طرح نگهداشت و افزایش تولید ۲۷ مخزن

Mechanical Calculation Book For Fire Water Tank (TK-2301A/B)

نگهداشت و افزایش تولید میدان نفتی بینک

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	Mechanical Calculation Book For Fire Water Tank (TK-2301A/B)	

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Design Data:

ITEM		Description	Unit
Tank Tag. No.		TK-2301 A / B	
Site Location		IRAN- Bushehr	
Design code		API Standard 650, 13th Ed	
Service		Fire Water	
Roof Type		Fix Roof Cone Roof Suported by Rafter	
Applicable Annexes		E	
Tank Inside Diameter		13000	mm
Shell height		9500	mm
HLL		8500	mm
LLL		850	mm
Nominal capacity		1,260	m3
Working capacity		1040	m3
Design pressure	Internal	0	Kpa
	External	0	Kpa
Design Liquid Level		ATM+Full of Water+50 H2O	mm
Design temp.		85	C°
M.D.M.T		AMB.	C°
Operation Temp.		AMB.	C°
Specific gravity		1	
Corrosion allowance	Shell	1.6	mm
	Roof	1.6	mm
	Bottom	1.6	mm
Insulation		NO	
Wind velocity		193	Km/h
Design wind velocity		232	Km/h
Wind Exposure		D	
Earthquake motion analysis		API 650An.E&F / ASCE 7-10	
Load code		API 650 / ASCE-7	
Seismic use group		II	
Importance factor		1.25	
Ss		1.125	
S1		0.46	
Fa		1	
Fv		1.33	

Related documents	
Document Title	Document Number
ROOF STRUCTURE CALCULATION FOR FIRE WATER TANKS (TK-2301 A/B)	BK-GCS-IDR-120-ST-CN-0002
VENT CALCULATION FOR FIRE WATER TANKS (TK-2301 A/B)	BK-GCS-IDR-120-NO-CN-0005

Material of Parts:

ITEM	Material	ITEM	Material
Shell	A-283 GR.C	Wind girder/Top angle	A36 or st37-2
Roof(Floating/Fix)	A-283 GR.C	Top Angle	A36 or st37-2
Annular plate/Bottom plate	A-283 GR.C	Anchor Bolt	F1554 Gr.36
Rafter	SA 36	Anchor chair	SA516Gr70
Manhole plate	A-283 GR.C	Internal pipes/Fitting	SA106B/A-234 Gr.WPB
Nozzle neck pipe	A-106 GR.B	Int., bolt/nut	SA193B7/194 H- Galv.
Nozzle neck plate	A-283 GR.C	Ext. bolt/nut	SA193B7/194 H
Pipe Flanges/Blind	A-105/A-106 GR.B	Ladder/Stair/supports	A36 or st37-2
Reinforcement Pad	A-283 GR.C	Gasket	Non asbestos
Sump plate	A-283 GR.C		

Shell plate:

Course No.	Material	Yield Stress(Mpa)	Design Stress(Mpa)	Test Stress(Mpa)
#1	A-283 GR.C	205	137	154
#2	A-283 GR.C	205	137	154
#3	A-283 GR.C	205	137	154
#4	A-283 GR.C	205	137	154
#5	A-283 GR.C	205	137	154
#6	A-283 GR.C	205	137	154

Shell Plate Design:

Based on API 650, Shell plates shall be designed for 2 filling condition. One for product and another for hydrostatic test.

Calculation method: One-foot method

$$t_d = \frac{4.9D(H-0.3)G}{S_d} + CA$$

$$t_t = \frac{4.9D(H-0.3)}{S_t}$$

D	13	m
G	1	
Sd	137	mpa
St	154	mpa
CA	1.6	mm

Min. thickness based on tank diameter is 5 mm. (API 650- 5.6.1.1)

Nominal Tank Diameter		Nominal Plate Thickness	
(m)	(ft)	(mm)	(in.)
< 15	< 50	5	3/16
15 to < 36	50 to < 120	6	1/4
36 to 60	120 to 200	8	5/16
> 60	> 200	10	3/8

NOTE 4 For diameters less than 15 m (50 ft) but greater than 3.2 m (10.5 ft), the nominal thickness of the lowest shell course shall not be less than 6 mm (1/4 in.).

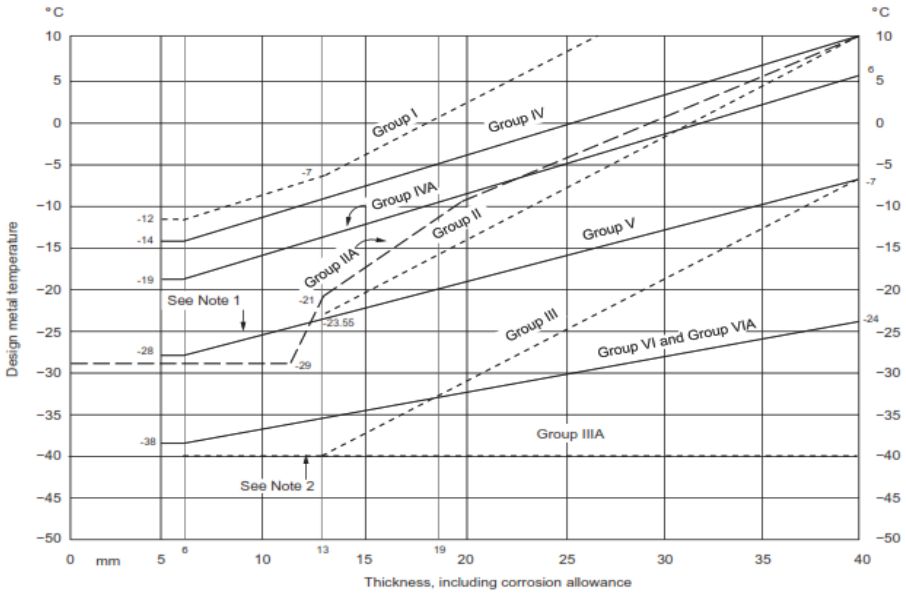
Course	Course width (mm)	Liq. Height for course (m)	Design thk. (td) (mm)	Test thk. (tt) (mm)	D.L.H.Sthk. (tt) (mm)	Selected thk. (mm)	Course weight (Kg)
#1	2000	9.5	5.9	3.8	8	8	5129.6
#2	2000	7.5	4.9	3.0	8	8	5129.6
#3	1500	5.5	4.0	2.2	6	6	2885.4
#4	1500	4.0	3.3	1.5	6	6	2885.4
#5	1500	2.5	2.6	0.9	6	6	2885.4
#6	1000	1.0	1.9	0.3	6	6	1923.6
SUM							20839.0

*Dynamic Liquid Hoop Stress

Total weight (Kg)-Corroded condition: 18755.1

Requirement for Impact Testing

Course	X(mm)	Thk. Range	Material	Material Group	Y(°C)	Required M.D.M.T.(°C)	Requirement for Impact Testing
#1	8	6≤X<13	A-283 GR.C	I	-10.6	5	**Not Requirement**
#2	8	6≤X<14	A-283 GR.C	I	-10.6	5	**Not Requirement**
#3	6	6≤X<15	A-283 GR.C	I	-10.6	5	**Not Requirement**
#4	6	6≤X<16	A-283 GR.C	I	-12.0	5	**Not Requirement**
#5	6	6≤X<17	A-283 GR.C	I	-12.0	5	**Not Requirement**
#6	6	6≤X<18	A-283 GR.C	I	-12.0	5	**Not Requirement**



Bottom plate design:

The Slope of bottom is 1:120

Corrosion allowance: 1.6 mm

The min required thickness for carbon steel is: 6 + 1.6 = 7.6 mm

Selected

The selected thickness is 8 mm → Outside Diameter of Bottom Plate: 13066.8 mm → 13100 mm

Annular plate design:

Based on API 650, considering annular plate is not required. Also based on Bob long, the recommended diameter for considering annular plate is 12.5 m. But for proper shell settlement and good stability of tank, the annular plate will be considered.

Min. required thickness: (API 650, table 5.1.a)

Plate Thickness[a] of First Shell Course (mm)	Stress[b] in First Shell Course (MPa)			
	≤ 190	≤ 210	≤ 220	≤ 250
$t \le 19$	6	6	7	9
$19 < t \le 25$	6	7	10	11
$25 < t \le 32$	6	9	12	14
$32 < t \le 40$	8	11	14	17
$40 < t \le 45$	9	13	16	19

Product Stress = $((t_d - CA)/$ corroded $t\,)\,(S_d)$

Hydrostatic Test Stress = $(t_t$ / nominal $t\,)\,(S_t)$

td	CA	Ct	tt	nt
5.88	1.6	6.4	3.81	8

Product stress= 91.57 Mpa

Hydrostatic test stress= 73.26 Mpa

Stress in first shell course is greater of product and hydrostatic stress. So 61 is used for above table.

First shell course: 8 mm

Annular plate thickness From table: 6 + 1.6 = 7.6 mm

Selected annular thickness: 8 mm

Min. required annular plate width:

Min. Width= Max. (L, 600 mm) + tc1+ 50mm

t_{cl}= 8 mm

$$L = 2\, t_b \sqrt{\frac{F_y}{2\Upsilon G H}}$$

Fv= 205 Mpa
tb= 8 mm
G= 1
H= 9.5 m
γ= 0.01

L= 531 mm

Max,(L,600)= **600** **mm**

Min. Width of annular = 600 + 8 + 50 = 658 mm

Bottom plate weight (including annular)	11346.8	kg
Total weight (Kg)-Corroded condition:	10212.1	kg

Fix Roof design:

Type Roof: Cone Roof Suported by Rafter

5.10.1.a:

A supported cone roof is a roof formed to approximately the surface of a right cone that is supported principally either by rafters on girders and columns or by rafters on trusses with or without columns.

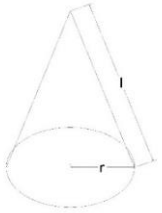
5.10.2.2

Roof Plate Thickness: Roof plates shall have a nominal thickness of not less than 5 mm (3/16 in.) or 7-gauge sheet. Increased thickness may be required for supported cone roofs (see 5.10.4.4). Any required corrosion allowance for the plates of self-supporting roofs shall be added to the calculated thickness unless otherwise specified by the Purchaser. Any corrosion allowance for the plates of supported roofs shall be added to the greater of the calculated thickness or the minimum thickness or [5 mm (3/16 in.) or 7-gauge sheet]. For frangible roof tanks, where a corrosion allowance is specified, the design must have frangible characteristics in the nominal (uncorroded) condition.

θ	= Angle of the elements to the horizontal , (Roof Slope) :		1					5.7	(Degree)
			10						
D	= Inside Tank Diameter							13	m
th	= Nominal Calculated Thickness of Roof plates =	5	+	1.6	=	6.6	→	8	mm
Wrp	= Weight of Roof Plates							10397	Kg
Wrcp	= Corroded Weight of Roof Plates							7797.8	Kg
Wraf	= Weight of Rafters & other structure							12000	Kg
Tw	=Total Weight (UnCorroded)							22397	Kg
Roof appurtenances center of graviti=								0.38	m

Note:Calculations related to behaviors will be provided in a separate file format with SAP software.
Roof Structure Calculation Book For Fire Water Storage Tank (TK-2301A/B)

Roof plate weight :	10397	
Structure weight* :	12000	kg
Insulation Weight:	0	
Total weight :	22397	



r=	6.5	m
l=	6.565	m
Roof Plate Thk.=	8	mm
Insulation Thk.=	0	mm

* will be finalized next revision.

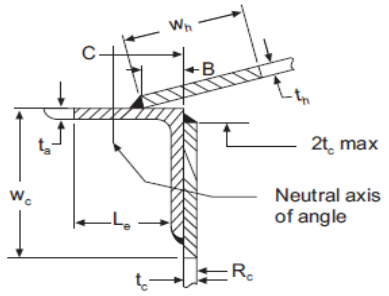
Top Angle:

Min. Required top angle is 80x80x80 (API 650, 5.1.5.9 (e)).

Tank Diameter (*D*)	Minimum Top Angle Size[a] (mm)	Minimum Top Angle Size[a] (in.)
$D \le 11$ m, ($D \le 35$ ft)	$50 \times 50 \times 5$	$2 \times 2 \times 3/16$
11 m < $D \le 18$ m, (35 ft < $D \le 60$ ft)	$50 \times 50 \times 6$	$2 \times 2 \times 1/4$
$D > 18$ m, ($D > 60$ ft)	$75 \times 75 \times 10$	$3 \times 3 \times 3/8$

[a] Approximate equivalent sizes may be used to accommodate local availability of materials.

Selected top angle:	L 80x80x8	
Top angle weight per meter:	9.63	Kg/m
Tank surrounding	40.8	m
Total weight of top angle	393.3	Kg
Top angle section area	1230	mm^2



Detail b

Intermediate wind girder:

H1: unstiffened shell height

$$H_1 = 9.47t\sqrt{\left(\frac{t}{D}\right)^3}\left(\frac{1.72}{P_{wd}}\right)$$

t(mm)	6
D(m)	13
V(km/h)	232
Pwd(kPa)=	2.45
Pwv (kPa)=	2.21
H_1(mm)=	12524.8

H_1 is the maximum height of the unstiffened shell, in meters;

t is the nominal thickness, unless otherwise specified, of the thinnest shell course, in millimeters (see Note 1);

D is the nominal tank diameter, in meters;

P_{wd} is design wind pressure including inward drag = $P_{wv} + 0.24$ in (kPa);

P_{wv} is wind pressure at 10 m above ground per applicable building code considering all applicable factors, such as gust factor, exposure factor, height factor, importance factor, in (kPa), or

P_{wv} is wind pressure = $1.48\left(\frac{V}{190}\right)^2$ in (kPa) where design wind speed (V) is used;

V is the design wind speed (3-sec gust), in km/h [see 5.2.1k)].

Course	W(mm)	t actual cor .(mm)	tu cor.(mm)	Wtr(mm)
#1	2000	6.4	4.4	784
#2	2000	6.4	4.4	784
#3	1500	4.4	4.4	1500
#4	1500	4.4	4.4	1500
#5	1500	4.4	4.4	1500
#6	1000	4.4	4.4	1000
$W_{tr} = W\sqrt{\left(\frac{t_{uniform}}{t_{actual}}\right)^5}$		∑Wtr		7068
According to API650 3.9.7.3				

If the height of the transformed shell is greater than the maximum height H1, an intermediate wind girder is required.

So intermediate wind girder is not required.

Note:Due to the protection of courses above 5 m of the tank during erection against the wind, it is recommended to use a girder connection.

Wind Girder Section: L80x80x8 Location: 3533.8 ±10%

Wind overturning stability:

Wind load has two major effects on the tank. One is lead to buckling of tank which will be restricted by wind girder and another may lead to tank overturning.

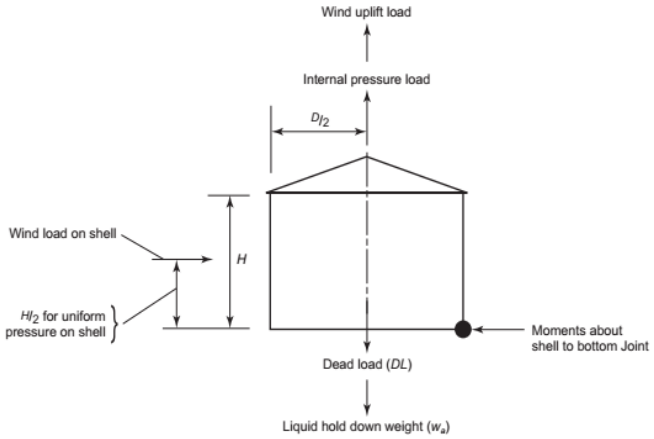


Figure 5.27—Overturning Check for Unanchored Tanks

Unanchored tank shall satisfy all of the following uplift criteria. If following criterial will not satisfy, tank shall be anchored.

1) $0.6M_w + M_{Pi} < M_{DL}/1.5 + M_{DLR}$

2) $M_w + F_p(M_{Pi}) < (M_{DL} + M_F)/2 + M_{DLR}$

3) $M_{ws} + F_p\,(M_{Pi}) < M_{DL}/1.5 + M_{DLR}$

F_P is the pressure combination factor, see 5.2.2;

M_{Pi} is the moment about the shell-to-bottom joint from design internal pressure;

M_w is the overturning moment about the shell-to-bottom joint from horizontal plus vertical wind pressure;

M_{DL} is the moment about the shell-to-bottom joint from the nominal weight of the shell;

M_F is the moment about the shell-to-bottom joint from liquid weight;

M_{DLR} is the moment about the shell-to-bottom joint from the nominal weight of the roof plate plus any attached structural;

M_{WS} is the overturning moment about the shell-to-bottom joint from horizontal wind pressure.

WIND PRESSURE ON TANK SHELL ,
WIND PRESSURE ON TANK ROOF ,
WIND FORCE ON TANK SHELL ,(on ver.projected areas of cyl.surfaces)
WIND FORCE ON TANK ROOF(on hor.projected areas of con.surfaces)

V	H	ID	M_{Pi}	F_P
232	9.5	13	0.00	0.4
KM/H	M	M	N.m	

W_l

wl = 59*(8-1.5)*(203.2*7.5)^0.5=	17735.99396	N/M
wl=140.8*H*D=	17388.8	N/M
Selected=	17388.8	N/M

MF= wl * (πD) * (D/2) = 4616110.48 N/M

Pw1 =	0.89(V/190)^2 =	1.3	N/M2
Pw2 =	1.48(V/190)^2 =	2.1	N/M2
Fw1=	Pw1* (ID*H) =	1754.6	N
Fw2=	Pw2* (ΠD²/4) =	284975.7	N
M1=	8334.519668	N.m	
M2=	1852342.122	N.m	
M_w =	1860676.641	N.m	
Fshear =	286730.3468	N	
Mdl=	shell weight *(ID/2)	1327442.4	N.m
Mdlr=	Roof&attach weight *(ID/2)	1426694.6	N.m

Checking for satisfying the above 3 equilibrium:

1) $0.6M_w + M_{Pi} < M_{DL}/1.5 + M_{DLR}$	→	1,116,406	<	2,311,656	PASS
2) $M_w + F_p(M_{Pi}) < (M_{DL} + M_F)/2 + M_{DLR}$	→	1,860,677	<	4,398,471	PASS
3) $M_{ws} + F_P\,(M_{Pi}) < M_{DL}/1.5 + M_{DLR}$	→	8,335	<	2,311,656	PASS

5.11.2.2 Unanchored tanks with supported cone roofs meeting the requirements of 5.10.4 shall satisfy the following criteria:

$M_{ws} + F_p\,(M_{Pi}) < M_{DL}/1.5 + M_{DLR}$	→	8,335	<	2,311,656	PASS

Seismic Design (APP."E")

Spectral Acceleration Coefficients

Seismic Factors & Parameters(Note1)		
Site Class	D	
I : Importance factor Coeff. Set by seismic use group	1.25	
Rwi : Force reduction factor for the Impulsive mode using Allow stress design method; Table E-4	4	
Rwc : Force reduction factor for the Convective mode using Allow stress design method; Table E-4	2	
Z : Zone Factor	0.3	
TL : Regional-Depend Transition Period, Para. E.4.6.1	4	S
TS : FVS1/FaSS	0.54	S
FV : Velocity Based on Site Coefficient,(as 1s Period) Table E-2	1.33	
Fa : Acceleration based site coefficient, (at 0.2s Period)Table E-1	1	
KS = 0.578 / (Tanh (3.68 H / D))^0.5 ; (Equ. E-4.5.2-c)	0.583	
TC : First sloshing wave period =1.8Ks (D)^ 0.5 (Equ. E-4.5.2-a)	3.8	S
K : Coefficient to adjust spectral acceleration fr	1.5	
Q :Scaling Factor	0.67	
Sp: Design Level Peak Ground Acceleration Parameter for Sites not	0.33	g
S0 : Spectral response acceleration parameter at zero second=Sp	0.33	g
S1 : Spectral response acceleration parameter at one second=1.25xSp	0.46	
Ss : Spectral response acceleration parameter at short period=2.5xSp	1.125	
SDS : Design Spectral response acceleration parameter at short period (2.5*Q*Fa*S0)	0.553	
SD1 : Design Spectral response acceleration parameter at short period	0.47	
D : Tank Inside Diameter	13	m
H:Maximum Design Product Level	8.5	m
G : Liquid Specific Gravity	1	

Table E.1—Value of F_a as a Function of Site Class

Site Class	Mapped Maximum Considered Earthquake Spectral Response Accelerations at Short Periods				
	$S_s \le 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.0$	$S_s \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	a	a	a	a	a

[a] Site-specific geotechnical investigation and dynamic site response analysis is required.

Table E.2—Value of F_v as a Function of Site Class

Site Class	Mapped Maximum Considered Earthquake Spectral Response Accelerations at 1 Sec Periods				
	$S_1 \le 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \ge 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	a	a	a	a	a

[a] Site-specific geotechnical investigation and dynamic site response analysis is required.

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

Table E.5—Importance Factor (*I*) and Seismic Use Group Classification

Seismic Use Group	*I*
I	1.0
II	1.25
III	1.5

Ai :Impulsive Design Response Spectrum Acceleration Coefficient ; per Equ. E.4.6.1-1:

Ai = SDS (I / Rwi) = 2.5 Q Fa So (I / Rwi) => .007

Ac:Convective Design Response Spectrum Acceleration Coefficient ; per Equ. E.4.6.1-4 & E.4.6.1-5:

If Tc ≤ TL: Ac =K SD1 (1 / TC)(I / Rwc) ≤ Ai

If Tc > TL : Ac =K SDI (TL / Tc ²)(I / Rwc) ≤ Ai

Tc ≤ TL.

Av: Vertical earthquake acceleration coefficient. ; Para. E.6.1.3 :Av = 0.47 SDS

		RESULT			
	Ai=	0.17	≥	0.007	
Tc ≤ TL	Ac=	0.12	≤	Ai	YES
Tc > TL	Ac=	0.12	≤	Ai	NO
	Av=	0.26			

Dynamic Liquid Hoop Stress, Para. E.6.1.4

Ni: Impulsive hoop membrane force in tank shell, N/mm
Nc: Convective hoop membrane force in tank shell, N/mm
Nh: Product hydrostatic membrane force, N/mm
Y: distance from liquid surface to analysis point

Course	D/H	Y
#1	1.53	8.50
#2	2.00	6.50
#3	2.89	4.50
#4	4.33	3.00
#5	8.67	1.50
#6	26.00	0.50

$D/H \geq 1.33$: $N_i = 8.48 A_i G D H \left[\frac{Y}{H} - 0.5\left(\frac{Y}{H}\right)^2\right] \tanh\left(0.866 \frac{D}{H}\right)$

When vertical acceleration is specified.

For all proportions of D/H:

In SI units:

$$N_c = \frac{1.85 A_c G D^2 \cosh\left[\frac{3.68(H-Y)}{D}\right]}{\cosh\left[\frac{3.68H}{D}\right]}$$

$$\sigma_T = \sigma_h \pm \sigma_s = \frac{N_h \pm \sqrt{N_i^2 + N_c^2 + (A_v N_h / 2.5)^2}}{t}$$

Nh = 4.9 D (Y - 0.3) G

Course No	Width	tcr	Y	Ni	Nc	Nh	sigma1 (Mpa)	sigma2 (Mpa)	Ratio(E.6.2.4/σT)	
#1	2	6.4	8.5	70.24	6.89	522.34	95.49	67.74	0.52	OK
#2	2	6.4	6.5	66.35	8.03	394.94	73.94	49.48	0.41	OK
#3	1.5	4.4	4.5	54.68	11.80	267.54	74.98	46.63	0.41	OK
#4	1.5	4.4	3	40.83	17.07	171.99	49.93	28.25	0.274	OK
#5	1.5	4.4	1.5	22.60	25.47	76.44	25.32	9.43	0.14	OK
#6	1	4.4	0.5	8.02	33.53	12.74	10.74	-4.95	0.06	OK
MAX, σT =							95			

E.6.2.4: The max. allowable hoop tension membrane stress = Min. (1.33 Sd , 0.9 Fy * E) = 182

E : Weld J.E. = 1

Fy= 205 Mpa min=(182 185)

Sd= 137 Mpa

Total Combined Hoop Stress in Shell < Max. Allow. Hoop Stress → **OK**

Effective Weight of Product-Para E.6.1.1

WS : TOTAL WEIGHT OF TANK SHELL AND APPURTENANCES (+10% for accessories) 224644.091 N

Wr :TOTAL WEIGHT OF FIXED TANK ROOF INCLUDING FRAMING, 219491.47 N

Wf : WEIGHT OF THE TANK BOTTOM 111198.825 N

Wp : TOTAL WEIGHT OF TANK CONTENT BASED ON PRODUCT SPECIFIC GRAVITY 11146528.9 N

Wi : EFFECTIVE IMPULSIVE WEIGHT OF THE LIQUID E.6.1.1-1

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:

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

E.6.1.1-1		Yes
Wi=	7304032.794	N

E.6.1.1-2		No
Wi=	7430145.051	N

WC : EFFECTIVE CONVECTIVE (SLOSHING) PORTION OF THE LIQUID WEIGHT, Equ. E-6.1.1-3 :

Wc = 0.230 D/H Tanh(3.67 H / D)*Wp = 3856896.46 N

Center of Action for Effective Lateral Forces E.6.1.2

Xr :Height from the bottom of the tank shell to the roof and roof appurtenances center of gravity 9.5 m

Xs : HEIGHT FROM BOTTOM OF THE TANK TO SHELL CENTER OF GRAVITY 4.66 m

NO.Course	thk(mm)	W(m)	Xi(m)	Wi(kg)	Wi.Xi(Kg.m)
#1	8	2	1	5129.6	5129.6
#2	8	2	3	5129.6	15388.8
#3	6	1.5	4.75	2885.4	13705.6
#4	6	1.5	6.25	2885.4	18033.7
#5	6	1.5	7.75	2885.4	22361.8
#6	6	1	7	1923.6	13465.2
Sum:		9.5	29.75	18915.4	88084.7

center of gravity(m) $Xs=\sum(Xi.Wi)/\sum Wi$ 4.7 m

Xis ::Height from the bottom of the tank shell to the center of action of the lateral seismic force related to the impulsive liquid force for slab moment

E.6.1.2.2-1

When D/H is greater than or equal to 1.3333, the height Xis is determined by Equation E.6.1.2.2-1:

$$X_{is} = 0.375\left[1.0 + 1.333\left(\frac{0.866\frac{D}{H}}{\tanh\left(0.866\frac{D}{H}\right)} - 1.0\right)\right]H$$

When D/H is less than 1.3333, the height Xis is determined by Equation E.6.1.2.2-2:

$$X_{is} = \left[0.500 + 0.060\frac{D}{H}\right]H$$

E.6.1.2.2-1	Yes

Xis= 5.42 m

E.6.1.2.2-2	No

Xis= 5.03 m

Xcs ::Height from the bottom of the tank shell to the center of action of the lateral seismic force related to the Convective liquid force ***for slab moment*** . E.6.1.2.2-3:

$$X_{cs} = \left[1.0 - \frac{\cosh\left(\frac{3.67H}{D}\right) - 1.937}{\frac{3.67H}{D}\sinh\left(\frac{3.67H}{D}\right)}\right]H \quad \rightarrow \quad 6.2 \text{ m}$$

Xi : Height from the bottom of the tank shell to the center of action of the lateral seismic force related to the impulsive liquid force ***for ringwall moment***

If D/H ≥ 1.3333 : $X_i = 0.375\ H$

If D/H < 1.3333 : $X_i = (0.5 - 0.094\frac{D}{H})H$

(E.6.1.2.1-1)	Yes
Xi= 3.1875 m	

(E.6.1.2.1-2)	No
Xi= 3.0 m	

Xc : Height from the bottom of the tank shell to the center of action of the lateral seismicforce related to the convective liquid force for ringwall moment

$$X_c = \left\{1 - \frac{\cosh(3.67\frac{H}{D}) - 1}{3.67\frac{H}{D}\sinh(3.67\frac{H}{D})}\right\}H \quad 5.5 \text{ m}$$

Design Load; para E.6.1 :

V = Total Design Base Shear : (Vi ² + Vc²)^0.5 = 1,430,022.78 N

Vi = Design Base shear due to impulsive force = Ai (Ws + Wr + Wf + Wi) = 1357582.878 N

Vc = Design Base shear due to Convective force = Ac Wc = 449370.546 N

Seismic overturning moments

Ring wall Seismic moment:

$$M_{rw} = \sqrt{[A_i(W_iX_i + W_sX_s + W_rX_r)]^2 + [A_c(W_cX_c)]^2}$$

M_{rw}= 5,198,984.1 N.M

Slab Seismic moment:

$$M_s = \sqrt{[A_i(W_iX_{is} + W_sX_s + W_rX_r)]^2 + [A_c(W_cX_{cs})]^2}$$

M_S= 7,883,620.1 N.M

Checking the self-anchored Tank, Para E.6.2.1.1:

Wa = Resisting force of tank contents per unit length of shell circumference that may be used to resist the shell overturning moment, N/m

$w_a = 99 t_a \sqrt{F_y H G_e} \le 201.1\ HDG_e$ — No

Wa = 99 ta (Fy * Ge * H)^0.5 = 25046.9 N/M →

Wa>201.1G_eHD → $w_a = 5742\ HG_eL_s$ = 65656.6 — Yes

201.1Ge H D= 19928.7

Fy:Minimum specified yield strength of bottom annulus, Mpa = 205 Mpa

Ge:Effective specific gravity including vertical seismic effects=G(1 – 0.4Av)= 0.90

ta:Thickness of the bottom plate under the shell extending at least the distance, L,from the inside of the shell,less corrosion allowance, mm 6.4 mm

$$J = \frac{M_{rw}}{D^2[w_t(1-0.4A_v)+w_a-F_p w_{int}]}$$ → 2.90 > 0.785

Wt :Tank and roof weight acting at base of shell, N/m → $w_t = \left[\frac{W_s}{\pi D} + w_{rs}\right]$ 11412.3

Wrs: Roof load acting on the shell, including the specified snow load N/m = 5911.8

wint: Calculated design uplift load due to product pressure per unit circumferential length, N/m 0

Table E.6—Anchorage Ratio Criteria

Anchorage Ratio *J*	Criteria
$J \le 0.785$	No calculated uplift under the design seismic overturning moment. The tank is self-anchored.
$0.785 < J \le 1.54$	Tank is uplifting, but the tank is stable for the design load providing the shell compression requirements are satisfied. Tank is self-anchored.
$J > 1.54$	Tank is not stable and cannot be self-anchored for the design load. Modify the annular ring if $L < 0.035D$ is not controlling or add mechanical anchorage.

RESULT:

Tank is not stable and cannot be self-anchored for the design load.Modify the annular ring if L<0.0035 D is not controlling or add mechanical anchorage.

Shell Compression in Mechanically-Anchored Tanks E.6.2.2.2

Shell Compression in Mechanically-Anchored Tanks(Para.E.6.2.2.2)

E.6.2.2.2 Shell Compression in Mechanically-Anchored Tanks

The maximum longitudinal shell compression stress at the bottom of the shell for mechanically-anchored tanks shall be determined by the formula:

$$\sigma_c = \left(w_t(1+0.4A_v) + \frac{1.273M_{rw}}{D^2}\right)\frac{1}{1000t_s}$$

t	Thickness of Bottom Shell Course	8	mm
C.A.	Corrosion Allowance of Bottom Shell Course	1.6	mm
ts	Corroded Thickness of Bottom Shell Course	6.4	mm
σc	Max. Shell Compression Stress at the bottom of the shell	8.1	

No	Yes
When GHD^2/t^2 is ≥ 44 (SI units) (10^6 USC units), In SI units: $F_C = 83\ t_s/D$	When GHD^2/t^2 is < 44: $F_C = 83t_s/(2.5D) + 7.5\sqrt{(GH)} < 0.5F_{ty}$

GHD^2/t^2= 22.45
0.5Fty = 102.5

Fc	Allowable longitudinal shell membrane compression stress in tank shell	38.2	
Fty	Minimum specified yield strength of shell course, Mpa	205	Mpa

RESULT:

Fc < 0.5Fty	ok
σc < Fc	ok

SLIDING RESISTANCE (Para.E.7.6)

Self-anchored storage tanks shall be proportioned such that the calculated seismic base shear, V, does not exceed Vs:

$$V_s = \mu(W_s + W_r + W_f + W_p)(1.0 - 0.4A_v)$$

μ=Friction coefficient for tank sliding (Max. = 0.4)= 0.4

Vs=Max. seismic base shear Force= 4,197,786.02

RESULT:

Vs > V so Tank is stable against Seismic Sliding

LOCAL SHEAR TRANSFER (ParaE.7.7)

Vmax=Peak local tangential shear per unit length $V_{max} = \frac{2V}{\pi D}$ = 70029.3 N/M

σv=Peak local tangential shear Stress = Vmax/(t-C.A.) 10.94 Mpa

RESULT:

Since Shear Stress is Less than Shear Allowable Stress, So Local Shear Transfer is ok

FREEBOARD CHECKING (Para. E.7.2):

Note: E.4.6.1 Spectral Acceleration Coefficients
For tanks falling in SUG III, the mapped value of TL shall be used to determine both convective forces and sloshing wave height except that the importance factor, I, shall be set equal to 1.0 in the determination of sloshing wave height. In regions outside the USA, where the regulatory requirements for determining design ground motion differ from the ASCE 7 methods prescribed in this Annex, TL shall be taken as 4 seconds.

Height of the sloshing wave above the product design height will calculate by following equation:

δs = 0.42 D Af= 0.65 m

For SUG III

- **E.4.6.1 Spectral Acceleration Coefficients**

When probabilistic or mapped design methods are utilized, the spectral acceleration parameters for the design response spectrum are given in Equations E.4.6.1-1 through E.4.6.1-5. Unless otherwise specified by the Purchaser, T_L shall be taken as the mapped value found in ASCE 7. For tanks falling in SUG I or SUG II, the mapped value of T_L shall be used to determine convective forces except that a value of T_L equal to 4 seconds shall be permitted to be used to determine the sloshing wave height. For tanks falling in SUG III, the mapped value of T_L shall be used to determine both convective forces and sloshing wave height except that the importance factor, I, shall be set equal to 1.0 in the determination of sloshing wave height. In regions outside the USA, where the regulatory requirements for determining design ground motion differ from the ASCE 7 methods prescribed in this Annex, T_L shall be taken as 4 seconds.

I : Importance factor Coeff. Set by seismic use group= 1

$\delta_s = 0.42\,DA_f$ (see Note c in Table E.7) (E.7.2-1)

For SUG I and II,

When, $T_C \le 4$ $A_f = KS_{D1}I\left(\frac{1}{T_C}\right) = 2.5KQF_aS_0I\left(\frac{T_S}{T_C}\right)$ (E.7.2-2)

When, $T_C > 4$ $A_f = KS_{D1}I\left(\frac{4}{T_C^2}\right) = 2.5KQF_aS_0I\left(\frac{4T_S}{T_C^2}\right)$ (E.7.2-3)

For SUG III,

When, $T_C \le T_L$ $A_f = KS_{D1}\left(\frac{1}{T_C}\right) = 2.5KQF_aS_0\left(\frac{T_S}{T_C}\right)$ (E.7.2-4)

When, $T_C > T_L$ $A_f = KS_{D1}\left(\frac{T_L}{T_C^2}\right) = 2.5KQF_aS_0\left(\frac{T_ST_L}{T_C^2}\right)$ (E.7.2-5)

Tc= **3.8** → E.4.5.2-a $Tc = 1.8Ks\,D^{0.5}$

When, TC ≤ 4 Af= 0.12 → Yes
When, TC > 4 Af= 0.16 → No

Table E.7—Minimum Required Freeboard

Value of S_{DS}	SUG I	SUG II	SUG III
$S_{DS} < 0.33g$	(a)	(a)	δ_s (c)
$S_{DS} \ge 0.33g$	(a)	$0.7\delta_s$ (b)	δ_s (c)

a. A freeboard of $0.7\delta_s$ is recommended for economic considerations but not required.
b. A freeboard equal to $0.7\delta_s$ is required unless one of the following alternatives are provided.
1. Secondary containment is provided to control the product spill.
2. The roof and tank shell are designed to contain the sloshing liquid.
c. Freeboard equal to the calculated wave height, δ_s, is required unless one of the following alternatives are provided.
1. Secondary containment is provided to control the product spill.
2. The roof and tank shell are designed to contain the sloshing liquid.

S_{DS}= 0.55 g ≥ 0.33 g → 0.7 δs → 0.46 m

HLL = 8.5 m
depth of Submersion = 0 m → 1 m →
Shell height = 9.5 m

SO FREEBOARD REQUIREMENT HAS BEENSATISFIED

Anchor Bolt Sizing

Table 5.21a—Uplift Loads (SI)

Uplift Load Case	Net Uplift Formula, U (N)	Allowable Anchor Bolt or Anchor Strap Stress (MPa)	Allowable Shell Stress at Anchor Attachment (MPa)
Design Pressure	$[(P_i - 0.08t_h) \times D^2 \times 785] - W_1$	$^5/_{12} \times F_y$	$^2/_3 F_{ty}$
Test Pressure	$[(P_t - 0.08t_h) \times D^2 \times 785] - W_1$	$^5/_9 \times F_y$	$^5/_6 F_{ty}$
Failure Pressure[a]	$[(1.5 \times P_f - 0.08t_h) \times D^2 \times 785] - W_3$	F_y	F_{ty}
Wind Load	$P_{WR} \times D^2 \times 785 + [4 \times M_{WH}/D] - W_2$	$0.8 \times F_y$	$^5/_6 F_{ty}$
Seismic Load	$[4 \times M_{rw}/D] - W_2 (1 - 0.4A_V)$	$0.8 \times F_y$	$^5/_6 F_{ty}$
Design Pressure[b] + Wind	$[(F_p P_i + P_{WR} - 0.08t_h) \times D^2 \times 785] + [4 M_{WH}/D] - W_1$	$^5/_9 \times F_y$	$^5/_6 F_{ty}$
Design Pressure[b] + Seismic	$[(F_p P_i - 0.08t_h) \times D^2 \times 785] + [4 M_{rw}/D] - W_1 (1 - 0.4A_V)$	$0.8 \times F_y$	$^5/_6 F_{ty}$
Frangibility Pressure[c]	$[(3 \times P_f - 0.08t_h) \times D^2 \times 785] - W_3$	F_y	F_{ty}

where

A_v is the vertical earthquake acceleration coefficient, in % g;

D is the tank diameter, in meters;

F_p is the pressure combination factor;

F_{ty} is the minimum yield strength of the bottom shell course, in MPa;

F_y is the minimum yield strength of the anchor bolt or strap; bolts are limited to specified material minimum yield strength or 380 MPa, whichever is less, in MPa; anchor strap material minimum yield strength shall not exceed the minimum yield strength of the shell;

H is the tank height, in meters;

M_{WH} equals $P_{WS} \times D \times H^2/_2$, in N-m;

M_{rw} is the seismic moment, in N-m (see Annex E);

P_i is the design pressure, in kPa (see Annex F);

P_f is the failure pressure, in kPa (see Annex F);

P_t is the test pressure, in kPa (see Annex F);

P_{WR} is the wind uplift pressure on roof, in kPa;

P_{WS} is the wind pressure on shell, in N/m^2;

t_h is the roof plate thickness (the corroded thickness when used with W_1 and nominal thickness when used with W_3), in millimeters;

W_1 is the dead load of shell minus any corrosion allowance and any dead load other than roof plate acting on the shell minus any corrosion allowance, in N;

W_2 is the dead load of shell minus any corrosion allowance and any dead load including roof plate acting on the shell minus any corrosion allowance, in N;

W_3 is the dead load of the shell using nominal thicknesses and any dead load other than roof plate acting on the shell using nominal thicknesses, in N.

Failure pressure applies to tanks falling under F.1.3 only. The failure pressure shall be calculated using nominal thicknesses.

Refer to 5.2.2 concerning the pressure combination factor applied to the design pressure.

Frangibility pressure applies only to tanks designed to 5.10.2.6 d. The frangibility pressure shall be calculated using nominal thicknesses.

Min. qty. of bolts = 3.1415*D/2=	15.71				
Considered qty. of bolts =	16		Bolt Center Diameter=	13200 mm	
Outside Diameter of Bottom plate:	13100	→	Anchore Bolt will Not clash with Bottom Plate	→	Pass
Inside Diameter of Anchore Bolt:	13173				
Circumferential distance between bolts =		2.55	OK		

Anchor bolt material : F1554 Gr.36

Uplift Load Case	U(N)	tb = U/N	Sall=Allowable Anchor Bolt Stress (Mpa)	Sb=tb/Ab (Mpa)	Ab-anchor Bolt Area (mm2)	Bolt Size (Request)
Design Pressure	-714930.50	-44683.16	103.33	136.67	Not Required	-
Test Pressure	-843598.06	-52724.88	137.78	170.83	Not Required	-
Failure Pressure	-444982.64	-27811.41	248.00	205.00	Not Required	-
Frangibility Press.	-637983.98	-39874.00	248.00	205.00	Not Required	-
Wind Load	-666654.82	-41665.93	198.40	170.83	Not Required	-
Seismic Load	1001355.04	62584.69	198.40	170.83	Required	315.45
Pdesign+Wind	-714414.22	-44650.89	137.78	170.83	Not Required	-
Pdesign+seismic	1051422.79	65713.92	198.40	170.83	Required	331.22
required anchor boltdiameter						331.22

Av = vertical earthquake acceleration coefficient,%g	0.26
PWR = Wind uplift pressure on roof in (Kpa)	0.00
PWS = wind pressure on shell in (N/m2)	1.28
D= Tank diameter in (m)	13.00
H = tank height, in meters;	9.50
P= design pressure in (Kpa)	0.00
Pf = failure pressure in (KPa) = 1.6 P --((0.000746DLR)/D²)th [ACC. tO F.6.]	-0.97
DLR is the nominal weight of roof plate plus any attached structural, in N.	219715.44
th = roof plate thickness (mm) =	8.00
Mw = wind moment in (N-m) =	1860676.64
MWH = PWS × D × H²/2 (N-m)	752.19
Mrw = seismic moment in (N-m) =	5198984.13
W1 = dead load of shell minus any corrosion allowance and any dead load other than roof plate acting on the shell minus any corrosion allowance (N) = Shell(Cr.) + Shell attachements(Cr.) =	525824.32
W2 = dead load of shell minus any corrosion allowance and any dead load including roof plate acting on the shell minus any corrosion allowance (N) = W1 + Roof(Cr.) =	667171.10
W3 = dead load of the shell using as built thicknesses and any dead load other than roof plate acting on the shell using as built thicknesses (N). =	204221.90
N= Number of bolt using in the calculation	16.00
Fy=	248.00
Fty=	205.00

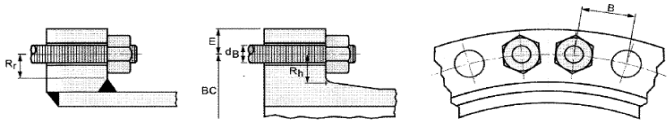
According to API 650 3.12.5

The minimum anchor bolt
diameter is 1" plus any specified corrosion allowance

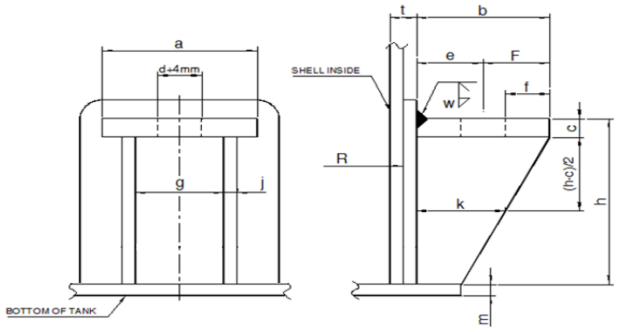
anchor bolt diameter=	M 27 → 414 mm^2	Yes

TABLE D-5M
METRIC BOLTING DATA – RECOMMENDED MINIMUM
(dimensions in millimeters unless noted)

Bolt Size dB	Threads		Nut Dimensions		Bolt Spacing B	Radial Distance Rh	Radial Distance Rr	Edge Distance E	Wrench Diameter a	Bolt Size dB
	Pitch	Root Area (mm^2)	Across Flats	Across Corners						
M12	1.75	72.396	21.00	24.25	31.60	20.64	15.40	15.40	38.00	M12
M14	2.00	99.773	24.00	27.71	35.60	22.36	16.90	16.90	42.50	M14
M16	2.00	138.324	27.00	31.18	39.70	24.10	19.50	19.50	47.00	M16
M18	2.50	167.968	30.00	34.64	43.70	26.25	21.50	21.00	51.50	M18
M20	2.50	217.051	34.00	39.26	46.80	28.20	23.00	22.50	53.00	M20
M22	2.50	272.419	36.00	41.57	51.50	30.50	26.50	26.00	60.00	M22
M24	3.00	312.748	41.00	47.34	57.50	33.50	29.50	29.00	66.00	M24
M27	3.00	413.852	46.00	53.12	65.00	38.00	31.00	30.50	75.00	M27
M30	3.50	502.965	50.00	57.74	69.90	40.50	33.00	32.50	80.00	M30
M33	3.50	630.218	55.00	63.25	76.50	44.25	36.00	35.50	87.50	M33
M36	4.00	738.015	60.00	69.28	82.60	47.25	38.00	37.50	93.50	M36
M39	4.00	889.535	65.00	74.75	89.20	51.00	42.00	41.50	101.00	M39
M42	4.50	1018.218	70.00	80.83	96.60	55.25	45.00	44.00	109.50	M42
M45	4.50	1194.958	75.00	86.25	101.90	57.75	47.50	46.50	114.50	M45
M48	5.00	1342.959	80.00	92.38	109.30	62.00	51.00	50.00	123.00	M48
M52	5.00	1616.336	85.00	97.75	115.00	65.00	56.00	54.00	129.00	M52
M56	5.50	1862.725	90.00	103.92	124.70	71.50	58.50	56.50	142.00	M56
M64	6.00	2467.150	100.00	115.47	135.70	76.50	64.00	61.50	152.00	M64
M72	6.00	3221.775	110.00	127.02	151.70	86.50	71.00	66.50	172.00	M72
M80	6.00	4076.831	120.00	138.56	162.60	91.50	78.50	74.00	182.00	M80
M90	6.00	5287.085	135.00	155.88	181.50	101.50	88.50	84.00	202.00	M90
M100	6.00	6651.528	150.00	173.21	202.50	113.50	93.50	90.50	226.00	M100



Anchor chair part calculation



Diameter of tank	D=	13	m		
Top Plate Width along shell	a=	300	mm	11.8	Inch
Bolt Circle diameter	B.C.D.=	13200	mm	519.7	Inch
Pad Palte Thickness	t_{Pad}=	20	mm	0.8	Inch
Shell Plate thickness	t_{shell}=	8	mm	0.3	Inch
Number of anchor bolts	n_{Bolt}=	16			
Anchor bolt diameter	d=	27	mm	1.1	Inch
Hole diameter	d_{hole}=	31	mm	1.2	Inch
Anchor bolt eccentricity	e=	72	mm	2.8	Inch
Distance from outside of top plate to centerline of bolt(min. 1.5*hole diameter)	F=	90	mm	3.5	Inch
Distance from outside of top plate to edge of hole	f=	74.5	mm	2.9	Inch
Top Plate length in raidial direction(min 3*hole diameter)	b=	162	mm	6.4	Inch
Distance between vertical plates	g=	160	mm	6.3	Inch
Chair height(minimum 6")	h=	360	mm	14.2	Inch
Vertical Palates(gusset) thickness	j=	15	mm	0.6	Inch
Gusset lowest width	L Gusset=	33	mm	1.3	Inch
Vertical plates width(average width for tapered plates)	k=	96.4	mm	3.8	Inch
Bottom plate thickness (Corroded)	m=	6.4	mm	0.3	Inch
Nominal Shell Radius	R=	6500	mm	255.9	Inch
Minimum yield stength of chair parts	S_y=	260	Mpa	38.0	ksi
Shell thickness(Corroded) also including the pad thickness	t=	26.4	mm	1.0	Inch
Ringwall moment	M_{rw}=	5198984	N.m		

Calculated design uplift load on anchors per unit circumferential length	W_a=	65714	N/m		
Actual bolt load	P_a=	167738	N	37.71	kip
Yield strenth of anchor bolt (A 36)	Fy=	248	Mpa	36.29	ksi
Deign load will be the lesser of bellow items:					
1- 3 thime of PA,B	P_1=	503213.057	Mpa	113.12	kip
Cross section area of bolt*yiled strenth of Anchol bolt	A_s=	414	mm^2	0.64	$inch^2$
Cross Section Area of Bolt	S_{d1}=	148.80	Mpa	21.58	ksi
Allowance design Stress for anchor chair parts	S_{d2}=	156.00	Mpa	22.62	ksi
	P2=	102672.00	N	23.29	kip
Desing load	P=	102672.00	N	23.29	kip
Reduction factor= $Z = \frac{1}{\frac{0.177 * a * m}{\sqrt{R * t}}(\frac{m}{t})^2 + 1}$	Z=	0.95			
Stress at point= $S = \frac{P * e}{t^2}\left[\frac{1.32 * Z}{\frac{1.43 * a * h^2}{R * t} + (4 * a * h^2)^{0.333}} + \frac{0.031}{\sqrt{R * t}}\right]$	S=	16.35	ksi		
	Sd=	22.62	ksi		

So stress is smaller than Allowance desing for anchor chair → Ok

Minimum chair height h = 6 in (152.4 mm) , except h = 12 in (304.8 mm) when base plate or bottom plate is 3/8 in (9.525 mm) or thinner and where earthquake or winds over 100 mph (160 km/h) must be considered.

Verification of Chair Height:	h=	360	mm	→ Ok	
Verification of Top Plate Thickness:					
Thickness of top plate $C = \sqrt{\frac{P}{S * f}[(0.375 * g) - (0.22 * d)]}$	C=	21.95	mm	0.86	Inch
	C=	25	mm	0.98	Inch
Verification of Gusset Thickness:					
jmin = Max (1/2 in , 0.04 (h - c))	j1=	12.70	mm	0.50	Inch
	j2=	13.40	mm	0.53	Inch
	j=	35.00	mm	1.38	Inch

Should be: j > P / (25*k) → Ok

WELD SIZE CHECKING:

Load per horizontal line	WH =	38.02	N/mm	0.22	kip/Inch
Load per vertical line	WV =	100.66	N/mm	0.58	kip/Inch
Total load per line	W=	107.60	N/mm	0.62	kip/Inch
Should be: w >= W / 9.6	W / 9.6=	11.21	mm	0.06	Inch
		10	mm	0.39	Inch

Fabrication Data		
Item	**Thickness(mm)**	**weight (Kg)**
Shell#1	8	5129.6
Shell#2	8	5129.6
Shell#3	6	2885.4
Shell#4	6	2885.4
Shell#5	6	2885.4
Shell#6	6	1923.6
Bottom plate weight (including annular)	8	11346.8
Fix Roof Plate(Including Structure)	8	22397.1
Top Angle	L 80x80x8	393
Intermediate wind girder	0	224.9
Nozzles	estimate	2500
Spiral Stair way	estimate	2598
Unseen(3% of total weight)	estimate	1809
Empty	Weight(kg)	62108.1
Hydrotest		1322108
Operating		1102108

Foundation Load Data			
Seismic	Shear(N)		1,430,022.8
	Moment (N.m)	Ring Wall	5,198,984.1
		Slab	7,883,620.1
Wind	Shear(N)		286,730.3
	Moment (N.m)		1,860,676.6