طرح نگهداشت و افزایش تولید 27 مخزن

Mechanical Calculation Book For Lean Glycol Storage Tank (TK-2102)

نگهداشت و افزایش تولید میدان نفتی بینک

V00	Nov.2024	IFI	iDrill M.E.	M.Fakharian	M.Sadeghian	
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Design Data:

ITEM		Description	Unit
Tank Tag. No.		TK-2102	
Site Location		IRAN- Bushehr	
Design code		API Standard 650, 13th Ed & IPS-G-ME-100	
Service		Lean Glycol Storage Tank	
Roof Type		Fix Roof Cone Roof & Self Suported	
Applicable Annexes		A,F,V	
Tank Inside Diameter		4000	mm
Shell height		5000	mm
HLL		4500	mm
LLL		600	mm
Nominal capacity		62	m3
Working capacity		44	m3
Design pressure	Internal	16	kpa
	External	0.7	kpa
Design Liquid Level		Full of Liquid +160 mbarg	mm
Design temp.		85	C°
M.D.M.T		AMB.	C°
Operation Temp.		AMB.	C°
Specific gravity		1.1	
Corrosion allowance	Shell	3.2	mm
	Roof	1.6	mm
	Bottom	3.2	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**
VENT CALCULATION FOR LEAN GLYCOL STORAGE TANK (TK-2102)	BK-GCS-IDR-120-NO-CN-0003

Material of Parts:

ITEM	Material	ITEM	Material
Shell	SA283-C	Wind girder/Top angle	A36 or st37-2
Roof	SA283-C	Top Angle	A36 or st37-2
Bottom plate	SA283-C	Anchor Bolt	F1554 Gr.36
Rafter	-	Anchor chair	SA283-C
Manhole plate	SA283-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	SA283-C	Ext. bolt/nut	SA193B7/194 H
Pipe Flanges/Blind	A-105/SA283-C	Ladder/Stair/supports	A36 or st37-2
Reinforcement Pad	SA283-C	Gasket	Non asbestos
Sump plate	SA283-C		

Shell plate:

Course No.	Material	Yield Stress(Mpa)	Design Stress(Mpa)	Test Stress(Mpa)
#1	SA283-C	205	137	154
#2	SA283-C	205	137	154
#3	SA283-C	205	137	154
#4	SA283-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.

Design pressure is Full of Liquid +160 mbarg So 1631 (H_2O)mm there is effect by pressure on the shell

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	4	m
G	1.1	
Sd	137	mpa
St	154	mpa
CA	3.2	mm

Max. thickness for SA283-C is 25mm.

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

Nominal Tank Diameter	
(m)	(ft)
< 15	< 50
15 to < 36	50 to < 120
36 to 60	120 to 200
> 60	> 200

Nominal Plate Thickness	
(mm)	(in.)
5	3/16
6	1/4
8	5/16
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	1500	6.6	4.2	0.8	6	6	887.8
#2	1500	5.1	4.0	0.6	6	6	887.8
#3	1500	3.6	3.7	0.4	6	6	887.8
#4	500	2.1	3.5	0.2	3.2	6	295.9
SUM							2959.4

*Dynamic Liquid Hoop Stress	Total weight (Kg)-Corroded condition	2515.5

V.8.1.1 For an unstiffened tank shell subjected to external pressure sufficient to cause buckling, buckling will occur elastically if the following criterion (see note below) is satisfied. Note that this criterion will typically be satisfied except for very small, exceptionally thick tanks. If this criterion is not satisfied, external pressure effects should be evaluated in accordance with the requirements of the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1.

V.8.1.1 → 0.025 > 0.00675

PASS

NOTE 1 Source is The Structural Research Council (SSRC) text, "Guide to Stability Design Criteria for Metal Structures," Section 14.3.5.

In SI units:

$$\left(\frac{D}{t_{s\min}}\right)^{0.75}\left[\left(\frac{H_{TS}}{D}\right)\left(\frac{F_y}{E}\right)^{0.5}\right] \geq 0.00675$$

V.8.1.2 The total design external pressure for the shell (P_s, using the appropriate ψ from V.8.1) and the specified design external pressure (P_e, using ψ = 3.0) shall not exceed for an unstiffened tank:

In SI units:

$$P_s \text{ or } P_e \leq \frac{E}{15{,}203\,\psi\left(\frac{H_{TS}}{D}\right)\left(\frac{D}{t_{s\min}}\right)^{2.5}}$$

E= 190000 Mpa

D= 4 m

H_{TS}= 5 m Transformed height of tank.

ψ= 3

Ps or Pe= 9.2

V.8.1.3 The equation in V.8.1.2 can be rewritten to calculate the nominal thickness of the thinnest shell course required for a specified design external pressure as:

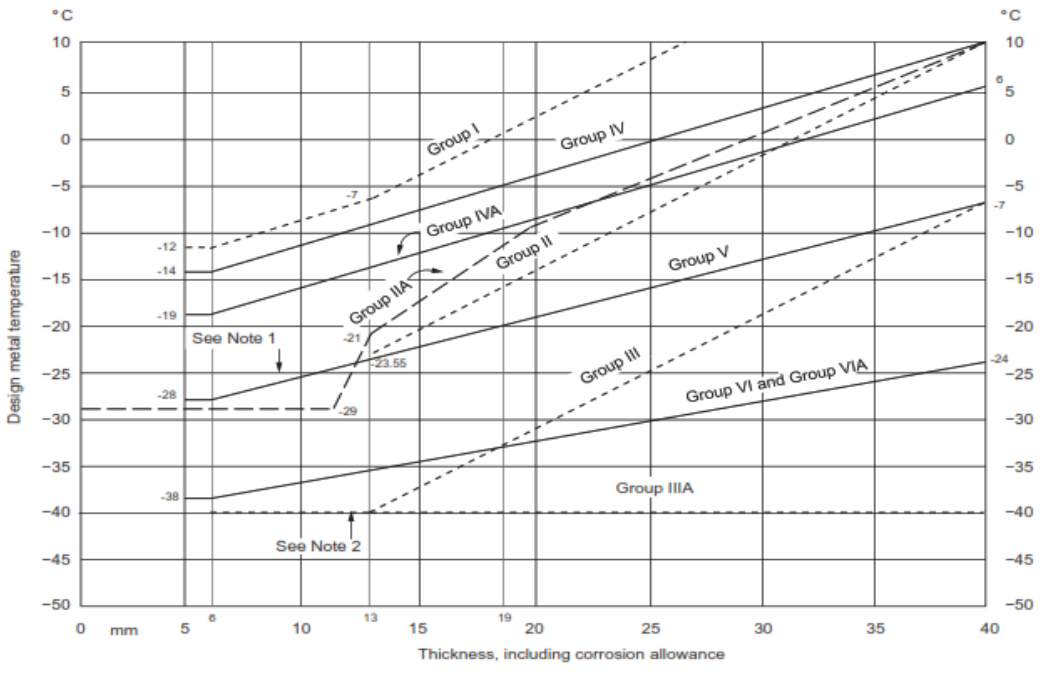
In SI units:

$$t_{s\min} \geq \frac{47.07(\psi H_{TS} P_s)^{0.4}\, D^{0.6}}{(E)^{0.4}}$$

t_{smin}= 6.00 mm t_{min}= 6 mm → PASS

Requirement for Impact Testing

Course	X(mm)	Material	Thk. Range	Material Group	Y(°C)	Required M.D.M.T.(°C)	Requirement for Impact Testing
#1	6	SA283-C	6≤X<13	I	-12.0	5	Not Requirement
#2	6	SA283-C	6≤X<13	I	-12.0	5	Not Requirement
#3	6	SA283-C	6≤X<13	I	-12.0	5	Not Requirement
#4	6	SA283-C	6≤X<13	I	-12.0	5	Not Requirement



Bottom plate design:

The Slope of bottom is 1:120

Corrosion allowance: 3 r 3.2 mm

The min required thickness for carbon steel is: 6 + 3.2 = 9.2 mm

Selected

The selected thickness is 10 mm → Outside Diameter of Bottom Plate: 4113.6 mm → 4150 mm

Annular plate design:

Note: Vendor shall consider annular plate for bottom of tank with diameter more than 10 m
(as per SPECIFICATION FOR ATMOSPHERIC ABOVE GROUND WELDED STEEL TANKS-5.5.6)

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 $t\ ) (S_t)$

t_d	CA	C_t	t_t	n_t
4.20	3.2	2.8	0.81	6

Product stress= 48.75 Mpa

Hydrostatic test stress= 20.68 Mpa

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

First shell course: 6 mm

Annular plate thickness From table: 6 + 3.2 = 9.2 mm Selected annular thickness: 10 mm

Min. required annular plate width:

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

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

Fy= 205 Mpa
tb= 10 mm
G= 1.1
H= 5 m
γ= 0.01

L= 872 mm

Max. (L, 600 mm)= 871.7 mm
tc1: first shell course = 6 mm
Min. Width= Max. (L, 600 mm) + tc1+ 50mm= 927.7 mm

Bottom plate weight (including annular)	1035.8	kg
Bottom plate weight (Corroded condition)	828.6	kg

Fix Roof design:

Type Roof: Cone Roof & Self Suported

- **5.10.5 Self-Supporting Cone Roofs**

NOTE Self-supporting roofs whose roof plates are stiffened by sections welded to the plates need not conform to the minimum thickness requirements, but the nominal thickness of the roof plates shall not be less than 4.8 mm ($^3/_{16}$ in.) when so designed by the Manufacturer, subject to the approval of the Purchaser.

5.10.5.1 Self-supporting cone roofs shall conform to the following requirements:

$\theta \leq 37$ degrees (slope = 9:12)

$\theta \geq 9.5$ degrees (slope = 2:12)

In SI units:

Nominal thickness shall not be less than the greatest of:

$$\frac{2x1000D}{\sin\theta}\sqrt{\frac{B}{1000xE}} + \text{CA, or } \frac{2x1000D}{\sin\theta}\sqrt{\frac{U}{1.33x1000E}} + \text{CA, or 5 mm}$$

Corroded thickness shall not be more than 13 mm.

where

D is the nominal diameter of the tank, in meters;

E is the modulus of elasticity (MPa) at maximum temperature;

B is the greater of load combinations 5.2.2 (e)(1) and (e)(2) with balanced snow load S_b, in kPa;

U is the greater of load combinations 5.2.2 (e)(1) and (e)(2) with unbalanced snow load S_u, in kPa;

θ is the angle of cone elements to the horizontal, in degrees;

CA is the corrosion allowance.

B=	0.4	kpa												
E=	190000	Mpa												
θ=	11	(degree)												
Sinθ=	0.19													
C.A.=	1.6	mm												
t=	3.5	mm	→	Pass										

θ = Angle of the elements to the horizontal , (Roof Slope) : 1 / 5 → 11 (Degree)
D = Inside Tank Diameter → 4 m
th = Nominal Calculated Thickness of Roof plates = 5 + 1.6 = 6.6 → Selected: 8 mm
Nominal thickness:

Note:F.6.1 Minimum thickness of supported and self-supporting cone roofs under internal pressure shall be calculated as follows:

$$t = \frac{(P \times R_t)}{\cos\alpha \times S_d \times E} + C_a$$

t is the minimum roof thickness required for internal pressure in mm (in.);

P is the internal Design pressure – minus effect of nominal roof dead load in kPa (lbf/in.^{2});

R_t is the nominal tank radius in m (in.);

a is the half apex angle of cone roof (degrees);

$\cos\alpha$ is the cosine of half apex angle expressed as a decimal quantity;

S_d is the allowable stress for the design condition per this Standard in MPa, (lbf/in.^{2});

E is the joint efficiency:

t=	8	mm	<	3.04 mm	→	Pass
P=	16	kpa				
R_t=	2	m				
α=	79	(Degree)				
Cosα=	0.19					
S_d=	137	Mpa				
E=	0.85					
C.A=	1.6	mm				

V.7.2 Self-Supporting Cone Roof

V.7.2.1 The required thickness of the roof plate is determined by the following equation. However, the thickness shall not be less than that required by 5.10.5.1.

In SI units:

$$t_{cone} = \frac{83D}{\sin\theta\sqrt{\frac{P_r}{1.72E}}}$$

θ= 11 (degree)

D= 4 m t_{cone}= 2.5 mm → Pass

Sinθ= 0.2

Pr= 0.7 kPa

E= 190000.0 Mpa

V.7.2.2 The total required cross-sectional area in the cone roof-to-shell joint region for external pressure on the roof is determined by the following equation.

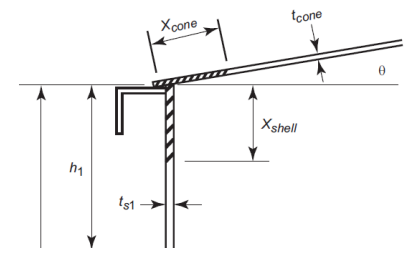
f= 137 Mpa

In SI units:

$$A_{reqd} = \frac{125P_rD^2}{f\tan\theta}$$

A_{reqd}= 52.6 mm^2

f is the smallest of the allowable tensile stresses of the roof plate material, shell plate material, or stiffener ring material at the maximum operating temperature, in MPa (lb/in.^{2});



V.7.2.3 The length of cone roof considered to be within the top tension/compression ring region is determined by the following equation (see Figure V.1a):

In SI units:

$$X_{cone} = 13.4\sqrt{\frac{Dt_{cone}}{\sin\theta}}$$

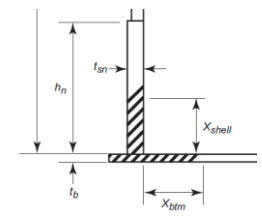
X_{cone}= 97.9 mm

V.7.2.4 The vertical dimension measured from the top of the shell or top angle considered to be within the tension/compression ring region is determined by the following equation (see Figure V.1a):

In SI units:

For the top tension/compression region: $X_{shell} = 13.4\sqrt{Dt_{s1}}$

For the bottom tension/compression region: $X_{shell} = 13.4\sqrt{Dt_{sn}}$



X_{shell}= 7.2 mm

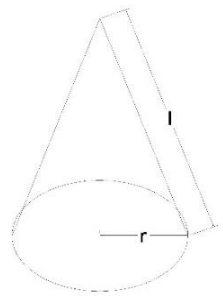
A_{Actual}= 292.5 mm^2 → Pass

V.7.2.5 The required cross-sectional area of the top stiffener structural shape is determined by the following equation:

$$A_{stiff} = A_{reqd} - t_{s1}X_{shell} - t_{cone}X_{cone}$$

Wrp = Weight of Roof Plates	994.09	Kg
Wrcp = Corroded Weight of Roof Plates	745.56	Kg
Wraf = Weight of Rafters & other structure	0	Kg
Tw =Total Weight (UnCorroded)	994.09	Kg
Roof appurtenances center of graviti=	0.35	m

Roof plate weight :	994.09	kg
Structure weight :	0	
Insulation Weight:	0	
Total weight :	994.09	



r=	2	m
l=	2.04	m
Roof Plate Thk.=	8	mm
Insulation Thk.=	0	mm

Total weight (Kg)-Corroded condition: 845

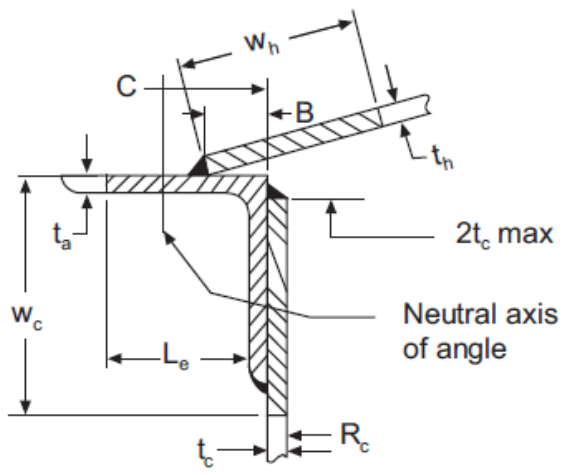
Top Angle:

Min. Required top angle is 80x80x8 (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	→	F.5:*Required Comprssion Area at the Roof–to–Shell Junvtion*	PASS
Top angle weight per meter:	9.63	Kg/m		
Tank surrounding	12.6	m		
Total weight of top angle	242.0	Kg		
Top angle section area	1230	mm^2		



Detail b

Intermediate wind girder:

H1: unstiffened shell height

t(mm)	2.8
D(m)	4
V(km/h)	232
Pwd (kPa)	2.45
Pwv (kPa)	2.21

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

$H_1(mm)$ 10917.28

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	1500	2.8	2.8	1500
#2	1500	2.8	2.8	1500
#3	1500	2.8	2.8	1500
#4	500	2.8	2.8	500
$W_{tr} = W\sqrt{\left(\frac{t_{uniform}}{t_{actual}}\right)^5}$		∑Wtr		5000
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.

Annex F. Figure F.1 Is Provided to Aid in The Determination of Applicability of Various of This Annex.

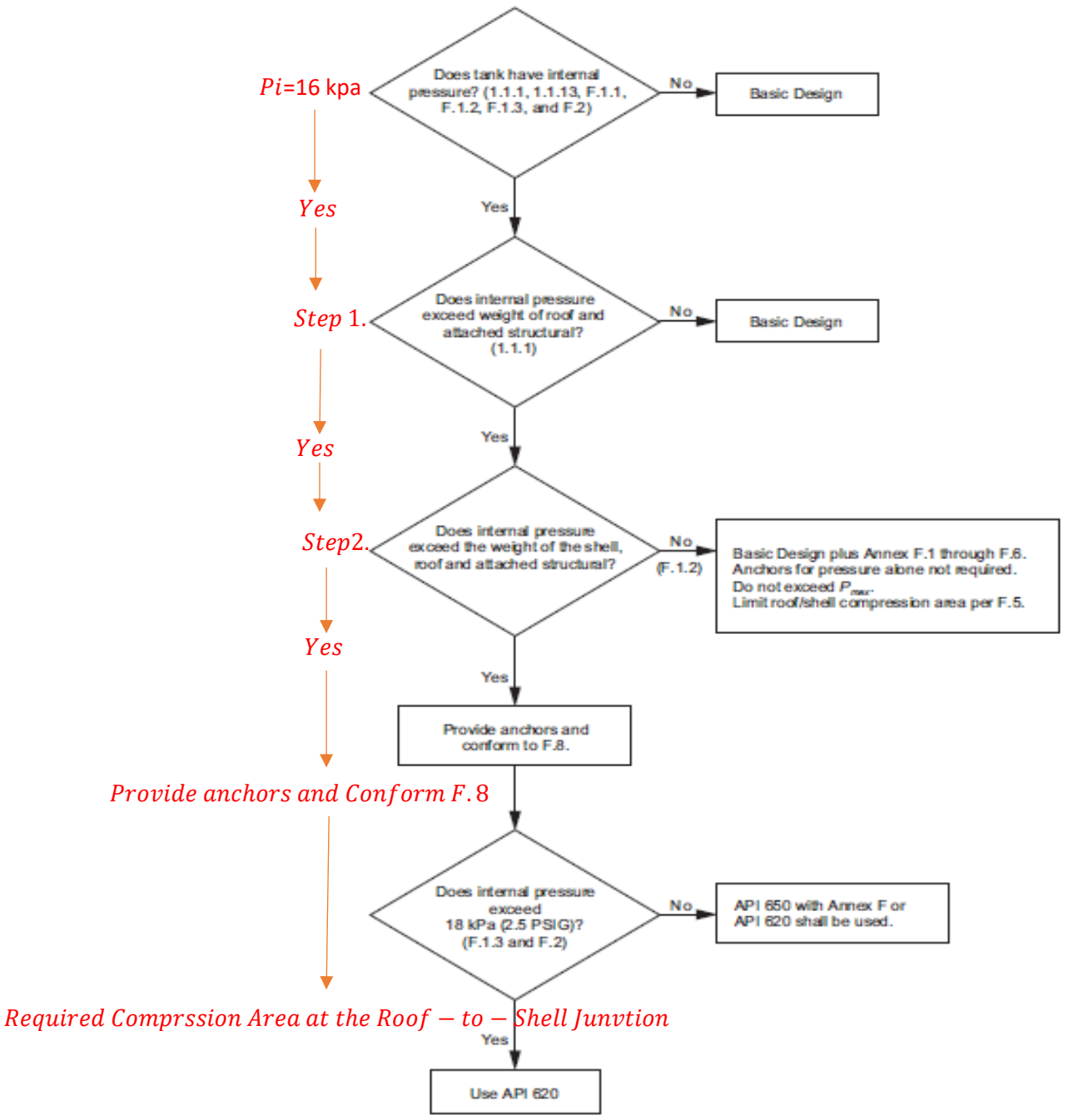


Figure F.1—Annex F Decision Tree

Roof to Shell Junction Control (Annex F)

Step1(Checking for Uplift of Roof Plates)

Pi	:Internal Pressure	16000	Pa(N/m2)		
Wr	:Weight of Roof Plates	994.1	kg	9742.0	N
Fpi	:Load Due to Internal Pressure	201061.9	N		

Fpi > Wr → Go Control Step 2.

Step2(Checking for Uplift of Tank Weight)

W1	: Weight of Shell Plates(Corroded condition)	2515.5	Kg		
W2	: Weight of Roof Plate(60%)(Corroded condition)	845.0	Kg		
W3	: Weight of Roof Structure(Corroded condition)	0	Kg		
W4	: Weight of Other Attachment on The Roof or Shell(Corroded condition)	169.0	Kg		
W5	: Weight of Top Angle(Corroded condition)	242.0	Kg		
Wt	= (W1+W2+W3+W4+W5)	3771.5	Kg	36960.4	N

Fpi > Wt → Provide anchors and Conform to F.8

F.8 Mechanically-anchored Tanks with Design Pressures up to 18 kPa (2.5 psi) Gauge

- **F.8.1** The design of the mechanical anchorage and its attachment to the tank shall be a matter of agreement between the Manufacturer and the Purchaser and shall meet the requirements of 5.12.

F.8.2 The counterbalancing weight, in addition to the requirements in 5.12, shall be designed so that the resistance to uplift at the bottom of the shell will be the greater of the following.

a) The uplift produced by 1.5 times the design pressure of the corroded empty tank plus the uplift from the design wind velocity on the tank.

b) The uplift produced by 1.25 times the test pressure applied to the empty tank (with the nominal thicknesses).

F.8.3 After the tank is filled with water, the shell and the anchorage shall be visually inspected for tightness. Air pressure of 1.25 times the design pressure shall be applied to the tank filled with water to the design liquid height. The air pressure shall be reduced to the design pressure, and the tank shall be checked for tightness. In addition, all seams above the water level shall be tested using a soap film or another material suitable for the detection of leaks. After the test water has been emptied from the tank (and the tank is at atmospheric pressure), the anchorage shall be checked for tightness. The design air pressure shall then be applied to the tank for a final check of the anchorage.

F.8.1	Go Control Page28.
F.8.2a	PASS
F.8.3	The requirements that shall be met during the hydrotest.
F.8	Conform

Step4(Checking of F.5:*Required Comprssion Area at the Roof–to–Shell Junvtion*)

$$A = \frac{200D^2\left(P_i - \frac{0.00127\ D_{LR}}{D^2}\right)}{F_y(\tan\theta)}$$

Ar	: Minimum Required Area At Roof to Shell Junction=	=	1238.3	mm^2	
Pi	:design internal pressure=	=	16.0	Kpa	
DLR	:nominal weight of roof plate plus any attached structural=	=	7306.5	N	
D	:tank diameter	=	4	m	
Fy	lowest minimum specified yield strength (modified for design temperature) of the materials in the roof-to-shell junction		205	Mpa	
ɵ	:angle between the roof and a horizontal plane at the roof-to-shell junction		11	degrees	
tan ɵ	:slope of the roof, expressed as a decimal quantity		0.19		
Sinɵ			0.19		
W_h	:maximum width of participating roof = $0.3(R_2\ t_h)^{1/2}$ or 300 mm (12 in.) whichever is		86.87		
Rc	: inside radius of tank shell		2000	mm	
R_2	:length of the normal to the roof, measured from the vertical centerline of the tank = R_c / (sin ɵ)		10481.6861		
Wc	:width of participating shell =$0.6\ (R_c\ t)^{1/2}$, where t = t_a, t_c, t_s, or t_f as applicable.	75.895			
$A_{participating\ roof}$		694.98		mm^2	
$A_{participating\ shell}$		607		mm^2	
$A_{top\ Angle}$	L 80x80x8	1230		mm^2	
A_{actual}	:Area of Angle+Aparticipating shell+Aparticipating roof	2532		mm^3	

A_{actual} > Ar → That's OK

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.

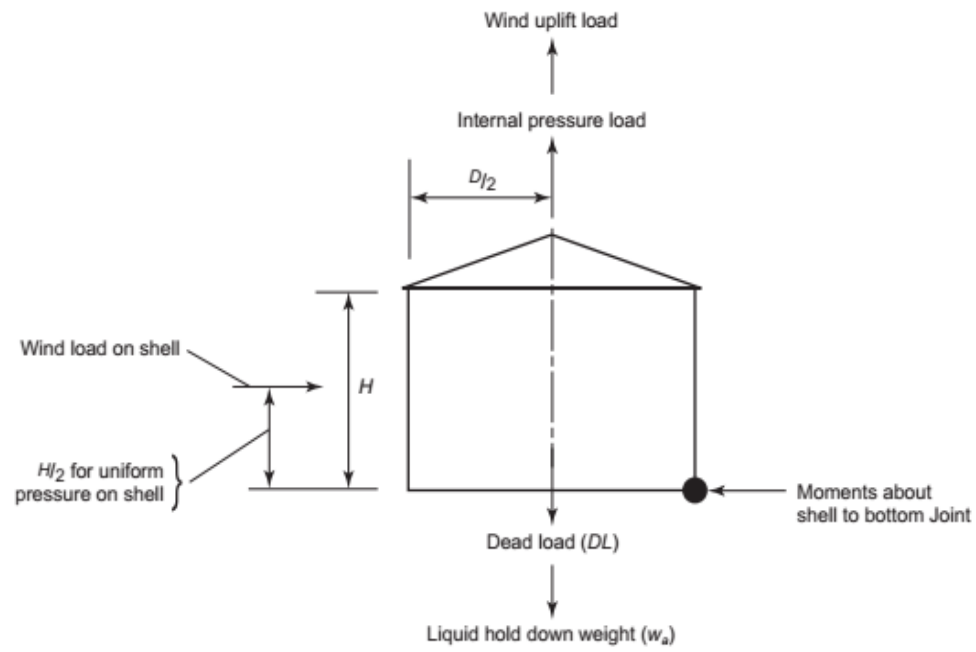


Figure 5.27—Overturning Check for Unanchored Tanks

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	5	4	2546.5	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=	2816	N/M
Selected=	2816	N/M
MF= wl * (πD) * (D/2) =	70773.7993	N/M

Pw1 =	0.89(V/190)^2 =	1.3	kPa
Pw2 =	1.48(V/190)^2 =	2.1	kPa
Fw1=	Pw1* (ID*H) =	1025.8	N
Fw2=	Pw2* (ΠD²/4) =	26979.9	N
M1=	2564.5	N.m	
M2=	53959.9	N.m	
M_w =	59070.8	N.m	
Fshear =	29279.0	N	
Mdl=	shell weight *(ID/2)	58003.9	N.m
Mdlr=	Roof&attach weight *(ID/2)	19484.1	N.m

Checking for satisfying the above 3 equilibrium:

1) $0.6M_w + M_{Pi} < M_{DL}/1.5 + M_{DLR}$	→	37,989	<	58,153	PASS
2) $M_w + F_p(M_{Pi}) < (M_{DL} + M_F)/2 + M_{DLR}$	→	60,089	<	83,873	PASS
3) $M_{ws} + F_p(M_{Pi}) < M_{DL}/1.5 + M_{DLR}$	→	3,583	<	58,153	PASS

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

$M_{ws} + F_p(M_{Pi}) < M_{DL}/1.5 + M_{DLR}$	→	3,583	<	58,153	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	
Anchor System:	Mechanical Anchor	
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)	0.578	
TC : First sloshing wave period =1.8Ks (D)^ 0.5 (Equ. E-4.5.2-a)	2.1	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 addressed by ASCE Method	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	4	m
H:Maximum Design Product Level	4.5	m
G : Liquid Specific Gravity	1.1	

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

Anchor Type: Mechanical Anchor Rwi= 4 Rwc= 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=	0.173	≥	0.007	
Tc ≤ TL	Ac=	0.17	≤	Ai	YES
Tc > TL	Ac=	0.407	≤	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	0.89	4.50	For $D/H < 1.33$ and $Y \geq 0.75D$: $N_i = 2.6A_iGD^2$
#2	1.333	3.00	$D/H \geq 1.33$: $N_i = 8.48A_iGDH\left[\frac{Y}{H} - 0.5\left(\frac{Y}{H}\right)^2\right]\tanh\left(0.866\frac{D}{H}\right)$
#3	2.67	1.50	
#4	8.00	0.50	

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	1.5	2.8	4.5	7.90	0.42	90.55	36.71	27.97	0.20	OK
#2	1.5	2.8	3	8.34	0.89	58.21	24.47	17.11	0.13	OK
#3	1.5	2.8	1.5	5.21	3.35	25.87	11.65	6.83	0.06	OK
#4	0.5	2.8	0.5	1.97	8.37	4.31	4.61	-1.53	0.025	OK
MAX, σT =							37			

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=(182.2 184.5)

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) 31902.1194 N

Wr :TOTAL WEIGHT OF FIXED TANK ROOF INCLUDING FRAMING, 9742.0399 N

Wf : WEIGHT OF THE TANK BOTTOM 10150.6744 N

Wp : TOTAL WEIGHT OF TANK CONTENT BASED ON PRODUCT SPECIFIC GRAVITY 554176.944 N

Wi : EFFECTIVE IMPULSIVE WEIGHT OF THE LIQUID E.6.1.1-2

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	No
Wi= 465643.1715	N

E.6.1.1-2	Yes
Wi= 446789.7674	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 = 113239.655 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 5 m

Xs : HEIGHT FROM BOTTOM OF THE TANK TO SHELL CENTER OF GRAVITY 2.39 m

NO.Course	thk(mm)	W(m)	Xi(m)	Wi(kg)	Wi.Xi(Kg.m)
#1	6	1.5	0.75	887.8	665.9
#2	6	1.5	2.25	887.8	1997.6
#3	6	1.5	3.75	887.8	3329.3
#4	3.2	0.5	4.75	157.8	749.7
Sum:		5	11.5	2821.3	6742.5

center of gravity(m)	Xs=∑(Xi.Wi)/∑Wi	2.4	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.6.1.2.2-2

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	No

Xis= 2.12 m

E.6.1.2.2-2	Yes

Xis= 2.49 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:

$$X_{cs} = \left[1.0 - \frac{\cosh\left(\frac{3.67H}{D}\right) - 1.937}{\frac{3.67H}{D}\sinh\left(\frac{3.67H}{D}\right)}\right]H \quad \rightarrow \quad 3.5 \quad m$$

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)	No

Xi= 1.6875 m

(E.6.1.2.1-2)	Yes

Xi= 1.9 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

$$X_c = \left\{1 - \frac{\cosh(3.67\frac{H}{D}) - 1}{3.67\frac{H}{D}\sinh(3.67\frac{H}{D})}\right\}H \quad 3.4 \quad m$$

Design Load; para E.6.1 :

V = Total Design Base Shear : (Vi ² + Vc²)^0.5 = 100,880.92 N

Vi = Design Base shear due to impulsive force = Ai (Ws + Wr + Wf + Wi) = 99,041 N

Vc = Design Base shear due to Convective force = Ac Wc = 19,179 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}= 271,177.4 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= 264,219.5 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 = 20308.4 N/M

201.1Ge H D= 3570.9

→ Wa>201.1G_eHD → $w_a = 5742\ HG_eL_s$ = 38235.3 — Yes

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

Ge:Effective specific gravity including vertical seismic effects=G(1 – 0.4Av)= 0.99

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 6.8

$$J = \frac{M_{rw}}{D^2[w_t(1-0.4A_v) + w_a - F_p w_{int}]}$$ → 0.46 < 0.785

Wt :Tank and roof weight acting at base of shell, N/m → $w_t = \left[\frac{W_s}{\pi D} + w_{rs}\right]$ 3391.5

Wrs: Roof load acting on the shell, including the specified snow load N/m = 852.8

Wint: Calculated design uplift load due to product pressure per unit circumferential length, N/m 2546.5

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:

No Calculated uplif under the design seismic overturning moment.the tank is self - anchor.
Annex. F.8(Tank shall be anchors)

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	6	mm
C.A.	Corrosion Allowance of Bottom Shell Course	3.2	mm
ts	Corroded Thickness of Bottom Shell Course	2.8	mm
σc	Max. Shell Compression Stress at the bottom of the shell	9.0	

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= 2.20

0.5Fty = 102.5

Fc	Allowable longitudinal shell membrane compression stress in tank shell	39.9	
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= 217,379.04

RESULT:

Vs > V so Tank is stable against Seismic Sliding

LOCAL SHEAR TRANSFER (ParaE.7.7)

Vmax=Peak local tangential shear per unit length $V_{max} = \frac{2V}{\pi D}$ = 16055.7 N/M

σv=Peak local tangential shear Stress = Vmax/(t-C.A.) 5.73 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:

$\delta s = 0.42\ D\ Af =$ 0.36 m

For SUG II

$$\delta_s = 0.42\ DA_f \quad \text{(see Note c in Table E.7)} \qquad \text{(E.7.2-1)}$$

For SUG I and II,

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

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

For SUG III,

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

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

Tc= **2.1** → E.4.5.2-a Tc= $1.8Ks\ D^{0.5}$

When, TC ≤ 4 Af= 0.22 → Yes
When, TC > 4 Af= 0.81 → 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.

$S_{DS}=$ 0.6 g ≥ 0.33 g → 0.7δs → 0.25 m

HLL = 4.5 m
depth of Submersion = 0 m → 0.5 m → PASS
Shell height = 5 m

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=	4.19		Bolt Center Diameter=	4200 mm	
Considered qty. of bolts =	8				
Outside Diameter of Bottom plate:	4150	→	Anchore Bolt will Not clash with Bottom Plate	→	Pass
Inside Diameter of Anchore Bolt:	4164				
Circumferential distance between bolts =	1.57		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	Bolt Size (Request) Area (mm^2)
Design Pressure	1684775.56	210596.95	103.33	136.67	Required	50.9
Test Pressure	410430.59	51303.82	137.78	170.83	Required	372.4
Failure Pressure	671058.50	83882.31	248.00	205.00	Required	338.2
Frangibility Press.	1385422.10	173177.76	248.00	205.00	Required	698.3
Wind Load	-61105.19	-7638.15	198.40	170.83	Not Required	-
Seismic Load	216211.11	27026.39	198.40	170.83	Required	136.2
Pdesign+Wind	406103.58	50762.95	137.78	170.83	Required	368.4
Pdesign+seismic	256765.48	32095.69	198.40	170.83	Required	161.8
required anchor boltdiameter						698.3

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
F_P:the pressure combination factor:	0.40
D= Tank diameter in (m)	4.00
H = tank height, in meters;	5.00
P= design pressure in (Kpa) (Annex.F-8.2a=1.5 time the design pressure of the corroded empty tank)	24.00
Pf = failure pressure in (KPa) = 1.6 P -((0.000746DLR)/D^2)th [ACC. tO F.6.]	37.92
DLR is the nominal weight of roof plate plus any attached structural, in N.	10350.92
th = roof plate thickness (mm) =	8.00
Mw = wind moment in (N-m) =	59070.84
MWH = PWS × D × H^2/2 (N-m)	64.11
M_{rw} = seismic moment in (N-m) =	271177.39
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.) =	53001.02
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.) =	61290.20
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). =	38783.50
N= Number of bolt using in the calculation	8.00
F_y=	248.00
F_{ty}=	205.00

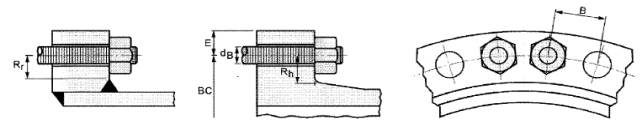
According to API 650 3.12.5

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

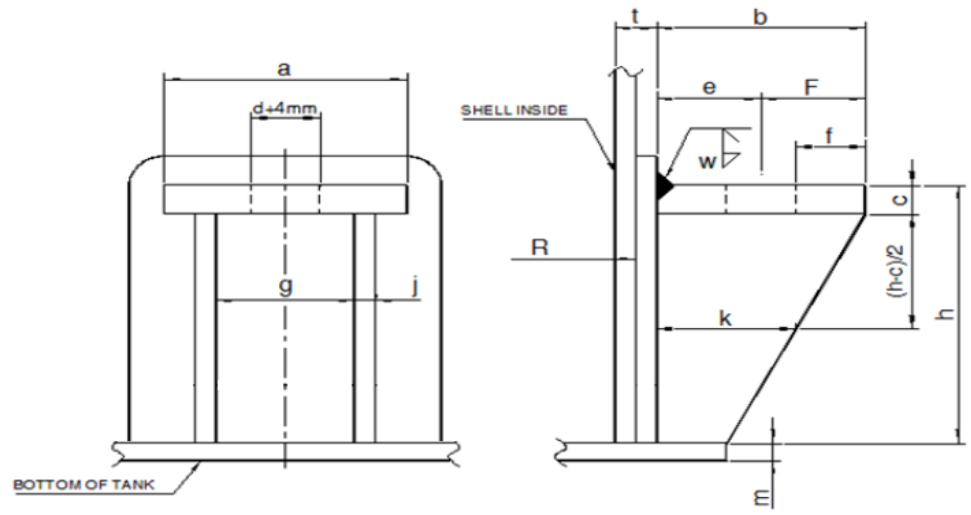
anchor bolt diameter=	M 36	PASS

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	167.966	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	68.50	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=	4	m		
Top Plate Width along shell	a=	350	mm	13.8	Inch
Bolt Circle diameter	B.C.D.=	4200	mm	165.4	Inch
Pad Palte Thickness	t_{Pad}=	15	mm	0.6	Inch
Shell Plate thickness	t_{shell}=	6	mm	0.2	Inch
Number of anchor bolts	n_{Bolt}=	8			
Anchor bolt diameter	d=	36	mm	1.4	Inch
Hole diameter	d_{hole}=	40	mm	1.6	Inch
Anchor bolt eccentricity	e=	79	mm	3.1	Inch
Distance from outside of top plate to centerline of bolt(min. 1.5*hole diameter)	F=	79	mm	3.1	Inch
Distance from outside of top plate to edge of hole	f=	59	mm	2.3	Inch
Top Plate length in raidial direction(min 3*hole diameter)	b=	158	mm	6.2	Inch
Distance between vertical plates	g=	210	mm	8.3	Inch
Chair height(minimum 6")	h=	360	mm	14.2	Inch
Vertical Palates(gusset) thickness	j=	15.00	mm	0.6	Inch
Gusset lowest width	L Gusset=	25	mm	1.0	Inch
Vertical plates width(average width for tapered plates)	k=	98	mm	3.9	Inch
Bottom plate thickness (Corroded)	m=	6.8	mm	0.3	Inch
Nominal Shell Radius	R=	2000	mm	78.7	Inch
Minimum yield stength of chair parts	S_y=	205	Mpa	30.0	ksi
Shell thickness(Corroded) also including the pad thickness	t=	17.8	mm	0.7	Inch
Ringwall moment	M_{rw}=	271177.4	N.m		

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=	38235.3	N/m		
Actual bolt load	P_a=	60059.9	N	13.50	kip
Yield strenth of anchor bolt (A 36)	Fy=	248.0	Mpa	36.29	ksi
Deign load will be the lesser of bellow items:					
1- 3 thime of PA,B	P_1=	180179.8	Mpa	40.50	kip
Cross section area of bolt*yiled strenth of Anchol bolt	A_s=	1017.8	mm^2	1.58	$inch^2$
Cross Section Area of Bolt	S_{d1}=	148.8	Mpa	21.58	ksi
Allowance design Stress for anchor chair parts	S_{d2}=	181.0	Mpa	26.25	ksi
	P2=	252425.8	N	57.26	kip
Desing load	P=	180179.8	N	40.50	kip
Reduction factor= $Z = \frac{1}{\frac{0.177 * a * m}{\sqrt{R * t}}(\frac{m}{t})^2 + 1}$	Z=	0.75			
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=	26.14	ksi		
	Sd=	26.25	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=	34.57	mm	1.36	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=	15.00	mm	0.59	Inch
Should be: j > P / (25*k)	→ Ok				
WELD SIZE CHECKING:					
Load per horizontal line	WH =	67.00	N/mm	0.38	kip/Inch
Load per vertical line	WV =	168.39	N/mm	0.96	kip/Inch
Total load per line	W=	181.23	N/mm	1.03	kip/Inch
Should be: w >= W / 9.6	W / 9.6=	18.88	mm	0.11	Inch
		10	mm	0.39	Inch

Fabrication Data		
Item	**Thickness(mm)**	**weight (Kg)**
Shell#1	6	887.8
Shell#2	6	887.8
Shell#3	6	887.8
Shell#4	6	295.9
Bottom plate weight (including annular)	10	1035.8
Fix Roof Plate(Including Structure)	8	994.1
Top Angle	L 80x80x8	242
Nozzles	estimate	800
ladder cage and accessory	estimate	500
Unseen(3% of total weight)	estimate	196
Empty	Weight(kg)	6727.2
Hydrotest		68727
Operating		55127

Foundation Load Data			
Seismic	Shear(N)		100,880.9
	Moment (N.m)	Ring Wall	271,177.4
		Slab	264,219.5
Wind	Shear(N)		29,279.0
	Moment (N.m)		59,070.8