wr-pl-add	639.628	lb

Plates Corroded Weight	Wr-pl-corr	(A * d * (t - CA)) + Wr-pl-add	639.628	lb
New Plates Dead Load Pressure	DL-pl	Wr-pl / Ah	7.93801	psf
Corroded Plates Dead Load Pressure	DL-pl-corr	Wr-pl-corr / Ah	7.93801	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	7.93801	psf
Total Nominal Dead Weight	Wr-DL	DL * Ah	639.628	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 = 0.40
Lr = 20.0 psf
Pe = 5.20219 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 = 7.93801 + MAX(20.0 , 0.0) + (0.40 * 5.20219)
e.1b = 30.0189 psf

e.2b = DL + Pe + (0.4 * MAX(Lr , Sb))
e.2b = 7.93801 + 5.20219 + (0.4 * MAX(20.0 , 0.0))
e.2b = 21.1402 psf

B = MAX(e.1b , e.2b)
B = MAX(30.0189 , 21.1402)
B = 30.0189 psf

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

e.1u = 7.93801 + MAX(20.0 , 0.0) + (0.40 * 5.20219)
e.1u = 30.0189 psf

e.2u = DL + Pe + (0.4 * MAX(Lr , Su))
e.2u = 7.93801 + 5.20219 + (0.4 * MAX(20.0 , 0.0))
e.2u = 21.1402 psf

U = MAX(e.1u , e.2u)
U = MAX(30.0189 , 21.1402)
U = 30.0189 psf

max-gravity-load = MAX(B , U)
max-gravity-load = MAX(30.0189 , 30.0189)
max-gravity-load = 30.0189 psf

W-max-gravity-load = max-gravity-load * Ah
W-max-gravity-load = 30.0189 * 80.5779
W-max-gravity-load = 2.41886e3 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) = 0.18750 in

t-erec-req = t-erec + CA
t-erec-req = 0.18750 + 0.0
t-erec-req = 0.18750 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 * 10.0) / SIN(9.46232)) * SQRT((30.0189 / (144 * 26.550e6)))) + 0.0
t-calc-1 = 0.129359 in

B-max = (((t-actual - CA) * (SIN(Theta) / (2 * 12 * D)))^2) * 144 * E
B-max = (((0.18750 - 0.0) * (SIN(9.46232) / (2 * 12 * 10.0)))^2) * 144 * 26.550e6
B-max = 63.0675 psf

Pe-max-1 = MAX(((L_max - DL - MAX(Lr , S)) / Fpe) , 0)
Pe-max-1 = MAX(((63.0675 - 7.93801 - MAX(20.0 , 0.0)) / 0.40) , 0)
Pe-max-1 = 87.8236 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 * 10.0) / SIN(9.46232)) * SQRT((30.0189 / (1.33 * 144 * 26.550e6)))) + 0.0
t-calc-2 = 0.112168 in

U-max = (((t-actual - CA) * (SIN(Theta) / (2 * 12 * D)))^2) * 1.33 * 144 * E
U-max = (((0.18750 - 0.0) * (SIN(9.46232) / (2 * 12 * 10.0)))^2) * 1.33 * 144 * 26.550e6

U-max = 83.8797 psf

Pe-max-2 = MAX(((L_max - DL - MAX(Lr , S)) / Fpe) , 0)
Pe-max-2 = MAX(((83.8797 - 7.93801 - MAX(20.0 , 0.0)) / 0.40) , 0)
Pe-max-2 = 139.854 psf

API-650 Appendix F Internal Pressure Thickness Calculation

Alpha = Half Apex Angle of Cone Roof (deg)
Ca = Corrosion Allowance (in)
DL-add = Additional Dead Load (psf)
DL-plates = Plates Dead Load (psf)
E = Joint Efficiency
L-max-F = Maximum Roof Load Based on Installed Thickness (psi)
P = Internal Design Pressure (psi)
P-max-F = Maximum Design Pressure (psi)
P-net = Net Internal Pressure (psi)
Rt = Nominal Tank Radius (in)
Sd = Allowable Stress for the Design Condition (psi)
t = Roof Actual Thickness (in)
t-calc-F = Minimum Roof Thickness Required for Internal Pressure per *API-650 F.6* (in)

Alpha = 80.5377 deg
Ca = 0.0 in
DL-add = 0.0 psf
DL-plates = 7.93801 psf
E = 0.70
P = 0.108379 psi
Rt = 60.0 in
Sd = 19.7250e3 psi
t = 0.18750 in

P-net = MAX((P - DL-plates - DL-add) , 0)
P-net = MAX((0.108379 - 0.0551250 - 0.0) , 0)
P-net = 0.0532538 psi

t-calc-F = ((P-net * Rt) / (COS(Alpha) * Sd * E)) + Ca
t-calc-F = ((0.0532538 * 60.0) / (COS(80.5377) * 19.7250e3 * 0.70)) + 0.0
t-calc-F = 0.00140763 in

L-max-F = ((t - Ca) * (COS(Alpha) * Sd * E)) / Rt
L-max-F = ((0.18750 - 0.0) * (COS(80.5377) * 19.7250e3 * 0.70)) / 60.0
L-max-F = 7.09356 psi

P-max-F = L-max-F + DL-plates + DL-add
P-max-F = 7.09356 + 0.0551250 + 0.0
P-max-F = 7.14868 psi

Required Thickness

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

t-act = 0.18750 in

t-req = MAX(t-erec-req , t-calc-1 , t-calc-2 , t-calc-F)
t-req = MAX(0.18750 , 0.129359 , 0.112168 , 0.00140763)
t-req = 0.18750 in

t >= t-req ==> PASS

MAWP-Roof = P-max-F
MAWP-Roof = 7.14868
MAWP-Roof = 7.14868 psi

MAWV-Roof = MIN(Pe-max-1 , Pe-max-2)
MAWV-Roof = MIN(87.8236 , 139.854)
MAWV-Roof = 87.8236 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 = 7.37830e3 + 103.391
DLS = 7.48169e3 lbf

DLR = Wr + W_structural
DLR = 639.628 + 260.865
DLR = 900.493 lbf

Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 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 = (120.0 / 2) / SIN(9.46232)
R2 = 364.966 in

Wh = 0.3 * SQRT((R2 * (th - CA-head)))
Wh = 0.3 * SQRT((364.966 * (0.18750 - 0.0)))
Wh = 2.48169 in

Wc = 0.6 * SQRT(((ID / 2) * (tc-nominal - CA-shell)))
Wc = 0.6 * SQRT(((120.0 / 2) * (0.18750 - 0.0)))
Wc = 2.01246 in

Angle Size L2X2X1/4 Section Properties

Description	Variable	New	Corroded	Unit

Weight	W	3.190	3.190	lbf/ft
Cross Sectional Area	A	0.9440	0.9440	in^2
Moment Of Inertia About X Axis	Ix	0.3460	0.3460	in^4
Moment Of Inertia About Y Axis	Iy	0.3460	0.3460	in^4
Section Modulus About X Axis	Sx	0.2440	0.2440	in^3
Section Modulus About Y Axis	Sy	0.2440	0.2440	in^3
Centroid X Coords	cx	0.5860	0.5860	in
Centroid Y Coords	cy	0.5860	0.5860	in
Angle Long Leg Length	L1-angle	2.0	2.0	in
Angle Short Leg Length	L2-angle	2.0	2.0	in
Angle Thickness	t-angle	0.250	0.250	in

I_shell = ((Wc - h) * ((tc-nominal - CA-shell)^3)) / 12
I_shell = ((2.01246 - 0.250) * ((0.18750 - 0.0)^3)) / 12
I_shell = 968.149e-6 in^4

A_shell = (Wc - h) * (tc-nominal - CA-shell)
A_shell = (2.01246 - 0.250) * (0.18750 - 0.0)
A_shell = 0.330461 in^2

A_roof = Wh * (th - CA-head)
A_roof = 2.48169 * (0.18750 - 0.0)
A_roof = 0.465317 in^2

A_detail = A_shell + A_roof + A-corr
A_detail = 0.330461 + 0.465317 + 0.9440
A_detail = 1.73978 in^2

Stiffener and Shell Combined Section Properties

Description	Variable	Equation	Value	Unit
Shell centroid	d_shell	(tc-nominal - CA-shell) / 2	0.093750	in
Stiffener centroid	d_stiff	cy + (tc-nominal - CA-shell)	0.77350	in
moment of inertia of first body	I_1	Ic + (Area * (Distance^2))	0.910797	in^4
moment of inertia of second body	I_2	Ic + (Area * (Distance^2))	0.00387260	in^4
Total area	A_sum	A_1 + A_2	1.27446	in^2
Sum of moments of inertia's	I_sum	I_1 + I_2	0.914670	in^4
Combined centroid	c_combined	((Centroid-1 * Area-1) + (Centroid-2 * Area-2)) / (Area-1 + Area-2)	0.597244	in
Combined moment of inertia	I_combined	Ic - (Area * (Distance^2))	0.460069	in^4
Distance from neutral axis to edge 1 (inside)	e1	c_combined	0.597244	in
Distance from neutral axis to edge 2 (outside)	e2	((tc-nominal - CA-shell) + L1-angle) - e1	1.59026	in

Combined stiffener shell section modulus	S	I / MAX(d-1 , d-2)	0.289305	in^3

d_shell = (tc-nominal - CA-shell) / 2
d_shell = (0.18750 - 0.0) / 2
d_shell = 0.093750 in

d_stiff = cy + (tc-nominal - CA-shell)
d_stiff = 0.5860 + (0.18750 - 0.0)
d_stiff = 0.77350 in

I_1 = Ic + (Area * (Distance^2))
I_1 = 0.3460 + (0.9440 * (0.77350^2))
I_1 = 0.910797 in^4

I_2 = Ic + (Area * (Distance^2))
I_2 = 968.149e-6 + (0.330461 * (0.093750^2))
I_2 = 0.00387260 in^4

A_sum = A_1 + A_2
A_sum = 0.9440 + 0.330461
A_sum = 1.27446 in^2

I_sum = I_1 + I_2
I_sum = 0.910797 + 0.00387260
I_sum = 0.914670 in^4

c_combined = ((Centroid-1 * Area-1) + (Centroid-2 * Area-2)) / (Area-1 + Area-2)
c_combined = ((0.77350 * 0.9440) + (0.093750 * 0.330461)) / (0.9440 + 0.330461)
c_combined = 0.597244 in

I_combined = Ic - (Area * (Distance^2))
I_combined = 0.914670 - (1.27446 * (0.597244^2))
I_combined = 0.460069 in^4

e1 = c_combined
e1 = 0.597244
e1 = 0.597244 in

e2 = ((tc-nominal - CA-shell) + L1-angle) - e1
e2 = ((0.18750 - 0.0) + 2.0) - 0.597244
e2 = 1.59026 in

S = I / MAX(d-1 , d-2)
S = 0.460069 / MAX(0.597244 , 1.59026)
S = 0.289305 in^3

Erection Requirement
As per API-650 5.1.5.9, Minimum Size of Top Corner Ring (Size-min) = L2x2x3/16
Minimum Section Modulus per Erection Requirement (Sx-min) = 0.1880 in^3
Section Modulus (Sx) = 0.289305 in^3

Sx >= Sx-min ==> PASS

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 = 21.8750e3 psi
p = 30.0189 psf

Fa = 0.6 * Fy
Fa = 0.6 * 21.8750e3
Fa = 13.1250e3 psi

A_roof = (p * (D^2)) / (8 * Fa * TAN(theta))
A_roof = (30.0189 * (10.0^2)) / (8 * 13.1250e3 * TAN(9.46232))
A_roof = 0.171536 in^2

A_detail >= A_roof ==> PASS

Max-p = (A_detail / (D^2)) * 8 * Fa * TAN(theta)
Max-p = (1.73978 / (10.0^2)) * 8 * 13.1250e3 * TAN(9.46232)
Max-p = 304.461 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)
Net_uplift = Net uplift due to internal pressure (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)
W_total = Weight of roof shell and attached-framing (lbf)

A_actual = 1.73978 in^2
D = 10.0 ft
DLR = 900.493 lbf
DLS = 7.48169e3 lbf
Fp = 0.40
Fy = 21.8750e3 psi

ID = 10.0 ft
MDL = 37.4085e3 ft.lbf
MDLR = 4.50247e3 ft.lbf
MF = 21.2058e3 ft.lbf
Mw = 44.9275e3 ft.lbf
Mws = 39.1098e3 ft.lbf
P = 0.108379 psi
Theta angle = 9.46232 deg
W_add_DL = 0.0 lbf
W_framing = 103.391 lbf
Wr = 639.628 lbf
Ws = 7.37830e3 lbf
W_structural = 260.865 lbf

P_uplift = P * pi * ((ID^2) / 4)
P_uplift = 0.108379 * pi * ((120.0^2) / 4)
P_uplift = 1.22574e3 lbf

W_total = Wr + Ws + W_framing + W_structural + W_add_DL
W_total = 639.628 + 7.37830e3 + 103.391 + 260.865 + 0.0
W_total = 8.38218e3 lbf

Net_uplift = MAX((P_uplift - W_total) , 0)
Net_uplift = MAX((1.22574e3 - 8.38218e3) , 0)
Net_uplift = 0.0 lbf

Wr < P_uplift <= W_total , Tank design should meet F.2 to F.7 requirements.

P_max_internal = Maximum allowable internal pressure (psi)

P_f = Calculated failure pressure for frangible roof per *API 650, Section F.7* (inH2O)
P_max = Maximum design pressure (inH2O)
P_max_F41 = Maximum design pressure per *API 650, Section F.4.1* (inH2O)

P_max_F41 = ((0.962 * A_actual * F_y * TAN(Theta)) / (D^2)) + ((0.245 * D_LR) / (D^2))
P_max_F41 = ((0.962 * 1.73978 * 21.8750e3 * TAN(9.46232)) / (10.0^2)) + ((0.245 * 900.493) / (10.0^2))
P_max_F41 = 63.2253 inH2O [2.28410 psi]

P_f = (1.6 * P) - ((0.147 * D_LR) / (D^2))
P_f = (1.6 * 63.2253) - ((0.147 * 900.493) / (10.0^2))
P_f = 99.8368 inH2O [3.60673 psi]

P_max = P_max_F41
P_max = 63.2253
P_max = 63.2253 inH2O [2.28410 psi]

P <= P_max ==> Design internal pressure is less than maximum allowable pressure per API-650 F.4

A_F51 = Required area per *API 650 F.5.1* (in^2)

A_F51 = ((D^2) * (P - ((0.245 * DLR) / (D^2)))) / (0.962 * Fy * TAN(Theta angle))
A_F51 = ((10.0^2) * (3.0 - ((0.245 * 900.493) / (10.0^2)))) / (0.962 * 21.8750e3 * TAN(9.46232))
A_F51 = 0.0226326 in^2

A_actual >= A_F51 ==> PASS

As per API-650 5.2.1 c), Maximum design internal pressure (P_std) = 2.50 psi

P_max_internal = MIN(P_std , P_max)
P_max_internal = MIN(2.50 , 2.28410)
P_max_internal = 2.28410 psi

Agitator Bridge Design [Back]

A-es-req = End Support Required Cross Sectional Area (in^2)
A-platform = Platform Total Area (ft^2)
As-available = End Support Compressive Stress Shell Available Area (in^2)
As-required = Shell Required Compressive Area Around End Supports (in^2)
CA-es = End Support Corrosion Allowance (in)
CA-ps = Primary Support Corrosion Allowance (in)
delta-d = Primary Support Static + Dynamic Loads Deflection (in)
delta-d-allowable = Primary Support Dynamic Load Allowable Deflection (in)
delta-sd = Primary Support Static + Dynamic Actual Deflection (in)
delta-sd-allowable = Primary Support Static + Dynamic Allowable Deflection (in)
d-ps = Primary Supports Distance (platform width) (in)
Fa-leg = Total Downward Force per Leg including Dead Load, Live Load, and Mixer Dynamic Loads, and Leg Weight (lbf)
Fa-total = Total Downward Force including Dead Load, Live Load, and Mixer Dynamic Loads (lbf)
fb-es = End Support Total Bending Stress (psi)
fb-es-req = End Support Allowable Bending Stress (psi)
fbx-es = End Support Bending Stress About X Axis (psi)
fby-es = End Support Bending Stress About Y Axis (psi)
fc-es = End Support Compressive Stress (psi)
fc-es-req = End Support Allowable Compressive Stress (psi)
k = End Support Effective Length Factor
L-es = End Support Length (in)
L-es-min = End Support Required Length (in)
L-es-min-overlap = End Support Shell Minimum Overlap (in)
L-es-shell-overlap = End Support Shell Overlap (in)
LL-platform = Platform Live Load (psf)
L-ps = Primary Support Length (ft)
L-ps-unbraced = Platform Primary Unbraced Length (in)
Ma-es = End Support Material
Ma-ps = Primary Support Material
M-max-support = Primary Support Maximum Bending Moment (ft.lbf)
Mx-es = End Support Bending Moment About X Axis (in.lbf)
My-es = End Support Bending Moment About Y Axis (in.lbf)
outside-proj-1-ps = Platform Outside Projection Side 2 (in)
outside-proj-2-ps = Platform Outside Projection Side 1 (in)
Pd = Primary Support Agitator Dynamic Point Load (lbf)
Ps = Primary Support Agitator Static Point Load (lbf)
Psd = Primary Support Agitator Center Load (lbf)
Sb-allowable-support = Primary Support Allowable Bending Stress (psi)
Scs = Maximum Allowable Compressive Stress per *API-620 5.5.4.2* (psi)
size-es = End Support Size
size-ps = Primary Support Size
Sx-reqd-support = Primary Support Required Section Modulus (in^3)
t/R = Thickness to Tank Radius Ratio
t-repad-es = End Support Repad Thickness (in)
t-req-repad = End Support Repad Required Thickness (in)
V-max-support = Primary Support Maximum Shear (lbf)
W-add-platform = Platform Additional Weight (lbf)
W-platform = Platform Weight (lbf)
w-repad-es = End Support Repad Width (in)
W-support = Primary Support Uniform Load (lbf/ft)
W-total-platform = Platform Total Weight (lbf)

CA-es = 0.0 in
CA-ps = 0.0 in
d-ps = 36.0 in
k = 2.10
L-es = 22.0 in
L-es-shell-overlap = 11.0 in
LL-platform = 20.0 psf
L-ps-unbraced = 48.50 in
Ma-es = A240-316
Ma-ps = A240-316
outside-proj-1-ps = 15.0 in
outside-proj-2-ps = 15.0 in
size-es = w6x20
size-ps = w6x20
t-repad-es = 0.3750 in
W-add-platform = 0.0 lbf
W-platform = 213.988 lbf
w-repad-es = 8.020 in

L-ps = OD
L-ps = 10.0313
L-ps = 10.0313 ft

A-platform = L-ps * d-ps
A-platform = 10.0313 * 3.0
A-platform = 30.0937 ft^2

W-total-platform = W-platform + W-add-platform
W-total-platform = 213.988 + 0.0
W-total-platform = 213.988 lbf

Agitator Bridge Primary Support Design

Agitator Bridge Primary Support Material Properties

Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
Modulus of Elasticity at Design Temperature (E) = 26.550e6 psi

Agitator Bridge Primary Support I-Beam Size W6X20 Section Properties

Description	Variable	New	Corroded	Unit
Weight	W	20.0	20.0	lbf/ft
Cross Sectional Area	A	5.870	5.870	in^2
Radius of Gyration About X Axis	rx	2.660	2.660	in
Radius of Gyration About Y Axis	ry	1.50	1.50	in
Moment Of Inertia About X Axis	Ix	41.40	41.40	in^4
Moment Of Inertia About Y Axis	Iy	13.30	13.30	in^4
Section Modulus About X Axis	Sx	13.40	13.40	in^3
Section Modulus About Y Axis	Sy	4.410	4.410	in^3
Plastic Section Modulus About X Axis	Zx	15.0	15.0	in^3
Plastic Section Modulus About Y Axis	Zy	6.720	6.720	in^3

Warping Constant	cw	113.0	113.0	in^6
Torsional Constant	j	0.240	0.240	in^4
Centroid to Edge Max x Distance	ex	3.010	3.010	in
Centroid to Edge Max y Distance	ey	3.10	3.10	in
I-Beam Flange Width	wf	6.020	6.020	in
I-Beam Flange Thickness	tf	0.3650	0.3650	in
I-Beam Depth	d	6.20	6.20	in
I-Beam Web Thickness	tw	0.260	0.260	in

Agitator Bridge Primary Support Allowable Flexural Strength per AISC-360
b = Flange Outstand Length per *AISC-360 table B4.1b* (in)
h_w = Web height (in)
lambda = Slenderness parameter
lambda_pf = Limiting slenderness parameter for compact flange
lambda_pw = Limiting slenderness parameter for compact web
lambda_rf = Limiting slenderness parameter for noncompact flange
lambda_rw = Limiting slenderness parameter for noncompact web
L_p = Limiting laterally unbraced length for the limit state of yielding per *AISC-360 Section F2, Eq F2-5* (in)
M_allow = Allowable Flexural Strength (lbf.in)
M_n = Nominal flexural strength per *AISC-360 Section F2* (lbf.in)
M_n_Y = Nominal Flexural Strength due to Yielding per *AISC-360 Section F2, Eq F2-1* (lbf.in)
M_n_Y_allow = Allowable Flexural Strength Assuming the Member is Braced (Yield Only) (lbf.in)
w_f = Flange Total width (in)

w_f = wf = 6.020 in

b = w_f / 2 = 3.010 in

h_w = d - (2 * tf) = 5.470 in

lambda = b / tf
lambda = 3.010 / 0.3650
lambda = 8.24658

lambda_pf = 0.38 * SQRT((E / Fy))
lambda_pf = 0.38 * SQRT((26.550e6 / 21.8750e3))
lambda_pf = 13.2386

lambda_rf = 1 * SQRT((E / Fy))
lambda_rf = 1 * SQRT((26.550e6 / 21.8750e3))
lambda_rf = 34.8384

lambda_pw = 3.76 * SQRT((E / Fy))
lambda_pw = 3.76 * SQRT((26.550e6 / 21.8750e3))
lambda_pw = 130.992

lambda_rw = 5.7 * SQRT((E / Fy))
lambda_rw = 5.7 * SQRT((26.550e6 / 21.8750e3))
lambda_rw = 198.579

As per AISC-360 table B4.1b Flange width to thickness ratio check :
lambda <= lambda_pf

==> Flange is compact

As per AISC-360 table B4.1b Web height to thickness ratio check :
(h_w / tw) <= lambda_pw

==> Web is compact

M_n_Y = Fy * Zx
M_n_Y = 21.8750e3 * 15.0
M_n_Y = 328.125e3 lbf.in

Unbraced length (Lb) = 48.50 in

L_p = 1.76 * ry * SQRT((E / Fy))
L_p = 1.76 * 1.50 * SQRT((26.550e6 / 21.8750e3))
L_p = 91.9734 in

Lb <= L_p

M_n = (M_n_Y) = 328.125e3 lbf.in

M_allow = M_n / 1.67
M_allow = 328.125e3 / 1.67
M_allow = 196.482e3 lbf.in

M_n_Y_allow = M_n_Y / 1.67
M_n_Y_allow = 328.125e3 / 1.67
M_n_Y_allow = 196.482e3 lbf.in

Agitator Bridge Primary Support Loads
Ps = W-agitator / 2
Ps = 500.0 / 2
Ps = 250.0 lbf

Pd = (Fa + (Mx / (0.5 * d-ps))) / 2
Pd = (0.0 + (0.0 / (0.5 * 36.0))) / 2
Pd = 0.0 lbf

Psd = Ps + Pd
Psd = 250.0 + 0.0
Psd = 250.0 lbf

W-support = W-primary-support + ((0.5 * (W-total-platform + (A-platform * LL-platform))) / L-ps)
W-support = 20.0 + ((0.5 * (213.988 + (30.0937 * 20.0))) / 10.0313)
W-support = 60.6661 lbf/ft

M-max-support = ((W-support * (L-ps^2)) / 8) + ((Psd * L-ps) / 4)
M-max-support = ((60.6661 * (10.0313^2)) / 8) + ((250.0 * 10.0313) / 4)
M-max-support = 1.39003e3 ft.lbf

V-max-support = ((W-support * (L-ps + outside-proj-1-ps + outside-proj-2-ps)) + (My / (L-ps / 2)) + Psd) / 2
V-max-support = ((60.6661 * (10.0313 + 1.250 + 1.250)) + (0.0 / (120.375 / 2)) + 250.0) / 2
V-max-support = 505.111 lbf

Agitator Bridge Primary Support Required Section Modulus
Sb-allowable-support = M_allow / Sx-primary-support
Sb-allowable-support = 196.482e3 / 13.40
Sb-allowable-support = 14.6628e3 psi

Sx-reqd-support = M-max-support / Sb-allowable-support
Sx-reqd-support = 16.6803e3 / 14.6628e3
Sx-reqd-support = 1.13759 in^3

Sx-primary-support >= Sx-reqd-support ==> PASS

Agitator Bridge Primary Support Maximum Allowable Deflection
delta-sd = ((5 * W-support * (L-ps^4)) / (384 * E * Ix-primary-support)) + ((Psd * (L-ps^3)) / (48 * E * Ix-primary-support))
delta-sd = ((5 * 5.05551 * (120.375^4)) / (384 * 26.550e6 * 41.40)) + ((250.0 * (120.375^3)) / (48 * 26.550e6 * 41.40))
delta-sd = 0.0208393 in

delta-sd-allowable = L-ps / 360
delta-sd-allowable = 120.375 / 360.0
delta-sd-allowable = 0.334375 in

delta-sd <= delta-sd-allowable ==> PASS

delta-d = (Pd * (L-ps^3)) / (48 * E * Ix-primary-support)
delta-d = (0.0 * (120.375^3)) / (48 * 26.550e6 * 41.40)
delta-d = 0.0 in

delta-d-allowable = 0.5 * L-ps * TAN(0.1)
delta-d-allowable = 0.5 * 120.375 * TAN(0.10)
delta-d-allowable = 0.105047 in

delta-d <= delta-d-allowable ==> PASS

Agitator Bridge End Support Design
Agitator Bridge End Support Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
Modulus of Elasticity at Design Temperature (E) = 26.550e6 psi

Agitator Bridge End Support I-Beam Size W6X20 Section Properties

Description	Variable	New	Corroded	Unit
Weight	W	20.0	20.0	lbf/ft
Cross Sectional Area	A	5.870	5.870	in^2
Radius of Gyration About X Axis	rx	2.660	2.660	in
Radius of Gyration About Y Axis	ry	1.50	1.50	in
Moment Of Inertia About X Axis	Ix	41.40	41.40	in^4
Moment Of Inertia About Y Axis	Iy	13.30	13.30	in^4
Section Modulus About X Axis	Sx	13.40	13.40	in^3
Section Modulus About Y Axis	Sy	4.410	4.410	in^3

Plastic Section Modulus About X Axis	Zx	15.0	15.0	in^3
Plastic Section Modulus About Y Axis	Zy	6.720	6.720	in^3
Warping Constant	cw	113.0	113.0	in^6
Torsional Constant	j	0.240	0.240	in^4
Centroid to Edge Max x Distance	ex	3.010	3.010	in
Centroid to Edge Max y Distance	ey	3.10	3.10	in
I-Beam Flange Width	wf	6.020	6.020	in
I-Beam Flange Thickness	tf	0.3650	0.3650	in
I-Beam Depth	d	6.20	6.20	in
I-Beam Web Thickness	tw	0.260	0.260	in

Agitator Bridge End Support Allowable Flexural Strength per AISC-360
b = Flange Outstand Length per *AISC-360 table B4.1b* (in)
h_w = Web height (in)
lambda = Slenderness parameter
lambda_pf = Limiting slenderness parameter for compact flange
lambda_pw = Limiting slenderness parameter for compact web
lambda_rf = Limiting slenderness parameter for noncompact flange
lambda_rw = Limiting slenderness parameter for noncompact web
L_p = Limiting laterally unbraced length for the limit state of yielding per *AISC-360 Section F2, Eq F2-5* (in)
M_allow = Allowable Flexural Strength (lbf.in)
M_n = Nominal flexural strength per *AISC-360 Section F2* (lbf.in)
M_n_Y = Nominal Flexural Strength due to Yielding per *AISC-360 Section F2, Eq F2-1* (lbf.in)
M_n_Y_allow = Allowable Flexural Strength Assuming the Member is Braced (Yield Only) (lbf.in)
w_f = Flange Total width (in)

w_f = wf = 6.020 in

b = w_f / 2 = 3.010 in

h_w = d - (2 * tf) = 5.470 in

lambda = b / tf
lambda = 3.010 / 0.3650
lambda = 8.24658

lambda_pf = 0.38 * SQRT((E / Fy))
lambda_pf = 0.38 * SQRT((26.550e6 / 21.8750e3))
lambda_pf = 13.2386

lambda_rf = 1 * SQRT((E / Fy))
lambda_rf = 1 * SQRT((26.550e6 / 21.8750e3))
lambda_rf = 34.8384

lambda_pw = 3.76 * SQRT((E / Fy))
lambda_pw = 3.76 * SQRT((26.550e6 / 21.8750e3))
lambda_pw = 130.992

lambda_rw = 5.7 * SQRT((E / Fy))
lambda_rw = 5.7 * SQRT((26.550e6 / 21.8750e3))

lambda_rw = 198.579

As per AISC-360 table B4.1b Flange width to thickness ratio check :
lambda <= lambda_pf

==> Flange is compact

As per AISC-360 table B4.1b Web height to thickness ratio check :
(h_w / tw) <= lambda_pw

==> Web is compact

M_n_Y = Fy * Zx
M_n_Y = 21.8750e3 * 15.0
M_n_Y = 328.125e3 lbf.in

Unbraced length (Lb) = 11.0 in

L_p = 1.76 * ry * SQRT((E / Fy))
L_p = 1.76 * 1.50 * SQRT((26.550e6 / 21.8750e3))
L_p = 91.9734 in

Lb <= L_p

M_n = (M_n_Y) = 328.125e3 lbf.in

M_allow = M_n / 1.67
M_allow = 328.125e3 / 1.67
M_allow = 196.482e3 lbf.in

M_n_Y_allow = M_n_Y / 1.67
M_n_Y_allow = 328.125e3 / 1.67
M_n_Y_allow = 196.482e3 lbf.in

Agitator Bridge End Support Allowable Compressive Strength per AISC-360
bf = Flange width (in)
Fe = Elastic Buckling Stress per *AISC-360 E3-4* (psi)
h = Web height (in)
lambda_rf = Limiting slenderness parameter for flanges per *AISC 360 Table B4.1a*
lambda_rw = Limiting slenderness parameter for web per *AISC 360 Table B4.1a*
Pa = Allowable Compressive Strength (lbf)
P_n = Nominal compressive strength per *AISC-360 E3-1* (lbf)

Radius of gyration :
((K * L_y) / ry) > ((K * L_x) / rx) ==> Radius of gyration about y axis governs

Fe = ((pi^2) * E) / (((K * L_y) / ry)^2)
Fe = ((pi^2) * 26.550e6) / (((2.10 * 22.0) / 1.50)^2)
Fe = 276.225e3 psi

bf = wf / 2
bf = 6.020 / 2
bf = 3.010 in

h = d - (2 * tf)

h = 6.20 - (2 * 0.3650)
h = 5.470 in

lambda_rf = 0.56 * SQRT((E / Fy))
lambda_rf = 0.56 * SQRT((26.550e6 / 21.8750e3))
lambda_rf = 19.5095

lambda_rw = 1.49 * SQRT((E / Fy))
lambda_rw = 1.49 * SQRT((26.550e6 / 21.8750e3))
lambda_rw = 51.9092

As per AISC-360 table B4.1a Flange width to thickness ratio check :
(bf / tf) <= lambda_rf ==> Flange is not slender

As per AISC-360 table B4.1a Web height to thickness ratio check :
(h / tw) <= lambda_rw ==> Web is not slender

F_cr = Critical stress per *AISC-360 Eq. E3-2* (psi)

(Fy / Fe) <= 2.25

F_cr = (0.658^(Fy / Fe)) * Fy
F_cr = (0.658^(21.8750e3 / 276.225e3)) * 21.8750e3
F_cr = 21.1618e3 psi

P_n = F_cr * A_g
P_n = 21.1618e3 * 5.870
P_n = 124.220e3 lbf

Pa = P_n / 1.67
Pa = 124.220e3 / 1.67
Pa = 74.3831e3 lbf

Agitator Bridge End Support Required Length
Fa-leg = V-max-support + (L-es * W-end-support)
Fa-leg = 505.111 + (22.0 * 1.66667)
Fa-leg = 541.777 lbf

t/R = (ts - CA) / (D / 2)
t/R = (0.18750 - 0.0) / (120.0 / 2)
t/R = 0.0031250

Scs = 1800000 * ratio
Scs = 1800000 * 0.0031250
Scs = 5.6250e3 psi

As-required = Fa-leg / Scs
As-required = 541.777 / 5.6250e3
As-required = 0.0963160 in^2

L-es-min-overlap = As-required / (2 * (ts - CA) * TAN(30))
L-es-min-overlap = 0.0963160 / (2 * (0.18750 - 0.0) * TAN(30))
L-es-min-overlap = 0.444865 in

L-es-min = L-es-min-overlap + (L-es - L-es-shell-overlap)
L-es-min = 0.444865 + (22.0 - 11.0)

L-es-min = 11.4449 in

L-es >= L-es-min ==> PASS

Agitator Bridge End Support Shell Reinforcement Requirements
(2 * L-es-min-overlap * TAN(30)) < d-ps ==> Supports compression zones are not overlapping

As-available = (2 * L-es-shell-overlap * TAN(30) * (ts - CA)) + (w-repad-es * t-repad-es)
As-available = (2 * 11.0 * TAN(30) * (0.18750 - 0.0)) + (8.020 * 0.3750)
As-available = 5.38907 in^2

t-req-repad = (As-required - (2 * L-es-shell-overlap * TAN(30) * (ts - CA))) / w-repad-es
t-req-repad = (0.0963160 - (2 * 11.0 * TAN(30) * (0.18750 - 0.0))) / 8.020
t-req-repad = -0.284944 (Set to 0.0 in since it cannot be less than 0.0)

t-repad-es >= t-req-repad ==> PASS

Agitator Bridge End Support Required Section Modulus
Mx-es = V-max-support * ey
Mx-es = 505.111 * 3.10
Mx-es = 1.56584e3 in.lbf

fbx-es = Mx-es / Sx-end-support
fbx-es = 1.56584e3 / 13.40
fbx-es = 116.854 psi

My-es = (Mz / (0.5 * L-ps)) * (L-es - L-es-shell-overlap)
My-es = (0.0 / (0.5 * 120.375)) * (22.0 - 11.0)
My-es = 0.0 in.lbf

fby-es = My-es / Sy-end-support
fby-es = 0.0 / 4.410
fby-es = 0.0 psi

fb-es = fbx-es + fby-es
fb-es = 116.854 + 0.0
fb-es = 116.854 psi

fb-es-req = M_allow / Sx-end-support
fb-es-req = 196.482e3 / 13.40
fb-es-req = 14.6628e3 psi

fb-es <= fb-es-req ==> PASS

Agitator Bridge End Support Required Cross Sectional Area
fc-es = Fa-leg / A-end-support
fc-es = 541.777 / 5.870
fc-es = 92.2960 psi

fc-es-req = Pa / A-end-support
fc-es-req = 74.3831e3 / 5.870
fc-es-req = 12.6717e3 psi

A-es-req = Fa-leg / fc-es-req
A-es-req = 541.777 / 12.6717e3
A-es-req = 0.0427548 in^2

A-end-support >= A-es-req ==> PASS

Agitator Bridge Total Downward Force (Including Dynamic Loads)
Fa-total = Fa-leg * 4
Fa-total = 541.777 * 4
Fa-total = 2.16711e3 lbf

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 = 0.05410
Ai = 0.060
Av = 0.08960
D = 10.0 ft
d-ins = 8.0 lbf/ft^3
G = 1.10
Gt = 1.0
H = 30.0 ft
H-Hydrotest-L = 30.0 ft
HL = 30.0 ft
h-min = 48.0 in
Pe = 5.20219 psf
Pi = 0.108379 psi
Rwi = 4.0
t-ins = 0.0 in
V = 81.90 mile/hr
W-shell-add = 0.0 lb

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

Rwi = Impulsive Force Reduction Factor

Rwi = 4.0

Course # 1 (bottom course) Design

A1 = Shell Course Cross Sectional Area (in^2)
CA = Corrosion allowance per *API-650 5.3.2* (in)
D1 = Shell Course Centerline Diameter (in)
H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)
H = Design Liquid Level per *API-650 5.6.3.2* (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 Section S.3.2.2.3* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *S.3.2.2.3* (in)
W-1 = Shell Course Nominal Weight (lb)
W-1-corr = Shell Course Nominal Weight (lb)
Ws-tot-top = Top Weight Total (lbf)

CA = 0.0 in
H = 30.0 ft
h1 = 5.0 ft
H-Hydrotest = 30.0 ft
JE = 0.70
loc = 0.0 ft
Ma = A240-316
Rwi = 4.0
t = 0.18750 in

Shell Course Center of Gravity (CG-1) = 2.50 ft

D1 = ID + t
D1 = 120.0 + 0.18750
D1 = 120.188 in

W-1 = pi * Dc * t * h1 * d
W-1 = pi * 120.188 * 0.18750 * 60.0 * 0.290
W-1 = 1.23186e3 lb

W-1-corr = pi * Dc * (t - CA) * h1 * d
W-1-corr = pi * 120.188 * (0.18750 - 0.0) * 60.0 * 0.290
W-1-corr = 1.23186e3 lb

Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
As per API-650 S.2b, Allowable Design Stress (Sd) = 19.7250e3 psi
As per API-650 S.2b, Allowable Hydrostatic Test Stress (St) = 27.0e3 psi

Thickness Required by Erection
As per API-650 S.3.2.1.1 and 5.6.1.1, Thickness Required by Erection (t_erec) = 0.18750 in

Thickness Required by Design
H' = H
H' = 30.0

H' = 30.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 10.0 * (30.0 - 1) * 1.10) / (0.70 * 19.7250e3)) + 0.0
t_d = 0.0600688 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 30.0
Ht' = 30.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 10.0 * (30.0 - 1) * 1.0) / (0.70 * 27.0e3)
t_t = 0.0398942 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) = 30.0 ft

Ni = 1.39 * Ai * G * (D^2)
Ni = 1.39 * 0.060 * 1.10 * (10.0^2)
Ni = 9.1740 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.05410 * 1.10 * (10.0^2) * COSH(((3.68 * (30.0 - 30.0)) / 10.0))) / COSH(((3.68 * 30.0) / 10.0))
Nc = 187.169e-6 lbf/in

Nh = 2.6 * (H - H_offset) * D * G
Nh = 2.6 * (30.0 - 0.0) * 10.0 * 1.10
Nh = 858.0 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+ = (858.0 + SQRT(((9.1740^2) + (187.169e-6^2) + (((0.08960 * 858.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T+ = 4.74715e3 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (858.0 - SQRT(((9.1740^2) + (187.169e-6^2) + (((0.08960 * 858.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T- = 4.40485e3 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 19.7250e3) , (0.9 * 21.8750e3 * 0.70))
Sd-seismic = 13.7813e3 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA
ts = ((4.74715e3 * (0.18750 - 0.0)) / 13.7813e3) + 0.0

ts = 0.0645870 in

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 2.41886e3 lbf
Upper Courses Weight (Ws-pl-top) = 6.14644e3 lbf

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-1 + Fd_agitator
Ws-tot-top = 2.41886e3 + 1.49951e3 + 6.14644e3 + 1.23186e3 + 2.16711e3
Ws-tot-top = 13.4638e3 lbf

A1 = pi * ((D1 / 2)^2)
A1 = pi * ((120.188 / 2)^2)
A1 = 11.3451e3 in^2 [78.7854 ft^2]

At = Cross Section Area (in^2)
c = Corrosion Allowance (in)
E = Joint Efficiency
F = Summation of Vertical Forces (lb)
P = Pressure (lbf/in^2)
P_Other_Loads = Pressure Other Loads (lbf/in^2)
Rc = Radius (in)
Sts = Maximum Allowable Tensile Stress (lbf/in^2)
t_Actual = Assumed Thickness (in)
W = Total Weight (lb)

At = 11.3451e3 in^2
c = 0.0 in
E = 0.70
F = nil
P = 0.0 lbf/in^2
P_Other_Loads = nil
Rc = 60.0938 in
Sts = 19.7250e3 lbf/in^2
t_Actual = 0.18750 in
W = -13.4638e3 lb

T_1 = Meridional unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 10* (lbf/in)
T_2 = Latitudinal (circumferential) unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 11* (lbf/in)

T_1 = (R_c / 2) * (P + (W / A_t))
T_1 = (60.0938 / 2) * (0.0 + (-13.4638e3 / 11.3451e3))
T_1 = -35.6581 lbf/in

T_2 = P * R_c
T_2 = 0.0 * 60.0938
T_2 = 0.0 lbf/in

(T_1 < 0) AND (T_2 = 0)

Thickness calculation based on T1

M = Compression factor
Scc = Computed Compressive Stress (psi)
Sta = Allowable Tensile Stress per *API-620 5.5.3.3* (psi)

Stc = Computed Tensile Stress (psi)
t_req = Minimum Required Thickness (in)

As per API-620 Section 5.5.4.5, Figure 5-1 and Figure F-1, Graphical solution (Ratio) = 0.00312012

t_req = (Ratio * R) + c
t_req = (0.00312012 * 60.0938) + 0.0
t_req = 0.18750 in

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-35.6581) / (0.18750 - 0.0)
Scc = 190.176 psi

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 5.61622e3 psi

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)
Stc = 0.0 / (0.18750 - 0.0)
Stc = 0.0 psi

M = Scc / 15000
M = 190.176 / 15000
M = 0.0126784

As per API-620 Figure F-1, Tension factor (N) = 0.993601

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((19.7250e3 * 0.993601) , (19.7250e3 * 0.70))
Sta = 13.8075e3 psi

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts , t-axial-load)
t-min = MAX(0.18750 , 0.0600688 , 0.0398942 , 0.0645870 , 0.18750)
t-min = 0.18750 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.18750 - 0.0) * 19.7250e3 * 0.70) / (2.6 * 10.0 * 1.10)) + 1) + 0.0
H-max = 91.5212 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(91.5212 , 0)
H-max-@-Pi = 91.5212 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((91.5212 - (30.0 + 0.0)) * (12 * 1.10)) + 3.0) , 0)
Pi-max-@-H = 815.080 inH2O

Course # 2 Design
A2 = Shell Course Cross Sectional Area (in^2)
CA = Corrosion allowance per *API-650 5.3.2* (in)
D2 = Shell Course Centerline Diameter (in)
H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)

H = Design Liquid Level per *API-650 5.6.3.2* (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 Section S.3.2.2.3* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *S.3.2.2.3* (in)
W-2 = Shell Course Nominal Weight (lb)
W-2-corr = Shell Course Nominal Weight (lb)
Ws-tot-top = Top Weight Total (lbf)

CA = 0.0 in
H = 25.0 ft
h2 = 5.0 ft
H-Hydrotest = 25.0 ft
JE = 0.70
loc = 5.0 ft
Ma = A240-316
Rwi = 4.0
t = 0.18750 in

Shell Course Center of Gravity (CG-2) = 7.50 ft

D2 = ID + t
D2 = 120.0 + 0.18750
D2 = 120.188 in

W-2 = pi * Dc * t * h2 * d
W-2 = pi * 120.188 * 0.18750 * 60.0 * 0.290
W-2 = 1.23186e3 lb

W-2-corr = pi * Dc * (t - CA) * h2 * d
W-2-corr = pi * 120.188 * (0.18750 - 0.0) * 60.0 * 0.290
W-2-corr = 1.23186e3 lb

Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
As per API-650 S.2b, Allowable Design Stress (Sd) = 19.7250e3 psi
As per API-650 S.2b, Allowable Hydrostatic Test Stress (St) = 27.0e3 psi

Thickness Required by Erection
As per API-650 S.3.2.1.1 and 5.6.1.1, Thickness Required by Erection (t_erec) = 0.18750 in

Thickness Required by Design
H' = H

H' = 25.0
H' = 25.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 10.0 * (25.0 - 1) * 1.10) / (0.70 * 19.7250e3)) + 0.0
t_d = 0.0497121 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 25.0
Ht' = 25.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 10.0 * (25.0 - 1) * 1.0) / (0.70 * 27.0e3)
t_t = 0.0330159 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) = 25.0 ft

Ni = 1.39 * Ai * G * (D^2)
Ni = 1.39 * 0.060 * 1.10 * (10.0^2)
Ni = 9.1740 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.05410 * 1.10 * (10.0^2) * COSH(((3.68 * (30.0 - 25.0)) / 10.0))) / COSH(((3.68 * 30.0) / 10.0))
Nc = 604.123e-6 lbf/in

Nh = 2.6 * (H - H_offset) * D * G
Nh = 2.6 * (25.0 - 0.0) * 10.0 * 1.10
Nh = 715.0 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+ = (715.0 + SQRT(((9.1740^2) + (604.123e-6^2) + (((0.08960 * 715.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T+ = 3.95850e3 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (715.0 - SQRT(((9.1740^2) + (604.123e-6^2) + (((0.08960 * 715.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T- = 3.66817e3 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 19.7250e3) , (0.9 * 21.8750e3 * 0.70))
Sd-seismic = 13.7813e3 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA

ts = ((3.95850e3 * (0.18750 - 0.0)) / 13.7813e3) + 0.0
ts = 0.0538571 in

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 2.41886e3 lbf
Upper Courses Weight (Ws-pl-top) = 4.91459e3 lbf

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-2 + Fd_agitator
Ws-tot-top = 2.41886e3 + 1.49951e3 + 4.91459e3 + 1.23186e3 + 2.16711e3
Ws-tot-top = 12.2319e3 lbf

A2 = pi * ((D2 / 2)^2)
A2 = pi * ((120.188 / 2)^2)
A2 = 11.3451e3 in^2 [78.7854 ft^2]

At = Cross Section Area (in^2)
c = Corrosion Allowance (in)
E = Joint Efficiency
F = Summation of Vertical Forces (lb)
P = Pressure (lbf/in^2)
P_Other_Loads = Pressure Other Loads (lbf/in^2)
Rc = Radius (in)
Sts = Maximum Allowable Tensile Stress (lbf/in^2)
t_Actual = Assumed Thickness (in)
W = Total Weight (lb)

At = 11.3451e3 in^2
c = 0.0 in
E = 0.70
F = nil
P = 0.0 lbf/in^2
P_Other_Loads = nil
Rc = 60.0938 in
Sts = 19.7250e3 lbf/in^2
t_Actual = 0.18750 in
W = -12.2319e3 lb

T_1 = Meridional unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 10* (lbf/in)
T_2 = Latitudinal (circumferential) unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 11* (lbf/in)

T_1 = (R_c / 2) * (P + (W / A_t))
T_1 = (60.0938 / 2) * (0.0 + (-12.2319e3 / 11.3451e3))
T_1 = -32.3956 lbf/in

T_2 = P * R_c
T_2 = 0.0 * 60.0938
T_2 = 0.0 lbf/in

(T_1 < 0) AND (T_2 = 0)

Thickness calculation based on T1

M = Compression factor
Scc = Computed Compressive Stress (psi)

Sta = Allowable Tensile Stress per *API-620 5.5.3.3* (psi)
Stc = Computed Tensile Stress (psi)
t_req = Minimum Required Thickness (in)

As per API-620 Section 5.5.4.5, Figure 5-1 and Figure F-1, Graphical solution (Ratio) = 0.00312012

t_req = (Ratio * R) + c
t_req = (0.00312012 * 60.0938) + 0.0
t_req = 0.18750 in

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-32.3956) / (0.18750 - 0.0)
Scc = 172.776 psi

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 5.61622e3 psi

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)
Stc = 0.0 / (0.18750 - 0.0)
Stc = 0.0 psi

M = Scc / 15000
M = 172.776 / 15000
M = 0.0115184

As per API-620 Figure F-1, Tension factor (N) = 0.994191

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((19.7250e3 * 0.994191) , (19.7250e3 * 0.70))
Sta = 13.8075e3 psi

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts , t-axial-load)
t-min = MAX(0.18750 , 0.0497121 , 0.0330159 , 0.0538571 , 0.18750)
t-min = 0.18750 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.18750 - 0.0) * 19.7250e3 * 0.70) / (2.6 * 10.0 * 1.10)) + 1) + 5.0
H-max = 96.5212 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(96.5212 , 0)
H-max-@-Pi = 96.5212 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((96.5212 - (25.0 + 5.0)) * (12 * 1.10)) + 3.0) , 0)
Pi-max-@-H = 881.080 inH2O

Course # 3 Design
A3 = Shell Course Cross Sectional Area (in^2)
CA = Corrosion allowance per *API-650 5.3.2* (in)
D3 = Shell Course Centerline Diameter (in)

H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)
H = Design Liquid Level per *API-650 5.6.3.2* (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 Section S.3.2.2.3* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *S.3.2.2.3* (in)
W-3 = Shell Course Nominal Weight (lb)
W-3-corr = Shell Course Nominal Weight (lb)
Ws-tot-top = Top Weight Total (lbf)

CA = 0.0 in
H = 20.0 ft
h3 = 5.0 ft
H-Hydrotest = 20.0 ft
JE = 0.70
loc = 10.0 ft
Ma = A240-316
Rwi = 4.0
t = 0.18750 in

Shell Course Center of Gravity (CG-3) = 12.50 ft

D3 = ID + t
D3 = 120.0 + 0.18750
D3 = 120.188 in

W-3 = pi * Dc * t * h3 * d
W-3 = pi * 120.188 * 0.18750 * 60.0 * 0.290
W-3 = 1.23186e3 lb

W-3-corr = pi * Dc * (t - CA) * h3 * d
W-3-corr = pi * 120.188 * (0.18750 - 0.0) * 60.0 * 0.290
W-3-corr = 1.23186e3 lb

Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
As per API-650 S.2b, Allowable Design Stress (Sd) = 19.7250e3 psi
As per API-650 S.2b, Allowable Hydrostatic Test Stress (St) = 27.0e3 psi

Thickness Required by Erection
As per API-650 S.3.2.1.1 and 5.6.1.1, Thickness Required by Erection (t_erec) = 0.18750 in

Thickness Required by Design

H' = H
H' = 20.0
H' = 20.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 10.0 * (20.0 - 1) * 1.10) / (0.70 * 19.7250e3)) + 0.0
t_d = 0.0393554 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 20.0
Ht' = 20.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 10.0 * (20.0 - 1) * 1.0) / (0.70 * 27.0e3)
t_t = 0.0261376 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) = 20.0 ft

Ni = 1.39 * Ai * G * (D^2)
Ni = 1.39 * 0.060 * 1.10 * (10.0^2)
Ni = 9.1740 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.05410 * 1.10 * (10.0^2) * COSH(((3.68 * (30.0 - 20.0)) / 10.0))) / COSH(((3.68 * 30.0) / 10.0))
Nc = 0.00371266 lbf/in

Nh = 2.6 * (H - H_offset) * D * G
Nh = 2.6 * (20.0 - 0.0) * 10.0 * 1.10
Nh = 572.0 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+ = (572.0 + SQRT(((9.1740^2) + (0.00371266^2) + (((0.08960 * 572.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T+ = 3.17045e3 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (572.0 - SQRT(((9.1740^2) + (0.00371266^2) + (((0.08960 * 572.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T- = 2.93088e3 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 19.7250e3) , (0.9 * 21.8750e3 * 0.70))
Sd-seismic = 13.7813e3 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA
ts = ((3.17045e3 * (0.18750 - 0.0)) / 13.7813e3) + 0.0
ts = 0.0431354 in

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 2.41886e3 lbf
Upper Courses Weight (Ws-pl-top) = 3.68273e3 lbf

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-3 + Fd_agitator
Ws-tot-top = 2.41886e3 + 1.49951e3 + 3.68273e3 + 1.23186e3 + 2.16711e3
Ws-tot-top = 11.0001e3 lbf

A3 = pi * ((D3 / 2)^2)
A3 = pi * ((120.188 / 2)^2)
A3 = 11.3451e3 in^2 [78.7854 ft^2]

At = Cross Section Area (in^2)
c = Corrosion Allowance (in)
E = Joint Efficiency
F = Summation of Vertical Forces (lb)
P = Pressure (lbf/in^2)
P_Other_Loads = Pressure Other Loads (lbf/in^2)
Rc = Radius (in)
Sts = Maximum Allowable Tensile Stress (lbf/in^2)
t_Actual = Assumed Thickness (in)
W = Total Weight (lb)

At = 11.3451e3 in^2
c = 0.0 in
E = 0.70
F = nil
P = 0.0 lbf/in^2
P_Other_Loads = nil
Rc = 60.0938 in
Sts = 19.7250e3 lbf/in^2
t_Actual = 0.18750 in
W = -11.0001e3 lb

T_1 = Meridional unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 10* (lbf/in)
T_2 = Latitudinal (circumferential) unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 11* (lbf/in)

T_1 = (R_c / 2) * (P + (W / A_t))
T_1 = (60.0938 / 2) * (0.0 + (-11.0001e3 / 11.3451e3))
T_1 = -29.1331 lbf/in

T_2 = P * R_c
T_2 = 0.0 * 60.0938
T_2 = 0.0 lbf/in

(T_1 < 0) AND (T_2 = 0)

Thickness calculation based on T1

M = Compression factor

Scc = Computed Compressive Stress (psi)
Sta = Allowable Tensile Stress per *API-620 5.5.3.3* (psi)
Stc = Computed Tensile Stress (psi)
t_req = Minimum Required Thickness (in)

As per API-620 Section 5.5.4.5, Figure 5-1 and Figure F-1, Graphical solution (Ratio) = 0.00312012

t_req = (Ratio * R) + c
t_req = (0.00312012 * 60.0938) + 0.0
t_req = 0.18750 in

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-29.1331) / (0.18750 - 0.0)
Scc = 155.376 psi

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 5.61622e3 psi

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)
Stc = 0.0 / (0.18750 - 0.0)
Stc = 0.0 psi

M = Scc / 15000
M = 155.376 / 15000
M = 0.0103584

As per API-620 Figure F-1, Tension factor (N) = 0.994781

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((19.7250e3 * 0.994781) , (19.7250e3 * 0.70))
Sta = 13.8075e3 psi

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts , t-axial-load)
t-min = MAX(0.18750 , 0.0393554 , 0.0261376 , 0.0431354 , 0.18750)
t-min = 0.18750 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.18750 - 0.0) * 19.7250e3 * 0.70) / (2.6 * 10.0 * 1.10)) + 1) + 10.0
H-max = 101.521 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(101.521 , 0)
H-max-@-Pi = 101.521 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((101.521 - (20.0 + 10.0)) * (12 * 1.10)) + 3.0) , 0)
Pi-max-@-H = 947.080 inH2O

Course # 4 Design
A4 = Shell Course Cross Sectional Area (in^2)
CA = Corrosion allowance per *API-650 5.3.2* (in)

D4 = Shell Course Centerline Diameter (in)
H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)
H = Design Liquid Level per *API-650 5.6.3.2* (ft)
h4 = 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 Section S.3.2.2.3* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *S.3.2.2.3* (in)
W-4 = Shell Course Nominal Weight (lb)
W-4-corr = Shell Course Nominal Weight (lb)
Ws-tot-top = Top Weight Total (lbf)

CA = 0.0 in
H = 15.0 ft
h4 = 5.0 ft
H-Hydrotest = 15.0 ft
JE = 0.70
loc = 15.0 ft
Ma = A240-316
Rwi = 4.0
t = 0.18750 in

Shell Course Center of Gravity (CG-4) = 17.50 ft

D4 = ID + t
D4 = 120.0 + 0.18750
D4 = 120.188 in

W-4 = pi * Dc * t * h4 * d
W-4 = pi * 120.188 * 0.18750 * 60.0 * 0.290
W-4 = 1.23186e3 lb

W-4-corr = pi * Dc * (t - CA) * h4 * d
W-4-corr = pi * 120.188 * (0.18750 - 0.0) * 60.0 * 0.290
W-4-corr = 1.23186e3 lb

Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
As per API-650 S.2b, Allowable Design Stress (Sd) = 19.7250e3 psi
As per API-650 S.2b, Allowable Hydrostatic Test Stress (St) = 27.0e3 psi

Thickness Required by Erection
As per API-650 S.3.2.1.1 and 5.6.1.1, Thickness Required by Erection (t_erec) = 0.18750 in

Thickness Required by Design
H' = H
H' = 15.0
H' = 15.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 10.0 * (15.0 - 1) * 1.10) / (0.70 * 19.7250e3)) + 0.0
t_d = 0.0289987 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 15.0
Ht' = 15.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 10.0 * (15.0 - 1) * 1.0) / (0.70 * 27.0e3)
t_t = 0.0192593 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) = 15.0 ft

Ni = 1.39 * Ai * G * (D^2)
Ni = 1.39 * 0.060 * 1.10 * (10.0^2)
Ni = 9.1740 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.05410 * 1.10 * (10.0^2) * COSH(((3.68 * (30.0 - 15.0)) / 10.0))) / COSH(((3.68 * 30.0) / 10.0))
Nc = 0.0233624 lbf/in

Nh = 2.6 * (H - H_offset) * D * G
Nh = 2.6 * (15.0 - 0.0) * 10.0 * 1.10
Nh = 429.0 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+ = (429.0 + SQRT(((9.1740^2) + (0.0233624^2) + (((0.08960 * 429.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T+ = 2.38349e3 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (429.0 - SQRT(((9.1740^2) + (0.0233624^2) + (((0.08960 * 429.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T- = 2.19251e3 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 19.7250e3) , (0.9 * 21.8750e3 * 0.70))
Sd-seismic = 13.7813e3 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA
ts = ((2.38349e3 * (0.18750 - 0.0)) / 13.7813e3) + 0.0
ts = 0.0324284 in

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 2.41886e3 lbf
Upper Courses Weight (Ws-pl-top) = 2.45088e3 lbf

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-4 + Fd_agitator
Ws-tot-top = 2.41886e3 + 1.49951e3 + 2.45088e3 + 1.23186e3 + 2.16711e3
Ws-tot-top = 9.76821e3 lbf

A4 = pi * ((D4 / 2)^2)
A4 = pi * ((120.188 / 2)^2)
A4 = 11.3451e3 in^2 [78.7854 ft^2]

At = Cross Section Area (in^2)
c = Corrosion Allowance (in)
E = Joint Efficiency
F = Summation of Vertical Forces (lb)
P = Pressure (lbf/in^2)
P_Other_Loads = Pressure Other Loads (lbf/in^2)
Rc = Radius (in)
Sts = Maximum Allowable Tensile Stress (lbf/in^2)
t_Actual = Assumed Thickness (in)
W = Total Weight (lb)

At = 11.3451e3 in^2
c = 0.0 in
E = 0.70
F = nil
P = 0.0 lbf/in^2
P_Other_Loads = nil
Rc = 60.0938 in
Sts = 19.7250e3 lbf/in^2
t_Actual = 0.18750 in
W = -9.76821e3 lb

T_1 = Meridional unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 10* (lbf/in)
T_2 = Latitudinal (circumferential) unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 11* (lbf/in)

T_1 = (R_c / 2) * (P + (W / A_t))
T_1 = (60.0938 / 2) * (0.0 + (-9.76821e3 / 11.3451e3))
T_1 = -25.8706 lbf/in

T_2 = P * R_c
T_2 = 0.0 * 60.0938
T_2 = 0.0 lbf/in

(T_1 < 0) AND (T_2 = 0)

Thickness calculation based on T1

M = Compression factor
Scc = Computed Compressive Stress (psi)
Sta = Allowable Tensile Stress per *API-620 5.5.3.3* (psi)
Stc = Computed Tensile Stress (psi)
t_req = Minimum Required Thickness (in)

As per API-620 Section 5.5.4.5, Figure 5-1 and Figure F-1, Graphical solution (Ratio) = 0.00312012

t_req = (Ratio * R) + c
t_req = (0.00312012 * 60.0938) + 0.0
t_req = 0.18750 in

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-25.8706) / (0.18750 - 0.0)
Scc = 137.976 psi

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 5.61622e3 psi

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)
Stc = 0.0 / (0.18750 - 0.0)
Stc = 0.0 psi

M = Scc / 15000
M = 137.976 / 15000
M = 0.00919842

As per API-620 Figure F-1, Tension factor (N) = 0.995369

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((19.7250e3 * 0.995369) , (19.7250e3 * 0.70))
Sta = 13.8075e3 psi

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts , t-axial-load)
t-min = MAX(0.18750 , 0.0289987 , 0.0192593 , 0.0324284 , 0.18750)
t-min = 0.18750 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.18750 - 0.0) * 19.7250e3 * 0.70) / (2.6 * 10.0 * 1.10)) + 1) + 15.0
H-max = 106.521 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(106.521 , 0)
H-max-@-Pi = 106.521 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((106.521 - (15.0 + 15.0)) * (12 * 1.10)) + 3.0) , 0)
Pi-max-@-H = 1.01308e3 inH2O

Course # 5 Design
A5 = Shell Course Cross Sectional Area (in^2)

CA = Corrosion allowance per *API-650 5.3.2* (in)
D5 = Shell Course Centerline Diameter (in)
H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)
H = Design Liquid Level per *API-650 5.6.3.2* (ft)
h5 = 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 Section S.3.2.2.3* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *S.3.2.2.3* (in)
W-5 = Shell Course Nominal Weight (lb)
W-5-corr = Shell Course Nominal Weight (lb)
Ws-tot-top = Top Weight Total (lbf)

CA = 0.0 in
H = 10.0 ft
h5 = 5.0 ft
H-Hydrotest = 10.0 ft
JE = 0.70
loc = 20.0 ft
Ma = A240-316
Rwi = 4.0
t = 0.18750 in

Shell Course Center of Gravity (CG-5) = 22.50 ft

D5 = ID + t
D5 = 120.0 + 0.18750
D5 = 120.188 in

W-5 = pi * Dc * t * h5 * d
W-5 = pi * 120.188 * 0.18750 * 60.0 * 0.290
W-5 = 1.23186e3 lb

W-5-corr = pi * Dc * (t - CA) * h5 * d
W-5-corr = pi * 120.188 * (0.18750 - 0.0) * 60.0 * 0.290
W-5-corr = 1.23186e3 lb

Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
As per API-650 S.2b, Allowable Design Stress (Sd) = 19.7250e3 psi
As per API-650 S.2b, Allowable Hydrostatic Test Stress (St) = 27.0e3 psi

Thickness Required by Erection
As per API-650 S.3.2.1.1 and 5.6.1.1, Thickness Required by Erection (t_erec) = 0.18750 in

Thickness Required by Design
H' = H
H' = 10.0
H' = 10.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 10.0 * (10.0 - 1) * 1.10) / (0.70 * 19.7250e3)) + 0.0
t_d = 0.0186420 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 10.0
Ht' = 10.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 10.0 * (10.0 - 1) * 1.0) / (0.70 * 27.0e3)
t_t = 0.0123810 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) = 10.0 ft

Ni = 1.39 * Ai * G * (D^2)
Ni = 1.39 * 0.060 * 1.10 * (10.0^2)
Ni = 9.1740 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.05410 * 1.10 * (10.0^2) * COSH(((3.68 * (30.0 - 10.0)) / 10.0))) / COSH(((3.68 * 30.0) / 10.0))
Nc = 0.14710 lbf/in

Nh = 2.6 * (H - H_offset) * D * G
Nh = 2.6 * (10.0 - 0.0) * 10.0 * 1.10
Nh = 286.0 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+ = (286.0 + SQRT(((9.1740^2) + (0.14710^2) + (((0.08960 * 286.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T+ = 1.59870e3 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (286.0 - SQRT(((9.1740^2) + (0.14710^2) + (((0.08960 * 286.0) / 2.5)^2)))) / MAX((0.18750 - 0.0) , 0.0001)
sigma_T- = 1.45196e3 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 19.7250e3) , (0.9 * 21.8750e3 * 0.70))

Sd-seismic = 13.7813e3 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA
ts = ((1.59870e3 * (0.18750 - 0.0)) / 13.7813e3) + 0.0
ts = 0.0217511 in

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 2.41886e3 lbf
Upper Courses Weight (Ws-pl-top) = 1.21902e3 lbf

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-5 + Fd_agitator
Ws-tot-top = 2.41886e3 + 1.49951e3 + 1.21902e3 + 1.23186e3 + 2.16711e3
Ws-tot-top = 8.53636e3 lbf

A5 = pi * ((D5 / 2)^2)
A5 = pi * ((120.188 / 2)^2)
A5 = 11.3451e3 in^2 [78.7854 ft^2]

At = Cross Section Area (in^2)
c = Corrosion Allowance (in)
E = Joint Efficiency
F = Summation of Vertical Forces (lb)
P = Pressure (lbf/in^2)
P_Other_Loads = Pressure Other Loads (lbf/in^2)
Rc = Radius (in)
Sts = Maximum Allowable Tensile Stress (lbf/in^2)
t_Actual = Assumed Thickness (in)
W = Total Weight (lb)

At = 11.3451e3 in^2
c = 0.0 in
E = 0.70
F = nil
P = 0.0 lbf/in^2
P_Other_Loads = nil
Rc = 60.0938 in
Sts = 19.7250e3 lbf/in^2
t_Actual = 0.18750 in
W = -8.53636e3 lb

T_1 = Meridional unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 10* (lbf/in)
T_2 = Latitudinal (circumferential) unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 11* (lbf/in)

T_1 = (R_c / 2) * (P + (W / A_t))
T_1 = (60.0938 / 2) * (0.0 + (-8.53636e3 / 11.3451e3))
T_1 = -22.6081 lbf/in

T_2 = P * R_c
T_2 = 0.0 * 60.0938
T_2 = 0.0 lbf/in

(T_1 < 0) AND (T_2 = 0)

Thickness calculation based on T1

M = Compression factor
Scc = Computed Compressive Stress (psi)
Sta = Allowable Tensile Stress per *API-620 5.5.3.3* (psi)
Stc = Computed Tensile Stress (psi)
t_req = Minimum Required Thickness (in)

As per API-620 Section 5.5.4.5, Figure 5-1 and Figure F-1, Graphical solution (Ratio) = 0.00312012

t_req = (Ratio * R) + c
t_req = (0.00312012 * 60.0938) + 0.0
t_req = 0.18750 in

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-22.6081) / (0.18750 - 0.0)
Scc = 120.576 psi

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 5.61622e3 psi

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)
Stc = 0.0 / (0.18750 - 0.0)
Stc = 0.0 psi

M = Scc / 15000
M = 120.576 / 15000
M = 0.00803842

As per API-620 Figure F-1, Tension factor (N) = 0.995957

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((19.7250e3 * 0.995957) , (19.7250e3 * 0.70))
Sta = 13.8075e3 psi

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts , t-axial-load)
t-min = MAX(0.18750 , 0.0186420 , 0.0123810 , 0.0217511 , 0.18750)
t-min = 0.18750 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.18750 - 0.0) * 19.7250e3 * 0.70) / (2.6 * 10.0 * 1.10)) + 1) + 20.0
H-max = 111.521 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(111.521 , 0)
H-max-@-Pi = 111.521 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((111.521 - (10.0 + 20.0)) * (12 * 1.10)) + 3.0) , 0)
Pi-max-@-H = 1.07908e3 inH2O

Course # 6 Design

A6 = Shell Course Cross Sectional Area (in^2)
CA = Corrosion allowance per *API-650 5.3.2* (in)
D6 = Shell Course Centerline Diameter (in)
H' = Effective Design Liquid Level per *API-650 Section F.2* (ft)
H = Design Liquid Level per *API-650 5.6.3.2* (ft)
h6 = 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 Section S.3.2.2.3* (in)
t-min = Minimum Required Thickness (in)
t_t = Course Hydrostatic Test Thickness per *S.3.2.2.3* (in)
W-6 = Shell Course Nominal Weight (lb)
W-6-corr = Shell Course Nominal Weight (lb)
Ws-tot-top = Top Weight Total (lbf)

CA = 0.0 in
H = 5.0 ft
h6 = 4.94792 ft
H-Hydrotest = 5.0 ft
JE = 0.70
loc = 25.0 ft
Ma = A240-316
Rwi = 4.0
t = 0.18750 in

Shell Course Center of Gravity (CG-6) = 27.4740 ft

D6 = ID + t
D6 = 120.0 + 0.18750
D6 = 120.188 in

W-6 = pi * Dc * t * h6 * d
W-6 = pi * 120.188 * 0.18750 * 59.3750 * 0.290
W-6 = 1.21902e3 lb

W-6-corr = pi * Dc * (t - CA) * h6 * d
W-6-corr = pi * 120.188 * (0.18750 - 0.0) * 59.3750 * 0.290
W-6-corr = 1.21902e3 lb

Material Properties
Material = A240-316
Minimum Tensile Strength (Sut) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy) = 21.8750e3 psi
As per API-650 S.2b, Allowable Design Stress (Sd) = 19.7250e3 psi
As per API-650 S.2b, Allowable Hydrostatic Test Stress (St) = 27.0e3 psi

Thickness Required by Erection

As per API-650 S.3.2.1.1 and 5.6.1.1, Thickness Required by Erection (t_erec) = 0.18750 in

Thickness Required by Design
H' = H
H' = 5.0
H' = 5.0 ft

t_d = ((2.6 * D * (H' - 1) * SG) / (JE * Sd)) + CA
t_d = ((2.6 * 10.0 * (5.0 - 1) * 1.10) / (0.70 * 19.7250e3)) + 0.0
t_d = 0.00828535 in

Hydrostatic Test Required Thickness
Ht' = H-Hydrotest
Ht' = 5.0
Ht' = 5.0 ft

t_t = (2.6 * D * (Ht' - 1) * SGt) / (JE * St)
t_t = (2.6 * 10.0 * (5.0 - 1) * 1.0) / (0.70 * 27.0e3)
t_t = 0.00550265 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) = 5.0 ft

Ni = 2.77 * Ai * G * (D^2) * ((Y / (0.75 * D)) - (0.5 * ((Y / (0.75 * D))^2)))
Ni = 2.77 * 0.060 * 1.10 * (10.0^2) * ((5.0 / (0.75 * 10.0)) - (0.5 * ((5.0 / (0.75 * 10.0))^2)))
Ni = 8.12533 lbf/in

Nc = (0.98 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (0.98 * 0.05410 * 1.10 * (10.0^2) * COSH(((3.68 * (30.0 - 5.0)) / 10.0))) / COSH(((3.68 * 30.0) / 10.0))
Nc = 0.926220 lbf/in

Nh = 2.6 * (H - H_offset) * D * G
Nh = 2.6 * (5.0 - 0.0) * 10.0 * 1.10
Nh = 143.0 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+ = (143.0 + SQRT(((8.12533^2) + (0.926220^2) + (((0.08960 * 143.0) / 2.5)^2)))) /
MAX((0.18750 - 0.0) , 0.0001)
sigma_T+ = 814.140 psi

sigma_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
sigma_T- = (143.0 - SQRT(((8.12533^2) + (0.926220^2) + (((0.08960 * 143.0) / 2.5)^2)))) / MAX((0.18750
- 0.0) , 0.0001)
sigma_T- = 711.194 psi

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 19.7250e3) , (0.9 * 21.8750e3 * 0.70))

Sd-seismic = 13.7813e3 psi

ts = ((sigma_T+ * (tn - CA)) / S_membrane) + CA
ts = ((814.140 * (0.18750 - 0.0)) / 13.7813e3) + 0.0
ts = 0.0110767 in

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 2.41886e3 lbf
Upper Courses Weight (Ws-pl-top) = 0.0 lbf

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-6 + Fd_agitator
Ws-tot-top = 2.41886e3 + 1.49951e3 + 0.0 + 1.21902e3 + 2.16711e3
Ws-tot-top = 7.30450e3 lbf

A6 = pi * ((D6 / 2)^2)
A6 = pi * ((120.188 / 2)^2)
A6 = 11.3451e3 in^2 [78.7854 ft^2]

At = Cross Section Area (in^2)
c = Corrosion Allowance (in)
E = Joint Efficiency
F = Summation of Vertical Forces (lb)
P = Pressure (lbf/in^2)
P_Other_Loads = Pressure Other Loads (lbf/in^2)
Rc = Radius (in)
Sts = Maximum Allowable Tensile Stress (lbf/in^2)
t_Actual = Assumed Thickness (in)
W = Total Weight (lb)

At = 11.3451e3 in^2
c = 0.0 in
E = 0.70
F = nil
P = 0.0 lbf/in^2
P_Other_Loads = nil
Rc = 60.0938 in
Sts = 19.7250e3 lbf/in^2
t_Actual = 0.18750 in
W = -7.30450e3 lb

T_1 = Meridional unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 10* (lbf/in)
T_2 = Latitudinal (circumferential) unit force for cylindrical walls per *API-620 5.10.2.5.c, Equation 11* (lbf/in)

T_1 = (R_c / 2) * (P + (W / A_t))
T_1 = (60.0938 / 2) * (0.0 + (-7.30450e3 / 11.3451e3))
T_1 = -19.3456 lbf/in

T_2 = P * R_c
T_2 = 0.0 * 60.0938
T_2 = 0.0 lbf/in

(T_1 < 0) AND (T_2 = 0)

Thickness calculation based on T1

M = Compression factor
Scc = Computed Compressive Stress (psi)
Sta = Allowable Tensile Stress per *API-620 5.5.3.3* (psi)
Stc = Computed Tensile Stress (psi)
t_req = Minimum Required Thickness (in)

As per API-620 Section 5.5.4.5, Figure 5-1 and Figure F-1, Graphical solution (Ratio) = 0.00312012

t_req = (Ratio * R) + c
t_req = (0.00312012 * 60.0938) + 0.0
t_req = 0.18750 in

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-19.3456) / (0.18750 - 0.0)
Scc = 103.176 psi

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 5.61622e3 psi

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)
Stc = 0.0 / (0.18750 - 0.0)
Stc = 0.0 psi

M = Scc / 15000
M = 103.176 / 15000
M = 0.00687842

As per API-620 Figure F-1, Tension factor (N) = 0.996543

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((19.7250e3 * 0.996543) , (19.7250e3 * 0.70))
Sta = 13.8075e3 psi

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t_erec , t_d , t_t , ts , t-axial-load)
t-min = MAX(0.18750 , 0.00828535 , 0.00550265 , 0.0110767 , 0.18750)
t-min = 0.18750 in

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (2.6 * D * SG)) + 1) + loc
H-max = ((((0.18750 - 0.0) * 19.7250e3 * 0.70) / (2.6 * 10.0 * 1.10)) + 1) + 25.0
H-max = 116.521 ft

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(116.521 , 0)
H-max-@-Pi = 116.521 ft

Pi-max-@-H = MAX((((H-max - (H + loc)) * (12 * SG)) + P) , 0)
Pi-max-@-H = MAX((((116.521 - (5.0 + 25.0)) * (12 * 1.10)) + 3.0) , 0)
Pi-max-@-H = 1.14508e3 inH2O

Shell Design Summary Results

W-ins = t-ins * d-ins * pi * (OD + t-ins) * H
W-ins = 0.0 * 8.0 * pi * (10.0313 + 0.0) * 30.0
W-ins = 0.0 lbf

W-shell-corr = (W-1-corr + W-2-corr + W-3-corr + W-4-corr + W-5-corr + W-6-corr) + W-shell-add
W-shell-corr = (1.23186e3 + 1.23186e3 + 1.23186e3 + 1.23186e3 + 1.23186e3 + 1.21902e3) + 0.0
W-shell-corr = 7.37830e3 lb

W-shell = (W-1 + W-2 + W-3 + W-4 + W-5 + W-6) + W-shell-add
W-shell = (1.23186e3 + 1.23186e3 + 1.23186e3 + 1.23186e3 + 1.23186e3 + 1.21902e3) + 0.0
W-shell = 7.37830e3 lb

CG-shell = ((CG-1 * W-1) + (CG-2 * W-2) + (CG-3 * W-3) + (CG-4 * W-4) + (CG-5 * W-5) + (CG-6 * W-6)) / W-shell
CG-shell = ((2.50 * 1.23186e3) + (7.50 * 1.23186e3) + (12.50 * 1.23186e3) + (17.50 * 1.23186e3) + (22.50 * 1.23186e3) + (27.4740 * 1.21902e3)) / 7.37830e3
CG-shell = 14.9740 ft

Shell Design Summary

Course	Height (ft)	Material	CA (in)	JE	Sy (psi)	Sut (psi)	Sd (psi)	St (psi)	t_erec (in)
6	4.94792	A240-316	0.0	0.70	21.8750e3	75.0e3	19.7250e3	27.0e3	0.18750
5	5.0	A240-316	0.0	0.70	21.8750e3	75.0e3	19.7250e3	27.0e3	0.18750
4	5.0	A240-316	0.0	0.70	21.8750e3	75.0e3	19.7250e3	27.0e3	0.18750
3	5.0	A240-316	0.0	0.70	21.8750e3	75.0e3	19.7250e3	27.0e3	0.18750
2	5.0	A240-316	0.0	0.70	21.8750e3	75.0e3	19.7250e3	27.0e3	0.18750
1	5.0	A240-316	0.0	0.70	21.8750e3	75.0e3	19.7250e3	27.0e3	0.18750

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)
6	0.00828535	0.00550265	0.0110767	N/A	0.18750	0.18750	PASS	116.521	41.3675
5	0.0186420	0.0123810	0.0217511	N/A	0.18750	0.18750	PASS	111.521	38.9831
4	0.0289987	0.0192593	0.0324284	N/A	0.18750	0.18750	PASS	106.521	36.5988
3	0.0393554	0.0261376	0.0431354	N/A	0.18750	0.18750	PASS	101.521	34.2145
2	0.0497121	0.0330159	0.0538571	N/A	0.18750	0.18750	PASS	96.5212	31.8301
1	0.0600688	0.0398942	0.0645870	N/A	0.18750	0.18750	PASS	91.5212	29.4458

Intermediate Stiffeners Design

Stiffeners Design For Wind Loading

D = Nominal Tank Diameter (ft)
E = Modulus Of Elasticity (psi)
E_ambient = Modulus Of Elasticity at Ambient Temperature (psi)
H1 = Maximum Unstiffened Transformed Shell Height per *API-650 5.9.6.1* (ft)
ME = Reduction Factor per *API-650 S.3.6.5*
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 = 10.0 ft
E = 26.550e6 psi
E_ambient = 28.10e6 psi
N = 0.0
V = 81.90 mile/hr

Shell Courses Heights (W) = [5.0 5.0 5.0 5.0 5.0 4.94792] ft

ts_min = MIN(ts_1 , ts_2 , ts_3 , ts_4 , ts_5 , ts_6)
ts_min = MIN(0.18750 , 0.18750 , 0.18750 , 0.18750 , 0.18750 , 0.18750)
ts_min = 0.18750 in

ME = E / E_ambient
ME = 26.550e6 / 28.10e6
ME = 0.944840

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))	5.0000	ft	N/A	N/A
Wtr_2	W_2 * SQRT(((t_min / ts_2)^5))	5.0000	ft	N/A	N/A
Wtr_3	W_3 * SQRT(((t_min / ts_3)^5))	5.0000	ft	N/A	N/A
Wtr_4	W_4 * SQRT(((t_min / ts_4)^5))	5.0000	ft	N/A	N/A
Wtr_5	W_5 * SQRT(((t_min / ts_5)^5))	5.0000	ft	N/A	N/A
Wtr_6	W_6 * SQRT(((t_min / ts_6)^5))	4.9479	ft	N/A	N/A

HTS = Wtr_1 + Wtr_2 + Wtr_3 + Wtr_4 + Wtr_5 + Wtr_6
HTS = 5.0 + 5.0 + 5.0 + 5.0 + 5.0 + 4.94792
HTS = 29.9479 ft

Pwv = 31 * ((V / 120)^2)
Pwv = 31 * ((81.90 / 120)^2)
Pwv = 14.440 psf

Pwd = Pwv + 5
Pwd = 14.440 + 5
Pwd = 19.440 psf

H1 = (600000 * ts_min * SQRT(((ts_min / D)^3)) * (36 / Pwd)) * ME
H1 = (600000 * 0.18750 * SQRT(((0.18750 / 10.0)^3)) * (36 / 19.440)) * 0.944840
H1 = 505.381 ft

Ns = CEILING(((HTS / Hsafe) - 1))
Ns = CEILING(((29.9479 / 505.381) - 1))
Ns = 0.0

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 = 0.0 in
CA_1 = 0.0 in
chime = 1.0 in
E = 0.70
Ma_1 = A240-316
Ma-bottom = A240-316
Sd_1 = 19.7250e3 psi
St_1 = 27.0e3 psi
tb = 0.18750 in
td_1 = 0.0600688 in
ts_1 = 0.18750 in
tt_1 = 0.0398942 in

Bottom Plates Material Properties
Material = A240-316
Minimum Tensile Strength (Sut-btm) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy-btm) = 21.8750e3 psi
Density (d-btm) = 0.290 lb/in^3

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 = ((0.0600688 - 0.0) / (0.18750 - 0.0)) * 19.7250e3
S1 = 6.31924e3 psi

As per API-650 5.5.1 and S.3.1.3, first shell course material, A240-316, is stainless steel and the stress is less than or equal to 23200; therefore, butt welded annular plates are not required

S2 = (tt_1 / ts_1) * St_1
S2 = (0.0398942 / 0.18750) * 27.0e3
S2 = 5.74476e3 psi

As per API-650 5.5.1 and S.3.1.3, first shell course material, A240-316, is stainless steel and the stress is less than or equal to 24900; therefore, butt welded annular plates are not required

S = MAX(S1 , S2)
S = MAX(6.31924e3 , 5.74476e3)
S = 6.31924e3 psi

As per API-650 M.4.1
D <= 100 ==> Butt welded annular ring is not required

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 = 0.0 in
chime = 1.0 in
tb = 0.18750 in
Wb-pl-add = 0.0 lb
Wb-pl-corroded-overlap = 0.0 lb
Wb-pl-overlap = 0.0 lb

OD-btm = OD + (chime * 2)
OD-btm = 10.0313 + (0.0833333 * 2)
OD-btm = 10.1979 ft

A-btm = pi * ((OD-btm / 2)^2)
A-btm = pi * ((10.1979 / 2)^2)
A-btm = 81.6794 ft^2

Wb-pl = (A-btm * tb * d-btm) + Wb-pl-overlap + Wb-pl-add
Wb-pl = (11.7618e3 * 0.18750 * 0.290) + 0.0 + 0.0
Wb-pl = 639.550 lb

Wb-pl-corr = (A-btm * (tb - CA) * d-btm) + Wb-pl-corroded-overlap + Wb-pl-add
Wb-pl-corr = (11.7618e3 * (0.18750 - 0.0) * 0.290) + 0.0 + 0.0
Wb-pl-corr = 639.550 lb

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

Liquid Height to Pressure Conversion Factor (f) = 0.433515

P-btm = (d-btm * (tb - CA-btm)) + (Lmin * f * SG)
P-btm = (0.290 * (0.18750 - 0.0)) + (1.0 * 0.433515 * 1.10)
P-btm = 0.531242 psi

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

Bottom Required Thickness

As per API-650 S.3.1.2, Required Thickness by Erection (tb-erec) = 0.18750 in

tb-req = tb-erec
tb-req = 0.18750
tb-req = 0.18750 in

tb >= tb-req ==> PASS

Bottom Outside Projection
As per API-650 J.3.2.3, Minimum Required Outside Projection (chime) = 1.0 in

chime >= chime ==> PASS

Wind Moment (Per API-650 Section 5.11)

Back

Wind Pressures per API-650 & ASCE7-16

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 7-16* (mph)
V_s = Adjusted Design Wind Velocity per *API 650 Section 5.2.1.k* (mph)

V = 105.0 mph

Wind Velocity per API-650 and ASCE7-16

V_s = 0.78 * V
V_s = 0.78 * 105.0
V_s = 81.90 mph

Roof Wind Pressure
P_WR = 31 * ((V_s / 120)^2)
P_WR = 31 * ((81.90 / 120)^2)
P_WR = 14.440 psf

Shell Wind Pressure
P_WS = 18.6 * ((V_s / 120)^2)
P_WS = 18.6 * ((81.90 / 120)^2)
P_WS = 8.6640 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 = 80.5779 ft^2
Av-roof = 4.27479 ft^2
CA_1 = 0.0 in
CA-btm = 0.0 in
CG-roof = 0.281359 ft
COF = 0.40
DLR = 900.493 lbf
DLS = 7.48169e3 lbf
Fby = 21.8750e3 psi
Rh = 5.06446 ft
tb = 0.18750 in
tr-ins = 0.0 in
ts_1 = 0.18750 in
ts-ins = 0.0 in
W-access-corr = 0.0 lbf
W-app-corr = 759.415 lbf
Wb-pl-corr = 639.550 lbf
Wr-pl = 639.628 lbf
Wr-pl-corr = 639.628 lbf
Ws-framing = 103.391 lbf
Ws-framing-corr = 100.397 lbf
Ws-pl = 7.37830e3 lbf
Ws-pl-corr = 7.37830e3 lbf
Ws-struct-corr = 0.0 lbf
W-stairs-corr = 0.0 lbf
W-struct = 1.49951e3 lbf
W-struct-corr = 0.0 lbf
W-windgirder-corr = 0.0 lbf

Design Uplift Pressure per API-650 5.2.1.k

The wind uplift is limited to the case where the roof to shell junction will fail and overturning is not possible.

wind-uplift = MIN(P_WR , ((1.6 * P_F41) - Pg))
wind-uplift = MIN(14.440 , ((1.6 * 328.910) - 15.6066))
wind-uplift = 14.440 psf

Overturning Moments

Xw = D / 2
Xw = 10.0 / 2
Xw = 5.0 ft

Ah-total = pi * ((Rh + tr-ins)^2)
Ah-total = pi * ((5.06446 + 0.0)^2)
Ah-total = 80.5779 ft^2

M_Pi = Pg * Ah * Xw
M_Pi = 15.6066 * 80.5779 * 5.0
M_Pi = 6.28772e3 ft.lbf

M_WR = wind-uplift * Ah-total * Xw
M_WR = 14.440 * 80.5779 * 5.0
M_WR = 5.81772e3 ft.lbf

D-outer = OD + (2 * (ts-ins / 12))
D-outer = 10.0313 + (2 * (0.0 / 12))
D-outer = 10.0313 ft

As = D-outer * H
As = 10.0313 * 30.0
As = 300.938 ft^2

Xs = H / 2
Xs = 30.0 / 2
Xs = 15.0 ft

M_WS = P_WS * As * Xs
M_WS = 8.6640 * 300.938 * 15.0
M_WS = 39.1098e3 ft.lbf

M_w = M_WR + M_WS
M_w = 5.81772e3 + 39.1098e3
M_w = 44.9275e3 ft.lbf

Resistance to Overturning per API-650 5.11.2

M_DL = (D / 2) * DLS
M_DL = (10.0 / 2) * 7.48169e3
M_DL = 37.4085e3 ft.lbf

M_DLR = (D / 2) * DLR
M_DLR = (10.0 / 2) * 900.493
M_DLR = 4.50247e3 ft.lbf

wL = MIN((0.45 * Lmax * D) , (4.67 * (tb-req - CA-btm) * SQRT((Fby * Lmax))))
wL = MIN((0.45 * 30.0 * 10.0) , (4.67 * (0.18750 - 0.0) * SQRT((21.8750e3 * 30.0))))
wL = 135.0 lbf/ft

M_F = (D / 2) * wL * pi * D
M_F = (10.0 / 2) * 135.0 * pi * 10.0
M_F = 21.2058e3 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 * 44.9275e3) + 6.28772e3) < ((37.4085e3 / 1.5) + 4.50247e3)
Since 33.2442e3 >= 29.4414e3 ==> Tank must be anchored

Criterion 2
(M_w + (Fp * M_Pi)) < (((M_DL + M_F) / 2) + M_DLR)
(44.9275e3 + (0.40 * 6.28772e3)) < (((37.4085e3 + 21.2058e3) / 2) + 4.50247e3)
Since 47.4426e3 >= 33.8096e3 ==> Tank must be anchored

Criterion 3
(M_WS + (Fp * M_Pi)) < ((M_DL / 1.5) + M_DLR)
(39.1098e3 + (0.40 * 6.28772e3)) < ((37.4085e3 / 1.5) + 4.50247e3)
Since 41.6249e3 >= 29.4414e3 ==> Tank must be anchored

Resistance to Sliding per API-650 5.11.4
F-wind = P_WS * As
F-wind = 8.6640 * 300.938
F-wind = 2.60732e3 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 = 0.40 * (639.628 + 0.0 + 7.37830e3 + 100.397 + 639.550 + 0.0 + 0.0 + 759.415 + 0.0)
F-friction = 3.80692e3 lbf

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

Anchorage Requirement
Tank must be anchored per API-650 5.11 by Criterion 1, 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 = 10.0 ft
Fa = 1.20
Fv = 1.70
H = 30.0 ft
I = 1.250
K = 1.50
Q = 0.666667
rho_product = 68.6707 lbf/ft^3
Rwc = 2.0
Rwi = 4.0
S1 = 0.0930
Seismic_Site_Class = SEISMIC-SITE-CLASS-C
Seismic_Use_Group = SEISMIC-USE-GROUP-II
shell-course-modulus-of-elasticity-information-list = [26.550e6 26.550e6 26.550e6] psi
shell-course-thickness-information-list = [0.18750 0.18750 0.18750] in
Ss = 0.240
TL = 12.0 sec

SDS = Q * Fa * Ss
SDS = 0.666667 * 1.20 * 0.240
SDS = 0.1920

SD1 = Q * Fv * S1
SD1 = 0.666667 * 1.70 * 0.0930
SD1 = 0.10540

Ks = 0.578 / SQRT(TANH(((3.68 * H) / D)))
Ks = 0.578 / SQRT(TANH(((3.68 * 30.0) / 10.0)))
Ks = 0.5780

Tc = Ks * SQRT(D)
Tc = 0.5780 * SQRT(10.0)
Tc = 1.82780 sec

Ai = SDS * (I / Rwi)
Ai = 0.1920 * (1.250 / 4.0)
Ai = 0.060

Ai = MAX(Ai , 0.007)
Ai = MAX(0.060 , 0.007)
Ai = 0.060

Tc <= TL

Ac = K * SD1 * (1 / Tc) * (I / Rwc)
Ac = 1.50 * 0.10540 * (1 / 1.82780) * (1.250 / 2.0)
Ac = 0.0540610

Ac-min = MIN(Ac , Ai)
Ac-min = MIN(0.0540610 , 0.060)
Ac-min = 0.0540610

Av = (2 / 3) * 0.7 * SDS
Av = (2 / 3) * 0.7 * 0.1920
Av = 0.08960

Af = K * SD1 * I * (1 / Tc)
Af = 1.50 * 0.10540 * 1.250 * (1 / 1.82780)
Af = 0.108122

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 = 81.6894 ft^2
Ac = 0.05410
Af = 0.10810
Ah-shell = 80.5779 ft^2
Ai = 0.060
Anchorage_System = MECHANICALLY-ANCHORED
A-rs = 81.6894 ft^2
Av = 0.08960
ca1 = 0.0 in
ca_bottom = 0.0 in
D = 10.0 ft
Event_Type = MAXIMUM-CONSIDERED-EARTHQUAKE-MCE
Fa = 1.20

Fv = 1.70
Fy = 21.8750e3 lb/in^2
G = 1.10
H = 30.0 ft
Hrcg = 0.281359 ft
hs = 0.0 ft
H_shell = 30.0 ft
I = 1.250
K = 1.50
Ks = 0.5780
Min_Anchor_Quantity = 4.0
Min_Anchor_Spacing = 10.0 ft
mu = 0.40
P = 0.108379 lbf/in^2
Q = 0.666667
S1 = 0.0930
Sb = 0.0 psf
SD1 = 0.10540
SDS = 0.1920
Seismic_Site_Class = SEISMIC-SITE-CLASS-C
Seismic_Use_Group = SEISMIC-USE-GROUP-II
Ss = 0.240
t_bottom = 0.18750 in
Tc = 1.82780 sec
TL = 12.0 sec
ts1 = 0.18750 in
Wb-attachments = 0.0 lb
Wb-pl = 639.550 lb
Wfd = 0.0 lbf
Wg = 0.0 lbf
Wp = 161.802e3 lbf
Wr-attachments = 260.865 lb
Wr-DL-add = 0.0 lb
Wr-pl = 639.628 lb
Ws-attachments = 593.550 lb
Ws-framing = 103.391 lb
Ws-pl = 7.37830e3 lb
Wss = 1.49951e3 lb
W-struct = 1.49951e3 lb
Xs = 14.9740 ft

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

Weights
Wf = Wb-pl
Wf = 639.550
Wf = 639.550 lbf

Wr = (Wr-pl + Wr-attachments + W-struct + Wr-DL-add) + (0.1 * Sb * Ah)
Wr = (639.628 + 260.865 + 1.49951e3 + 0.0) + (0.1 * 0.0 * 80.5779)
Wr = 2.40e3 lbf

Wrs = ((Wr-pl + Wr-attachments + Wr-DL-add) * (A-rs / A)) + Wss + (0.1 * Sb * Ah-shell)
Wrs = ((639.628 + 260.865 + 0.0) * (81.6894 / 81.6894)) + 1.49951e3 + (0.1 * 0.0 * 80.5779)
Wrs = 2.40e3 lbf

Ws = Ws-pl + Ws-framing + Ws-attachments
Ws = 7.37830e3 + 103.391 + 593.550
Ws = 8.07524e3 lbf

W_T = Ws + Wr + Wp + Wf
W_T = 8.07524e3 + 2.40e3 + 161.802e3 + 639.550
W_T = 172.916e3 lbf

Effective Weight of Product
Wi = (1.0 - (0.218 * (D / H))) * Wp
Wi = (1.0 - (0.218 * (10.0 / 30.0))) * 161.802e3
Wi = 150.044e3 lbf

Wc = 0.23 * (D / H) * TANH(((3.67 * H) / D)) * Wp
Wc = 0.23 * (10.0 / 30.0) * TANH(((3.67 * 30.0) / 10.0)) * 161.802e3
Wc = 12.4048e3 lbf

Weff = Wi + Wc
Weff = 150.044e3 + 12.4048e3
Weff = 162.449e3 lbf

Design Loads
Vi = Ai * (Ws + Wr + Wf + Wi)
Vi = 0.060 * (8.07524e3 + 2.40e3 + 639.550 + 150.044e3)
Vi = 9.66952e3 lbf

Vc = Ac * Wc
Vc = 0.05410 * 12.4048e3
Vc = 671.099 lbf

V = SQRT(((Vi^2) + (Vc^2)))
V = SQRT(((9.66952e3^2) + (671.099^2)))
V = 9.69278e3 lbf

Center of Action for Effective Lateral Forces
Xr = H_shell + Hrcg
Xr = 30.0 + 0.281359
Xr = 30.2814 ft

Xi = (0.5 - (0.094 * (D / H))) * H
Xi = (0.5 - (0.094 * (10.0 / 30.0))) * 30.0
Xi = 14.060 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 * 30.0) / 10.0)) - 1) / (((3.67 * 30.0) / 10.0) * SINH(((3.67 * 30.0) / 10.0))))) * 30.0
Xc = 27.2753 ft

Xis = (0.5 + (0.06 * (D / H))) * H
Xis = (0.5 + (0.06 * (10.0 / 30.0))) * 30.0
Xis = 15.60 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 * 30.0) / 10.0)) - 1.937) / (((3.67 * 30.0) / 10.0) * SINH(((3.67 * 30.0) / 10.0))))) * 30.0
Xcs = 27.2754 ft

Overturning Moment
Mrw = SQRT((((Ai * ((Wi * Xi) + (Ws * Xs) + (Wr * Xr)))^2) + ((Ac * (Wc * Xc))^2)))
Mrw = SQRT((((0.060 * ((150.044e3 * 14.060) + (8.07524e3 * 14.9740) + (2.40e3 * 30.2814)))^2) + ((0.05410 * (12.4048e3 * 27.2753))^2)))
Mrw = 139.40e3 ft.lb

Ms = SQRT((((Ai * ((Wi * Xis) + (Ws * Xs) + (Wr * Xr)))^2) + ((Ac * (Wc * Xcs))^2)))
Ms = SQRT((((0.060 * ((150.044e3 * 15.60) + (8.07524e3 * 14.9740) + (2.40e3 * 30.2814)))^2) + ((0.05410 * (12.4048e3 * 27.2754))^2)))
Ms = 153.155e3 ft.lb

Resistance to Design Loads
Ge = G * (1 - (0.4 * Av))
Ge = 1.10 * (1 - (0.4 * 0.08960))
Ge = 1.06058

wrs = Wrs / (pi * D)
wrs = 2.40e3 / (pi * 10.0)
wrs = 76.3945 lbf/ft

wt = (Ws / (pi * D)) + wrs
wt = (8.07524e3 / (pi * 10.0)) + 76.3945
wt = 333.437 lbf/ft

wint = P * 144 * ((pi * ((D^2) / 4)) / (pi * D))
wint = 0.108379 * 144 * ((pi * ((10.0^2) / 4)) / (pi * 10.0))
wint = 39.0164 lbf/ft

Bottom Annular Plates Requirements
tb-corr = t_bottom - ca_bottom
tb-corr = 0.18750 - 0.0
tb-corr = 0.18750 in

ts1_c = ts1 - ca1
ts1_c = 0.18750 - 0.0
ts1_c = 0.18750 in

ta = MIN(tb-corr , ts1_c)
ta = MIN(0.18750 , 0.18750)
ta = 0.18750 in

wa_limit = 1.28 * H * D * Ge
wa_limit = 1.28 * 30.0 * 10.0 * 1.06058
wa_limit = 407.261 lbf/ft

w_a_self-anchored = 7.9 * ta * SQRT((Fy * H * Ge))
w_a_self-anchored = 7.9 * 0.18750 * SQRT((21.8750e3 * 30.0 * 1.06058))
w_a_self-anchored = 1.23576e3 lbf/ft

w_a = MIN(w_a_self-anchored , wa_limit)
w_a = MIN(1.23576e3 , 407.261)
w_a = 407.261 lbf/ft

w_a = w_a
w_a = 407.261

w_a = 407.261 lbf/ft

Tank Stability
J = Mrw / ((D^2) * (((wt * (1 - (0.4 * Av))) + wa) - (Fp * wint)))
J = 139.40e3 / ((10.0^2) * (((333.437 * (1 - (0.4 * 0.08960))) + 407.261) - (0.40 * 39.0164)))
J = 1.95473

As per API 650, Section E.6.2.1.1.1, Table E.6
J > 1.54 ==> Tank is not stable, anchoring is 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 = ((333.437 * (1 + (0.4 * 0.08960))) + ((1.273 * 139.40e3) / (10.0^2))) * (1 / (12 * 0.18750))
sigma_c = 942.198 lbf/in^2

F_c = (1.0E6 * (ts / (2.5 * D))) + (600 * SQRT((G * H)))
F_c = (1.0E6 * (0.18750 / (2.5 * 10.0))) + (600 * SQRT((1.10 * 30.0)))
F_c = 10.9467e3 lbf/in^2

sigma_c < F_c

Overturn_Stability_Ratio = (0.5 * D * (W_T + Wfd + Wg)) / Ms
Overturn_Stability_Ratio = (0.5 * 10.0 * (172.916e3 + 0.0 + 0.0)) / 153.155e3
Overturn_Stability_Ratio = 5.64516

Overturn_Stability_Ratio >= 2.0 ==> PASS

Freeboard
DELTAs = 0.42 * D * Af
DELTAs = 0.42 * 10.0 * 0.10810
DELTAs = 0.454020 ft

Freeboard = H_shell - Lmax-operating
Freeboard = 30.0 - 30.0
Freeboard = 3.55271e-15 ft [42.6326e-15 in]

Freeboard_recommended = 0.7 * DELTAs
Freeboard_recommended = 0.7 * 0.454020
Freeboard_recommended = 0.317814 ft [3.81377 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 = 0.40 * (8.07524e3 + 2.40e3 + 639.550 + 161.802e3) * (1.0 - (0.4 * 0.08960))
Vs = 66.6876e3 lbf

V <= Vs

Local Shear Transfer
Vmax = (2 * V) / (pi * D)
Vmax = (2 * 9.69278e3) / (pi * 10.0)
Vmax = 617.062 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 = 0.08960 g
Ca-anchor = 0.0 in
D = 10.0 ft
d = 1.0 in

Dac = 10.3646 ft
Fp = 0.40
Fty = 21.8750e3 psi
H = 30.0 ft
Ma-anchor = A36
Mrw = 139.40e3 ft.lbf
MWS = 39.1098e3 ft.lbf
n = 8.0 in
N = 4.0
OD = 10.0313 ft
p = 0.130
P = 3.0 inH2O
position_angles = [22.50 112.50 202.50 292.50] deg
Pt = 3.750 inH2O
PWR = 2.77576 inH2O
Wr-pl = 639.628 lb
Wr-pl-corr = 639.628 lb
Wrs-pl-corr = 639.628 lb
Ws-framing = 103.391 lbf
Ws-framing-corr = 100.397 lbf
Ws-pl = 7.37830e3 lb
Ws-pl-corr = 7.37830e3 lb
Wss = 1.49951e3 lb
Wss-corr = 0.0 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) = 10.0 ft
Actual Spacing (actual_spacing) = 7.87853 ft

actual_spacing <= max_allowable_spacing ==> PASS

N-min = CEILING(((pi * OD) / 10))
N-min = CEILING(((pi * 10.0313) / 10))
N-min = 4.0

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) = 8.140 ft
Bolt loads will be based on equally spaced anchors.

Anchor Material Properties

Material = A36
Minimum Tensile Strength (Sut-anchor) = 58.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength at Ambient Temperature (Sy-ambient-anchor) = 36.0e3 psi
As per API-650 Table M.1.b, Minimum Yield Strength (Sy-anchor) = 30.870e3 psi

Fy = MIN(Sy-anchor , 55000)
Fy = MIN(30.870e3 , 55000)
Fy = 30.870e3 psi

Fy-ambient = MIN(Sy-ambient-anchor , 55000)
Fy-ambient = MIN(36.0e3 , 55000)
Fy-ambient = 36.0e3 psi

Uplift Load Cases per API-650 Table 5.20b

W1 = Ws-pl-corr + Ws-framing-corr + Wr-pl-corr
W1 = 7.37830e3 + 100.397 + 639.628
W1 = 8.11832e3 lbf

W2 = Ws-pl-corr + Ws-framing-corr + Wrs-pl-corr + Wss-corr
W2 = 7.37830e3 + 100.397 + 639.628 + 0.0
W2 = 8.11832e3 lbf

W3 = Ws-pl + Ws-framing + Wr-pl + Wss
W3 = 7.37830e3 + 103.391 + 639.628 + 1.49951e3
W3 = 9.62083e3 lbf

As per API-650 Section 5.12.13, Seismic Attachment Load Multiplier (f_seismic) = 3.0
Seismic anchoring is required and API-650 Section 5.12.13 requires a multiplier of 3.

Uplift Case 1: Design Pressure Only
U = (P * (D^2) * 4.08) - W1
U = (3.0 * (10.0^2) * 4.08) - 8.11832e3
U = -6.89432e3 (Set to 0.0 lbf since it cannot be less than 0.0)

T_b = U / N
T_b = 0.0 / 4.0
T_b = 0.0 lbf

S_d = (5 / 12) * Fy
S_d = (5 / 12) * 30.870e3
S_d = 12.8625e3 psi

A-s-r = T_b / S_d
A-s-r = 0.0 / 12.8625e3
A-s-r = 0.0 in^2

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

S_d_shell = (2 / 3) * Fty
S_d_shell = (2 / 3) * 21.8750e3
S_d_shell = 14.5833e3 psi

Uplift Case 2: Test Pressure Only
U = (Pt * (D^2) * 4.08) - W3
U = (3.750 * (10.0^2) * 4.08) - 9.62083e3
U = -8.09083e3 (Set to 0.0 lbf since it cannot be less than 0.0)

T_b = U / N
T_b = 0.0 / 4.0
T_b = 0.0 lbf

S_d = (5 / 9) * Fy-ambient
S_d = (5 / 9) * 36.0e3

S_d = 20.0e3 psi

A-s-r = T_b / S_d
A-s-r = 0.0 / 20.0e3
A-s-r = 0.0 in^2

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

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 21.8750e3
S_d_shell = 18.2292e3 psi

Uplift Case 3: Wind Load Only
U = ((PWR * (D^2) * 4.08) + ((4 * MWS) / D)) - W2
U = ((2.77576 * (10.0^2) * 4.08) + ((4 * 39.1098e3) / 10.0)) - 8.11832e3
U = 8.65811e3 lbf

T_b = U / N
T_b = 8.65811e3 / 4.0
T_b = 2.16453e3 lbf

S_d = 0.8 * Fy
S_d = 0.8 * 30.870e3
S_d = 24.6960e3 psi

A-s-r = T_b / S_d
A-s-r = 2.16453e3 / 24.6960e3
A-s-r = 0.0876469 in^2

P_attachment = 1.5 * T_b
P_attachment = 1.5 * 2.16453e3
P_attachment = 3.24679e3 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 21.8750e3
S_d_shell = 18.2292e3 psi

Uplift Case 4: Seismic Load Only
U = ((4 * Mrw) / D) - (W2 * (1 - (0.4 * Av)))
U = ((4 * 139.40e3) / 10.0) - (8.11832e3 * (1 - (0.4 * 0.08960)))
U = 47.9325e3 lbf

T_b = U / N
T_b = 47.9325e3 / 4.0
T_b = 11.9831e3 lbf

S_d = 0.8 * Fy
S_d = 0.8 * 30.870e3
S_d = 24.6960e3 psi

A-s-r = T_b / S_d
A-s-r = 11.9831e3 / 24.6960e3
A-s-r = 0.485225 in^2

P_attachment = f_seismic * T_b
P_attachment = 3.0 * 11.9831e3
P_attachment = 35.9494e3 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 21.8750e3
S_d_shell = 18.2292e3 psi

Uplift Case 5: Design Pressure + Wind Load
U = ((((Fp * P) + PWR) * (D^2) * 4.08) + ((4 * MWS) / D)) - W1
U = ((((0.40 * 3.0) + 2.77576) * (10.0^2) * 4.08) + ((4 * 39.1098e3) / 10.0)) - 8.11832e3
U = 9.14771e3 lbf

T_b = U / N
T_b = 9.14771e3 / 4.0
T_b = 2.28693e3 lbf

S_d = (5 / 9) * Fy
S_d = (5 / 9) * 30.870e3
S_d = 17.150e3 psi

A-s-r = T_b / S_d
A-s-r = 2.28693e3 / 17.150e3
A-s-r = 0.133349 in^2

P_attachment = 1.5 * T_b
P_attachment = 1.5 * 2.28693e3
P_attachment = 3.43039e3 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 21.8750e3
S_d_shell = 18.2292e3 psi

Uplift Case 6: Design Pressure + Seismic Load
U = ((Fp * P * (D^2) * 4.08) + ((4 * Mrw) / D)) - (W1 * (1 - (0.4 * Av)))
U = ((0.40 * 3.0 * (10.0^2) * 4.08) + ((4 * 139.40e3) / 10.0)) - (8.11832e3 * (1 - (0.4 * 0.08960)))
U = 48.4221e3 lbf

T_b = U / N
T_b = 48.4221e3 / 4.0
T_b = 12.1055e3 lbf

S_d = 0.8 * Fy
S_d = 0.8 * 30.870e3
S_d = 24.6960e3 psi

A-s-r = T_b / S_d
A-s-r = 12.1055e3 / 24.6960e3
A-s-r = 0.490182 in^2

P_attachment = f_seismic * T_b
P_attachment = 3.0 * 12.1055e3
P_attachment = 36.3166e3 lbf

S_d_shell = (5 / 6) * Fty
S_d_shell = (5 / 6) * 21.8750e3

S_d_shell = 18.2292e3 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	0.0	12.8625e3	0.0	0.16250	0.0	14.5833e3
Test Pressure	0.0	0.0	20.0e3	0.0	0.16250	0.0	18.2292e3
Wind Load	8.65811e3	2.16453e3	24.6960e3	0.0876469	0.496559	3.24679e3	18.2292e3
Seismic Load	47.9325e3	11.9831e3	24.6960e3	0.485225	0.948508	35.9494e3	18.2292e3
Design Pressure + Wind	9.14771e3	2.28693e3	17.150e3	0.133349	0.574549	3.43039e3	18.2292e3
Design Pressure + Seismic	48.4221e3	12.1055e3	24.6960e3	0.490182	0.952512	36.3166e3	18.2292e3

- Anchor Bolt Required Diameter = SQRT((A-s-r * (4 / pi))) + (1.3 / n) + (Ca-anchor * 2)
- Governing Uplift Case = Design Pressure + Seismic
- Anchor Bolt Minimum Required Area = 0.490182 in^2

Bolt Required Diameter per ANSI B1.1

d-req = SQRT((A * (4 / pi))) + (1.3 / n) + (Ca * 2)
d-req = SQRT((0.490182 * (4 / pi))) + (1.3 / 8.0) + (0.0 * 2)
d-req = 0.952512 in

d >= d-req ==> PASS

A-s = (pi / 4) * ((d - (1.3 / n))^2)
A-s = (pi / 4) * ((1.0 - (1.3 / 8.0))^2)
A-s = 0.550883 in^2

Y-bolt = A-s * Sy-ambient-anchor
Y-bolt = 0.550883 * 36.0e3
Y-bolt = 19.8318e3 lbf

Anchorage Summary

Required Number of Anchors = 4.0
Actual Number of Anchors = 4.0
Bolt Hole Circle Radius = 5.18229 ft

Required Bolt Diameter = 0.952512 in
Actual Bolt Diameter = 1.0 in
Bolt Thread Pitch = 0.130
Bolt Embedded Depth = 10.0 in
Bolt Length = 30.1875 in

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 = 10.0 in
b = 10.0 in
c = 0.50 in

CA = 0.0 in
d = 1.0 in
D = 10.0 ft
e = 2.0 in
Earthquakes-Considered = ASCE7-MAPPED-SS-AND-S1
Et = 7.070e-6 in/in.fdeg
f = 6.0 in
g = 4.250 in
h = 14.0 in
j = 0.56250 in
k = 5.47902 in
m = 0.18750 in
Ma-chair = A240-316
outside-projection = 1.0 in
R = 60.0 in
t = 0.18750 in
T_ambient = 70.0 °F
T_design = 375.0 °F
V = 81.90 mph
Y-bolt = 19.8318e3 lbf

Anchor Chair Material Properties
Material = A240-316
Minimum Tensile Strength (Sut-chair) = 75.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy-chair) = 21.8750e3 psi
As per API-650 S.2b, Allowable Design Stress (Sd-chair) = 19.7250e3 psi
As per API-650 S.2b, Allowable Hydrostatic Test Stress (St-chair) = 27.0e3 psi

Ssw-chair = 1.33 * Sd-chair
Ssw-chair = 1.33 * 19.7250e3
Ssw-chair = 26.2342e3 psi

Size Requirements
c_corr = c - (2 * CA)
c_corr = 0.50 - (2 * 0.0)
c_corr = 0.50 in

j_corr = j - (2 * CA)
j_corr = 0.56250 - (2 * 0.0)
j_corr = 0.56250 in

Chair Minimum Height (hmin) = 12.0 in

h >= hmin ==> PASS

hmax = 3 * a
hmax = 3 * 10.0
hmax = 30.0 in

h-eff = MIN(hmax , h)
h-eff = MIN(30.0 , 14.0)
h-eff = 14.0 in

emin = (0.886 * d) + 0.572
emin = (0.886 * 1.0) + 0.572
emin = 1.4580 in

T = T_design - T_ambient
T = 375.0 - 70.0
T = 305.0 °F

emin-btm = (d / 2) + outside-projection + 0.125 + (6 * Et * D * T)
emin-btm = (1.0 / 2) + 1.0 + 0.125 + (6 * 7.070e-6 * 10.0 * 305.0)
emin-btm = 1.75438 in

emin-req = MAX(emin , emin-btm)
emin-req = MAX(1.4580 , 1.75438)
emin-req = 1.75438 in

e >= emin-req ==> PASS

g_min = d + 1
g_min = 1.0 + 1
g_min = 2.0 in

g >= g_min ==> PASS

f_min = (d / 2) + 0.125
f_min = (1.0 / 2) + 0.125
f_min = 0.6250 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 * (14.0 - 0.50)) , ((19.8318e3 / (25000 * 5.47902)) + (2 * 0.0)))
j_min = 0.540 in

j >= j_min ==> PASS

bmin = emin + d + 0.25
bmin = 1.4580 + 1.0 + 0.25
bmin = 2.7080 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	19.7250e3	0.0	PASS
Test Pressure	0.0	0.0	27.0e3	0.0	PASS
Wind Load	3.24679e3	3.24679e3	26.2342e3	0.168334	PASS
Seismic Load	35.9494e3	19.8318e3	26.2342e3	0.416030	PASS
Design Pressure + Wind	3.43039e3	3.43039e3	26.2342e3	0.173028	PASS
Design Pressure + Seismic	36.3166e3	19.8318e3	26.2342e3	0.416030	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) = 0.416030 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	19.7250e3	0.0%	PASS
Test Pressure	0.0	0.0	0.0	27.0e3	0.0%	PASS
Wind Load	3.24679e3	3.24679e3	2.97352e3	26.2342e3	11.3345%	PASS
Seismic Load	35.9494e3	19.8318e3	18.1626e3	26.2342e3	69.2325%	PASS
Design Pressure + Wind	3.43039e3	3.43039e3	3.14167e3	26.2342e3	11.9754%	PASS
Design Pressure + Seismic	36.3166e3	19.8318e3	18.1626e3	26.2342e3	69.2325%	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) = 18.1626e3 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 * 10.0 * 0.18750) / SQRT((60.0 * 0.18750))) * ((0.18750 / 0.18750)^2)) + 1)
Z = 0.909963

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	14.5833e3	0.0%	PASS
Test Pressure	0.0	0.0	0.0	18.2292e3	0.0%	PASS

Wind Load	3.24679e3	3.24679e3	2.53206e3	18.2292e3	13.8902%	PASS
Seismic Load	35.9494e3	19.8318e3	15.4661e3	18.2292e3	84.8429%	PASS
Design Pressure + Wind	3.43039e3	3.43039e3	2.67525e3	18.2292e3	14.6756%	PASS
Design Pressure + Seismic	36.3166e3	19.8318e3	15.4661e3	18.2292e3	84.8429%	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) = 15.4661e3 psi
- Governing Allowable Stress (Sd-Shell) = 18.2292e3 psi

Appurtenances Design [Back]

Plan View

LABEL	MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (in)	INSIDE PROJ (in)	ORIENT	RADIUS (in)	REMARKS	REF DWG
Agitator-Bridge	AB01		AGITATOR BRIDGE	--	--	0 '	--		
M1	RM01A		24" ROOF MANWAY	10"	1"	270 '	3'-4"		
N1	RN01A		6" ROOF NOZZLE	6"	1"	0 '	3'-9"		
N2	RN01A		6" ROOF NOZZLE	6"	1"	45 '	3'-9"		
N3	RN01A		6" ROOF NOZZLE	6"	1"	90 '	3'-9"		
N4	RN01A		6" ROOF NOZZLE	6"	1"	135 '	3'-9"		

Elevation View

LABEL	MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (in)	INSIDE PROJ (in)	ORIENT	ELEVATION (in)	REMARKS	REF DWG
Agitator-Bridge	AB01		AGITATOR BRIDGE	--	--	0 '	2'-5"		
Anchor-Chair-Bolts	AC01A		ANCHOR CHAIRS	--	--	SEE TABLE	--		
M2	SM01A		24" SHELL MANWAY	10"	1"	325 '	2'-6"	W/ DAVIT	
N5	SN01A		6" SHELL NOZZLE	8"	1"	0 '	1'-0 1/8"		
N6	SN01A		6" SHELL NOZZLE	8"	1"	45 '	1'-0 1/8"		
N7	SN01A		6" SHELL NOZZLE	8"	1"	90 '	1'-0 1/8"		
N8	SN01A		6" SHELL NOZZLE	8"	1"	135 '	1'-0 1/8"		

N9	SN02A		3" SHELL NOZZLE	7"	1"	180 '	9 1/2"	
N10	SN02A		3" SHELL NOZZLE	7"	1"	160 '	9 1/2"	
N11	SN02A		3" SHELL NOZZLE	7"	1"	220 '	9 1/2"	
N12	SN02A		3" SHELL NOZZLE	7"	1"	240 '	9 1/2"	
Name-Plate	NP01A		STD API	--	--	0 '	3'-4"	

Shell Nozzle: N5

Repad Design

NOZZLE Description : 6 in SCH 40S TYPE RFSO
Material: A312-TP316

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 = 1.0104 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL NOZZLE REF. API-650 S.3.3.1, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 6.625
Required Area = 0.4279 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 6.625
Available Shell Area = 0.8143 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 * (0.28 - 0)) + 0.1875] * (0.28 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.7322 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.4279 - 0.8143 - 0.7322

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 = A312-TP316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 6.0 in
Group = None
t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for Thermal Stress Relief (PWHT) is unknown.

Shell Nozzle: N6

Repad Design

NOZZLE Description : 6 in SCH 40S TYPE RFSO
Material: A312-TP316

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 = 1.0104 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL NOZZLE REF. API-650 S.3.3.1, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 6.625
Required Area = 0.4279 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 6.625
Available Shell Area = 0.8143 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 * (0.28 - 0)) + 0.1875] * (0.28 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.7322 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.4279 - 0.8143 - 0.7322
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 = A312-TP316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 6.0 in
Group = None
t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for Thermal Stress Relief (PWHT) is unknown.

Shell Nozzle: N7

Repad Design

NOZZLE Description : 6 in SCH 40S TYPE RFSO
Material: A312-TP316

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 = 1.0104 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL NOZZLE REF. API-650 S.3.3.1, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 6.625
Required Area = 0.4279 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 6.625
Available Shell Area = 0.8143 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 * (0.28 - 0)) + 0.1875] * (0.28 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.7322 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.4279 - 0.8143 - 0.7322
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 = A312-TP316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 6.0 in
Group = None
t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for

Thermal Stress Relief (PWHT) is unknown.

Shell Nozzle: N8

Repad Design

NOZZLE Description : 6 in SCH 40S TYPE RFSO
Material: A312-TP316

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 = 1.0104 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL NOZZLE REF. API-650 S.3.3.1, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 6.625
Required Area = 0.4279 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 6.625
Available Shell Area = 0.8143 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 * (0.28 - 0)) + 0.1875] * (0.28 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.7322 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.4279 - 0.8143 - 0.7322
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 = A312-TP316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 6.0 in
Group = None
t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for Thermal Stress Relief (PWHT) is unknown.

Shell Nozzle: N9

Repad Design

NOZZLE Description : 3 in SCH 40S TYPE RFSO
Material: A312-TP316

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 = 0.7917 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL NOZZLE REF. API-650 S.3.3.1, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 3.5
Required Area = 0.2261 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 3.5
Available Shell Area = 0.4302 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 * (0.216 - 0)) + 0.1875] * (0.216 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.4542 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2261 - 0.4302 - 0.4542
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 = A312-TP316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 3.0 in
Group = None
t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for Thermal Stress Relief (PWHT) is unknown.

Shell Nozzle: N10

Repad Design

NOZZLE Description : 3 in SCH 40S TYPE RFSO
Material: A312-TP316

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 = 0.7917 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL NOZZLE REF. API-650 S.3.3.1, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 3.5
Required Area = 0.2261 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 3.5
Available Shell Area = 0.4302 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 * (0.216 - 0)) + 0.1875] * (0.216 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.4542 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2261 - 0.4302 - 0.4542
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 = A312-TP316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 3.0 in
Group = None
t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for Thermal Stress Relief (PWHT) is unknown.

Shell Nozzle: N11

Repad Design

NOZZLE Description : 3 in SCH 40S TYPE RFSO
Material: A312-TP316

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 = 0.7917 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL NOZZLE REF. API-650 S.3.3.1, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 3.5
Required Area = 0.2261 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 3.5
Available Shell Area = 0.4302 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 * (0.216 - 0)) + 0.1875] * (0.216 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.4542 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2261 - 0.4302 - 0.4542
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 = A312-TP316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 3.0 in
Group = None

t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for Thermal Stress Relief (PWHT) is unknown.

Shell Nozzle: N12

Repad Design

NOZZLE Description : 3 in SCH 40S TYPE RFSO
Material: A312-TP316

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 = 0.7917 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL NOZZLE REF. API-650 S.3.3.1, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 3.5
Required Area = 0.2261 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 3.5
Available Shell Area = 0.4302 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 * (0.216 - 0)) + 0.1875] * (0.216 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.4542 in2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 0.2261 - 0.4302 - 0.4542
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 = A312-TP316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 3.0 in
Group = None
t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for Thermal Stress Relief (PWHT) is unknown.

Shell Manway: M2

Repad Design

MANWAY Description : 24 in Neck Thickness 0.25
Material: A240-316

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 = 2.5 ft

COURSE PARAMETERS:
t-calc = 0.0646 in
t_cr = 0.0646 in (Course t-calc less C.A)
t_c = 0.1875 in (Course t less C.A.)
t_Basis = 0.0646 in

(SHELL MANWAY REF. API-650 TABLE 5-6, AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 0.0646 * 24
Required Area = 1.5501 in2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (0.1875 - 0.0646) * 24
Available Shell Area = 2.9499 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)) + 0.1875] * (0.25 - 0) * MIN((19,725/19,725) 1)
Available Manway Neck Area = 0.5938 in2

A-rpr = (Required Area - Available Shell Area - Available Manway Neck Area)
A-rpr = 1.5501 - 2.9499 - 0.5938
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)

Manway Neck Material Properties
Material = A240-316
As per API-650 S.2b, Allowable Design Stress (Sd-neck) = 19.7250e3 psi

t_shell_PWHT = t-plate
t_shell_PWHT = 0.18750
t_shell_PWHT = 0.18750 in

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

D = 24.0 in
Group = None
t_shell = 0.18750 in

Shell material group (None) is not a group specified by API 650, 13th Ed, Section 5.7.4. Requirement for Thermal Stress Relief (PWHT) is unknown.

Cover Plate and Bolting Flange Design
CA-cover = Cover Plate and Bolting Flange Corrosion Allowance (in)
Db = Bolt Circle Diameter (in)
H = Design Liquid Level (ft)
M = Cover Plate Thickness Multiplication Factor per *API-650 S.3.3.3*
M = Bolting Flange Thickness Multiplication Factor per *API-650 S.3.3.3*
Ma-cover = Cover Plate Material
Ma-flange = Bolting Flange Material
Sd = Allowable Stress per *API-650 5.7.5.6* (psi)
SG = Product Specific Gravity
tc = Cover Plate Thickness (in)
tc-design = Cover Plate Required Thickness per *API-650 5.7.5.6* (in)
tc-req = Cover Plate Minimum Required Thickness (in)
tf = Bolting Flange Thickness (in)
tf-design = Cover Plate Required Thickness per *API-650 5.7.5.6* (in)
tf-req = Bolting Flange Minimum Required Thickness (in)
t-neck = Neck Thickness (in)

CA-cover = 0.0 in
Db = 30.250 in

H = 30.0 ft
Ma-cover = A240-316
Ma-flange = A240-316
SG = 1.10
tc = 0.6250 in
tf = 0.50 in
t-neck = 0.250 in

Water Density (Y) = 0.4330 psi/ft
As per API-650 5.7.5.6, Coefficient For Circular Plate (C) = 0.30

Cover Plate Material Properties and Required Thickness
Material = A240-316
As per API-650 S.5.b, Minimum Yield Strength at Ambient Temperature (Sy-ambient-cover) = 30.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy-cover) = 21.8750e3 psi
Thickness for MDMT-permissible-cover (per API-650 Figure 4.3) = 0.156250 in

Sd = MIN(Sy-ambient-cover , 30000) / 2 = 15.0e3 psi

M = MAX(SQRT((Sy-ambient-cover / Sy-cover)) , SQRT((30000 / Sy-cover)) , 1) = 1.17108

As per API-650 5.7.5.6, Cover Plate Erection Thickness (tc-erec) = 0.31250 in

tc-design = ((Db * SQRT(((C * Y * H * MAX(SG , 1)) / Sd))) + CA-cover) * M
tc-design = ((30.250 * SQRT(((0.30 * 0.4330 * 30.0 * MAX(1.10 , 1)) / 15.0e3))) + 0.0) * 1.17108
tc-design = 0.598864 in

tc-req = MAX(tc-erec , tc-design)
tc-req = MAX(0.31250 , 0.598864)
tc-req = 0.598864 in

t-cover >= tc-req ==> PASS

Bolting Flange Material Properties and Required Thickness
Material = A240-316
As per API-650 S.5.b, Minimum Yield Strength at Ambient Temperature (Sy-ambient-flange) = 30.0e3 psi
As per API-650 S.5.b, Minimum Yield Strength (Sy-flange) = 21.8750e3 psi
Thickness for MDMT-permissible-flange (per API-650 Figure 4.3) = 0.250 in

M = MAX(SQRT((Sy-ambient-flange / Sy-flange)) , SQRT((30000 / Sy-flange)) , 1) = 1.17108

As per API-650 5.7.5.6, Bolting Flange Erection Thickness (tf-erec) = 0.250 in

tf-design = tc-design - 0.125
tf-design = 0.598864 - 0.125
tf-design = 0.473864 in

tf-req = MAX(tf-erec , tf-design)
tf-req = MAX(0.250 , 0.473864)
tf-req = 0.473864 in

t-flange >= tf-req ==> PASS

Roof Nozzle: N1

Repad Design

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 40 TYPE RFSO
Material: A312-TP316

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

MOUNTED ON ROOF: Elevation = 30.2558 ft

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

(FOR ROOF NOZZLES, REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 0.1875 * 6.625
Required Area = 1.2422 in2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (0.1875 - 0.1875) * 6.625
Available Roof Area = 0 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 * (0.28 - 0)) + 0.1875] * (0.28 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.7322 in2

A_rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A_rpr = 1.2422 - 0 - 0.7322
A_rpr = 0.51 in2

As per API-650 J.3.6.3, reinforcement pad is not required since roof loads do not exceed 25 psf.

No Reinforcement Pad required.

Roof Nozzle: N2

Repad Design

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 40 TYPE RFSO
Material: A312-TP316

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

MOUNTED ON ROOF: Elevation = 30.2558 ft

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

(FOR ROOF NOZZLES, REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 0.1875 * 6.625
Required Area = 1.2422 in2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (0.1875 - 0.1875) * 6.625
Available Roof Area = 0 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 * (0.28 - 0)) + 0.1875] * (0.28 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.7322 in2

A_rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A_rpr = 1.2422 - 0 - 0.7322
A_rpr = 0.51 in2

As per API-650 J.3.6.3, reinforcement pad is not required since roof loads do not exceed 25 psf.

No Reinforcement Pad required.

Roof Nozzle: N3

Repad Design

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 40 TYPE RFSO
Material: A312-TP316

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

MOUNTED ON ROOF: Elevation = 30.2558 ft

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

(FOR ROOF NOZZLES, REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 0.1875 * 6.625
Required Area = 1.2422 in2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (0.1875 - 0.1875) * 6.625
Available Roof Area = 0 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 * (0.28 - 0)) + 0.1875] * (0.28 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.7322 in2

A_rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A_rpr = 1.2422 - 0 - 0.7322
A_rpr = 0.51 in2

As per API-650 J.3.6.3, reinforcement pad is not required since roof loads do not exceed 25 psf.

No Reinforcement Pad required.

Roof Nozzle: N4

Repad Design

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 40 TYPE RFSO
Material: A312-TP316

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

MOUNTED ON ROOF: Elevation = 30.2558 ft

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

(FOR ROOF NOZZLES, REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 0.1875 * 6.625
Required Area = 1.2422 in2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (0.1875 - 0.1875) * 6.625
Available Roof Area = 0 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 * (0.28 - 0)) + 0.1875] * (0.28 - 0) * MIN((19,725/19,725) 1)
Available Nozzle Neck Area = 0.7322 in2

A_rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A_rpr = 1.2422 - 0 - 0.7322
A_rpr = 0.51 in2

As per API-650 J.3.6.3, reinforcement pad is not required since roof loads do not exceed 25 psf.

No Reinforcement Pad required.

Roof Manway: M1

Repad Design

(Per API-650 Section 5.8.4 and other references below)
MANWAY Description : 24 in Neck Thickness 0.25
Material: A240-316

t_rpr = (Repad Required Thickness)
MOUNTED ON ROOF: Elevation = 30.3252 ft

ROOF PARAMETERS:
t-calc = 0.1875 in
t_cr = 0.1875 in (Roof t-act less C.A)
t_c = 0.1875 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 = (0.1875 - 0.1875) * 24
Available Roof Area = 0 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)) + 0.1875] * (0.25 - 0) * MIN((19,725/19,725) 1)
Available Manway Neck Area = 0.5938 in2

A-rpr = (Required Area - Available Roof Area - Available Manway Neck Area)
A-rpr = 4.5 - 0 - 0.5938
A-rpr = 3.9063 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 = 0.0 °F
vapor-pressure-type = HEXANE-OR-SIMILAR
V_pe = 100.0 gpm
V_pf = 100.0 gpm
V_tk = 17.7952e3 gal

R_i = 1
R_i = 1
R_i = 1.0

In-breathing
V_ip = 8.02 * V_pe
V_ip = 8.02 * 100.0
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) = 3.0

V_IT = 3.08 * C * (V_tk^0.7) * R_i
V_IT = 3.08 * 3.0 * (2.37887e3^0.7) * 1.0
V_IT = 2.13369e3 ft^3/hr

V_IT = 2,133.688 ft^3/hr of air

Vi = V_ip + V_IT
Vi = 802.0 + 2.13369e3
Vi = 2.93569e3 ft^3/hr

Vi = 2,935.688 ft^3/hr of air

Out-breathing
V_op = 8.02 * V_pf
V_op = 8.02 * 100.0
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) = 0.250

V_OT = 1.51 * Y * (V_tk^0.9) * R_i
V_OT = 1.51 * 0.250 * (2.37887e3^0.9) * 1.0
V_OT = 412.715 ft^3/hr

V_OT = 412.7146 ft^3/hr of air

Vo = V_op + V_OT
Vo = 802.0 + 412.715
Vo = 1.21471e3 ft^3/hr

Vo = 1,214.7146 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 = 10.0 ft
H = 30.0 ft
insulation_type = NO-INSULATION
P_g = 0.108379 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 * 10.0 * MIN(30.0 , 30)
ATWS = 942.478 ft^2

q = 506168.1168 * F
q = 506168.1168 * 1.0
q = 506.168e3 ft^3/hr

Capacities and Weights Back

Capacity to Top of Shell (to Tank Height) : 17,625 gal
Capacity to Design Liquid Level : 17,625 gal
Capacity to Maximum Liquid Level : 17,625 gal
Working Capacity (to Normal Working Level) : 0 gal
Net working Capacity (Working Capacity - Min Capacity) : 0 gal
Minimum Capacity (to Min Liq Level) : 587 gal

Component	New Condition (lbf)	Corroded (lbf)
SHELL	7,379	7,379
ROOF	634	634
RAFTERS	0	0
GIRDERS	0	0
FRAMING	0	0
COLUMNS	0	0
TRUSS	0	0
STRUCTURE COMPONENTS	0	0
BOTTOM	626	626
STAIRWAYS	0	0
ACCESS	0	0
STIFFENERS	101	101
WIND GIRDERS	0	0
AGITATOR BRIDGE	1,000	1,000
ANCHOR CHAIRS	95	95
SHELL APPURTENANCES	498	498
ROOF APPURTENANCES	260	260
BOTTOM APPURTENANCES	0	0
INSULATION	0	0
FLOATING ROOF	0	0
TOTAL	10,594.4152	10,594.4152

Weight of Tank, Empty : 10,594.4152 lbf
Weight of Tank, Full of Product (Design SG = 1.1) : 172,396.4152 lbf
Weight of Tank, Full of Water : 157,686.6893 lbf
Net Working Weight, Full of Product (Design SG = 1.1) : 167,002.5333 lbf
Net Working Weight Full of Water : 152,783.6135 lbf

Foundation Area Req'd : 81.6794 ft2
Foundation Loading, Empty : 129.7072 lbf/ft2
Foundation Loading, Full of Product Design : 2,110.6461 lbf/ft2
Foundation Loading, Full of Water : 1,930.5552 lbf/ft2

SURFACE AREAS
Roof : 81.6893 ft2
Shell : 942.4777 ft2

Bottom : 81.6794 ft2

Internal Pressure Moment : 6,128.6806 lbf-ft
Wind Moment : 44,927.5415 lbf-ft
Seismic Moment (Ringwall) : 139,399.6676 lbf-ft
Seismic Moment (Slab) : 153,154.5112 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 = 81.6894 ft^2
A_v = 0.08960 g
D = 10.0 ft
F-wind = 2.60732e3 lbf
gamma_b = 0.290 lbf/in^3 [501.120 lbf/ft^3]
gamma_w = 62.4279 lb/ft^3
Hs = 30.0 ft
Lmax = 30.0 ft
Lr = 20.0 psf
M_rw = 139.40e3 ft.lbf
M_s = 153.155e3 ft.lbf

P = 0.108379 psi
Pt = 0.135474 psi
Pv = 0.0361263 psi
P_WS = 0.0601666 psi
S = 0.0 psf
SG = 1.10
tb = 0.18750 in [0.0156250 ft]
Wr-attachments = 260.865 lb
Wr-ins = 0.0 lb
Wr-pl = 639.628 lb
Ws-attachments = 593.550 lb
Ws-framing = 103.391 lb
Ws-ins = 0.0 lb
Ws-pl = 7.37830e3 lb
W-wind = 44.9275e3 ft.lbf

W_rss = Wr-pl + Wr-ins + Wr-attachments
W_rss = 639.628 + 0.0 + 260.865
W_rss = 900.493 lbf

Ws = Ws-pl + Ws-ins + Ws-attachments + Ws-framing
Ws = 7.37830e3 + 0.0 + 593.550 + 103.391
Ws = 8.07524e3 lbf

Unfactored (Working Stress) Downward Reactions on Foundations

Load Case	Location	Equation	Value	Unit
Dead Load	Shell	(Ws + W_rss) / (pi * D)	285.706	lbf/ft
Dead Load	Bottom	tb * gamma_b	7.830	psf
Internal Pressure	Bottom	P	15.6066	psf
Vacuum	Shell	(Pv * A_rss) / (pi * D)	13.5270	lbf/ft
Hydrostatic Test	bottom	Lmax * gamma_w	1.87284e3	psf
Minimum Roof Live Load	Shell	(Lr * A_rss) / (pi * D)	52.0051	lbf/ft
Seismic	Shell	((4 * (M_rw / D)) + (0.4 * (Ws + W_rss) * A_v)) / (pi * D)	1.78513e3	lbf/ft
Seismic	Bottom	(32 * M_s) / (pi * (D^3))	1.56002e3	psf
Snow	Shell	(S * A_rss) / (pi * D)	0.0	lbf/ft
Stored Liquid	Bottom	SG * Lmax * gamma_w	2.06012e3	psf
Pressure Test	Bottom	Pt	19.5082	psf
Wind	Shell	(2 * (Hs^2) * P_WS) / (pi * D)	496.410	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 = (8.07524e3 + 900.493) / (pi * 10.0)
L_dead_shell = 285.706 lbf/ft

L_dead_bottom = tb * gamma_b
L_dead_bottom = 0.0156250 * 501.120
L_dead_bottom = 7.830 psf

L_internal-pressure_bottom = P
L_internal-pressure_bottom = 15.6066
L_internal-pressure_bottom = 15.6066 psf

L_vacuum_shell = (Pv * A_rss) / (pi * D)
L_vacuum_shell = (5.20219 * 81.6894) / (pi * 10.0)
L_vacuum_shell = 13.5270 lbf/ft

L_hydrostatic_bottom = Lmax * gamma_w
L_hydrostatic_bottom = 30.0 * 62.4279
L_hydrostatic_bottom = 1.87284e3 psf

L_minimum-roof-live-load_shell = (Lr * A_rss) / (pi * D)
L_minimum-roof-live-load_shell = (20.0 * 81.6894) / (pi * 10.0)
L_minimum-roof-live-load_shell = 52.0051 lbf/ft

L_seismic_shell = ((4 * (M_rw / D)) + (0.4 * (Ws + W_rss) * A_v)) / (pi * D)
L_seismic_shell = ((4 * (139.40e3 / 10.0)) + (0.4 * (8.07524e3 + 900.493) * 0.08960)) / (pi * 10.0)
L_seismic_shell = 1.78513e3 lbf/ft

L_seismic_bottom = (32 * M_s) / (pi * (D^3))
L_seismic_bottom = (32 * 153.155e3) / (pi * (10.0^3))
L_seismic_bottom = 1.56002e3 psf

L_snow_shell = (S * A_rss) / (pi * D)
L_snow_shell = (0.0 * 81.6894) / (pi * 10.0)
L_snow_shell = 0.0 lbf/ft

L_stored-liquid_bottom = SG * Lmax * gamma_w
L_stored-liquid_bottom = 1.10 * 30.0 * 62.4279
L_stored-liquid_bottom = 2.06012e3 psf

L_pressure-test_bottom = Pt
L_pressure-test_bottom = 19.5082
L_pressure-test_bottom = 19.5082 psf

L_wind_shell = (2 * (Hs^2) * P_WS) / (pi * D)
L_wind_shell = (2 * (30.0^2) * 8.6640) / (pi * 10.0)
L_wind_shell = 496.410 lbf/ft

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