OBJECT

Strength Calculation for 4840-TK-120
Poboya 2000tpd Expansion Project

Client No.: 2000-4840-MES-CAL-001

REFERENCES

3655.15-61.08-4000-F-BOD-001	Process Design Criteria
3655.15-61.08-4000-F-CAL-001	Mass Balance

ASSUMPTIONS

0	Issued for Information	22-May-26	Wawan	Ardiyanto	Muraasato	
A	Issued for Review	14-Apr-26	Wawan	Ardiyanto	Muraasato	
Revision	Description	Date	Prepared By	Reviewed By	Approved	Client App

CLIENT **PT Citra Palu Minerals**		TITLE **Strength Calculation for Tailing Thickener Overflow**	REV **0**
PROJECT **Poboya 2000tpd Expansion Project**		**COMO ENGINEERS**	PROJECT No. **E2602**
BY Wawan	DATE 22-May-26	CHECKED Ardiyanto	DATE 22-May-26
			Doc No E2602-4840-CAL-101

Revision History

REV. No.	DATE	DESCRIPTION	REVISION BY
A	April, 14, 2026	Issued for Review	
0	May, 22, 2026	Issued for Information	

CONTENTS

1. Introduction

This document consist of additional analysis for tailing overflow tank shell thickness. The dimension is 4.5 m height and 7 m for the diameter. Additional analysis needed to calculate the strength of shell tank to resist walkway platform load that located on top of the tank.

2. Support Document

- *3655.15-61.08-4840-M-DWG-001 – GA – Tailing Thickener Overflow Tank*

3. Code and Reference

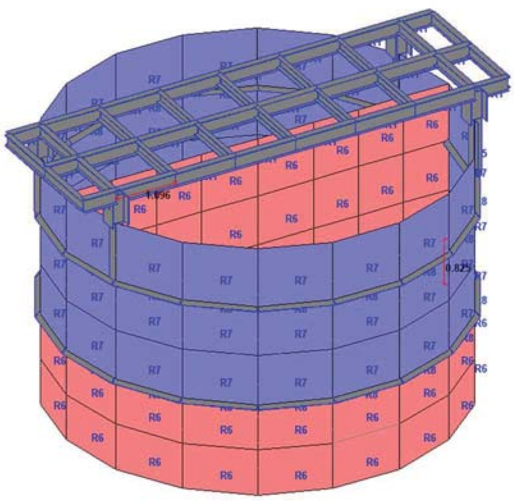
Code and reference that used for this calculation listed below :

- API STD 650 2018 – Welded Tanks for Oil Storage
- SNI 1729:2020 – Spesifikasi untuk Bangunan Gedung Baja Struktural

4. Design

4.1 Isometric Model

Analysis design for the tank use STAAD Pro software. Tank model picture showed below :



Material			
PLATE			
Shell elev. (m)	Main Thickness (mm)	Corrosion Allowance (mm)	Design Thickness (mm)
Bottom Plate	7	3	10
0 - 4.5	5	3	8
STIFFENER			
Profile elev. (m)	Type		
1.65	L.130.130.12		
3.45	L.130.130.12		
4.5	L.200.200.25		
PLATFORM SUPPORT			
Profile elev. (m)	Type		
4.5	Half Tee. 300.300.10.15		

Picture 1. Tank Model and Properties

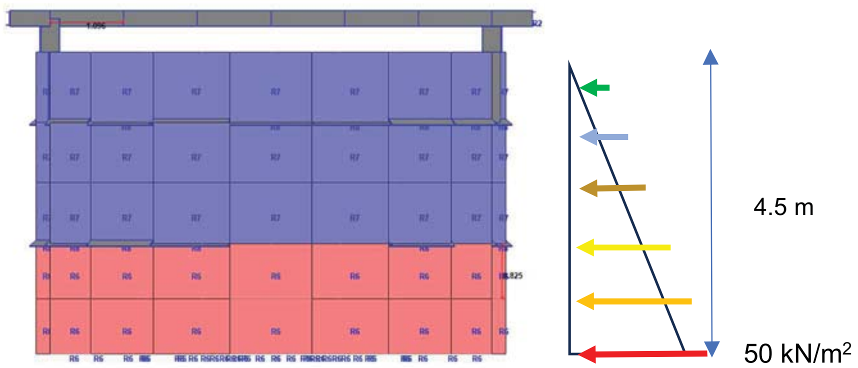
4.2 Load and Combination

4.2.1 Daad Load

Unit weight of steel used as calculation is 78.5 kN/m3.

4.2.2 Hidrostatic Load

Hidrostatic load is pressure load from fluida content. Specific gravity fluida is 1.11 Ton/m^3



Hidrostatic load : 1.11 x 4.5 = 4.99 Ton/m^2 → 50 kN/m^2

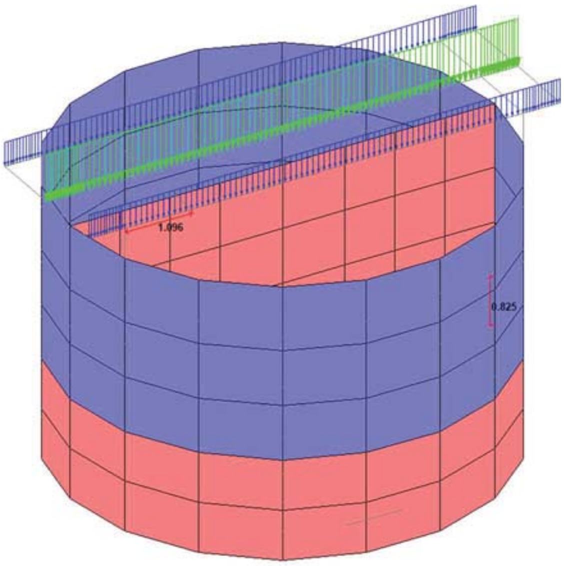
4.2.3 Walkway Platform Load

GRATING

q	=	0.45 kN/m2
Tributary 1	=	1 m
Tributary 2	=	0.5 m
Input load 1	=	0.45 kN/m
Input load 2	=	0.225 kN/m

LIVE LOAD

q	=	2.5 kN/m2
Tributary 1	=	1 m
Tributary 2	=	0.5 m
Input load 1	=	2.5 kN/m
Input load 2	=	1.25 kN/m



Picture 2. Walkway Input Load

4.2.4 Seismic Load

Seismic load calculated based on API 650.

- The seismic overturning moment at the base of the tank shell shall be the SRSS summation of the impulsive and convective components multiplied by the respective moment arms to the center of action of the forces unless otherwise specified.

Ringwall Moment, M_{rw}:

$$M_{rw} = \sqrt{[A_i(W_iX_i + W_sX_s + W_rX_r)]^2 + [A_c(W_cX_c)]^2} \quad \text{(E.6.1.5-1)}$$

Equation Ai :

Impulsive spectral acceleration parameter, A_i:

$$A_i = S_{DS}\left(\frac{I}{R_{wi}}\right) = 2.5QF_aS_0\left(\frac{I}{R_{wi}}\right) \quad \text{(E.4.6.1-1)}$$

However, $A_i \geq 0.007$ (E.4.6.1-2)

and, for $S_1 \geq 0.6$:

$$A_i \geq 0.5S_1\left(\frac{I}{R_{wi}}\right) = 0.625S_P\left(\frac{I}{R_{wi}}\right) \quad \text{(E.4.6.1-3)}$$

I = 1 *(category II)*

Sds = 0.806

Rwi 3.5

Table E.4—Response Modification Factors for ASD Methods

Anchorage system	R_{wi}, (impulsive)	R_{wc}, (convective)
Self-anchored	3.5	2
Mechanically-anchored	4	2

Ai = 0.23

Equation Ac

Convective spectral acceleration parameter, A_c:

When, $T_C \le T_L$ $$A_c = KS_{D1}\left(\frac{1}{T_c}\right)\left(\frac{I}{R_{wc}}\right) = 2.5KQF_aS_0\left(\frac{T_s}{T_c}\right)\left(\frac{I}{R_{wc}}\right) \le A_i \quad \text{(E.4.6.1-4)}$$

When, $T_C > T_L$ $$A_c = KS_{D1}\left(\frac{T_L}{T_c^2}\right)\left(\frac{I}{R_{wc}}\right) = 2.5KQF_aS_0\left(\frac{T_sT_L}{T_c^2}\right)\left(\frac{I}{R_{wc}}\right) \le A_i \quad \text{(E.4.6.1-5)}$$

Ai = 0.23

Ks = 0.58

Tc = 2.78

Rwc = 2

K = 1.5

S_{D1} = 0.582

Ac = 0.16

Equation Wi and Xi :

E.6.1.1 Effective Weight of Product

The effective weights W_i and W_c shall be determined by multiplying the total product weight, W_p, by the ratios W_i/W_p and W_c/W_p, respectively, Equations E.6.1.1-1 through E.6.1.1-3.

When D/H is greater than or equal to 1.333, the effective impulsive weight is defined in Equation E.6.1.1-1:

$$W_i = \frac{\tanh\left(0.866\frac{D}{H}\right)}{0.866\frac{D}{H}} W_p \qquad \text{(E.6.1.1-1)}$$

When D/H is less than 1.333, the effective impulsive weight is defined in Equation E.6.1.1-2:

$$W_i = \left[1.0 - 0.218\frac{D}{H}\right] W_p \qquad \text{(E.6.1.1-2)}$$

When D/H is greater than or equal to 1.3333, the height X_i is determined by Equation E.6.1.2.1-1:

$$X_i = 0.375H \qquad \text{(E.6.1.2.1-1)}$$

When D/H is less than 1.3333, the height X_i is determined by Equation E.6.1.2.1-2:

$$X_i = \left[0.5 - 0.094\frac{D}{H}\right] H \qquad \text{(E.6.1.2.1-2)}$$

D	=	7	m
H	=	4.5	m
D/H	=	1.56	
ɣ	=	1.11	
Wp	=	1886.54	kN
perimeter	=	22.00	m
3.67H/D	=	2.36	
Wi	**=**	**1223.09**	**kN**
Xi	**=**	**1.69**	**m**

Equation Wc and Xc :

The effective convective weight is defined in Equation E.6.1.1-3:

$$W_c = 0.230\frac{D}{H}\tanh\left(\frac{3.67H}{D}\right)W_p \qquad \text{(E.6.1.1-3)}$$

The height X_c is determined by Equation E.6.1.2.1-3:

$$X_c = \left[1.0 - \frac{\cosh\left(\frac{3.67H}{D}\right) - 1}{\frac{3.67H}{D}\sinh\left(\frac{3.67H}{D}\right)}\right]H \qquad \text{(E.6.1.2.1-3)}$$

Wc	**=**	**663.02 kN**
Xc	**=**	**2.92 m**

Value of Ws and Xs :

Ws = Total weight of tank shell and appurtenances

Xs = Height from bottom of the tank shell to the shell's center of gravity

L.130.130.12

A	=	2976 mm^2	=	0.002976 m^2
w	=		=	5.14 kN
n			=	2
Weight Total L.130			=	10.28 kN

L.200.200.25

A	=	9375 mm^2	=	0.009375 m^2
w			=	16.19 kN
n			=	1
Weight Total L.130			=	16.19 kN

H.300.300.15.10 H.Tee

A	=	11850 mm^2	=	0.01185 m^2
w			=	1.53 kN
n			=	4
Weight Total L.130			=	6.14 kN

Shell T 8 mm

A	=	0.18 m^2
w	=	24.87 kN

Shell T 8 mm

A	=	0.18 m^2
w	=	37.30 kN

TOTAL WEIGHT (Ws)		**94.78 kN**
Xs	**=**	**2.25 m**

From calculation above,

(Ai . Wi) / perimeter	=	12.80 kN/m, at H =	1.69 m
(Ai . Ws) / perimeter	=	0.99 kN/m, at H =	2.25 m
(Ac . Wc) / perimeter	=	4.74 kN/m, at H =	2.92 m

For simplification :

W	=	18.53 kN/m
H	=	2.03 m

ANCHORAGE

Bolt Pitch Circle Diameter	=	7.2	m	
Perimeter Bolt Pitch Circle	=	22.63	m	
Anchor Bolt Diameter	=	27.00	mm	
Root area anchor	=	572.79	mm^2	
Bolt Material		Grade 307 Class C		
	fy =	235	MPa	
	fu =	400	MPa	
D	=	7.00	m	
Mrw	=	606.41	kNm	
Av (0.47 Sds)	=	1.43		
W2	=	71.47	kN	
U	=	315.82	kN	
N	=	12		
Tb	=	26.32	kN	
Allowable Anchor Stress, Sd	=	188	MPa	(0.8 . Fy)
Tn	=	80.76	kN	(Sd . Ab . 0.75)
Ø Tn	=	72.69	kN	(0.9 Tn)
Tb < Ø Tn		OK		
Depth of Anchor, *hef*	=	500	mm	*(embedded to concrete)*
kc	=	10		
λ	=	1		
fc'	=	28.00	MPa	
Concrete breakout strength, *Nb*	=	591.61	kN	$(kc \cdot \lambda \cdot \sqrt{fc'} \cdot hef^{1.5})$
Nb > Tb		OK		

4.2.5 Wind Load

Wind load calculated based on SNI 1727 : 2020.

4.2.6 Load Combination

Load combination based on SNI 1729 : 2020

Service load combination :

1. D
2. $D + L$
3. $D + (L_r \text{ atau } R)$
4. $D + 0{,}75\,L + 0{,}75(L_r \text{ atau } R)$
5. $D + 0{,}6\,W$
6. $D + 0{,}75\,(0{,}6\,W) + 0{,}75\,L + 0{,}75\,(L_r \text{ atau } R)$
7. $0{,}6D + 0{,}6\,W$

8. $1{,}0D + 0{,}7E_v + 0{,}7E_h$
9. $1{,}0D + 0{,}525E_v + 0{,}525E_h + 0{,}75L$
10. $0{,}6D - 0{,}7E_v + 0{,}7E_h$

Ultimate load combination :

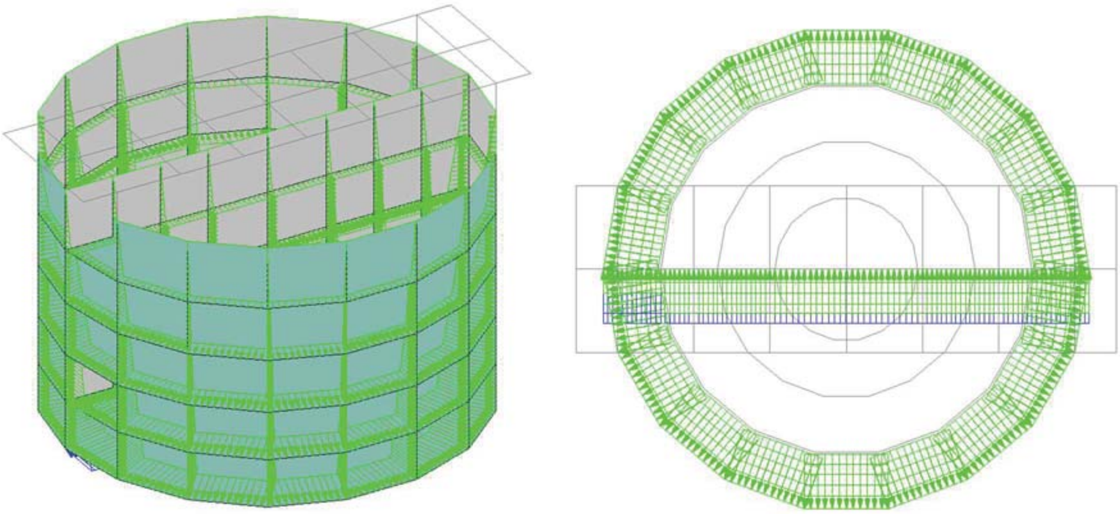
1. $1{,}4D$
2. $1{,}2\,D + 1{,}6\,L + 0{,}5\,(L_r \text{ atau } R)$
3. $1{,}2D + 1{,}6\,(L_r \text{ atau } R) + (L \text{ atau } 0{,}5\,W)$
4. $1{,}2D + 1{,}0\,W + L + 0{,}5(L_r \text{ atau } R)$
5. $0{,}9\,D + 1{,}0\,W$

6. $1{,}2D + E_v + E_h + L$
7. $0{,}9D - E_v + E_h$

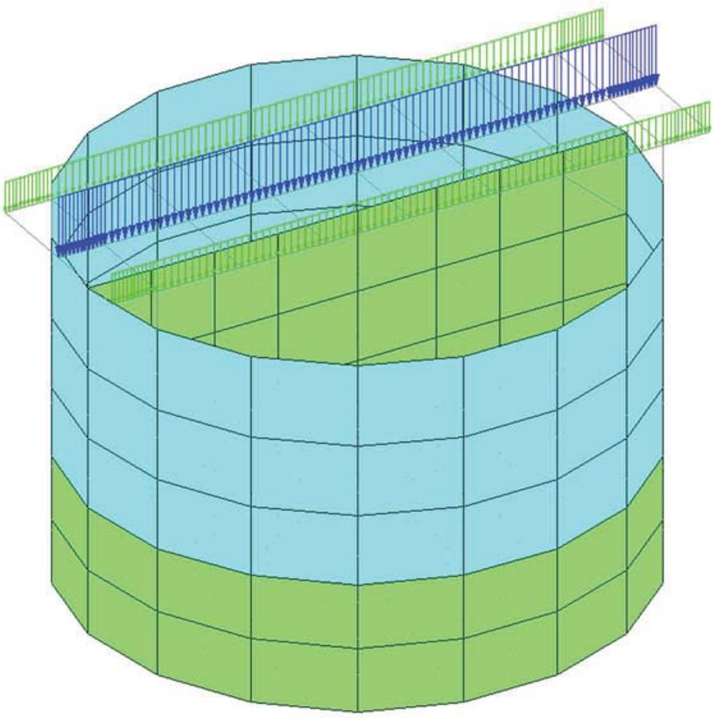
4.3 Analysis Design

4.3.1 Input Model

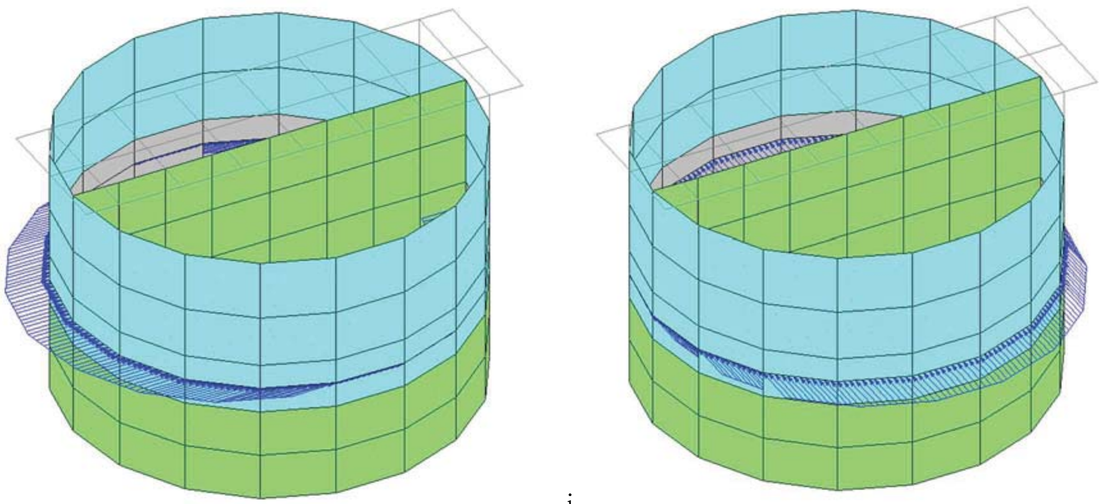
a. Hidrostatic Load (MAX =80.34 kN/m²)



b. Walkway Platform Load

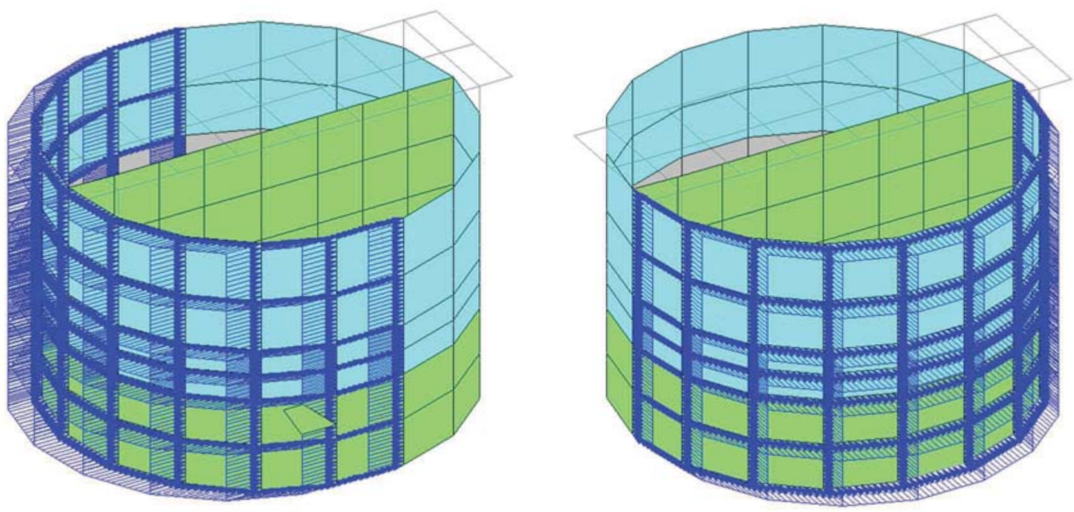


c. Seismic Load (Wi = 29.91 kN/m)

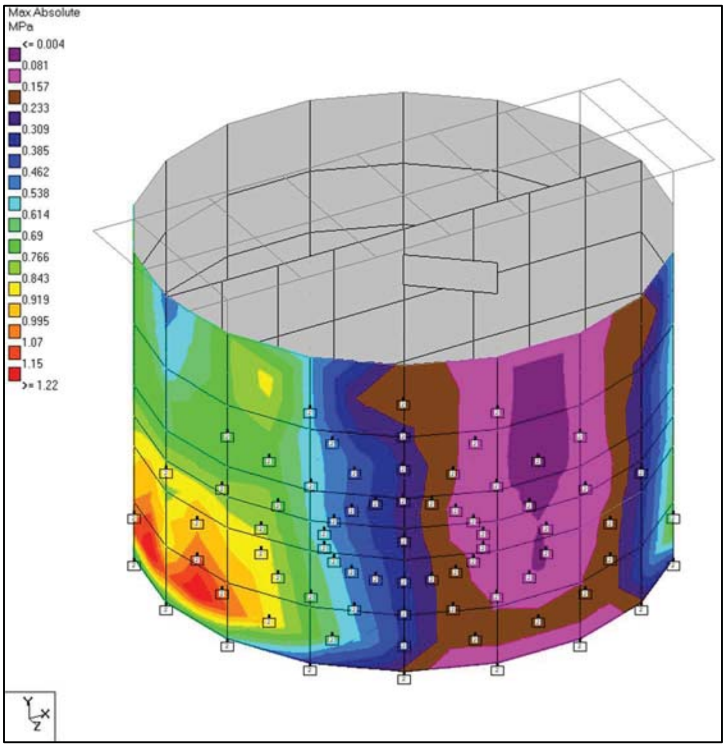


i

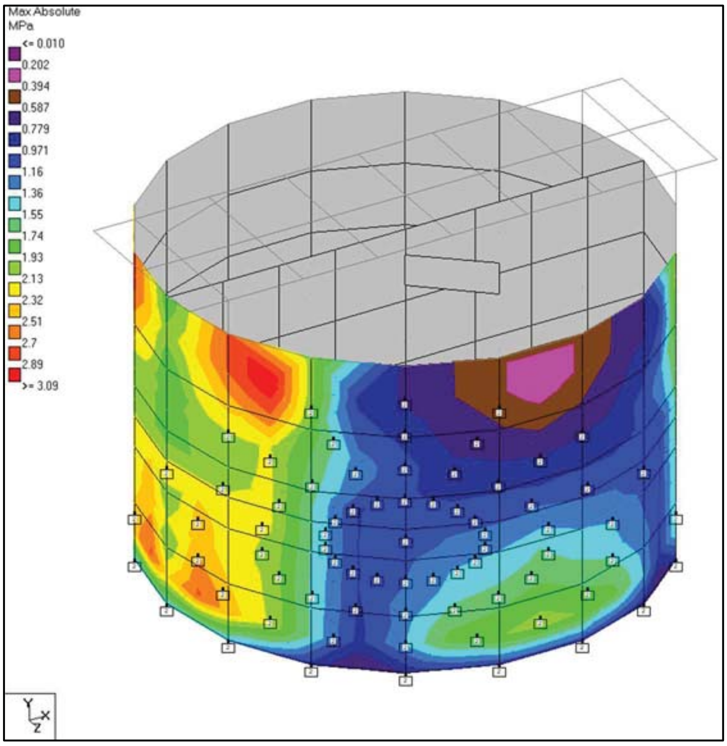
d. Wind Load (0.6 kN/m2)



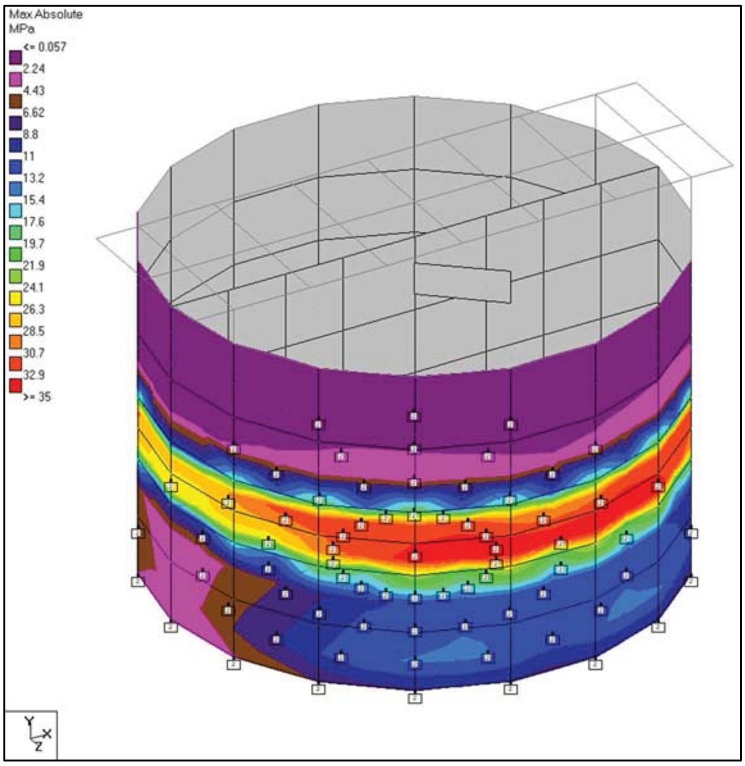
4.3.2 Output Data



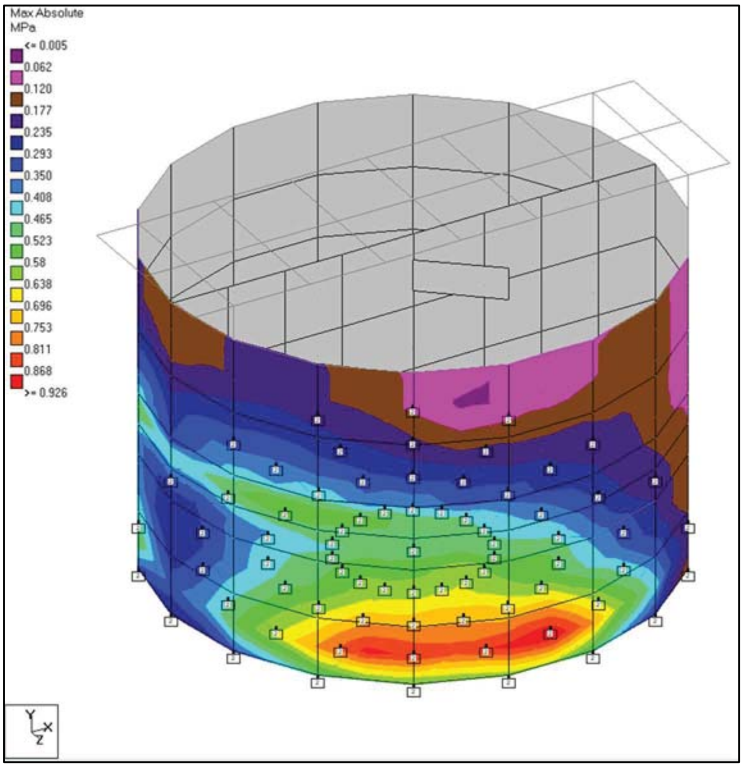
Stress Shell due Selfweight (max : 1.22 MPa)



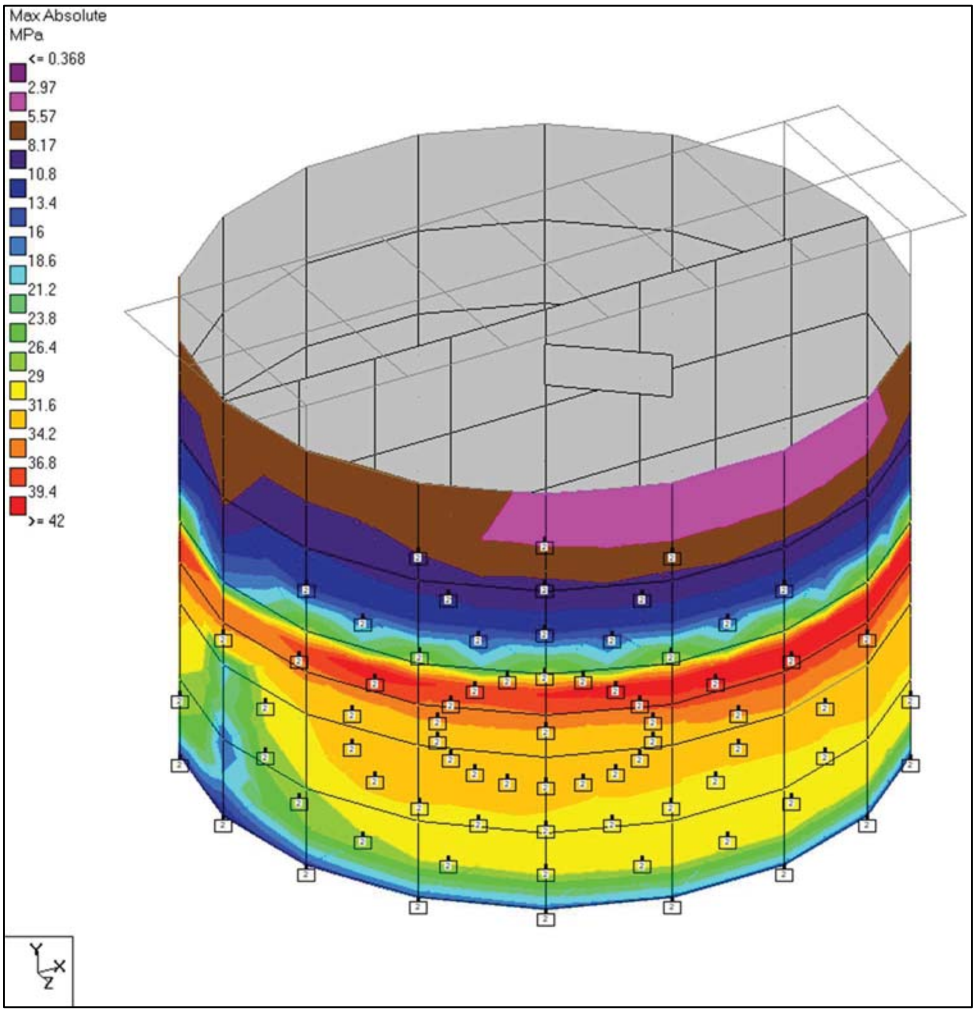
Stress Shell due Platform Support (max : 3.1 MPa)



Stress Shell due Seismic Load EQx (max : 35 MPa)



Stress due Windload Wx+ (max : 1 MPa)

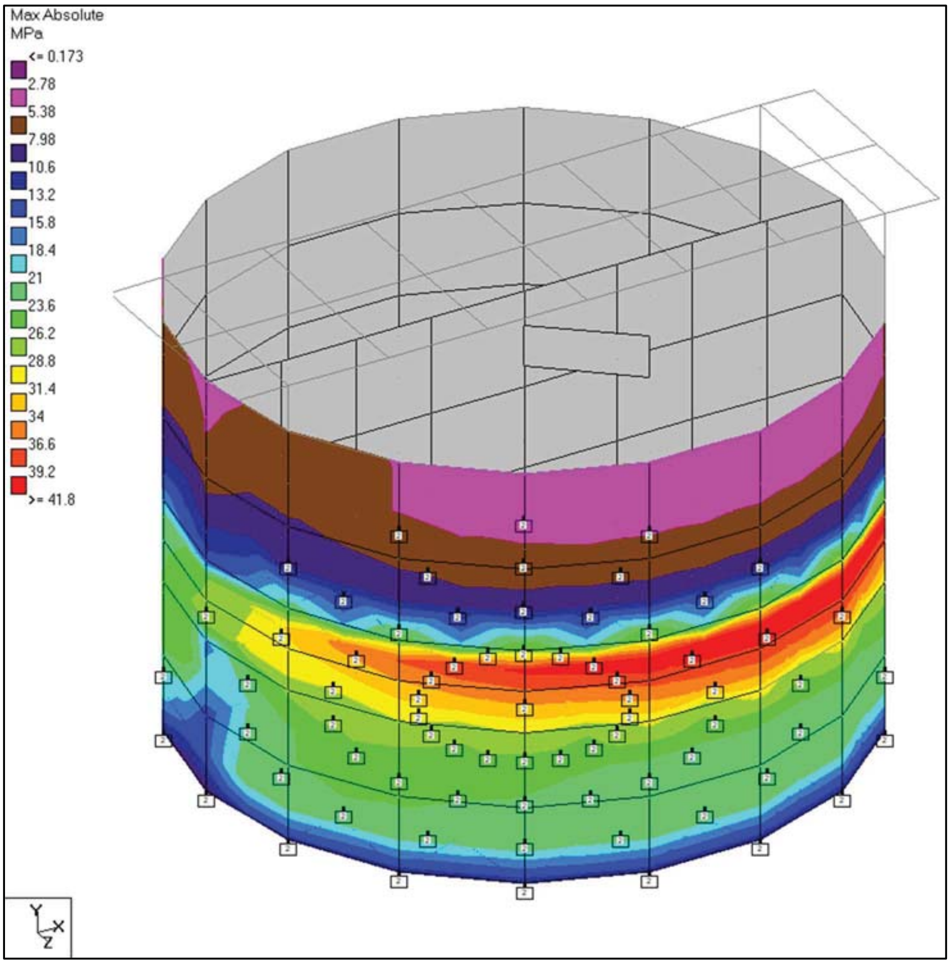


Stress due Load Combination (Service) (max : 70.5 MPa)

Stress Summary Table

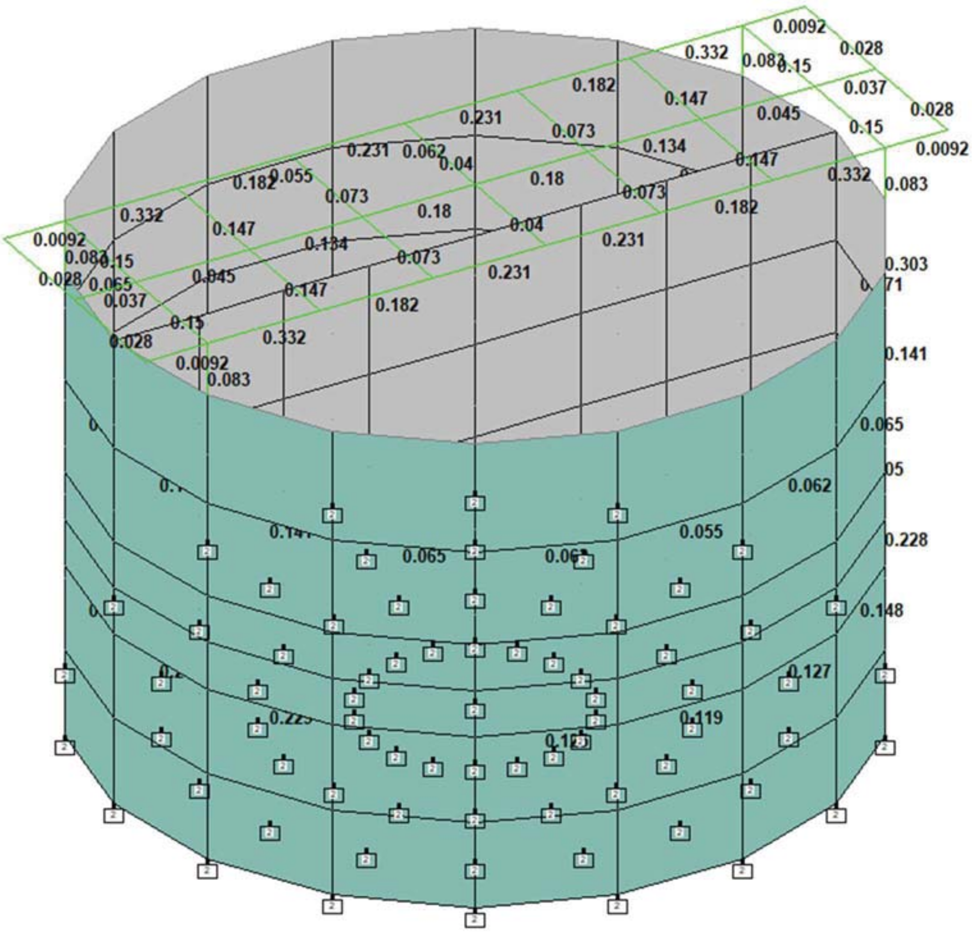
	Plate	L/C	Shear (Local)		Membrane (Local)			Bending Moment (Local)		
			SQX MPa	SQY MPa	SX MPa	SY MPa	SXY MPa	MX kN-m/m	MY kN-m/m	MXY kN-m/m
Max Qx	400	19 201	0.259	0.003	-0.411	0.447	8.497	0	0	-0.07
Min Qx	382	19 201	-0.259	-0.003	0.399	-0.49	-8.771	0	0	0.07
Max Qy	403	20 202	-0.006	0.142	18.419	-0.18	0.113	0.011	0.006	-0.002
Min Qy	385	20 202	0.006	-0.142	-18.386	0.137	0.16	-0.011	-0.006	0.002
Max Sx	403	24 206	-0.004	0.101	**39.427**	0.454	0.538	0.01	0.01	-0.002
Min Sx	385	20 202	0.006	-0.142	-18.386	0.137	0.16	-0.011	-0.006	0.002
Max Sy	39	24 206	0	-0.008	24.936	4.583	0.846	0	0.001	0
Min Sy	268	18 103	0	0	-0.33	-7.609	3.725	0	0	0
Max Sxy	43	24 206	-0.002	-0.008	15.462	-3.049	14.214	0	0	0
Min Sxy	51	24 206	0.003	-0.009	15.006	-4.551	-14.05	0	0	0
Max Mx	276	20 202	0.004	-0.011	0.27	-0.816	0.218	0.018	0.009	-0.008
Min Mx	275	22 204	0.004	0.011	0.27	-0.816	-0.218	-0.018	-0.009	-0.008
Max My	405	23 205	0.028	0.097	38.763	-0.488	1.611	0.011	0.01	0.013
Min My	275	22 204	0.004	0.011	0.27	-0.816	-0.218	-0.018	-0.009	-0.008
Max Mxy	399	19 201	0.202	-0.004	-0.502	0.37	-0.091	0	0	0.086
Min Mxy	381	19 201	-0.202	0.004	0.535	-0.413	-0.182	0	0	-0.086

Maximum stress Sx occurred due combination load 206 : 1.0DL + 0.525 EQ + 0.75LL + 0.75Hidrostatic (Load Combination service no 9, Hidrostatic included as live load)



Stress due Combination 103 (max : 41.8 MPa)

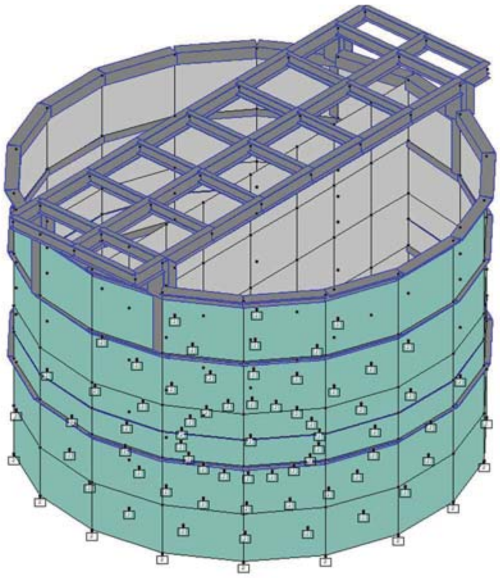
All Stress ratio stiffener frame condition are under allowance (1) :



5. Conclusion

- All component, steel frame and steel shell with current configuration is capable to resist the loads.

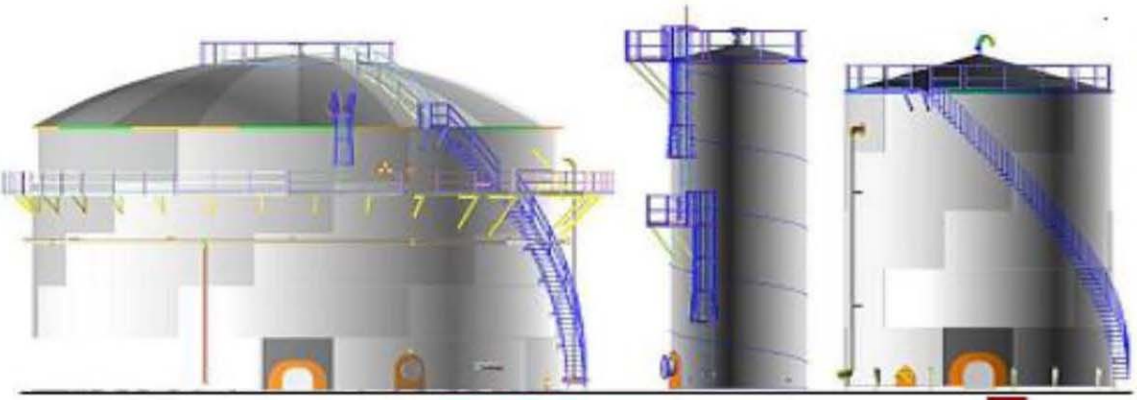
- The configuration as follows :



Material			
PLATE			
Shell elev. (m)	Main Thickness (mm)	Corrosion Allowance (mm)	Design Thickness (mm)
Bottom Plate	7	3	10
0 - 4.5	5	3	8
STIFFENER			
Profile elev. (m)	Type		
1.65	L.130.130.12		
3.45	L.130.130.12		
4.5	L.200.200.25		
PLATFORM SUPPORT			
Profile elev. (m)	Type		
4.5	Half Tee. 300.300.10.15		

- Anchorage Data :
  - Diameter = 27 mm
  - Embedded Length = 500 mm (from top of concrete foundation)
  - n = 12

AMETANK REPORT



AMETank

Field Erected and Shop Built Storage Tanks

Engineering Application Software

DESIGN DATA

PROJECT NAME	**POBOYA 2000 TPD EXPANSION PROJECT**	
TAG NO.	**4840-TK-120**	
DESCRIPTION	**TAILING THICKENER OVERFLOW TANK**	
CODE	**API-650 13TH EDITION**	
FLUID NAME	**SLURRY / PROCESS WATER**	
SPECIFIC GRAVITY	1,11	gr/cm3
DESIGN PRESSURE	FULL OF CONTENT	kPa
DESIGN TEMPERATURE	32	DEG. C
M.D.M.T	0	DEG. C
OPERATING PRESSURE	ATM	kPa
OPERATING TEMP. (MIN/MAX.)	AMB	DEG. C
CORROSION ALLOWANCE	SHELL : 3	MM
	BOTTOM : 3	MM
	STRUCTURE : 3	MM
RADIOGRAPHY / JOINT EFICIENCY	SPOT / 0.85	
P.W.H.T	NO	
INSULATION THICKNESS	NO	MM
DESIGN WIND VELOCITY	40	m/s
WIND & SEISMIC CODE	API-650 - ASCE7	
MATERIAL	SHELL : ASTM A36	
	ROOF : -	
	BOTTOM : ASTM A36	
	NOZZLE (PIPE/PLATE) : ASTM A106 Gr.B / ASTM A36	
	FLANGE : ASTM A36 / ASTM A105	
	NOZZLE PAD : ASTM A36	
	TOP ANGLE : ASTM A36	
M.A.W.P	-	
HYDRO. TEST PRESSURE	FULLOF WATER	kPa
PNEUMATIC TEST PRESSURE	-	kPa

Table of Contents

No Warnings!!

Project Design Data and Summary

Back

Project Data

Designer : Wawan
Tag ID : 4840-TK-120
Site : Poboya
Design Basis : API-650 13th Edition Errata 1, 2021

Design Parameters and Operating Conditions

Design Parameters

Design Internal Pressure = 0 KPa or 0 mmh2o
Design External Pressure = -0 KPa or -0 mmh2o

D of Tank = 7 m
OD of Tank = 7.02 m
ID of Tank = 7 m
CL of Tank = 7.01 m
Shell Height = 4.5 m
S.G of Contents = 1.11
S.G of Hydrotest = 1.02
Max Design Liq. Level = 3.71 m
Max Operating Liq. Level = 3.71 m
Min Liq. Level = 0 m
Design Temperature = 32 ºC
MDMT (Minimum Design Metal Temperature) = 0 ºC
Tank Joint Efficiency = 0.85
Ground Snow Load = 0 KPa
Roof Live Load = 1.17 KPa
Additional Roof Dead Load = 0 KPa

Wind Load Basis: ASCE7-10
3 Second Gust Wind Speed (entered), Vg = 40 m/s = 144 kph
Wind Importance Factor, Iw = 1.5
Design Wind Speed, V = Vg * 0.78 = 112.32 kph

Seismic Method: API-650 - ASCE7 Mapped(Ss & S1)
Seismic Use Group = III
Site Class = D
T_L (sec) = 4
Ss (g) = 1.2
S1 (g) = 0.5
Av (g) = 0.38
Q = 0.67
Importance Factor = 1.5

Design Remarks

Summary Results

Shell

Shell #	Width (mm)	Material	CA (mm)	JE	Min Yield Strength (MPa)	Tensile Strength (MPa)	Sd (MPa)	St (MPa)	Weight (kg)
1	1828	A36	3	0.70	250	400	145	145	2,518
2	1828	A36	3	0.70	250	400	145	145	2,518
3	844	A36	3	0.70	250	400	145	145	1,162

(continued)

Shell #	Weight CA (kg)	t-min Erection (mm)	t-Des (mm)	t-Test (mm)	t-min Seismic (mm)	t-min Ext-Pe (mm)	t-min (mm)	t-Actual (mm)	Status
1	1,574	6	4.28	1.18	4.16	NA	6	8	OK
2	1,574	5	3.59	0.55	3.64	NA	5	8	OK
3	727	5	2.91	0	3.14	NA	5	8	OK

Total Weight of Shell = 6,213.87 kg

Stiffeners

Stiffener #	Size	Elevation (m)	Z-Req'd (cm3)	Z-Actual (cm3)	Weight (kg)
1	L75X75X6	1.65	2.21	20.65	154.21
2	L75X75X6	3.45	1.29	20.65	154.21

Roof

Type = No Roof
Plates Material = None
Structure Support Type = None

Bottom

Type : Flat Bottom Non Annular
Bottom Material = A36
t.required = 9 mm
t.actual = 10 mm
Bottom corrosion allowance = 3 mm
Bottom Joint Efficiency = 0.7
Total Weight of Bottom = 3,118.01 kg

Top Member

Type = Detail B
Size = L130x130x12
Material = A36
Weight = 517.97 kg

Anchors

Quantity = 12
Size = M27 mm
Material = A307-B
Bolt Hole Circle Radius = 3.59 m

Nameplate Information

Pressure Combination Factor	0.4
Design Standard	API-650 13th Edition Errata 1, 2021
Appendices Used	A, E
Shell (1)	A36 : 8 mm
Shell (2)	A36 : 8 mm
Shell (3)	A36 : 8 mm
Bottom	A36 : 10 mm

Roof Design Details [Back]

Roof Type (Open Top) = Open Top

Top Member Detail B Design Back

Material Properties
Material (A36) = A36
Minimum Tensile Strength (Sut) = 400.0 MPa
Minimum Yield Strength (Sy) = 250.0 MPa

Compression Ring Detail b Properties
A_detail = Detail Total Area (mm^2)
A_roof = Contributing Roof Area (mm^2)
A_shell = Contributing Shell Area (mm^2)
I_shell = Contributing Shell Moment Of Inertia (mm^4)
Wc = Maximum Width of Participating Shell per API-650 Figure F-2 (mm)

Wc = 0.6 * SQRT(((ID / 2) * (tc-nominal - CA-shell)))
Wc = 0.6 * SQRT(((7,000 / 2) * (8 - 3)))
Wc = 79.37 mm

Angle Size L130X130X12 Section Properties

Description	Variable	New	Corroded	Unit
Weight	W	23.5	11.47	kg/m
Cross Sectional Area	A	3,000	1,463.71	mm^2
Moment Of Inertia About X Axis	Ix	4,719,999.0	2,182,294.92	mm^4
Moment Of Inertia About Y Axis	Iy	4,719,999.0	2,182,294.92	mm^4
Section Modulus About X Axis	Sx	50,400	23,893.96	mm^3
Section Modulus About Y Axis	Sy	50,400	23,893.96	mm^3
Centroid X Coords	cx	36.4	36.4	mm
Centroid Y Coords	cy	36.4	36.4	mm
Angle Long Leg Length	L1-angle	130	124	mm
Angle Short Leg Length	L2-angle	130	124	mm
Angle Thickness	t-angle	12.0	6.0	mm
• Corrosion allowance, 3 mm, is applied to all sides of the structural member.				

I_shell = ((Wc - h) * ((tc-nominal - CA-shell)^3)) / 12
I_shell = ((79.3725 - 8.0) * ((8 - 3)^3)) / 12
I_shell = 743.46 mm^4

A_shell = (Wc - h) * (tc-nominal - CA-shell)
A_shell = (79.3725 - 8.0) * (8 - 3)
A_shell = 356.86 mm^2

A_roof = 0
A_roof = 0
A_roof = 0 mm^2

A_detail = A_shell + A_roof + A-corr
A_detail = 356.8627 + 0 + 1,463.7097

A_detail = 1,820.57 mm^2

Stiffener and Shell Combined Section Properties

Description	Variable	Equation	Value	Unit
Shell centroid	d_shell	(tc-nominal - CA-shell) / 2	2.5	mm
Stiffener centroid	d_stiff	cy + (tc-nominal - CA-shell)	41.4	mm
moment of inertia of first body	I_1	Ic + (Area * (Distance^2))	4,691,034.76	mm^4
moment of inertia of second body	I_2	Ic + (Area * (Distance^2))	2,973.86	mm^4
Total area	A_sum	A_1 + A_2	1,820.57	mm^2
Sum of moments of inertia's	I_sum	I_1 + I_2	4,694,008.61	mm^4
Combined centroid	c_combined	((Centroid-1 * Area-1) + (Centroid-2 * Area-2)) / (Area-1 + Area-2)	33.77	mm
Combined moment of inertia	I_combined	Ic - (Area * (Distance^2))	2,617,195.93	mm^4
Distance from neutral axis to edge 1 (inside)	e1	c_combined	33.77	mm
Distance from neutral axis to edge 2 (outside)	e2	((tc-nominal - CA-shell) + L1-angle) - e1	101.23	mm
Combined stiffener shell section modulus	S	I / MAX(d-1 , d-2)	25,855.22	mm^3

Erection Requirement
As per API-650 5.9.5.2, Minimum Size of Top Corner Ring (Size-min) = L75x75x6
Minimum Section Modulus per Erection Requirement (Sx-min) = 8.41 cm^3

Sx >= Sx-min ==> PASS

Top Wind Girder Design

Fy = Least Minimum Yield Strength of Shell and Stiffening Ring Material at Maximum Temperature per API-650 5.9.5.3 (MPa)
Pwd = Design Wind Pressure Including Inward Drag per API-650 5.9.5.3 (kPa)
Pwv = Wind Pressure where Design Wind Speed V is Used per API-650 5.9.5.3 (kPa)
Wc = Shell Contributing Length (mm)
Z_req = Required minimum section modulus of the stiffening ring per API-650 5.9.5.3 (cm^3)
tc = Thickness Of Shell Plate (mm)

tc = 8 mm

Wc = (2 * 16 * tc) + (t - CA)
Wc = (2 * 16 * 8) + (0 - nil)
Wc = 256 mm

Pwv = 1.48 * ((V / 190)^2)
Pwv = 1.48 * ((112.32 / 190)^2)
Pwv = 0.52 kPa

Pwd = Pwv + 0.24
Pwd = 0.5172 + 0.24
Pwd = 0.76 kPa

Fy = MIN(Sy , Sy-shell)
Fy = MIN(250.0 , 250.0)
Fy = 250.0 (Set to 210 MPa since it cannot be greater than 210)

Z_req = ((6 * H2 * (D^2)) / (0.5 * Fy)) * (Pwd / 1.72)
Z_req = ((6 * 4.5 * (7.0^2)) / (0.5 * 210)) * (0.7572 / 1.72)
Z_req = 5.55 cm^3

S >= Z_req ==> PASS

Agitator Bridge Design Back

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

CA-es = 0 mm
CA-ps = 0 mm
L-es = 800 mm
L-es-shell-overlap = 300 mm
L-ps-unbraced = 1,030 mm

LL-platform = 0.01 kPa
Ma-es = A36
Ma-ps = A36
W-add-platform = 0 kg
W-platform = 1,192.06 kg
d-ps = 2,035 mm
k = 2.1
l-lateral-platform = 8,305 mm
outside-proj-1-ps = 381 mm
outside-proj-2-ps = 381 mm
size-es = h300x300
size-ps = h300x150
w-lateral-platform = 0 mm

L-ps = OD
L-ps = 7.016
L-ps = 7.02 m

A-platform = (L-ps * d-ps) + (2 * w-lateral-platform * l-lateral-platform)
A-platform = (7.016 * 2.035) + (2 * 0.0 * 8.305)
A-platform = 14.28 m^2

W-total-platform = W-platform + W-add-platform
W-total-platform = 1,192.0605 + 0
W-total-platform = 1,192.06 kg

Agitator Bridge Primary Support Design
Agitator Bridge Primary Support Material Properties
Material (A36) = A36
Minimum Tensile Strength (Sut) = 400.0 MPa
Minimum Yield Strength (Sy) = 250.0 MPa
Modulus of Elasticity at Design Temperature (E) = 199,000 MPa

Agitator Bridge Primary Support I-Beam Size H300X150 Section Properties

Description	Variable	New	Corroded	Unit
Weight	W	36.7	36.7	kg/m
Cross Sectional Area	A	4,678	4,678	mm^2
Radius of Gyration About X Axis	rx	124.0	124.0	mm
Radius of Gyration About Y Axis	ry	32.9	32.9	mm
Moment Of Inertia About X Axis	Ix	72,100,000	72,100,000	mm^4
Moment Of Inertia About Y Axis	Iy	5,080,000	5,080,000	mm^4
Section Modulus About X Axis	Sx	481,000	481,000	mm^3
Section Modulus About Y Axis	Sy	67,700	67,700	mm^3
Plastic Section Modulus About X Axis	Zx	542,000	542,000	mm^3
Plastic Section Modulus About Y Axis	Zy	105,000	105,000	mm^3
Warping Constant	cw	107,000,000,000	107,000,000,000	mm^6
Torsional Constant	j	124,000	124,000	mm^4
Centroid to Edge Max x Distance	ex	75.0	75.0	mm
Centroid to Edge Max y Distance	ey	150.0	150.0	mm
I-Beam Flange Width	wf	150.0	150.0	mm
I-Beam Flange Thickness	tf	9.0	9.0	mm
I-Beam Depth	d	300.0	300.0	mm

I-Beam Web Thickness	tw	6.5	6.5	mm

Agitator Bridge Primary Support Allowable Flexural Strength per AISC-360
Lp = Limiting laterally unbraced length for the limit state of yielding per AISC-360 F2-5 (mm)
Ma = Allowable Flexural Strength (N.mm)
Mn = Nominal flexural strength per AISC-360 F2 (N.mm)
Mp = Yielding per AISC-360 F2-1 (N.mm)
Mpa = Allowable Flexural Strength Assuming the Member is Braced (N.mm)
Ypf = Limiting slenderness parameter for compact flange
Ypw = Limiting slenderness parameter for compact web
Yrf = Limiting slenderness parameter for noncompact flange
Yrw = Limiting slenderness parameter for noncompact web
bf = Flange width (mm)
h = Web height (mm)

bf = wf / 2 = 75.0 mm

h = d - (2 * tf) = 282.0 mm

Ypf = 0.38 * SQRT((E / Fy))
Ypf = 0.38 * SQRT((199,000 / 250.0))
Ypf = 10.72

Yrf = 1 * SQRT((E / Fy))
Yrf = 1 * SQRT((199,000 / 250.0))
Yrf = 28.21

Ypw = 3.76 * SQRT((E / Fy))
Ypw = 3.76 * SQRT((199,000 / 250.0))
Ypw = 106.08

Yrw = 5.7 * SQRT((E / Fy))
Yrw = 5.7 * SQRT((199,000 / 250.0))
Yrw = 160.82

As per AISC-360 table B4.1b Flange width to thickness ratio check :
(bf / tf) <= Ypf

==> Flange is compact

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

==> Web is compact

Mp = Fy * Zx
Mp = 250.0 * 542,000
Mp = 135,500,000 N.mm

Unbraced length (Lb) = 1,030 mm

Lp = 1.76 * ry * SQRT((E / Fy))
Lp = 1.76 * 32.9 * SQRT((199,000 / 250.0))
Lp = 1,633.67 mm

Lb <= Lp

Mpa = Mp / 1.67
Mpa = 135,500,000 / 1.67
Mpa = 81,137,724.55 N.mm

Mn = (Mp) = 135,500,000 N.mm

Ma = Mn / 1.67
Ma = 135,500,000 / 1.67
Ma = 81,137,724.55 N.mm

Agitator Bridge Primary Support Loads
Ps = W-agitator / 2
Ps = 0 / 2
Ps = 0 N

Pd = (Fa + (Mx / (0.5 * d-ps))) / 2
Pd = (0 + (0.0 / (0.5 * 2,035))) / 2
Pd = 0.0 N

Psd = Ps + Pd
Psd = 0 + 0.0
Psd = 0.0 N

W-support = W-primary-support + ((0.5 * (W-total-platform + (A-platform * LL-platform))) / L-ps)
W-support = 359.9041 + ((0.5 * (11,690.1196 + (14.2776 * 11.5))) / 7.016)
W-support = 1,204.71 N/m

M-max-support = ((W-support * (L-ps^2)) / 8) + ((Psd * L-ps) / 4)
M-max-support = ((1,204.7096 * (7.016^2)) / 8) + ((0.0 * 7.016) / 4)
M-max-support = 7,412.62 N.m

V-max-support = ((W-support * (L-ps + outside-proj-1-ps + outside-proj-2-ps)) + (My / (L-ps / 2)) + Psd) / 2
V-max-support = ((1,204.7096 * (7.016 + 0.381 + 0.381)) + (0.0 / (7,016 / 2)) + 0.0) / 2
V-max-support = 4,685.12 N

Agitator Bridge Primary Support Required Section Modulus
Sb-allowable-support = Ma / Sx-primary-support
Sb-allowable-support = 81,137,724.5509 / 481,000
Sb-allowable-support = 168.69 MPa

Sx-reqd-support = M-max-support / Sb-allowable-support
Sx-reqd-support = 7,412,616.7912 / 168.6855
Sx-reqd-support = 43,943.41 mm^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 * 1.2047 * (7,016^4)) / (384 * 199,000 * 72,100,000)) + ((0.0 * (7,016^3)) / (48 * 199,000 * 72,100,000))
delta-sd = 2.65 mm

delta-sd-allowable = L-ps / 240
delta-sd-allowable = 7,016 / 240
delta-sd-allowable = 29.23 mm

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

delta-d = (Pd * (L-ps^3)) / (48 * E * Ix-primary-support)
delta-d = (0.0 * (7,016^3)) / (48 * 199,000 * 72,100,000)
delta-d = 0.0 mm

delta-d-allowable = 0.5 * L-ps * TAN(0.1)
delta-d-allowable = 0.5 * 7,016 * TAN(0.1)
delta-d-allowable = 6.12 mm

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

Agitator Bridge End Support Design
Agitator Bridge End Support Material Properties
Material (A36) = A36
Minimum Tensile Strength (Sut) = 400.0 MPa
Minimum Yield Strength (Sy) = 250.0 MPa
Modulus of Elasticity at Design Temperature (E) = 199,000 MPa

Agitator Bridge End Support I-Beam Size H300X300 Section Properties

Description	Variable	New	Corroded	Unit
Weight	W	94.0	94.0	kg/m
Cross Sectional Area	A	11,980	11,980	mm^2
Radius of Gyration About X Axis	rx	131.0	131.0	mm
Radius of Gyration About Y Axis	ry	75.1	75.1	mm
Moment Of Inertia About X Axis	Ix	204,000,000	204,000,000	mm^4
Moment Of Inertia About Y Axis	Iy	67,500,000	67,500,000	mm^4
Section Modulus About X Axis	Sx	1,360,000	1,360,000	mm^3
Section Modulus About Y Axis	Sy	450,000	450,000	mm^3
Plastic Section Modulus About X Axis	Zx	1,500,000	1,500,000	mm^3
Plastic Section Modulus About Y Axis	Zy	684,000	684,000	mm^3

Warping Constant	cw	1,372,000,000,000	1,372,000,000,000	mm^6
Torsional Constant	j	881,000	881,000	mm^4
Centroid to Edge Max x Distance	ex	150.0	150.0	mm
Centroid to Edge Max y Distance	ey	150.0	150.0	mm
I-Beam Flange Width	wf	300.0	300.0	mm
I-Beam Flange Thickness	tf	15.0	15.0	mm
I-Beam Depth	d	300.0	300.0	mm
I-Beam Web Thickness	tw	10.0	10.0	mm

Agitator Bridge End Support Allowable Flexural Strength per AISC-360
Lp = Limiting laterally unbraced length for the limit state of yielding per AISC-360 F2-5 (mm)
Ma = Allowable Flexural Strength (N.mm)
Mn = Nominal flexural strength per AISC-360 F2 (N.mm)
Mp = Yielding per AISC-360 F2-1 (N.mm)
Mpa = Allowable Flexural Strength Assuming the Member is Braced (N.mm)
Ypf = Limiting slenderness parameter for compact flange
Ypw = Limiting slenderness parameter for compact web
Yrf = Limiting slenderness parameter for noncompact flange
Yrw = Limiting slenderness parameter for noncompact web
bf = Flange width (mm)
h = Web height (mm)

bf = wf / 2 = 150.0 mm

h = d - (2 * tf) = 270.0 mm

Ypf = 0.38 * SQRT((E / Fy))
Ypf = 0.38 * SQRT((199,000 / 250.0))
Ypf = 10.72

Yrf = 1 * SQRT((E / Fy))
Yrf = 1 * SQRT((199,000 / 250.0))
Yrf = 28.21

Ypw = 3.76 * SQRT((E / Fy))
Ypw = 3.76 * SQRT((199,000 / 250.0))
Ypw = 106.08

Yrw = 5.7 * SQRT((E / Fy))
Yrw = 5.7 * SQRT((199,000 / 250.0))
Yrw = 160.82

As per AISC-360 table B4.1b Flange width to thickness ratio check :
(bf / tf) <= Ypf

==> Flange is compact

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

==> Web is compact

Mp = Fy * Zx
Mp = 250.0 * 1,500,000
Mp = 375,000,000 N.mm

Unbraced length (Lb) = 500 mm

Lp = 1.76 * ry * SQRT((E / Fy))
Lp = 1.76 * 75.1 * SQRT((199,000 / 250.0))
Lp = 3,729.14 mm

Lb <= Lp

Mpa = Mp / 1.67
Mpa = 375,000,000 / 1.67
Mpa = 224,550,898.2 N.mm

Mn = (Mp) = 375,000,000 N.mm

Ma = Mn / 1.67
Ma = 375,000,000 / 1.67
Ma = 224,550,898.2 N.mm

Agitator Bridge End Support Allowable Compressive Strength per AISC-360
Fe = Elastic Buckling Stress per AISC-360 E3-4 (MPa)
Pa = Allowable Compressive Strength (N)
Pn = Nominal compressive strength per AISC-360 E3-1 (N)
Yrf = Limiting slenderness parameter for flanges
Yrw = Limiting slenderness parameter for web
bf = Flange width (mm)
h = Web height (mm)

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

Fe = ((pi^2) * E) / (((K * Ly) / ry)^2)
Fe = ((pi^2) * 199,000) / (((2.1 * 800) / 75.1)^2)
Fe = 3,924.77 MPa

bf = wf / 2
bf = 300.0 / 2
bf = 150.0 mm

h = d - (2 * tf)
h = 300.0 - (2 * 15.0)

h = 270.0 mm

Yrf = 0.56 * SQRT((E / Fy))
Yrf = 0.56 * SQRT((199,000 / 250.0))
Yrf = 15.8

Yrw = 1.49 * SQRT((E / Fy))
Yrw = 1.49 * SQRT((199,000 / 250.0))
Yrw = 42.04

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

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

Fcr = Critical stress per AISC-360 E3-2 (MPa)

(Fy / Fe) <= 2.25

Fcr = (0.658^(Fy / Fe)) * Fy
Fcr = (0.658^(250.0 / 3,924.7693)) * 250.0
Fcr = 243.42 MPa

Pn = Fcr * Ag
Pn = 243.4229 * 11,980
Pn = 2,916,205.85 N

Pa = Pn / 1.67
Pa = 2,916,205.8549 / 1.67
Pa = 1,746,231.05 N

Agitator Bridge End Support Required Length
Fa-leg = V-max-support + (L-es * W-end-support)
Fa-leg = 4,685.1157 + (800 * 0.9218)
Fa-leg = 5,422.58 N

t/R = (ts - CA) / (D / 2)
t/R = (8 - 3) / (7,000 / 2)
t/R = 0.0014285714285714286

Scs = 12410.56312772094 * ratio
Scs = 12410.56312772094 * 0.0014
Scs = 17.73 MPa

As-required = Fa-leg / Scs
As-required = 5,422.5758 / 17.7294
As-required = 305.85 mm^2

L-es-min-overlap = As-required / (2 * (ts - CA) * TAN(30))

L-es-min-overlap = 305.8526 / (2 * (8 - 3) * TAN(30))
L-es-min-overlap = 52.98 mm

L-es-min = L-es-min-overlap + (L-es - L-es-shell-overlap)
L-es-min = 52.9752 + (800 - 300)
L-es-min = 552.98 mm

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)
As-available = 2 * 300 * TAN(30) * (8 - 3)
As-available = 1,732.05 mm^2

As-available >= As-required ==> PASS

Agitator Bridge End Support Required Section Modulus
Mx-es = V-max-support * ey
Mx-es = 4,685.1157 * 150.0
Mx-es = 702,767.35 N.mm

fbx-es = Mx-es / Sx-end-support
fbx-es = 702,767.352 / 1,360,000
fbx-es = 0.52 MPa

My-es = (Mz / (0.5 * L-ps)) * (L-es - L-es-shell-overlap)
My-es = (0.0 / (0.5 * 7,016)) * (800 - 300)
My-es = 0.0 N.mm

fby-es = My-es / Sy-end-support
fby-es = 0.0 / 450,000
fby-es = 0.0 MPa

fb-es = fbx-es + fby-es
fb-es = 0.5167 + 0.0
fb-es = 0.52 MPa

fb-es-req = Ma / Sx-end-support
fb-es-req = 224,550,898.2036 / 1,360,000
fb-es-req = 165.11 MPa

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

Agitator Bridge End Support Required Cross Sectional Area
fc-es = Fa-leg / A-end-support
fc-es = 5,422.5758 / 11,980
fc-es = 0.45 MPa

fc-es-req = Pa / A-end-support
fc-es-req = 1,746,231.0509 / 11,980
fc-es-req = 145.76 MPa

A-es-req = Fa-leg / fc-es-req
A-es-req = 5,422.5758 / 145.7622
A-es-req = 37.2 mm^2

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

Agitator Bridge Total Downward Force (Including Dynamic Loads)
Fa-total = Fa-leg * 4
Fa-total = 5,422.5758 * 4
Fa-total = 21,690.3 N

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 (m)
D = Tank Nominal Diameter per API-650 5.6.1.1 Note 1 (m)
G = Product Design Specific Gravity
Gt = Hydrotest Specific Gravity
H = Shell height (m)
HL = Max Liquid Level (m)
Pe = Design External Pressure (kPa)
Pi = Design Internal Pressure (kPa)
Rwi = Impulsive Force Reduction Factor
V = Wind velocity (km/hr)
W-ins = Shell Insulation Weight (kg)
W-shell = Shell Nominal Weight (kg)
W-shell-corr = Shell Corroded Weight (kg)
d-ins = Insulation Density (kg/m^3)
h-min = Minimum Shell Course Height per API-650 5.6.1.2 (mm)
t-ins = Insulation Thickness (mm)

Ac = 0.2
Ai = 0.31
Av = 0.38
D = 7.0 m
G = 1.11
Gt = 1.02
H = 4.5 m
HL = 3.71 m
Pe = 0.0 kPa
Pi = 0.0 kPa
Rwi = 4
V = 112.32 km/hr
d-ins = 130 kg/m^3
h-min = 800 mm
t-ins = 0 mm

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

Rwi = Impulsive Force Reduction Factor

Rwi = 4

Course # 1 (bottom course) Design
A1 = Shell Course Cross Sectional Area (mm^2)
CA = Corrosion allowance per API-650 5.3.2 (mm)
D1 = Shell Course Centerline Diameter (m)
H = Design Liquid Level per API-650 5.6.3.2 (m)
H' = Effective Design Liquid Level per API-650 F.2 (m)
H-max = Maximum Liquid Level for the Installed Thickness (m)
H-max-@-Pi = Maximum Liquid Level for the Installed Thickness @ Design Internal Pressure (m)
Ht' = Effective Hydrostatic Test Liquid Level per API-650 F.2 (m)
JE = Joint efficiency
Ma = Course Material
Pi-max-@-H = Maximum Allowable Internal Pressure for the Installed Thickness @ Design Liquid Level (kPa)
Rwi = Impulsive Force Reduction Factor

W-1 = Shell Course Nominal Weight (kg)
W-1-corr = Shell Course Nominal Weight (kg)
Ws-tot-top = Top Weight Total (N)
h1 = Course Height (m)
loc = Course Location (m)
t = Installed Thickness (mm)
t-min = Minimum Required Thickness (mm)
td = Course Design Thickness per A.4.1 (mm)
tt = Course Hydrostatic Test Thickness per A.4.1 (mm)

CA = 3 mm
H = 3.71 m
JE = 0.7
Ma = A36
Rwi = 4
h1 = 1.83 m
loc = 0 m
t = 8 mm

Shell Course Center of Gravity (CG-1) = 0.91 m

D1 = ID + t
D1 = 7.0 + 0.008
D1 = 7.01 m

W-1 = pi * Dc * t * h1 * d
W-1 = pi * 7.008 * 0.008 * 1.828 * 7,840
W-1 = 2,524.21 kg

W-1-corr = pi * Dc * (t - CA) * h1 * d
W-1-corr = pi * 7.008 * (0.008 - 0.003) * 1.828 * 7,840
W-1-corr = 1,577.63 kg

Material Properties
Material (A36) = A36
Minimum Tensile Strength (Sut) = 400.0 MPa
Minimum Yield Strength (Sy) = 250.0 MPa
As per API-650 A.4.1, Allowable Design Stress (Sd) = 145 MPa
As per API-650 A.4.1, Allowable Hydrostatic Test Stress (St) = 145 MPa
Permissible Design Metal Temperature (MDMT-permissible) = -30 °C

Thickness Required by Erection
As per API-650 5.6.1.1 NOTE 4, Thickness Required by Erection (t-erec) = 6 mm

Thickness Required by Design
H' = H
H' = 3.71
H' = 3.71 m

td = ((4.9 * D * (H' - 0.3) * SG) / (JE * Sd)) + CA
td = ((4.9 * 7.0 * (3.71 - 0.3) * 1.11) / (0.7 * 145)) + 3
td = 4.28 mm

Hydrostatic Test Required Thickness
Ht' = H
Ht' = 3.71
Ht' = 3.71 m

tt = (4.9 * D * (Ht' - 0.3) * SGt) / (JE * St)
tt = (4.9 * 7.0 * (3.71 - 0.3) * 1.025) / (0.7 * 145)

tt = 1.18 mm

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

As per API 650 Section E.6.1.4, Shell Course Liquid Surface to Analysis Point Distance (Y) = 3.71 m

Ni = 8.48 * Ai * G * D * H * ((Y / H) - (0.5 * ((Y / H)^2))) * TANH((0.866 * (D / H)))
Ni = 8.48 * 0.306 * 1.11 * 7.0 * 3.71 * ((3.71 / 3.71) - (0.5 * ((3.71 / 3.71)^2))) * TANH((0.866 * (7.0 / 3.71)))
Ni = 34.66 N/mm

Nc = (1.85 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (1.85 * 0.2003 * 1.11 * (7.0^2) * COSH(((3.68 * (3.71 - 3.71)) / 7.0))) / COSH(((3.68 * 3.71) / 7.0))
Nc = 5.62 N/mm

Nh = 4.9 * (H - H_offset) * D * G
Nh = 4.9 * (3.71 - 0) * 7.0 * 1.11
Nh = 141.25 N/mm

S_T+ = Total Combined Hoop Stress per API 650 Sections E.6.1.4, EC.6.1.3 (MPa)
S_T- = Total Combined Hoop Stress per API 650 Sections E.6.1.4, EC.6.1.3 (MPa)

S_T+ = (Nh + SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
S_T+ = (141.2508 + SQRT(((34.6566^2) + (5.619^2) + (((0.3808 * 141.2508) / 2.5)^2)))) / MAX((8 - 3) , 0.0001)
S_T+ = 36.49 MPa

S_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
S_T- = (141.2508 - SQRT(((34.6566^2) + (5.619^2) + (((0.3808 * 141.2508) / 2.5)^2)))) / MAX((8 - 3) , 0.0001)
S_T- = 20.01 MPa

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 145) , (0.9 * 250.0 * 0.7))
Sd-seismic = 157.5 MPa

ts = ((SIGMAt+ * (tn - CA)) / S_membrane) + CA
ts = ((36.4856 * (8 - 3)) / 157.5) + 3
ts = 4.16 mm

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 0.0 kg
Upper Courses Weight (Ws-pl-top) = 36,183.21 N

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-1 + Fd_agitator
Ws-tot-top = 0.0 + 21,458.4928 + 36,183.2143 + 24,754.0853 + 21,690.303
Ws-tot-top = 104,086.1 N

A1 = pi * ((D1 / 2)^2)
A1 = pi * ((7,008 / 2)^2)
A1 = 38,572,524.87 mm^2 [38.57 m^2]

T1 = Meridional unit force for cylindrical walls T1 per API-620 5.10.2.5.c Equation 10 (lbf/in)
T2 = Latitudinal unit force for cylindrical walls T2 per API-620 5.10.2.5.c Equation 11 (lbf/in)

T1 = (Rc / 2) * (P + (W / At))
T1 = (137.9528 / 2) * (0 + (-23,399.4851 / 59,787.5331))
T1 = -27.0 lbf/in [-4,727.69 N/m]

T2 = P * Rc
T2 = 0 * 137.9528
T2 = 0.0 lbf/in [0.0 N/m]

(T1 < 0) AND (T2 = 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) = 0.0013591609589041094

t_req = (Ratio * R) + c
t_req = (0.0014 * 137.9528) + 0
t_req = 0.19 in [4.76 mm]

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-26.9958) / (0.315 - 0)
Scc = 85.71 psi [0.59 MPa]

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 2,446.49 psi [16.87 MPa]

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)
Stc = 0.0 / (0.315 - 0)
Stc = 0.0 psi [0.0 kPa]

M = Scc / 15000
M = 85.7116 / 15000
M = 0.0057141090267562

As per API-620 Figure F-1, Tension factor (N) = 1.0

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((21,030.472 * 0.9971) , (21,030.472 * 0.7))
Sta = 14,721.33 psi [101,500 kPa]

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t-erec , td , tt , ts , t-axial-load)
t-min = MAX(6 , 4.2791 , 1.1812 , 4.1583 , 4.7625)
t-min = 6 mm

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (4.9 * D * SG)) + 0.3) + loc
H-max = ((((8 - 3) * 145 * 0.7) / (4.9 * 7.0 * 1.11)) + 0.3) + 0
H-max = 13.63 m

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(13.6297 , 0)
H-max-@-Pi = 13.63 m

Pi-max-@-H = MAX((((H-max - (H + loc)) * (9.8 * SG)) + P) , 0)
Pi-max-@-H = MAX((((13.6297 - (3.71 + 0)) * (9.8 * 1.11)) + 0.0) , 0)
Pi-max-@-H = 107.91 kPa

Course # 2 Design
A2 = Shell Course Cross Sectional Area (mm^2)
CA = Corrosion allowance per API-650 5.3.2 (mm)
D2 = Shell Course Centerline Diameter (m)
H = Design Liquid Level per API-650 5.6.3.2 (m)
H' = Effective Design Liquid Level per API-650 F.2 (m)
H-max = Maximum Liquid Level for the Installed Thickness (m)
H-max-@-Pi = Maximum Liquid Level for the Installed Thickness @ Design Internal Pressure (m)
Ht' = Effective Hydrostatic Test Liquid Level per API-650 F.2 (m)
JE = Joint efficiency
Ma = Course Material
Pi-max-@-H = Maximum Allowable Internal Pressure for the Installed Thickness @ Design Liquid Level (kPa)
Rwi = Impulsive Force Reduction Factor
W-2 = Shell Course Nominal Weight (kg)
W-2-corr = Shell Course Nominal Weight (kg)
Ws-tot-top = Top Weight Total (N)
h2 = Course Height (m)
loc = Course Location (m)
t = Installed Thickness (mm)
t-min = Minimum Required Thickness (mm)
td = Course Design Thickness per A.4.1 (mm)
tt = Course Hydrostatic Test Thickness per A.4.1 (mm)

CA = 3 mm
H = 1.88 m
JE = 0.7
Ma = A36
Rwi = 4
h2 = 1.83 m
loc = 1.83 m
t = 8 mm

Shell Course Center of Gravity (CG-2) = 2.74 m

D2 = ID + t
D2 = 7.0 + 0.008
D2 = 7.01 m

W-2 = pi * Dc * t * h2 * d
W-2 = pi * 7.008 * 0.008 * 1.828 * 7,840
W-2 = 2,524.21 kg

W-2-corr = pi * Dc * (t - CA) * h2 * d
W-2-corr = pi * 7.008 * (0.008 - 0.003) * 1.828 * 7,840
W-2-corr = 1,577.63 kg

Material Properties
Material (A36) = A36
Minimum Tensile Strength (Sut) = 400.0 MPa
Minimum Yield Strength (Sy) = 250.0 MPa

As per API-650 A.4.1, Allowable Design Stress (Sd) = 145 MPa
As per API-650 A.4.1, Allowable Hydrostatic Test Stress (St) = 145 MPa
Permissible Design Metal Temperature (MDMT-permissible) = -30 °C

Thickness Required by Erection
As per API-650 5.6.1.1, Thickness Required by Erection (t-erec) = 5 mm

Thickness Required by Design
H' = H
H' = 1.882
H' = 1.88 m

td = ((4.9 * D * (H' - 0.3) * SG) / (JE * Sd)) + CA
td = ((4.9 * 7.0 * (1.882 - 0.3) * 1.11) / (0.7 * 145)) + 3
td = 3.59 mm

Hydrostatic Test Required Thickness
Ht' = H
Ht' = 1.882
Ht' = 1.88 m

tt = (4.9 * D * (Ht' - 0.3) * SGt) / (JE * St)
tt = (4.9 * 7.0 * (1.882 - 0.3) * 1.025) / (0.7 * 145)
tt = 0.55 mm

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

As per API 650 Section E.6.1.4, Shell Course Liquid Surface to Analysis Point Distance (Y) = 1.88 m

Ni = 8.48 * Ai * G * D * H * ((Y / H) - (0.5 * ((Y / H)^2))) * TANH((0.866 * (D / H)))
Ni = 8.48 * 0.306 * 1.11 * 7.0 * 3.71 * ((1.882 / 3.71) - (0.5 * ((1.882 / 3.71)^2))) * TANH((0.866 * (7.0 / 3.71)))
Ni = 26.24 N/mm

Nc = (1.85 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (1.85 * 0.2003 * 1.11 * (7.0^2) * COSH(((3.68 * (3.71 - 1.882)) / 7.0))) / COSH(((3.68 * 3.71) / 7.0))
Nc = 8.42 N/mm

Nh = 4.9 * (H - H_offset) * D * G
Nh = 4.9 * (1.882 - 0) * 7.0 * 1.11
Nh = 71.65 N/mm

S_T+ = Total Combined Hoop Stress per API 650 Sections E.6.1.4, EC.6.1.3 (MPa)
S_T- = Total Combined Hoop Stress per API 650 Sections E.6.1.4, EC.6.1.3 (MPa)

S_T+ = (Nh + SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
S_T+ = (71.6534 + SQRT(((26.2428^2) + (8.4196^2) + (((0.3808 * 71.6534) / 2.5)^2)))) / MAX((8 - 3) , 0.0001)
S_T+ = 20.26 MPa

S_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
S_T- = (71.6534 - SQRT(((26.2428^2) + (8.4196^2) + (((0.3808 * 71.6534) / 2.5)^2)))) / MAX((8 - 3) , 0.0001)
S_T- = 8.4 MPa

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 145) , (0.9 * 250.0 * 0.7))
Sd-seismic = 157.5 MPa

ts = ((SIGMAt+ * (tn - CA)) / S_membrane) + CA
ts = ((20.2592 * (8 - 3)) / 157.5) + 3
ts = 3.64 mm

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 0.0 kg
Upper Courses Weight (Ws-pl-top) = 11,429.13 N

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-2 + Fd_agitator
Ws-tot-top = 0.0 + 21,458.4928 + 11,429.1291 + 24,754.0853 + 21,690.303
Ws-tot-top = 79,332.01 N

A2 = pi * ((D2 / 2)^2)
A2 = pi * ((7,008 / 2)^2)
A2 = 38,572,524.87 mm^2 [38.57 m^2]

T1 = Meridional unit force for cylindrical walls T1 per API-620 5.10.2.5.c Equation 10 (lbf/in)
T2 = Latitudinal unit force for cylindrical walls T2 per API-620 5.10.2.5.c Equation 11 (lbf/in)

T1 = (Rc / 2) * (P + (W / At))
T1 = (137.9528 / 2) * (0 + (-17,834.5454 / 59,787.5331))
T1 = -20.58 lbf/in [-3,603.33 N/m]

T2 = P * Rc
T2 = 0 * 137.9528
T2 = 0.0 lbf/in [0.0 N/m]

(T1 < 0) AND (T2 = 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) = 0.0013591609589041094

t_req = (Ratio * R) + c
t_req = (0.0014 * 137.9528) + 0
t_req = 0.19 in [4.76 mm]

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-20.5756) / (0.315 - 0)
Scc = 65.33 psi [0.45 MPa]

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 2,446.49 psi [16.87 MPa]

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)

Stc = 0.0 / (0.315 - 0)
Stc = 0.0 psi [0.0 kPa]

M = Scc / 15000
M = 65.3274 / 15000
M = 0.004355161499603866

As per API-620 Figure F-1, Tension factor (N) = 1.0

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((21,030.472 * 0.9978) , (21,030.472 * 0.7))
Sta = 14,721.33 psi [101,500 kPa]

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t-erec , td , tt , ts , t-axial-load)
t-min = MAX(5 , 3.5934 , 0.548 , 3.6432 , 4.7625)
t-min = 5 mm

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (4.9 * D * SG)) + 0.3) + loc
H-max = ((((8 - 3) * 145 * 0.7) / (4.9 * 7.0 * 1.11)) + 0.3) + 1.828
H-max = 15.46 m

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(15.4577 , 0)
H-max-@-Pi = 15.46 m

Pi-max-@-H = MAX((((H-max - (H + loc)) * (9.8 * SG)) + P) , 0)
Pi-max-@-H = MAX((((15.4577 - (1.882 + 1.828)) * (9.8 * 1.11)) + 0.0) , 0)
Pi-max-@-H = 127.79 kPa

Course # 3 Design
A3 = Shell Course Cross Sectional Area (mm^2)
CA = Corrosion allowance per API-650 5.3.2 (mm)
D3 = Shell Course Centerline Diameter (m)
H = Design Liquid Level per API-650 5.6.3.2 (m)
H' = Effective Design Liquid Level per API-650 F.2 (m)
H-max = Maximum Liquid Level for the Installed Thickness (m)
H-max-@-Pi = Maximum Liquid Level for the Installed Thickness @ Design Internal Pressure (m)
Ht' = Effective Hydrostatic Test Liquid Level per API-650 F.2 (m)
JE = Joint efficiency
Ma = Course Material
Pi-max-@-H = Maximum Allowable Internal Pressure for the Installed Thickness @ Design Liquid Level (kPa)
Rwi = Impulsive Force Reduction Factor
W-3 = Shell Course Nominal Weight (kg)
W-3-corr = Shell Course Nominal Weight (kg)
Ws-tot-top = Top Weight Total (N)
h3 = Course Height (m)
loc = Course Location (m)
t = Installed Thickness (mm)
t-min = Minimum Required Thickness (mm)
td = Course Design Thickness per A.4.1 (mm)
tt = Course Hydrostatic Test Thickness per A.4.1 (mm)

CA = 3 mm
H = 0.05 m
JE = 0.7

Ma = A36
Rwi = 4
h3 = 0.84 m
loc = 3.66 m
t = 8 mm

Shell Course Center of Gravity (CG-3) = 4.08 m

D3 = ID + t
D3 = 7.0 + 0.008
D3 = 7.01 m

W-3 = pi * Dc * t * h3 * d
W-3 = pi * 7.008 * 0.008 * 0.844 * 7,840
W-3 = 1,165.45 kg

W-3-corr = pi * Dc * (t - CA) * h3 * d
W-3-corr = pi * 7.008 * (0.008 - 0.003) * 0.844 * 7,840
W-3-corr = 728.4 kg

Material Properties
Material (A36) = A36
Minimum Tensile Strength (Sut) = 400.0 MPa
Minimum Yield Strength (Sy) = 250.0 MPa
As per API-650 A.4.1, Allowable Design Stress (Sd) = 145 MPa
As per API-650 A.4.1, Allowable Hydrostatic Test Stress (St) = 145 MPa
Permissible Design Metal Temperature (MDMT-permissible) = -30 °C

Thickness Required by Erection
As per API-650 5.6.1.1, Thickness Required by Erection (t-erec) = 5 mm

Thickness Required by Design
H' = H
H' = 0.054
H' = 0.05 m

Design liquid level is below the design point under consideration

td = ((4.9 * D * (H' - 0.3) * SG) / (JE * Sd)) + CA
td = ((4.9 * 7.0 * (0.054 - 0.3) * 1.11) / (0.7 * 145)) + 3
td = 2.91 mm

Hydrostatic Test Required Thickness
Ht' = H
Ht' = 0.054
Ht' = 0.05 m

Hydrotest Design liquid level is below the design point under consideration

tt = (4.9 * D * (Ht' - 0.3) * SGt) / (JE * St)
tt = (4.9 * 7.0 * (0.054 - 0.3) * 1.025) / (0.7 * 145)
tt = -0.09 (Set to 0 mm since it cannot be less than 0)

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

As per API 650 Section E.6.1.4, Shell Course Liquid Surface to Analysis Point Distance (Y) = 0.05 m

Ni = 8.48 * Ai * G * D * H * ((Y / H) - (0.5 * ((Y / H)^2))) * TANH((0.866 * (D / H)))
Ni = 8.48 * 0.306 * 1.11 * 7.0 * 3.71 * ((0.054 / 3.71) - (0.5 * ((0.054 / 3.71)^2))) * TANH((0.866 * (7.0 / 3.71)))
Ni = 1.0 N/mm

Nc = (1.85 * Ac * G * (D^2) * COSH(((3.68 * (H - Y)) / D))) / COSH(((3.68 * H) / D))
Nc = (1.85 * 0.2003 * 1.11 * (7.0^2) * COSH(((3.68 * (3.71 - 0.054)) / 7.0))) / COSH(((3.68 * 3.71) / 7.0))
Nc = 19.61 N/mm

Nh = 4.9 * (H - H_offset) * D * G
Nh = 4.9 * (0.054 - 0) * 7.0 * 1.11
Nh = 2.06 N/mm

S_T+ = Total Combined Hoop Stress per API 650 Sections E.6.1.4, EC.6.1.3 (MPa)
S_T- = Total Combined Hoop Stress per API 650 Sections E.6.1.4, EC.6.1.3 (MPa)

S_T+ = (Nh + SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
S_T+ = (2.0559 + SQRT(((1.0015^2) + (19.6131^2) + (((0.3808 * 2.0559) / 2.5)^2)))) / MAX((8 - 3) , 0.0001)
S_T+ = 4.34 MPa

S_T- = (Nh - SQRT(((Ni^2) + (Nc^2) + (((Av * Nh) / 2.5)^2)))) / MAX((t - CA) , 0.0001)
S_T- = (2.0559 - SQRT(((1.0015^2) + (19.6131^2) + (((0.3808 * 2.0559) / 2.5)^2)))) / MAX((8 - 3) , 0.0001)
S_T- = -3.52 MPa

Sd-seismic = MIN((1.33 * Sd) , (0.9 * Fy * E))
Sd-seismic = MIN((1.33 * 145) , (0.9 * 250.0 * 0.7))
Sd-seismic = 157.5 MPa

ts = ((SIGMAt+ * (tn - CA)) / S_membrane) + CA
ts = ((4.3394 * (8 - 3)) / 157.5) + 3
ts = 3.14 mm

Vertical Axial Load Design (Empty Tank)
Roof Total Weight (Wr-tot) = 0.0 kg
Upper Courses Weight (Ws-pl-top) = 0 N

Ws-tot-top = Wr-tot + Wss + Ws-pl-top + W-3 + Fd_agitator
Ws-tot-top = 0.0 + 21,458.4928 + 0 + 11,429.1291 + 21,690.303
Ws-tot-top = 54,577.92 N

A3 = pi * ((D3 / 2)^2)
A3 = pi * ((7,008 / 2)^2)
A3 = 38,572,524.87 mm^2 [38.57 m^2]

T1 = Meridional unit force for cylindrical walls T1 per API-620 5.10.2.5.c Equation 10 (lbf/in)
T2 = Latitudinal unit force for cylindrical walls T2 per API-620 5.10.2.5.c Equation 11 (lbf/in)

T1 = (Rc / 2) * (P + (W / At))
T1 = (137.9528 / 2) * (0 + (-12,269.6056 / 59,787.5331))
T1 = -14.16 lbf/in [-2,478.98 N/m]

T2 = P * Rc
T2 = 0 * 137.9528
T2 = 0.0 lbf/in [0.0 N/m]

(T1 < 0) AND (T2 = 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) = 0.0013591609589041094

t_req = (Ratio * R) + c
t_req = (0.0014 * 137.9528) + 0
t_req = 0.19 in [4.76 mm]

Scc = ABS(T1) / (t-installed - c)
Scc = ABS(-14.1553) / (0.315 - 0)
Scc = 44.94 psi [0.31 MPa]

As per API-620 Section 5.5.4.2, Maximum Allowable Compressive Stress (Scs) = 2,446.49 psi [16.87 MPa]

Scc <= Scs ==> PASS

Stc = T2 / (t-installed - c)
Stc = 0.0 / (0.315 - 0)
Stc = 0.0 psi [0.0 kPa]

M = Scc / 15000
M = 44.9432 / 15000
M = 0.002996213972451531

As per API-620 Figure F-1, Tension factor (N) = 1.0

Sta = MIN((Sts * N) , (Sts * E))
Sta = MIN((21,030.472 * 0.9985) , (21,030.472 * 0.7))
Sta = 14,721.33 psi [101,500 kPa]

Stc <= Sta ==> PASS

Minimum Required Thickness
t-min = MAX(t-erec , td , tt , ts , t-axial-load)
t-min = MAX(5 , 2.9077 , 0 , 3.1378 , 4.7625)
t-min = 5 mm

Rating of Installed Thickness
H-max = ((((t - CA) * Sd * JE) / (4.9 * D * SG)) + 0.3) + loc
H-max = ((((8 - 3) * 145 * 0.7) / (4.9 * 7.0 * 1.11)) + 0.3) + 3.656
H-max = 17.29 m

H-max-@-Pi = MAX(H-max , 0)
H-max-@-Pi = MAX(17.2857 , 0)
H-max-@-Pi = 17.29 m

Pi-max-@-H = MAX((((H-max - (H + loc)) * (9.8 * SG)) + P) , 0)
Pi-max-@-H = MAX((((17.2857 - (0.054 + 3.656)) * (9.8 * 1.11)) + 0.0) , 0)
Pi-max-@-H = 147.68 kPa

Shell Design Summary Results
W-ins = t-ins * d-ins * pi * (OD + t-ins) * H
W-ins = 0.0 * 130 * pi * (7.016 + 0.0) * 4.5
W-ins = 0.0 kg

W-shell-corr = W-1-corr + W-2-corr + W-3-corr
W-shell-corr = 1,577.6339 + 1,577.6339 + 728.4043
W-shell-corr = 3,883.67 kg

W-shell = W-1 + W-2 + W-3
W-shell = 2,524.2142 + 2,524.2142 + 1,165.4468
W-shell = 6,213.88 kg

CG-shell = ((CG-1 * W-1) + (CG-2 * W-2) + (CG-3 * W-3)) / W-shell
CG-shell = ((0.914 * 2,524.2142) + (2.742 * 2,524.2142) + (4.078 * 1,165.4468)) / 6,213.8752
CG-shell = 2.25 m

Shell Design Summary

Course	Height (m)	Material	CA (mm)	JE	Sy (mpa)	Sut (mpa)	Sd (mpa)	St (mpa)	t-erec (mm)
3	0.84	A36	3	0.7	250.0	400.0	145	145	5
2	1.83	A36	3	0.7	250.0	400.0	145	145	5
1	1.83	A36	3	0.7	250.0	400.0	145	145	6

Shell Design Summary (continued)

Course	t-design (mm)	t-test (mm)	t-seismic (mm)	t-ext (mm)	t-min (mm)	t-installed (mm)	Status	H-max-@-Pi (m)	Pi-max-@-H (kPa)
3	2.91	0	3.14	N/A	5	8	PASS	17.29	147.68
2	3.59	0.55	3.64	N/A	5	8	PASS	15.46	127.79
1	4.28	1.18	4.16	N/A	6	8	PASS	13.63	107.91

Intermediate Stiffeners Design

Stiffeners Design For Wind Loading

D = Nominal Tank Diameter (m)
H1 = Maximum Unstiffened Transformed Shell Height per API-650 5.9.6.1 (m)
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 (kPa)
Pwv = Wind Pressure where Design Wind Speed V is Used per API-650 5.9.6.1 (kPa)
V = Wind velocity (km/hr)
ts_min = Thickness of the Thinnest Shell Course (mm)

D = 7.0 m
N = 2
V = 112.32 km/hr

Shell Courses Heights (W) = [1.83 1.83 0.84] m

ts_min = MIN(ts_1 , ts_2 , ts_3)
ts_min = MIN(8 , 8 , 8)
ts_min = 8 mm

Stiffeners Required Quantity

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

Transformed shell courses heights

Variable	Equation	Value	Unit		
Wtr_1	W_1 * SQRT(((t_min / ts_1)^5))	1.83	m	N/A	N/A
Wtr_2	W_2 * SQRT(((t_min / ts_2)^5))	1.83	m	N/A	N/A
Wtr_3	W_3 * SQRT(((t_min / ts_3)^5))	0.84	m	N/A	N/A

HTS = Wtr_1 + Wtr_2 + Wtr_3
HTS = 1.828 + 1.828 + 0.844
HTS = 4.5 m

Pwv = 1.48 * ((V / 190)^2)
Pwv = 1.48 * ((112.32 / 190)^2)
Pwv = 0.52 kPa

Pwd = Pwv + 0.24
Pwd = 0.5172 + 0.24
Pwd = 0.76 kPa

H1 = 9.47 * ts_min * SQRT(((ts_min / D)^3)) * (1.72 / Pwd)
H1 = 9.47 * 8 * SQRT(((8 / 7.0)^3)) * (1.72 / 0.7572)
H1 = 210.25 m

Ns = CEILING(((HTS / Hsafe) - 1))
Ns = CEILING(((4.5 / 210.2513) - 1))
Ns = 0

N >= Ns ==> PASS

Stiffeners Design

Real Elevations

Stiffener #	Size	Elevation (ft)	Spacing below (ft)	Spacing above (ft)	Average Spacing Ls (ft)
1	L75X75X6	1.65	1.65	1.80	1.73
2	L75X75X6	3.45	1.80	1.05	1.42

Transformed Elevations

Stiffener #	Size	Transformed Elevation (ft)	Transformed Spacing below (ft)	Transformed Spacing above (ft)	Transformed Average Spacing (ft)
1	L75X75X6	1.65	1.65	1.80	1.73
2	L75X75X6	3.45	1.80	1.05	1.42

Stiffener #1 Design

Fy = Intermediate Wind Girder and Shell Yield Strength per API 650 5.9.6.6 (MPa)
Z_act = Stiffener Region Section Modulus per API-650 5.9.6.6.2 (cm^3)
Z_req = Intermediate Wind Girder Minimum Required Section Modulus per API-650 5.9.6.6 (cm^3)
h1 = Vertical Distance Between the Intermediate Stiffener and the Top Angle of the Shell or the Top Wind Girder of an Open-top Tank (m)

Z_act = 20.66 cm^3
h1 = 1.8 m

Shell Yield Strength (Fy_shell) = 250.0 MPa
Stiffener Yield Strength (Fy_stiffener) = 250.0 MPa

Fy = MIN(Fy_stiffener , Fy_shell)
Fy = MIN(250.0 , 250.0)
Fy = 250.0 (Set to 210 MPa since it cannot be greater than 210)

Z_req = ((6 * h1 * (D^2)) / (0.5 * Fy)) * (Pwd / 1.72)
Z_req = ((6 * 1.8 * (7.0^2)) / (0.5 * 210)) * (0.7572 / 1.72)
Z_req = 2.22 cm^3

Z_act >= Z_req

Stiffener #2 Design
Fy = Intermediate Wind Girder and Shell Yield Strength per API 650 5.9.6.6 (MPa)
Z_act = Stiffener Region Section Modulus per API-650 5.9.6.6.2 (cm^3)
Z_req = Intermediate Wind Girder Minimum Required Section Modulus per API-650 5.9.6.6 (cm^3)
h1 = Vertical Distance Between the Intermediate Stiffener and the Top Angle of the Shell or the Top Wind Girder of an Open-top Tank (m)

Z_act = 20.66 cm^3
h1 = 1.05 m

Shell Yield Strength (Fy_shell) = 250.0 MPa
Stiffener Yield Strength (Fy_stiffener) = 250.0 MPa

Fy = MIN(Fy_stiffener , Fy_shell)
Fy = MIN(250.0 , 250.0)
Fy = 250.0 (Set to 210 MPa since it cannot be greater than 210)

Z_req = ((6 * h1 * (D^2)) / (0.5 * Fy)) * (Pwd / 1.72)
Z_req = ((6 * 1.05 * (7.0^2)) / (0.5 * 210)) * (0.7572 / 1.72)
Z_req = 1.29 cm^3

Z_act >= Z_req

Intermediate Stiffeners Summary

Intermediate Stiffeners Summary Table

Stiffener #	Size	Elevation (m)	Z reqd (cm^3)	Z act (cm^3)	Weight (kg)
1	L75X75X6	1.65	2.22	20.66	154.21
2	L75X75X6	3.45	1.29	20.66	154.21

Flat Bottom: non Annular Plate Design

Back

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

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

CA = 3 mm
CA_1 = 3 mm
E = 0.7
Ma-bottom = A36
Ma_1 = A36
Sd_1 = 145 MPa
St_1 = 145 MPa
chime = 50 mm
tb = 10 mm
td_1 = 4.28 mm
ts_1 = 8 mm
tt_1 = 1.18 mm

Bottom Plates Material Properties
Material (A36) = A36
Minimum Tensile Strength (Sut-btm) = 400.0 MPa
Minimum Yield Strength (Sy-btm) = 250.0 MPa
Density (d-btm) = 7,840 kg/m^3
Permissible Design Metal Temperature (MDMT-permissible-btm) = -30 °C

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 = ((4.2791 - 3) / (8 - 3)) * 145
S1 = 37.09 MPa

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

S2 = (tt_1 / ts_1) * St_1
S2 = (1.1812 / 8) * 145
S2 = 21.41 MPa

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

S = MAX(S1 , S2)
S = MAX(37.094 , 21.4084)
S = 37.09 MPa

Bottom Weight
A-btm = Bottom Surface Area (m^2)
CA = Corrosion allowance (mm)
OD-btm = Bottom Outer Diameter (m)
Wb-pl = Bottom Plates Weight (kg)
Wb-pl-corr = Bottom Corroded Plates Weight (kg)
chime = Outside Projection (Chime Distance) (mm)
tb = Installed Thickness (mm)

CA = 3 mm
chime = 50 mm
tb = 10 mm

OD-btm = OD + (chime * 2)
OD-btm = 7.016 + (0.05 * 2)
OD-btm = 7.12 m

A-btm = pi * ((OD-btm / 2)^2)
A-btm = pi * ((7.116 / 2)^2)
A-btm = 39.77 m^2

Wb-pl = A-btm * tb * d-btm
Wb-pl = 39,770,564.9415 * 10 * 7.840000000000001E-6
Wb-pl = 3,118.01 kg

Wb-pl-corr = A-btm * (tb - CA) * d-btm
Wb-pl-corr = 39,770,564.9415 * (10 - 3) * 7.840000000000001E-6
Wb-pl-corr = 2,182.61 kg

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

Liquid Height to Pressure Conversion Factor (f) = 9.81

P-btm = (d-btm * 9.80665 * (tb - CA-btm) * (1 / 1.0E6)) + (Lmin * f * SG)
P-btm = (7,840 * 9.80665 * (10 - 3) * (1 / 1.0E6)) + (0.0 * 9.8064 * 1.11)
P-btm = 0.54 kPa

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

Bottom Required Thickness
As per API-650 5.4.1, Required Thickness by Erection (tb-erec) = 9 mm

tb-req = tb-erec
tb-req = 9
tb-req = 9 mm

tb >= tb-req ==> PASS

Bottom Outside Projection
As per API-650 5.4.2, Minimum Required Outside Projection (chime) = 50 mm

chime >= chime ==> PASS

Wind Moment (Per API-650 Section 5.11) Back

Wind Pressures per API-650 & ASCE7-10

PWR = Roof Design Wind Pressure per API-650 5.2.1.k (kPa)
PWS = Shell Design Wind Pressure per API-650 5.2.1.k (kPa)
V = Design Wind Velocity (3-sec gust) (kph)
Vs = Adjusted Design Wind Velocity (kph)

V = 144.0 kph

Wind Velocity per API-650 and ASCE7-10

Vs = 0.78 * V
Vs = 0.78 * 144.0
Vs = 112.32 kph

Roof Wind Pressure
PWR = 1.48 * ((Vs / 190)^2)
PWR = 1.48 * ((112.32 / 190)^2)
PWR = 0.52 kPa

Shell Wind Pressure
PWS = 0.89 * ((Vs / 190)^2)
PWS = 0.89 * ((112.32 / 190)^2)
PWS = 0.31 kPa

Wind Overturning and Sliding Stability

As = Shell Total Vertical Projected Area (m^2)
CA-btm = Corrosion Allowance of Bottom Plates Under the Shell (mm)
CA_1 = Bottom Shell Course Corrosion Allowance (mm)
COF = Maximum Allowable Sliding Friction Coefficient
D-outer = Tank Max Outer Diameter (m)
DLR = Nominal Weight of Roof Plates and Attached Structural (N)
DLS = Nominal Weight of Shell Plates and Framing (N)
F-friction = Friction Force (N)
F-wind = Sliding Force (N)
Fby = Yield Strength of Bottom Plates Under the Shell (MPa)
MDL = Moment About the Shell-To-Bottom Joint from the Nominal Weight of the Shell (N.m)
MF = Moment About the Shell-To-Bottom Joint From Liquid Weight (N.m)
MWS = Shell Wind Overturning Moment per API-650 5.11.2.2 (N.m)
Mw = Overturning Moment About the Shell-To-Bottom Joint from Wind Pressures per API-650 5.11.2.2 (N.m)
Wb-pl-corr = Bottom Corroded Plates Weight (N)
Ws-framing = Shell New Framing Weight (N)
Ws-framing-corr = Shell Corroded Framing Weight (N)
Ws-pl = Shell New Plates Weight (N)
Ws-pl-corr = Shell Corroded Plates Weight (N)
Xs = Moment Arm of Wind Force on Shell (m)
tb = Thickness of Bottom Plates Under the Shell (mm)
ts-ins = Shell Insulation Thickness (mm)
ts_1 = Bottom Shell Course Nominal Thickness (mm)
wL = Tank Content Resisting Weight per API-650 5.11.2.3 (N/m)

CA-btm = 3 mm
CA_1 = 3 mm
COF = 0.4
DLR = 0.0 N
DLS = 69,045.8 N
Fby = 250.0 MPa
Wb-pl-corr = 21,404.08 N
Ws-framing = 8,123.97 N
Ws-framing-corr = 5,520.52 N
Ws-pl = 60,937.3 N
Ws-pl-corr = 38,085.81 N
tb = 10 mm
ts-ins = 0 mm
ts_1 = 8 mm

Overturning Moments
D-outer = OD + (2 * (ts-ins / 1000))
D-outer = 7.016 + (2 * (0 / 1000))
D-outer = 7.02 m

As = D-outer * H
As = 7.016 * 4.5
As = 31.57 m^2

Xs = H / 2
Xs = 4.5 / 2
Xs = 2.25 m

MWS = PWS * As * Xs
MWS = 311.0262 * 31.572 * 2.25
MWS = 22,094.37 N.m

Mw = MWR + MWS
Mw = 0.0 + 22,094.3692
Mw = 22,094.37 N.m

Resistance to Overturning per API-650 5.11.2
MDL = (D / 2) * DLS
MDL = (7.0 / 2) * 69,045.8046
MDL = 241,660.32 N.m

As per API-650 5.11.2.3, the corroded thickness of plates under the shell used in the liquid resisting weight calculation shall not be greater than first shell course corroded thickness

wL = MIN((70.4 * Lmax * D) , (59 * (ts_1 - CA_1) * SQRT((Fby * Lmax))))
wL = MIN((70.4 * 3.71 * 7.0) , (59 * (8 - 3) * SQRT((250.0 * 3.71))))
wL = 1,828.29 N/m

MF = (D / 2) * wL * pi * D
MF = (7.0 / 2) * 1,828.288 * pi * 7.0
MF = 140,721.54 N.m

An unanchored tank must meet the criteria from API-650 5.11.2.1
Criterion 1
((0.6 * Mw) + MPi) < ((MDL / 1.5) + MDLR)
((0.6 * 22,094.3692) + 0.0) < ((241,660.3162 / 1.5) + 0.0)
13,256.6215 < 161,106.8775 ==> Tank is stable

Criterion 2
(Mw + (Fp * MPi)) < (((MDL + MF) / 2) + MDLR)

(22,094.3692 + (0.4 * 0.0)) < (((241,660.3162 + 140,721.5357) / 2) + 0.0)
22,094.3692 < 191,190.9259 ==> Tank is stable

Criterion 3
(MWS + (Fp * MPi)) < ((MDL / 1.5) + MDLR)
(22,094.3692 + (0.4 * 0.0)) < ((241,660.3162 / 1.5) + 0.0)
22,094.3692 < 161,106.8775 ==> Tank is stable

Resistance to Sliding per API-650 5.11.4
F-wind = PWS * As
F-wind = 311.0262 * 31.572
F-wind = 9,819.72 N

F-friction = COF * (Wr-pl-corr + W-struct-corr + Ws-pl-corr + Ws-framing-corr + Wb-pl-corr)
F-friction = 0.4 * (0.0 + 0.0 + 38,085.8123 + 5,520.5153 + 21,404.0787)
F-friction = 26,004.16 N

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

Anchorage Requirement
Tank anchorage due to wind is not required per API-650 5.11

Seismic Design [Back]

Site Ground Motion Design

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 (m)
Fa = Site Acceleration Coefficient
Fv = Site Velocity Coefficient
H = Maximum Design Product Level (m)
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
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
Ss = Spectral Response Acceleration Short Period
TL = Regional Dependent Transistion Period for Longer Period Ground Motion (sec)
Tc = Convective Natural Period per API 650 Section E.4.5.2 (sec)

Anchorage_System = MECHANICALLY-ANCHORED
D = 7.0 m
Fa = 1.02
Fv = 1.5
H = 3.71 m
I = 1.5
K = 1.5
Q = 0.67
Rwc = 2
Rwi = 4
S1 = 0.5
Seismic_Site_Class = SEISMIC-SITE-CLASS-D
Seismic_Use_Group = SEISMIC-USE-GROUP-III
Ss = 1.2
TL = 4 sec

SDS = Q * Fa * Ss
SDS = 0.6667 * 1.02 * 1.2
SDS = 0.82

SD1 = Q * Fv * S1
SD1 = 0.6667 * 1.5 * 0.5
SD1 = 0.5

Ks = 0.578 / SQRT(TANH(((3.68 * H) / D)))
Ks = 0.578 / SQRT(TANH(((3.68 * 3.71) / 7.0)))
Ks = 0.59

Tc = 1.8 * Ks * SQRT(D)
Tc = 1.8 * 0.5898 * SQRT(7.0)
Tc = 2.81 sec

Ai = SDS * (I / Rwi)
Ai = 0.816 * (1.5 / 4)
Ai = 0.31

Ai = MAX(Ai , 0.007)
Ai = MAX(0.306 , 0.007)
Ai = 0.31

Tc <= TL

Ac = K * SD1 * (1 / Tc) * (I / Rwc)
Ac = 1.5 * 0.5 * (1 / 2.8089) * (1.5 / 2)
Ac = 0.2

Ac-min = MIN(Ac , Ai)
Ac-min = MIN(0.2003 , 0.306)
Ac-min = 0.2

Av = (2 / 3) * 0.7 * SDS
Av = (2 / 3) * 0.7 * 0.816
Av = 0.38

Vertical Ground Acceleration Coefficient Specified by user (Av) = 0.38

Af = K * SD1 * I * (1 / Tc)
Af = 1.5 * 0.5 * 1 * (1 / 2.8089)
Af = 0.27

As per API-650 E.4.6.1, for tanks falling in SUG III, the importance factor shall be set equal to 1 in the determination of sloshing wave height = for tanks falling in SUG III, the importance factor shall be set equal to 1 in the determination of sloshing wave height

Seismic Design

A = Roof Surface Area (m^2)
A-rs = Roof Area Supported by The Shell (m^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 (m^2)
Ai = Impulsive Design Response Spectrum Acceleration Coefficient
Anchorage_System = Anchorage System
Av = Vertical Ground Acceleration Coefficient
D = Nominal Tank Diameter (m)
DELTAs = Sloshing Wave Height Above Product Design Height per API 650 Section E.7.2 (m)
Event_Type = Event Type
Fa = Site Acceleration Coefficient
Fc = Allowable Longitudinal Shell Compression Stress per API 650 Section E.6.2.2.3 (MPa)
Freeboard = Actual Freeboard (m)
Freeboard_required = Minimum Required Freeboard per API-650 Table E.7 (m)
Fv = Site Velocity Coefficient
Fy = Yield Strength (MPa)
G = Specific Gravity
Ge = Effective Specific Gravity per API 650 Section E.2.2
H = Maximum Design Product Level (m)
H_shell = Shell height (m)
Hrcg = Top of Shell to Roof and roof appurtenances Center of Gravity (m)

I = Importance Factor
J = Anchorage Ratio per API 650 Section E.6.2.1.1.1
K = Spectral Acceleration Adjustment Coefficient
Ks = Sloshing Coefficient
MU = Friction Coefficient
Min_Anchor_Quantity = Minimum Anchor Quantity
Min_Anchor_Spacing = Minimum Anchor Spacing (m)
Mrw = Ringwall Overturning Moment per API 650 Section E.6.1.5 (N.m)
Ms = Slab Overturning Moment per API 650 Section E.6.1.5 (N.m)
Overturn_Stability_Ratio = Overturning Stability Ratio per API 650 Section E.6.2.3
P = Design Pressure (MPa)
Q = MCE to Design Level Scale Factor
S1 = Spectral Response Acceleration at a Period of One Second
SD1 = Design Spectral Response Acceleration at a Period of 1 Second
SDS = Design Spectral Response Acceleration at Short Period
Sb = Roof Balanced Snow Load (Pa)
Sc = Mechanically Anchored Maximum Longitudinal Shell Compression Stress per API 650 Section E.6.2.2.2 (MPa)
Seismic_Site_Class = Seismic Site Class
Seismic_Use_Group = Seismic Use Group
Ss = Spectral Response Acceleration Short Period
TL = Regional Dependent Transistion Period for Longer Period Ground Motion (sec)
Tc = Convective Natural Period (sec)
V = Total Design Base Shear per API 650 Section E.6.1 (N)
Vc = Design Base Shear for Convective Component per API 650 Section E.6.1 (N)
Vi = Design Base Shear for Impulsive Component per API 650 Section E.6.1 (N)
Vmax = Local Shear Transfer per API 650 Section E.7.7 (N/m)
Vs = Self Anchored Sliding Resistance Maximum Allowable Base Shear per API 650 Section E.7.6 (N)
W-struct = Roof Structure Weight (kg)
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 (N)
Wb-attachments = Bottom Attachments Weight (kg)
Wb-pl = Bottom Plates Weight (kg)
Wc = Convective Effective Weight per API 650 Section E.6.1.1 (N)
Weff = Total Effective Weight per API 650 Section E.6.1.1 (N)
Wf = Tank Bottom Total Weight (N)
Wfd = Tank Foundation Weight (N)
Wg = Soil Weight (N)
Wi = Impulsive Effective Weight per API 650 Section E.6.1.1 (N)
Wp = Tank Contents Total Weight (N)
Wr = Total Weight of Fixed Tank Roof including Framing, Knuckles, any Permanent Attachments and 10 % of the Roof Balanced Design Snow Load (N)
Wr-DL-add = Roof Additional Dead Weight (kg)
Wr-attachments = Roof Attachments Weight (kg)
Wr-pl = Roof Plates Nominal Weight (kg)
Wrs = Roof Load Acting on The Tank Shell Including 10 % of the Roof Balanced Design Snow Load (N)
Ws = Total Weight of Tank Shell and Appurtenances (N)
Ws-attachments = Shell Attachments Weight (kg)
Ws-framing = Shell Framing Weight (kg)
Ws-pl = Shell Plates Nominal Weight (kg)
Wss = Roof Structure Weight Supported by The Tank Shell (kg)
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 (m)
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 (m)
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 (m)
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 (m)
Xr = Height from tank shell bottom to the center of gravity of roof and roof appurtenances per API 650 Section E.6.1.2 (m)
Xs = Height from tank shell bottom to shell's center of gravity (m)
ca1 = Bottom Shell Course Corrosion Allowance (mm)
ca_bottom = Bottom Corrosion Allowance (mm)
hs = Additional Shell Height Required Above Sloshing Height (mm)
t_bottom = Bottom Plate Thickness (mm)
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 (mm)
tb-corr = Bottom Plates Corroded Thickness (mm)
ts1 = Bottom Shell Course Thickness (mm)
ts1_c = Shell Course 1 Corroded Thickness (mm)
wa = (N/m)
wa = Self Anchored Force Resisting Uplift per API 650 Section E.6.2.1.1 (N/m)
wa_max = Self Anchored Force Resisting Uplift Max Limit per API 650 Section E.6.2.1.1 (N/m)
wint = Calculated Design Uplift Due to Product Pressure (N/m)
wrs = Specified Tank Roof Load Acting on Tank Shell (N/m)
wt = Tank and Roof Weight Acting at base of Shell per API 650 Section E.6.2.1.1.1 (N/m)

A = 0 m^2
A-rs = 0 m^2
Ac = 0.2
Af = 0.27
Ah-shell = 0 m^2
Ai = 0.31
Anchorage_System = MECHANICALLY-ANCHORED
Av = 0.38
D = 7.0 m
Event_Type = MAXIMUM-CONSIDERED-EARTHQUAKE-MCE
Fa = 1.02
Fv = 1.5
Fy = 250.0 MPa
G = 1.11
H = 3.71 m
H_shell = 4.5 m
Hrcg = 0.0 m
I = 1.5
K = 1.5
Ks = 0.59
MU = 0.4
Min_Anchor_Quantity = 6
Min_Anchor_Spacing = 3 m
P = 0.0 MPa
Q = 0.67
S1 = 0.5
SD1 = 0.5
SDS = 0.82
Sb = 0.0 Pa
Seismic_Site_Class = SEISMIC-SITE-CLASS-D
Seismic_Use_Group = SEISMIC-USE-GROUP-III
Ss = 1.2
TL = 4 sec
Tc = 2.81 sec
W-struct = 2,188.16 kg
Wb-attachments = 0 kg
Wb-pl = 3,118.01 kg
Wfd = 0 N
Wg = 0 N
Wp = 1,554,187.91 N

Wr-DL-add = 0 kg
Wr-attachments = 0 kg
Wr-pl = 0 kg
Ws-attachments = 2,120.18 kg
Ws-framing = 828.41 kg
Ws-pl = 6,213.88 kg
Wss = 2,188.16 kg
Xs = 2.25 m
ca1 = 3 mm
ca_bottom = 3 mm
hs = 0 mm
t_bottom = 10 mm
ts1 = 8 mm

Wf = Wb-pl
Wf = 30,577.2552
Wf = 30,577.26 N

Wr = (Wr-pl + Wr-attachments + W-struct + Wr-DL-add) + (0.1 * Sb * Ah)
Wr = (0.0 + 0.0 + 21,458.4928 + 0.0) + (0.1 * 0.0 * 0)
Wr = 21,458.49 N

Wrs = ((Wr-pl + Wr-attachments + Wr-DL-add) * 1) + Wss + (0.1 * Sb * Ah-shell)
Wrs = ((0.0 + 0.0 + 0.0) * 1) + 21,458.4928 + (0.1 * 0.0 * 0)
Wrs = 21,458.49 N

Ws = Ws-pl + Ws-framing + Ws-attachments
Ws = 60,937.2996 + 8,123.9667 + 20,791.8972
Ws = 89,853.16 N

W_T = Ws + Wr + Wp + Wf
W_T = 89,853.1635 + 21,458.4928 + 1,554,187.9068 + 30,577.2552
W_T = 1,696,076.82 N

Effective Weight of Product
Wi = (TANH((0.866 * (D / H))) / (0.866 * (D / H))) * Wp
Wi = (TANH((0.866 * (7.0 / 3.71))) / (0.866 * (7.0 / 3.71))) * 1,554,187.9068
Wi = 881,383.56 N

Wc = 0.23 * (D / H) * TANH(((3.67 * H) / D)) * Wp
Wc = 0.23 * (7.0 / 3.71) * TANH(((3.67 * 3.71) / 7.0)) * 1,554,187.9068
Wc = 647,437.67 N

Weff = Wi + Wc
Weff = 881,383.5587 + 647,437.6748
Weff = 1,528,821.23 N

Design Loads
Vi = Ai * (Ws + Wr + Wf + Wi)
Vi = 0.306 * (89,853.1635 + 21,458.4928 + 30,577.2552 + 881,383.5587)
Vi = 313,121.38 N

Vc = Ac * Wc
Vc = 0.2003 * 647,437.6748
Vc = 129,681.77 N

V = SQRT(((Vi^2) + (Vc^2)))
V = SQRT(((313,121.3759^2) + (129,681.7663^2)))
V = 338,913.49 N

Center of Action for Effective Lateral Forces
Xr = H_shell + Hrcg
Xr = 4.5 + 0.0
Xr = 4.5 m

Xi = 0.375 * H
Xi = 0.375 * 3.71
Xi = 1.39 m

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 * 3.71) / 7.0)) - 1) / (((3.67 * 3.71) / 7.0) * SINH(((3.67 * 3.71) / 7.0))))) * 3.71
Xc = 2.28 m

Xis = 0.375 * (1.0 + (1.333 * (((0.866 * (D / H)) / TANH((0.866 * (D / H)))) - 1.0))) * H
Xis = 0.375 * (1.0 + (1.333 * (((0.866 * (7.0 / 3.71)) / TANH((0.866 * (7.0 / 3.71)))) - 1.0))) * 3.71
Xis = 2.81 m

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 * 3.71) / 7.0)) - 1.937) / (((3.67 * 3.71) / 7.0) * SINH(((3.67 * 3.71) / 7.0))))) * 3.71
Xcs = 2.8 m

Overturning Moment
Mrw = SQRT((((Ai * ((Wi * Xi) + (Ws * Xs) + (Wr * Xr)))^2) + ((Ac * (Wc * Xc))^2)))
Mrw = SQRT((((0.306 * ((881,383.5587 * 1.3912) + (89,853.1635 * 2.25) + (21,458.4928 * 4.5)))^2) + ((0.2003 * (647,437.6748 * 2.2798))^2)))
Mrw = 552,412.65 N.m

Ms = SQRT((((Ai * ((Wi * Xis) + (Ws * Xs) + (Wr * Xr)))^2) + ((Ac * (Wc * Xcs))^2)))
Ms = SQRT((((0.306 * ((881,383.5587 * 2.8069) + (89,853.1635 * 2.25) + (21,458.4928 * 4.5)))^2) + ((0.2003 * (647,437.6748 * 2.8015))^2)))
Ms = 922,958.06 N.m

Resistance to Design Loads
Ge = G * (1 - (0.4 * Av))
Ge = 1.11 * (1 - (0.4 * 0.3808))
Ge = 0.94

wrs = Wrs / (pi * D)
wrs = 21,458.4928 / (pi * 7.0)
wrs = 975.78 N/m

wt = (Ws / (pi * D)) + wrs
wt = (89,853.1635 / (pi * 7.0)) + 975.7786
wt = 5,061.66 N/m

wint = P * 1000000 * ((pi * ((D^2) / 4)) / (pi * D))
wint = 0.0 * 1000000 * ((pi * ((7.0^2) / 4)) / (pi * 7.0))
wint = 0.0 N/m

Bottom Annular Plates Requirements
tb-corr = t_bottom - ca_bottom
tb-corr = 10 - 3
tb-corr = 7 mm

ts1_c = ts1 - ca1
ts1_c = 8 - 3
ts1_c = 5 mm

ta = MIN(tb-corr , ts1_c)
ta = MIN(7 , 5)
ta = 5 mm

wa_max = 201.1 * H * D * Ge
wa_max = 201.1 * 3.71 * 7.0 * 0.9409
wa_max = 4,914.04 N/m

wa = 99 * ta * SQRT((Fy * H * Ge))
wa = 99 * 5 * SQRT((250.0 * 3.71 * 0.9409))
wa = 14,623.11 N/m

wa > wa_max

wa = wa_max
wa = 4,914.0428
wa = 4,914.04 N/m

Tank Stability
J = Mrw / ((D^2) * (((wt * (1 - (0.4 * Av))) + wa) - (Fp * wint)))
J = 552,412.6546 / ((7.0^2) * (((5,061.6572 * (1 - (0.4 * 0.3808))) + 4,914.0428) - (0.4 * 0.0)))
J = 1.22

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

Sc = ((wt * (1 + (0.4 * Av))) + ((1.273 * Mrw) / (D^2))) * (1 / (1000 * ts))
Sc = ((5,061.6572 * (1 + (0.4 * 0.3808))) + ((1.273 * 552,412.6546) / (7.0^2))) * (1 / (1000 * 5))
Sc = 4.04 MPa

Fc = (83 * (ts / (2.5 * D))) + (7.5 * SQRT((G * H)))
Fc = (83 * (5 / (2.5 * 7.0))) + (7.5 * SQRT((1.11 * 3.71)))
Fc = 38.93 MPa

Sc < Fc

Overturn_Stability_Ratio = (0.5 * D * (W_T + Wfd + Wg)) / Ms
Overturn_Stability_Ratio = (0.5 * 7.0 * (1,696,076.8184 + 0 + 0)) / 922,958.0622
Overturn_Stability_Ratio = 6.43

Overturn_Stability_Ratio >= 2.0 ==> PASS

Freeboard
DELTAs = 0.42 * D * Af
DELTAs = 0.42 * 7.0 * 0.267
DELTAs = 0.78 m

Freeboard = H_shell - Lmax-operating
Freeboard = 4.5 - 3.71
Freeboard = 0.79 m [790.0 mm]

Freeboard_required = DELTAs
Freeboard_required = 0.785
Freeboard_required = 0.78 m [784.98 mm]

Freeboard >= Freeboard_required ==> PASS

Sliding Resistance
Vs = MU * (Ws + Wr + Wf + Wp) * (1.0 - (0.4 * Av))
Vs = 0.4 * (89,853.1635 + 21,458.4928 + 30,577.2552 + 1,554,187.9068) * (1.0 - (0.4 * 0.3808))
Vs = 575,092.16 N

V <= Vs

Local Shear Transfer
Vmax = (2 * V) / (pi * D)
Vmax = (2 * 338,913.4942) / (pi * 7.0)
Vmax = 30,822.72 N/m

Anchor Bolt Design Back

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

Av = 0.38 g
Ca-anchor = 1.5 mm
D = 7.0 m
Dac = 7.18 m
Fp = 0.4
Fty = 250.0 MPa
H = 4.5 m
MWS = 22,094.37 N.m
Ma-anchor = A307-B
Mrw = 552,412.65 N.m

N = 12
OD = 7.02 m
P = 0.0 kPa
PWR = 0 kPa
Pt = 0.0 kPa
Wr-pl = 0.0 N
Wr-pl-corr = 0.0 N
Wrs-pl-corr = 0 N
Ws-framing = 8,123.97 N
Ws-framing-corr = 5,520.52 N
Ws-pl = 60,937.3 N
Ws-pl-corr = 38,085.81 N
Wss = 21,458.49 N
Wss-corr = 0.0 N
d = 27 mm
p = 3.0 mm
position_angles = [0 30 60 90 120 150 180 210 240 270 300 330] deg

Anchors Spacing Requirements
Max Allowable Spacing Between Anchors at Shell Outer Diameter per API-650 5.12.3
Max Allowable Spacing (max_allowable_spacing) = 3 m
Actual Spacing (actual_spacing) = 1.84 m

actual_spacing <= max_allowable_spacing ==> PASS

N-min = CEILING(((pi * OD) / 3))
N-min = CEILING(((pi * 7.016) / 3))
N-min = 8

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) = 1.88 m
Bolt loads will be based on equally spaced anchors.

Anchor Material Properties
Material (A307-B) = A307-B
Minimum Tensile Strength (Sut-anchor) = 415 MPa
Minimum Yield Strength (Sy-anchor) = 250 MPa
Minimum Yield Strength at Ambient Temperature (Sy-ambient-anchor) = 250 MPa

Fy = MIN(Sy-ambient-anchor , 380)
Fy = MIN(250 , 380)
Fy = 250 MPa

Fy-ambient = MIN(Sy-ambient-anchor , 380)
Fy-ambient = MIN(250 , 380)
Fy-ambient = 250 MPa

Uplift Load Cases per API-650 Table 5.21a
W1 = Ws-pl-corr + Ws-framing-corr + Wr-pl-corr
W1 = 38,085.8123 + 5,520.5153 + 0.0
W1 = 43,606.33 N

W2 = Ws-pl-corr + Ws-framing-corr + Wrs-pl-corr + Wss-corr
W2 = 38,085.8123 + 5,520.5153 + 0 + 0.0
W2 = 43,606.33 N

W3 = Ws-pl + Ws-framing + Wr-pl + Wss
W3 = 60,937.2996 + 8,123.9667 + 0.0 + 21,458.4928
W3 = 90,519.76 N

Uplift Case 1: Design Pressure Only
U = (P * (D^2) * 785) - W1
U = (0.0 * (7.0^2) * 785) - 43,606.3275
U = -43,606.33 (Set to 0 N since it cannot be less than 0)

Tb = U / N
Tb = 0 / 12
Tb = 0 N

Sd = (5 / 12) * Fy
Sd = (5 / 12) * 250
Sd = 104.17 MPa

A-s-r = Tb / Sd
A-s-r = 0 / 104.1667
A-s-r = 0.0 mm^2

P-attachment = 1.5 * Tb
P-attachment = 1.5 * 0
P-attachment = 0.0 N

Sd-shell = (2 / 3) * Fty
Sd-shell = (2 / 3) * 250.0
Sd-shell = 166.67 MPa

Uplift Case 2: Test Pressure Only
U = (Pt * (D^2) * 785) - W3
U = (0.0 * (7.0^2) * 785) - 90,519.7592
U = -90,519.76 (Set to 0 N since it cannot be less than 0)

Tb = U / N
Tb = 0 / 12
Tb = 0 N

Sd = (5 / 9) * Fy-ambient
Sd = (5 / 9) * 250
Sd = 138.89 MPa

A-s-r = Tb / Sd
A-s-r = 0 / 138.8889
A-s-r = 0.0 mm^2

P-attachment = 1.5 * Tb
P-attachment = 1.5 * 0
P-attachment = 0.0 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 3: Wind Load Only
U = ((PWR * (D^2) * 785) + ((4 * MWS) / D)) - W2
U = ((0 * (7.0^2) * 785) + ((4 * 22,094.3692) / 7.0)) - 43,606.3275
U = -30,980.97 (Set to 0 N since it cannot be less than 0)

Tb = U / N
Tb = 0 / 12
Tb = 0 N

Sd = 0.8 * Fy
Sd = 0.8 * 250
Sd = 200.0 MPa

A-s-r = Tb / Sd
A-s-r = 0 / 200.0
A-s-r = 0.0 mm^2

P-attachment = 1.5 * Tb
P-attachment = 1.5 * 0
P-attachment = 0.0 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 4: Seismic Load Only
U = ((4 * Mrw) / D) - (W2 * (1 - (0.4 * Av)))
U = ((4 * 552,412.6546) / 7.0) - (43,606.3275 * (1 - (0.4 * 0.3808)))
U = 278,700.16 N

Tb = U / N
Tb = 278,700.1623 / 12
Tb = 23,225.01 N

Sd = 0.8 * Fy
Sd = 0.8 * 250
Sd = 200.0 MPa

A-s-r = Tb / Sd
A-s-r = 23,225.0135 / 200.0
A-s-r = 116.13 mm^2

P-attachment = 3 * Tb
P-attachment = 3 * 23,225.0135
P-attachment = 69,675.04 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 5: Design Pressure + Wind Load
U = ((((Fp * P) + PWR) * (D^2) * 785) + ((4 * MWS) / D)) - W1
U = ((((0.4 * 0.0) + 0) * (7.0^2) * 785) + ((4 * 22,094.3692) / 7.0)) - 43,606.3275
U = -30,980.97 (Set to 0 N since it cannot be less than 0)

Tb = U / N
Tb = 0 / 12
Tb = 0 N

Sd = (5 / 9) * Fy
Sd = (5 / 9) * 250
Sd = 138.89 MPa

A-s-r = Tb / Sd
A-s-r = 0 / 138.8889

A-s-r = 0.0 mm^2

P-attachment = 1.5 * Tb
P-attachment = 1.5 * 0
P-attachment = 0.0 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

Uplift Case 6: Design Pressure + Seismic Load
U = ((Fp * P * (D^2) * 785) + ((4 * Mrw) / D)) - (W1 * (1 - (0.4 * Av)))
U = ((0.4 * 0.0 * (7.0^2) * 785) + ((4 * 552,412.6546) / 7.0)) - (43,606.3275 * (1 - (0.4 * 0.3808)))
U = 278,700.16 N

Tb = U / N
Tb = 278,700.1623 / 12
Tb = 23,225.01 N

Sd = 0.8 * Fy
Sd = 0.8 * 250
Sd = 200.0 MPa

A-s-r = Tb / Sd
A-s-r = 23,225.0135 / 200.0
A-s-r = 116.13 mm^2

P-attachment = 3 * Tb
P-attachment = 3 * 23,225.0135
P-attachment = 69,675.04 N

Sd-shell = (5 / 6) * Fty
Sd-shell = (5 / 6) * 250.0
Sd-shell = 208.33 MPa

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 (N)	Load per Anchor (N)	Anchor Allowable Stress (MPa)	Anchor Required Area (mm^2)	Anchor Bolt Required Diameter (mm)	Attachment Design Load (N)	Allowable Shell Stress at Anchor Attachment (MPa)
Design Pressure	0	0	104.17	0.0	6.68	0.0	166.67
Test Pressure	0	0	138.89	0.0	6.68	0.0	208.33
Wind Load	0	0	200.0	0.0	6.68	0.0	208.33
Seismic Load	278,700.16	23,225.01	200.0	116.13	18.84	69,675.04	208.33
Design Pressure + Wind	0	0	138.89	0.0	6.68	0.0	208.33

Design Pressure + Seismic	278,700.16	23,225.01	200.0	116.13	18.84	69,675.04	208.33

- Anchor Bolt Required Diameter = SQRT((A-s-r * (4 / pi))) + (1.22687 * p) + (Ca-anchor * 2)
- Governing Uplift Case = Seismic Load
- Anchor Bolt Minimum Required Area = 116.13 mm^2

Bolt Required Diameter per ANSI B1.1

d-req = SQRT((A * (4 / pi))) + (1.22687 * n) + (Ca * 2)
d-req = SQRT((116.1251 * (4 / pi))) + (1.22687 * 3.0) + (1.5 * 2)
d-req = 18.84 mm

d >= d-req ==> PASS

A-s = (pi / 4) * ((d - (1.22687 * n))^2)
A-s = (pi / 4) * ((27 - (1.22687 * 3.0))^2)
A-s = 427.09 mm^2

Y-bolt = A-s * Sy-ambient-anchor
Y-bolt = 427.0948 * 250
Y-bolt = 106,773.69 N

Anchorage Summary

Required Number of Anchors = 8
Actual Number of Anchors = 12
Bolt Hole Circle Radius = 3.59 m
Required Bolt Diameter = 18.84 mm
Actual Bolt Diameter = 27 mm
Bolt Thread Pitch = 3.0 mm

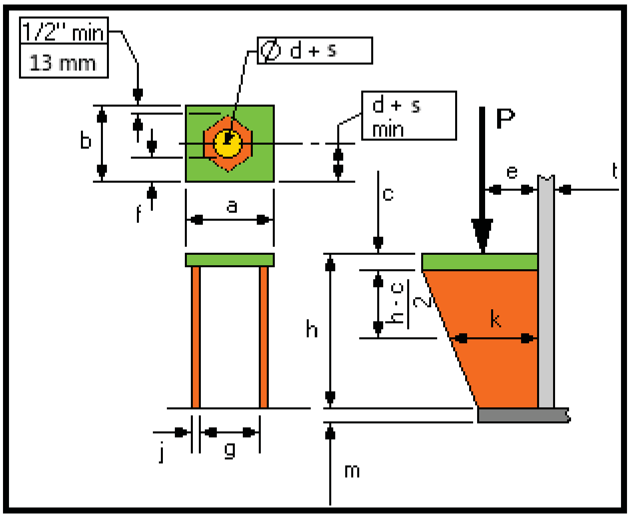
Anchor Chair Design Back

Anchor Chair Design per AISI Steel Plate Engineering Data-Volume 2 Part V

CA = Chair Corrosion Allowance (mm)
D = Tank Nominal Diameter (m)
Earthquakes-Considered = Earthquakes Considered
Et = Bottom Plates Thermal Expansion Coefficient per API-650 Table P.1a (mm/m.cdeg)
Ma-chair = Chair Material
R = Nominal Shell Radius (mm)
Ssw-chair = Chair Allowable Stress for Seismic or Wind Design per API-650 5.12.9 (MPa)
T = Difference Between the Ambient Temperature and the Maximum Design Temperature (°C)
V = Wind Velocity (kph)
Y-bolt = Anchor Bolt Yield Load (N)
a = Top Plate Width Along Shell (mm)
b = Top Plate Length (mm)
bmin = Top Plate Minimum Length (mm)
c = Top Plate Thickness (mm)
c-corr = Top Plate Corroded Thickness (mm)
d = Anchor Bolt Diameter (mm)
e = Anchor Bolt Eccentricity (mm)
emin = Minimum Calculated Eccentricity (mm)
emin-btm = Minimum Eccentricity Based on Bolt Clearance From Bottom Plates per API-650 5.12.4 (mm)
emin-req = Minimum Required Eccentricity (mm)
f = Top Plate Outside To Hole Edge Distance (mm)
fmin = Top Plate Outside to Hole Edge Minimum Distance (mm)
g = Vertical Plates Distance (mm)
gmin = Vertical Plates Minimum Distance (mm)
h = Chair Height (mm)
h-eff = Effective Chair Height (mm)
hmax = Chair Maximum Height (mm)
j = Vertical Plate Thickness (mm)
j-corr = Vertical Plate Corroded Thickness (mm)
jmin = Vertical Plate Minimum Thickness (mm)
k = Vertical Plates Average Width (mm)
m = Base or Bottom Plate Thickness (mm)
outside-projection = Bottom Outside Projection (mm)
t = Shell Thickness (mm)

CA = 1.5 mm
D = 7.0 m
Earthquakes-Considered = ASCE7-MAPPED-SS-AND-S1
Et = 1.2E-5 mm/m.cdeg
Ma-chair = A36
R = 3,500 mm
T = 12 °C
V = 112.32 kph

Y-bolt = 106,773.69 N
a = 180 mm
b = 180 mm
c = 16 mm
d = 27 mm
e = 83 mm
f = 76.5 mm
g = 90 mm
h = 305 mm
j = 14 mm
k = 115.58 mm
m = 10 mm
outside-projection = 50 mm
t = 8 mm



Anchor Chair Material Properties
Material (A36) = A36
Minimum Tensile Strength (Sut-chair) = 400.0 MPa
Minimum Yield Strength (Sy-chair) = 250.0 MPa
As per API-650 A.4.1, Allowable Design Stress (Sd-chair) = 145 MPa
As per API-650 A.4.1, Allowable Hydrostatic Test Stress (St-chair) = 145 MPa

Ssw-chair = 1.33 * Sd-chair
Ssw-chair = 1.33 * 145
Ssw-chair = 192.85 MPa

Size Requirements
c-corr = c - (2 * CA)
c-corr = 16 - (2 * 1.5)
c-corr = 13.0 mm

j-corr = j - (2 * CA)
j-corr = 14 - (2 * 1.5)
j-corr = 11.0 mm

Chair Minimum Height (hmin) = 305 mm

h >= hmin ==> PASS

hmax = 3 * a
hmax = 3 * 180
hmax = 540 mm

h-eff = MIN(hmax , h)
h-eff = MIN(540 , 305)
h-eff = 305 mm

emin = (0.886 * d) + 15
emin = (0.886 * 27) + 15
emin = 38.92 mm

emin-btm = (d / 2) + outside-projection + 3 + (500 * Et * D * T)
emin-btm = (27 / 2) + 50 + 3 + (500 * 1.2E-5 * 7.0 * 12)
emin-btm = 67.0 mm

emin-req = MAX(emin , emin-btm)
emin-req = MAX(38.922 , 67.004)
emin-req = 67.0 mm

e >= emin-req ==> PASS

gmin = d + 26
gmin = 27 + 26
gmin = 53 mm

g >= gmin ==> PASS

fmin = (d / 2) + 4
fmin = (27 / 2) + 4
fmin = 17.5 mm

f >= fmin ==> PASS

jmin = MAX(13 , (0.04 * (h-eff - c-corr)) , ((P-design / (172.3689 * k)) + (2 * CA)))
jmin = MAX(13 , (0.04 * (305 - 13.0)) , ((69,675.0406 / (172.3689 * 115.5773)) + (2 * 1.5)))
jmin = 13 mm

j >= jmin ==> PASS

bmin = emin + d + 7
bmin = 38.922 + 27 + 7
bmin = 72.92 mm

b >= bmin ==> PASS

Top Plate Minimum Required Thickness

Uplift Cases	P-chair (N)	P-design (N)	Sd-chair (MPa)	c-min (mm)	Status
Design Pressure	0.0	0.0	145	3.0	PASS
Test Pressure	0.0	0.0	145	3.0	PASS
Wind Load	0.0	0.0	192.85	3.0	PASS
Seismic Load	69,675.04	69,675.04	192.85	14.46	PASS
Design Pressure + Wind	0.0	0.0	192.85	3.0	PASS

Design Pressure + Seismic	69,675.04	69,675.04	192.85	14.46	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) = 14.46 mm

Top Plate Stress

Uplift Cases	P-chair (N)	P-design (N)	S-top-plate (MPa)	Sd-chair (MPa)	Stress Ratio	Status
Design Pressure	0.0	0.0	0.0	145	0.0%	PASS
Test Pressure	0.0	0.0	0.0	145	0.0%	PASS
Wind Load	0.0	0.0	0.0	192.85	0.0%	PASS
Seismic Load	69,675.04	69,675.04	149.88	192.85	77.72%	PASS
Design Pressure + Wind	0.0	0.0	0.0	192.85	0.0%	PASS
Design Pressure + Seismic	69,675.04	69,675.04	149.88	192.85	77.72%	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) = 149.88 MPa

Z = Chair Reduction Factor

Shell Stress at Anchor Attachment

Z = 26 / ((((0.177 * a * m) / SQRT((R * t))) * ((m / t)^2)) + 26)
Z = 26 / ((((0.177 * 180 * 10) / SQRT((3,500 * 8))) * ((10 / 8)^2)) + 26)
Z = 0.9

Uplift Cases	P-chair (N)	P-design (N)	S-Shell (MPa)	Sd-shell (MPa)	Stress Ratio	Status
Design Pressure	0.0	0.0	0.0	166.67	0.0%	PASS
Test Pressure	0.0	0.0	0.0	208.33	0.0%	PASS
Wind Load	0.0	0.0	0.0	208.33	0.0%	PASS
Seismic Load	69,675.04	69,675.04	101.76	208.33	48.85%	PASS
Design Pressure + Wind	0.0	0.0	0.0	208.33	0.0%	PASS
Design Pressure + Seismic	69,675.04	69,675.04	101.76	208.33	48.85%	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) = 101.76 MPa
- Governing Allowable Stress (Sd-Shell) = 208.33 MPa

Appuntenances Design Back

Plan View

LABEL	MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (mm)	INSIDE PROJ (mm)	ORIENT	RADIUS (mm)	REMARKS	REF DWG
Agitator-Bridge	AB01		AGITATOR BRIDGE	--	--	90'	--		

Elevation View

LABEL	MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (mm)	INSIDE PROJ (mm)	ORIENT	ELEVATION (mm)	REMARKS	REF DWG
Agitator-Bridge	AB01		AGITATOR BRIDGE	--	--	90'	1136		
Anchor-Chair-Bolts	AC01A		ANCHOR CHAIRS	--	--	SEE TABLE	--		
Angle-Baffle-0001	BF01A		BAFFLE WALL	--	--	90'	0		
Circular-Clean-Out-N3 (8")	CCD01A		CIRCULAR CLEAN OUT	200	0	145'	110		
MH1 (24")	SM01A		24" SHELL MANWAY	250	0	60'	750	W/ DAVIT	
MH2 (24")	SM01A		24" SHELL MANWAY	250	0	200'	750	W/ DAVIT	
N1 (10")	SN01A		10" SHELL NOZZLE	225	0	115'	350		
N2A (6")	SN02A		6" SHELL NOZZLE	200	0	145'	75		
N2B (6")	SN02A		6" SHELL NOZZLE	200	0	350'	75		
N3 (6")	SN03A		6" SHELL NOZZLE	200	0	330'	4075		
Name-Plate	NP01A		STD API	--	--	0'	1010		

Shell Nozzle: N1 (10")

Repad Design

NOZZLE Description : 10 in SCH 80 TYPE RFSO
Material: A106-B

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

MOUNTED ON SHELL 1 : Elevation = 0.35 m

COURSE PARAMETERS:
t-calc = 4.28 mm
t_cr = 1.28 mm (Course t-calc less C.A)
t_c = 5 mm (Course t less C.A.)
t_Basis = 1.28 mm
Repad Type: Circular
Repad Size (Do): 585 mm

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

Required Area = t_Basis * D
Required Area = 1.28 * 273.05
Required Area = 349.26 mm^2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (5 - 1.28) * 273.05
Available Shell Area = 1015.99 mm^2

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 * (15.1 - 3)) + 5] * (15.1 - 3) * MIN((124.1/145) 1)
Available Nozzle Neck Area = 1106.06 mm^2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 349.26 - 1015.99 - 1106.06
A-rpr = -1772.8 mm^2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

Shell Nozzle: N2A (6")

Repad Design

NOZZLE Description : 6 in SCH 80 TYPE RFSO

Material: A106-B

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

MOUNTED ON SHELL 1 : Elevation = 0.075 m

COURSE PARAMETERS:
t-calc = 4.28 mm
t_cr = 1.28 mm (Course t-calc less C.A)
t_c = 5 mm (Course t less C.A.)
t_Basis = 1.28 mm
Repad Type: Dog House
Repad Size (Do): 400 mm

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

Required Area = t_Basis * D
Required Area = 1.28 * 168.27
Required Area = 215.24 mm^2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (5 - 1.28) * 168.27
Available Shell Area = 626.13 mm^2

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 * (10.97 - 3)) + 5] * (10.97 - 3) * MIN((124.1/145) 1)
Available Nozzle Neck Area = 503.16 mm^2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 215.24 - 626.13 - 503.16
A-rpr = -914.05 mm^2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

Shell Nozzle: N2B (6")

Repad Design

NOZZLE Description : 6 in SCH 80 TYPE RFSO
Material: A106-B

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

MOUNTED ON SHELL 1 : Elevation = 0.075 m

COURSE PARAMETERS:
t-calc = 4.28 mm
t_cr = 1.28 mm (Course t-calc less C.A)
t_c = 5 mm (Course t less C.A.)
t_Basis = 1.28 mm
Repad Type: Dog House
Repad Size (Do): 400 mm

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

Required Area = t_Basis * D
Required Area = 1.28 * 168.27
Required Area = 215.24 mm^2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (5 - 1.28) * 168.27
Available Shell Area = 626.13 mm^2

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 * (10.97 - 3)) + 5] * (10.97 - 3) * MIN((124.1/145) 1)
Available Nozzle Neck Area = 503.16 mm^2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 215.24 - 626.13 - 503.16
A-rpr = -914.05 mm^2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

Shell Nozzle: N3 (6")

Repad Design

NOZZLE Description : 6 in SCH 80 TYPE RFSO
Material: A106-B

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

MOUNTED ON SHELL 3 : Elevation = 4.075 m

COURSE PARAMETERS:
t-calc = 3.14 mm
t_cr = 0.14 mm (Course t-calc less C.A)
t_c = 5 mm (Course t less C.A.)
t_Basis = 0.14 mm
Repad Type: Circular

Repad Size (Do): 400 mm

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

Required Area = t_Basis * D
Required Area = 0.14 * 168.27
Required Area = 23.18 mm^2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (5 - 0.14) * 168.27
Available Shell Area = 818.19 mm^2

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 * (10.97 - 3)) + 5] * (10.97 - 3) * MIN((124.1/145) 1)
Available Nozzle Neck Area = 503.16 mm^2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 23.18 - 818.19 - 503.16
A-rpr = -1298.17 mm^2

Since A-rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

Shell Manway: MH1 (24")

Repad Design

MANWAY Description : 24 in Neck Thickness 8
Material: A36

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 = 0.75 m

COURSE PARAMETERS:
t-calc = 4.28 mm
t_cr = 1.28 mm (Course t-calc less C.A)
t_c = 5 mm (Course t less C.A.)
t_Basis = 1.28 mm
Repad Type: Circular
Repad Size (Do): 1257.3 mm

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

Required Area = t_Basis * D
Required Area = 1.28 * 625.6
Required Area = 800.21 mm^2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (5 - 1.28) * 625.6
Available Shell Area = 2327.79 mm^2

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 * (8 - 3)) + 5] * (8 - 3) * MIN((160/145) 1)
Available Manway Neck Area = 250 mm^2

A-rpr = (Required Area - Available Shell Area - Available Manway Neck Area)
A-rpr = 800.21 - 2327.79 - 250
A-rpr = -1777.59 mm^2

Since A_rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

Manway Neck Material Properties
Material (A36) = A36
As per API-650 A.4.1, Allowable Design Stress (Sd-neck) = 145 MPa
Permissible Design Metal Temperature (MDMT-permissible-neck) = -30 °C

Manway Repad Material Properties
Material (A36) = A36
Permissible Design Metal Temperature (MDMT-permissible-repad) = -30 °C

Cover Plate and Bolting Flange Design
CA-cover = Cover Plate and Bolting Flange Corrosion Allowance (mm)
Db = Bolt Circle Diameter (mm)
H = Design Liquid Level (m)
Ma-cover = Cover Plate Material
Ma-flange = Bolting Flange Material
SG = Product Specific Gravity
Sd = Allowable Stress per API-650 5.7.5.6 (MPa)
tc = Cover Plate Thickness (mm)
tc-design = Cover Plate Required Thickness per API-650 5.7.5.6 (mm)
tc-req = Cover Plate Minimum Required Thickness (mm)
tf = Bolting Flange Thickness (mm)
tf-design = Cover Plate Required Thickness per API-650 5.7.5.6 (mm)
tf-req = Bolting Flange Minimum Required Thickness (mm)

CA-cover = 3 mm
Db = 768.35 mm
H = 3.71 m
Ma-cover = A36
Ma-flange = A36
SG = 1.11
tc = 19 mm
tf = 16 mm

Water Density (Y) = 0.00981 MPa/m
As per API-650 5.7.5.6, Coefficient For Circular Plate (C) = 0.3

Cover Plate Material Properties and Required Thickness
Material (A36) = A36
Minimum Yield Strength (Sy-cover) = 250.0 MPa
Plate is impact tested

Sd = MIN(Sy-cover , 205) / 2 = 102.5 MPa

As per API-650 5.7.5.6, Cover Plate Erection Thickness (tc-erec) = 8 mm

tc-design = (Db * SQRT(((C * Y * H * MAX(SG , 1)) / Sd))) + CA-cover
tc-design = (768.35 * SQRT(((0.3 * 0.0098 * 3.71 * MAX(1.11 , 1)) / 102.5))) + 3
tc-design = 11.35 mm

tc-req = MAX(tc-erec , tc-design)
tc-req = MAX(8 , 11.3549)
tc-req = 11.35 mm

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

Bolting Flange Material Properties and Required Thickness
Material (A36) = A36
Minimum Yield Strength (Sy-flange) = 250.0 MPa
Permissible Design Metal Temperature (MDMT-permissible-flange) = -2.75 °C

As per API-650 5.7.5.6, Bolting Flange Erection Thickness (tf-erec) = 6 mm

tf-design = tc-design - 3
tf-design = 11.3549 - 3
tf-design = 8.35 mm

tf-req = MAX(tf-erec , tf-design)
tf-req = MAX(6 , 8.3549)
tf-req = 8.35 mm

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

Shell Manway: MH2 (24")

Repad Design

MANWAY Description : 24 in Neck Thickness 8
Material: A36

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 = 0.75 m

COURSE PARAMETERS:
t-calc = 4.28 mm
t_cr = 1.28 mm (Course t-calc less C.A)
t_c = 5 mm (Course t less C.A.)
t_Basis = 1.28 mm
Repad Type: Circular
Repad Size (Do): 1257.3 mm

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

Required Area = t_Basis * D

Required Area = 1.28 * 625.6
Required Area = 800.21 mm^2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (5 - 1.28) * 625.6
Available Shell Area = 2327.79 mm^2

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 * (8 - 3)) + 5] * (8 - 3) * MIN((160/145) 1)
Available Manway Neck Area = 250 mm^2

A-rpr = (Required Area - Available Shell Area - Available Manway Neck Area)
A-rpr = 800.21 - 2327.79 - 250
A-rpr = -1777.59 mm^2

Since A_rpr <= 0, t_rpr = 0

No Reinforcement Pad required.

Manway Neck Material Properties
Material (A36) = A36
As per API-650 A.4.1, Allowable Design Stress (Sd-neck) = 145 MPa
Permissible Design Metal Temperature (MDMT-permissible-neck) = -30 °C

Manway Repad Material Properties
Material (A36) = A36
Permissible Design Metal Temperature (MDMT-permissible-repad) = -30 °C

Cover Plate and Bolting Flange Design
CA-cover = Cover Plate and Bolting Flange Corrosion Allowance (mm)
Db = Bolt Circle Diameter (mm)
H = Design Liquid Level (m)
Ma-cover = Cover Plate Material
Ma-flange = Bolting Flange Material
SG = Product Specific Gravity
Sd = Allowable Stress per API-650 5.7.5.6 (MPa)
tc = Cover Plate Thickness (mm)
tc-design = Cover Plate Required Thickness per API-650 5.7.5.6 (mm)
tc-req = Cover Plate Minimum Required Thickness (mm)
tf = Bolting Flange Thickness (mm)
tf-design = Cover Plate Required Thickness per API-650 5.7.5.6 (mm)
tf-req = Bolting Flange Minimum Required Thickness (mm)

CA-cover = 3 mm
Db = 768.35 mm
H = 3.71 m
Ma-cover = A36
Ma-flange = A36
SG = 1.11
tc = 19 mm
tf = 16 mm

Water Density (Y) = 0.00981 MPa/m
As per API-650 5.7.5.6, Coefficient For Circular Plate (C) = 0.3

Cover Plate Material Properties and Required Thickness
Material (A36) = A36
Minimum Yield Strength (Sy-cover) = 250.0 MPa
Plate is impact tested

Sd = MIN(Sy-cover , 205) / 2 = 102.5 MPa

As per API-650 5.7.5.6, Cover Plate Erection Thickness (tc-erec) = 8 mm

tc-design = (Db * SQRT(((C * Y * H * MAX(SG , 1)) / Sd))) + CA-cover
tc-design = (768.35 * SQRT(((0.3 * 0.0098 * 3.71 * MAX(1.11 , 1)) / 102.5))) + 3
tc-design = 11.35 mm

tc-req = MAX(tc-erec , tc-design)
tc-req = MAX(8 , 11.3549)
tc-req = 11.35 mm

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

Bolting Flange Material Properties and Required Thickness
Material (A36) = A36
Minimum Yield Strength (Sy-flange) = 250.0 MPa
Permissible Design Metal Temperature (MDMT-permissible-flange) = -2.75 °C

As per API-650 5.7.5.6, Bolting Flange Erection Thickness (tf-erec) = 6 mm

tf-design = tc-design - 3
tf-design = 11.3549 - 3
tf-design = 8.35 mm

tf-req = MAX(tf-erec , tf-design)
tf-req = MAX(6 , 8.3549)
tf-req = 8.35 mm

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

Capacities and Weights Back

Capacity to Top of Shell (to Tank Height) : 173 M^3
Capacity to Design Liquid Level : 142 M^3
Capacity to Maximum Liquid Level : 142 M^3
Working Capacity (to Normal Working Level) : 0 M^3
Net working Capacity (Working Capacity - Min Capacity) : 0 M^3
Minimum Capacity (to Min Liq Level) : 0 M^3

Component	New Condition (N)	New Condition (Kg)	Corroded (N)	Corroded (Kg)
SHELL	60,938	6,214	38,086	3,884
ROOF	0	0	0	0
RAFTERS	0	0	0	0
GIRDERS	0	0	0	0
FRAMING	0	0	0	0
COLUMNS	0	0	0	0
TRUSS	0	0	0	0
STRUCTURE COMPONENTS	0	0	0	0
BOTTOM	30,578	3,119	21,405	2,183
STAIRWAYS	0	0	0	0
STIFFENERS	8,105	827	3,962	404
WIND GIRDERS	0	0	0	0
AGITATOR BRIDGE	21,459	2,189	21,459	2,189
ANCHOR CHAIRS	1,864	190	1,864	190
APPURTENANCES	18,929	1,931	18,929	1,931
INSULATION	0	0	0	0
FLOATING ROOF	0	0	0	0
TOTAL	141,873	14,470	105,705	10,781

Weight of Tank, Empty : 14,470 Kg
Weight of Tank, Full of Product (Design SG = 1.11) : 172,953 Kg
Weight of Tank, Full of Water : 160,816.97 Kg
Net Working Weight, Full of Product (Design SG = 1.11) : 172,953.06 Kg
Net Working Weight Full of Water : 160,816.97 Kg

Foundation Area Req'd : 39.77 m^2
Foundation Loading, Empty : 3,567.28 N/m^2
Foundation Loading, Full of Product Design : 42,646.12 N/m^2
Foundation Loading, Full of Water : 39,653.61 N/m^2

SURFACE AREAS
Roof : 40 m^2
Shell : 98.96 m^2
Bottom : 39.77 m^2

Internal Pressure Moment : 0 N-m
Wind Moment : 22,094.36 N-m
Seismic Moment (Ringwall) : 552,412.65 N-m
Seismic Moment (Slab) : 922,958.06 N-m

MISCELLANEOUS ATTACHED ROOF ITEMS
MISCELLANEOUS ATTACHED SHELL ITEMS

Reactions on Foundation Back

Arss = Area of Tank Roof Supported by the Tank Shell (m^2)
Wrss = Weight of Tank Roof Supported by the Tank Shell (kg)
Ws = Weight of the Tank Shell and Shell Appurtenances (kg)
Wss = Roof Structure Weight Supported by The Tank Shell (kg)
yb = Bottom Plate Density (kg/m^3)
yw = Water Density (kg/m^3)

Arss = 0 m^2
Wss = 2,188.16 kg
yb = 7,840 kg/m^3
yw = 1,000 kg/m^3

Wrss = (Wr-pl + Wr-ins + Wr-attachments) + Wss
Wrss = (0 + 0 + 0) + 2,188.1573
Wrss = 2,188.16 kg

Ws = Ws-pl + Ws-ins + Ws-attachments + Ws-framing
Ws = 6,213.8752 + 0.0 + 2,120.1835 + 828.4141
Ws = 9,162.47 kg

Unfactored (Working Stress) Downward Reactions on Foundations

Load Case	Location	Equation	Value	Unit
Dead Load	Shell	(Ws + Wrss) / (pi * D)	5,061.66	N/m
Dead Load	Bottom	tb * yb * 9.806649999999999E-6	0.77	kPa
Internal Pressure	Bottom	P	0.0	kPa
Vacuum	Shell	(Pv * Arss) / (pi * D)	0.0	N/m
Hydrostatic Test	Bottom	Lmax * yw * (9.80665 / 1000)	36.38	kPa
Minimum Roof Live Load	Shell	(Lr * Arss) / (pi * D)	0.0	N/m
Seismic	Shell	((4 * (Mrw / D)) + (0.4 * (Ws + Wrss) * Av)) / (pi * D)	15,125.15	N/m
Seismic	Bottom	(32 * Ms) / (pi * (D^3) * 1000)	27.41	kPa
Snow	Shell	(S * Arss) / (pi * D)	0.0	N/m
Stored Liquid	Bottom	SG * Lmax * yw * (9.80665 / 1000)	40.38	kPa
Pressure Test	Bottom	Pt	0.0	kPa
Wind	Shell	(2 * (Hs^2) * PWS) / (pi * D)	572.8	N/m

- Seismic bottom reaction varies linearly from 32*Ms/(PI*D^3) at the tank shell to zero at the center of the tank

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