STD API650 STRENGTH CALCULATION

API 650-Storage Tank Dia < 60m-Calculation-Cone Roof Type-11th /2007 Edition

INPUT DATA PGM ***V2.9***

* ITEM NO.	E-1004		* DESCRIPTION	pes21	
DESIGN DATA-ROOF					
* Nominal diameter of tank, D	23	m	* Design Temperature, Td	80	oC
* Roof material	A516-70		* Roof specified th'k by user, Ut	8	mm
* Cone Angle, Θ	9	o	* Used thickness,Rt	8	mm
* Increas factor of dead weight	1.05		* External Pressure, Pe	0.0	Kg/cm^2
* Snow Load, Ls	0.0	Kgf/m^2	* Roof Live Load, La	120	Kgf/m^2
* Roof insulation thickness, Lt	50	mm	* Roof insulation density, Ld	180	Kgf/m^3
* Rafter Size	H100x100x6x8		* Vacuum Pressure, Pv	0.0	mm
* Corrosion allowance, CA	1.6	mm	* Roof support Radius from Center, R	6	m
DESIGN DATA-COMPRESSION RING					
* Rafter / Ring material	A516-70		* Ring O.D	3670	mm
* Ring Height, d	300	mm	* Ring I.D	3430	mm
* Ring Vertical Thickness. "t"	10	mm	* Ring Flat Thickness "s"	10	mm
DESIGN DATA-ANGLE					
* Top Plate material	A516-70				
* Top Angle Material	A516-70		* Top Plate Used thickness,Rt	8	mm
* Top Angle Size	ㄱ130x130x9		* Corrosion allowance, CA, on one side	1.6	mm
DESIGN DATA-TOP PLATE					
* Dim, "a"	1300	mm	* Dim, "b"	1300	mm
DESIGN DATA-SHELL					
* Shell material	A516-70		* Design specific gravity of liquid stored, G	1.0	
* Roof tension ring	ㄱ130x130x9		* Height from bottom to top of the shell, H	15	m
* Height of Max. design liquid level, Hd	15	m	* Internal pressure corresponding to static head, Hi	0	m
* Height of Low design liquid level, HL	0.6	m	* Corrosion allowance, CA	1.6	m
* Shell used thickness-in top, Tu	8	mm	* Shell course width	3000	mm
* Shell used thickness-in bottom,Ta	13	mm	* Design wind velocity, V	45	m/sec
STIFFENER RING DATA-T BAR IN SHELL					
* WEB THICKNESS, t	8	mm	* FLANGE THICKNESS, s	8	mm

* FLANGE WIDTH, b	80	mm	* WEB HEIGHT, d	100	mm

DESIGN DATA-BOTTOM PLATE

* Bottom Plate Material	A283-C		* Bottom Plate Corrosion Allowance, CA	1.6	mm
* Bottom Plate User specified thickness, Ut	8		* Bottom Plate Used thickness, Bt	8	mm

DESIGN DATA-ANNULAR PLATE

* Annular Bottom Plate Material	A283-C		* Nominal Plate Thickness in First Shell	10	mm
* Annular Bottom Plate Corrosion Allowance, CA	1.6	mm	* Annular Bottom Plate User specified thickness, Ut	10	mm
* Annular Bottom Plate Used thickness, tb	10	mm	* Annular projection outside bottom shell	100	mm

DESIGN DATA-SEISMIC DESIGN

* Seismic Zone No.	2A		* Seismic Zone Factor, E-2,API650	0.15
* Soil Profile Type	S3		* Site coefficient, E-3,API650	1.5
* Importance Factor, I	1.25			

DESIGN DATA-COLUMN SUPPORT

* Pipe Column O.D	457.2	mm	* Column Thickness	14.2	mm
* Column Length	17	MR	* Column Q'TY	10	

DESIGN DATA-ACCESSORY WEIGHT

* Nozzle & Flange	700	Kg	* Internal Ladder	YES
* Wind Girder	0	Kg		

FABRICATION & WELDING DATA

* Shell Plate Size-Length	12000	mm	* R/T Inspection	SPOT R/T
* Welding process	SMAW		* Groove Type	SING-V
* Groove Angle	75		* Welding Overlay	10%

RESULT OF CALCULATION

RESULT OF CALCULATION SUMMARY

* 1.1. Roof Calculation	O.K	* 2.1. Compression Ring Proporties	O.K
* 3. Rafter load Calculation	Check !	* 4.3. Top Plate Thickness	O.K
* 4.4. Top Angle		* Limition Check for Para 5.6.3 below 60m	

calculation	O.K		of Diameter	O.K	
* 5. Roof tension ring required area	Check !		* Used top plate check	O.K	
* 6. Roof tension ring required area & Buckling check	O.K		* 8.2. The number of waves under uniform external pressure	O.K	
* 12. The required inertia moment of intermediate stiffener region	O.K		* 13. The required cross-sectional area of intermediate stiffener region	O.K	
* 17. Required sectional area of shape where attached to shell part	O.K		* 17.Available stiffener check	Check !	
* 3.3. Max. Longitudinal Compressive Stress in the Shell	Check !		* 3. OVERTURNING MOMENT due to WIND LOAD	O.K	

PART-"A" FOR ROOF CALCULATION

1. Material proporties & General requiremenst as per API650 STD-ROOF

* Tensile Strength @ ambient temp.	4,921.5	Kg/cm^2	* Yield Stress reduction factor as per table M.3, k	0.91	
* Yield Strength @ ambient temp.	2,671.7	Kg/cm^2	* Allowable Stress,Ss	1,620.8	Kg/cm^2

1.1. Roof Calculation (Exc. Corrosion Allowance)

			* The length of Cone, considering tension ring, Xcone	459.6	mm
* Req'd thickness in case of selfsupporting as per API650, V.7.2.1,tcone	7.65	mm	* Req'd thickness in case of as per API620, 5.10.5.1 or V.7.2.1, the less one	7.65	mm
* Roof Height from Top shell to Apex of Cone	1.822	m	* Used thickness Check	O.K	
* Cone roof dead weight, Dw	28,084.1	Kgf	* Cone roof area, Aw	425.90	m^2
* Total design external pressure loading, Pr	307.94	Kgf/m^2			

1.2. Tension/Compression RIng Location

* Permissible Top tension/compression ring location,Xshell	181.8	mm	* Permissible Bottom tension/compression ring location, Xbtm	231.7	mm

1.3 Material proporties a for Comprssion Ring & Rafter as per API650 STD

* Yield Stress reduction factor as per table M.3, k	0.91		* Rafter unit weight	17.2	Kgf/m
* Yield Strength @ ambient temp.	2,671.7	Kg/cm^2	* Tensile Strength @ ambient temp.	4,921.5	Kg/cm^2
* Allowable Bending Stress,Sb	1,620.81	Kg/cm^2			

1.4 Roof Load Calculation

* Required Rafter Q'ty, Rn	38	EA	* Rafter Spacing,Rs	1.901	m
* Rafter Length per One,Rl	1,164.3	cm			
* Load per Rafter,W	2,363.2	Kgf	* Triangular Distr. of Tra.Load,q	248.76	Kgf/m

2. Compression RIng Load Calculation

* Horizontal reaction load at end point of each Rafter, Rh= (q*R1)/(Rs*6)	253.9	Kgf	* Vertical reaction load at end point of each Rafter, Rv	2,363.2	Kgf

2.1 Compression Ring Proporties

* Available sectional Area, Ac	52.0	cm^2	* Available section modulus(x-x), Zc	458.5	cm^3
* α = π / Rn	0.083	radian			

2.2 Max. stress resulting from bending moment and circumferential tension at reaction point, Sc1

RhxDc/(10x4)x(1/α-1)/{tan(α)}/Zc+Rh/{2xtan(α)xAc}

=253.9*/(100*4)*(1/0.083-1)/(tan(0.083))/(458.5+253.9)/(2*tan(0.083)*52.	50.8	Kgf/cm^2

2.3 Max. stress resulting from bending moment and circumferential tension at mid-point between reactions, Sc2

RhxDc/(10x4)x[1/sin(α)-1/α]/Zc+Rh/{2xsin(α)xAc}

=253.9*3670/(100*4)*(1/sin(0.083)-1)/(0.083)/(458.5+253.9)/(2*sin(0.083)	51.2	Kgf/cm^2
Results	O.K	

3. Rafter load Calculation

3.1 Applied initial Roof unit load, RFL

=8*7.85*1.05+120+(50*180/1000)*1.05+0.0	195.4	Kgf/m^2

3.2 Roof Plate Weight, RWT

=23^2*3.14/4*8*7.85*1.05	27,396.4	Kgf

* Vertical Reaction at both ends on top shell ring,R	2,363.2	Kgf	* Horizontal Reaction at both ends on top shell ring,H	4,971.99	Kgf
* Max. Bending Moment, Mx	343,950.43	Kgf-cm	* Req'd section modulus, Zr=Mx/Ss	212	cm^3
* Rafter section modulus,Zi	76.5	cm^3	* Results	Check !	

4. Material proporties-Top Plate as per API650 STD

* Yield Strength @ ambient temp.	2,671.7	Kg/cm^2	* Tensile Strength @ ambient temp.	4,921.5	Kg/cm^2
* Allowable Stress,Ss	1,620.81	Kg/cm^2	* Elastic Modulus @ Design Temp	2,038,950	Kg/cm^2

4.1 Top Angle

* Yield Stress reduction factor as per table M.3, k	0.91		* Top Angle unit weight	17.9	Kgf/m
* Yield Strength @ ambient temp.	2,671.7	Kg/cm^2	* Tensile Strength @ ambient temp.	4,921.5	Kg/cm^2

4.2 Roof Load Calculation

* Cone Area, A	4,259,045	cm^2	* Cone Roof Weight, Dw	28,084.1	Kgf
* Applied total load on Top plate, Aw	28,335.6	Kgf	* Unit load on top plate, Uw	0.007	Kgf/cm^2

4.3 Top Plate Thickness

* Min. Req'd thickness	3.06	mm	* Max. Deflection, y	0.49	mm
			* Top Plate check	O.K	

4.4 Top Angle calculation

* Max. Bending Moment,Max.=UwxLxL/8	14.05	Kgf-cm	* Angle section modulus,Zi	38.7	cm^3
* Bending Stress, σb	0.36	Kgf/cm	* Stress Check	O.K	

PART-"B" FOR BOTTOM CALCULATION

1. Bottom Plate & Annular Plate Thickness based on Para. 5.4.1,5.4, API650-BOTTOM PLATE

* Bottom mininum nominal thickness, including CA	7.6	mm	* Annular Bottom Plate Thickness including CA	7.6	mm
* Hydrostatic Test Stress,St	1,581.9	Kg/cm^2	* Annular radial width,Aw2=215tb/(HG)^0.5	565.5	mm

* Annular radial width,Aw1 as per Para.5.5.3, API650	600.0	mm	* Annular radial width, the greater of Aw1 or Aw2	600.0	mm

PART-"C" FOR SHELL CALCULATION

1. Material proporties & General requiremenst as per API650 STD-SHELL

* Limition Check for Para 5.6.3 below 60m of Diameter	O.K		* Min. shell thickness based on API650 STD	6.35	mm
* Yield Stress reduction factor as per table M.3, k	0.91		* Used top plate check	O.K	
* Yield Strength @ ambient temp.,Fy	2,671.7	Kg/cm^2	* Tensile Strength @ ambient temp.,Ft	4,921.5	Kg/cm^2

1.1 Allowable stress in Design condition

* 2/3xYield Strength*k	158.9	Kg/cm^2	* 2/5xTensile Strength	1,968.6	Kg/cm^2
			* Allowable stress, Sd	1,620.8	Kg/cm^2

1.2 Allowable stress in Hydro. Test condition

* 3/4xYield Strength	2,003.7	Kg/cm^2	* 3/7xTensile Strength	2,109.2	Kg/cm^2
			* Allowable stress, St	2,003.7	Kg/cm^2

1.3 Shell Thickness in Design condition={50xDx(Hd(i)+Hi-0.3048)xG}/Sd(i) + CA(i)

Course No.	No.1	No.2	No.3	No.4	No.5		
Height,(m), Hd(i)	15.000	12.000	9.000	6.000	3.000		
Thickness,(mm), td(i)	12.03	9.90	7.77	5.64	3.51		

1.4 Shell Thickness in Hydro. test condition={50xDx(Hd(i)-0.3048)}/St(i)

Course No.	No.1	No.2	No.3	No.4	No.5		
Height,(m), Hd(i)	15.000	12.000	9.000	6.000	3.000		
Thickness,(mm), tt(i)	8.43	6.71	4.99	3.27	1.55		

2. Shell Used Thickness,The greater of Design or Hydro test

Used Thickness (mm), Ut(i)	13	10	8	8	8		
Shell weight in used Thickness (Kg)	22,121	17,016	13,613	13,613	13,613		

3. Weight & Volume Calculation-Shell

* Full Volume	6,232.13	m^3	* Total Weight of Shell Course@used thickness	79,976	Kg

4. Transformed shell height, as per API650, Para 5.9.7.2, Wtr=Wx{(Tu/Ta)}^(5/2)

Actual shell course height,(m)	3.000	3.000	3.000	3.000	3.000		
Transformed shell course height,(m)	3.000	1.557	1.717	3.000	3.000		

Total height of actual shell	15	m	* Total height of transformed shell, Hts	12.274	m

* Total Used shell course height Vs Total design shell height(H) 0.000 m

4.1 Shell stability and intermediate wind girder deign

4.2 Critical Bucking vertical distance of last shell course as per,Para 5.9.7.1, API650 ,H1= 9.46465 x Tu x { Tu/D}^1.5 x {44.7/V}^2 x k

=9.46465*8*(8/23)^1.5*(44.7/45)^2*0.91 13.947 m

4.3 Intermediate wind girder requirement and Location

If H1>= Wtr then, Intermediate Wind Girder is not required or Required Not requirec

5. Roof tension ring required area

* Required cross sectional Area, Areq	8,004.88	mm^2	* Used cross sectional Area, Aact	2,274.00	mm^2

* Results, Check !

6. Roof tension ring required area & Buckling check in unstiffened shell

* Unstiffened shell buckling coefficient,(D/tsmin)^0.75*(Hts/D)(Fy/E)^0.5

=(23/8)^0.75*(12.274/23)*(238.42/19,608.69)^0.5	0.12992

* Results, shall not be less then 0.00675 as per V.8.1.1 API650 — O.K

7. Minimum shell thickness required for combined loading considering external pressure and wind for unstiffened shell as per V.8.1.2, API650

7.1 Max. permissible design external pressure for unstiffened shell as per V.8.1.2, Ps<E/45,609(Hts/D)(D/(tsmin)^2.5

Ps=19,608.69/(45609*(12.274/23)*(23/8)^2.5)	0.00059	Kg/cm^2

7.2 Minimum shell thickness for combined loading for unstiffened shell, as per V.8.1.3, tsmin>73.05(HtsPs)^0.4D^0.6/(E)^0.4

tsmin=(73.05*(12.274*0.0575)^0.4*(23^0.6))/(19,608.69^0.	8.00	mm

8. Numberand Spacing of Intermediate Stiffener Rings as per V.8.2.1, API650

8.1 Maximum permissible spacing of intermediate stiffeners based on calculated Min. thickness, as per V.8.2.1.2, Hsafe=(tsmin)^2.5(E)/45,609D^1.5(Ps)

Hsafe=((8.00^2.5*19,608.69)/45609)*23^1.5)*0.0575	493.5	mm

* Required Number of Stiffeners, Ns+1=Ls/Hsafe, 2<(Ns+1)>10	10	EA	* Required Spacing of Stiffeners, =Ls/(Ns+1)	1,227.4	mm

8.2 The number of waves under uniform external pressure, as per V.8.2.2.1, N2=(445D^3/tsminHts^2)^0.5, this shall not be greater than 100

=((445*23^3)/(8.00*12.274^2))^0.5	67

* Results, O.K

9. Maximum permissible spacing of intermediate stiffeners based on individual shell thickness, [Hts/(Ns+1)](tsx/tsmin)^2.5 as per V.8.2.2.2

Max. Spacing of stiffener ring for each shell course(mm),Ls	4,132	2,144	1,227	1,227	1,227		

10. The radial load imposed on the the stiffener by the shell, as per V.8.2.2.3

Q=1000 Ps*Ls, Kgf/m	24.22	12.57	7.19	7.19	7.19		

11. The both side of contributing shell width at intermediate stiffener, as per V.8.2.2.4

Wshell=2*13.4(Dtshell)^0.5,(mm)	463.4	406.4	363.5	363.5	363.5		

12. The required inertia moment of intermediate stiffener region, as per V.8.2.2.5

Ireq=37.5QD^3/[E(Ne-1)],(cm^4)	8.5	4.4	2.5	2.5	2.5		
Available stiffener inertia moment,Iact,(cm^4)	1,378	1,378	1,378	1,378	1,378		

* Results, O.K

13. The required cross-sectional area of intermediate stiffener region, as per V.8.2.2.6.1&V.8.2.2.6.2

Required, Arq=QD/2fc,in shell part, (cm^2)	2.7	1.4	0.8	0.8	0.8		
Required, Srq=(Arq/2) in shape part,(cm^2)	1.4	0.7	0.4	0.4	0.4		
Available stiffener cross-sectiona Area.Alav,(cm^2)	13.8	13.8	13.8	13.8	13.8		

* Results, O.K

14. Required proporties of the top stiffener region in shell part, as per V.8.2.3

* Contributing distance for the top width,Wshell=13.4(Dtst)^0.5	181.8	mm	* The radial load on the top stiffener by shell, as per V.8.2.3.1,V1=250*Ps*H	22.0	Kg/m
* The required, Arq=V1D/2f,in shell part for top stiffener	15.6	mm^2	* The required moment of inertia of the top shell, Iact=37.5V1D^3/[E(N2-1)]	76.0	cm^4

15. Required proporties of the bottom stiffener region in shell part, as per V.8.2.3

* Contributing distance for the bottom width,Wshell=13.4(Dtsb)^0.5	231.7	mm	* The radial load on the bottom stiffener by shell, as per V.8.2.3.1,V1=250*Ps*H	22.0	Kg/m
* The required, Arq=V1D/2f,in shell part for bottom stiffener	15.6	mm^2	* The required moment of inertia of the bottom shell, Iact=37.5V1D^3/[E(N2-1)]	76.0	cm^4

16. Required sectional area of shape where attached to shell part, as per V.8.2.3.3.2-for top stiffener

=(15.6-((0.85)*8*181.8)-((0.7)*7.7*459.6))	-37	cm^2

17. Required sectional area of shape where attached to shell part, as per V.8.2.3.3.2-for bottom stiffener

=(15.6-((0.85)*8*231.7)-((1.0)*13*181.8))	-39	cm^2

* Required sectional area check as per API650, Greater than 5.80 cm^2	O.K	* Available stiffener check	Check !

PART-"D" FOR SEISMIC DESIGN CALCULATION as per (Appendix E) ; OPERATING CONDITION

1. OVERTURNING MOMENT

* Total weight of the tank contents	6,232,129	Kg	* D/H Ratio	1.533	
* Natural Period, T	87.810	sec	* Lateral Force Coefficient for Sloshing Mode	0.013	
* W1 = (W1/WT)WT	4,811,204	Kg	* W2 = (W2/WT)WT	1,495,711	Kg
* X1 = (X1/H)H	6,030	mm	* X2 = (X2/H)H	10,965	mm
* Seismic Factor, Cs = products of Z*I*C1 or Z*I*C2	0.00240		* Total weight of the tank shell, Ws	79,976	Kg
* Height from the bottom of the shell to the C.G of the shell, Xs	6,523.0	mm	* Total weight of the tank roof plus the live load portion, Wr	131,153	Kg
* Total height of the tank shell, Ht	15,000	mm	* M = Z*I (C1*Ws*Xs + C1*Wr*Ht + C1*W1*X1 + C2*W2*X2)	3,381,685	Kg-m

2. RESISTANCE TO OVERTURNING

* WL : Maximum weight of the tank contents that may be used to resist the shell overturning moment, in pound per foot of shell circumference.	* Resistance to overturning	5,064 Kg/m

3. SHELL COMPRESSION as per E.5

3.1 Max. Longitudinal Compressive Force at the bottom of the Shell, b

* Y = M/(D2(Wt+WL))	0.0010	* b = Wt + 1.273*M/D2	6,240,267	Kg/m

3.2 Max. allowable Stress (Para. E.5.3), Fa

* U = G*H*D2/t2	786,236,780	* Fa	35,984	Kg/cm^2

3.3 Max. Longitudinal Compressive Stress in the Shell

* Fc = b/(12*t)	40,002	* Judgement	Check !

PART-"E" FOR WIND LOAD DESIGN CALCULATION as per (Para.E.3.11 & ASCE 7-88) ; OPERATING CONDITION

1. VELOCITY PRESSURE

* Qz = 0.00256 * Kz (I*V2)	4.7	Lb/sq ft	* Qz =	23.1	Kg/m^2

2. WIND LOAD for Entire Area of the Tank

* De : Effective diameter, (greater of 1.2*Do or Do + 0.6	27.6	m	* Fw = Qz*Gh*Cf*De*L	8,654	Kg

3. OVERTURNING MOMENT due to WIND LOAD

* M = Fw*L/2	64,901.8	Kg-m	* Limition, 2/3*(W*D/2)	1,006,643	Kg-m
* D : Nominal Tank Diameter	23.026	m	* Judgement	O.K	

PART-"F" FOR WEIGHT CALCULATION

* Shell(Assumed)	79,976	Kg	* Bottom	26,092	Kg
* Roof	28,084	Kg	* Nozzle & Flange	700	Kg
* Column Support	27,218	Kg	* Ladder & Platfom	6,448	Kg
* Top Angle	1,293	Kg	* Compression Ring	54	Kg
* Rafter	7,610	Kg	* Winder Girder	0	Kg
* Live Load of Roof	51,109	Kg	* Insulation	13,588	Kg
* Contents	6,232,129	Kg	* Hydro Static Test Water	6,232,129	Kg

PART-"G" FOR WEIGHT SUMMARY

* Fabrication Weight	177,476	Kg			
* Empty Weight	191,064	Kg	* Erection Weight	171,028	Kg
* Operating Weight	6,474,302	Kg	* Test Weight	6,403,157	Kg

PART-"H" FOR LOADING DATA SUMMARY

* LOAD	OPERATING	EMPTY+WIND	* OPERATING+SEISMIC	HYDRO. TEST	UNIT
* ON SHELL	1.20	1.35	9.34	1.20	ton/m^2
* ON BOTTOM	15.06	1.31	80.18	15.06	ton/m^2
* OVERTURING MOMENT		64.90	3,381.68		ton-m
* SHEAR FORCE		8.65			ton
* SLIDING FORCE		85.98			ton

THE END OF STRENGTH CALCULATION !

ROOF GEOMETRY

* Roof Straight Length	11,643	mm	* Roof Height	1,822	mm

PLATFORM & STAIR WAY WEIGHT

* Spiral Stairway-Length	21	MR	* Stairway-Top Length	12	MR
* Spiral Stairway-Weight	955	Kg	* Stairway-Top Weight	489	Kg
* WalkWay-Top Length	72	MR	* Internal Ladder	15	MR
* WalkWay-Top Weight	4,550	Kg	* Internal Ladder-Weight	455	Kg

FABRICATION INFORMATION

* Total surface Area	2,118	M^2	* Total Plate Piece Q'ty	59	PC
* Total volume	6,232	M^3	* Total plate welding length	1,765	MR
* Total Rafter length	442	MR	* R/T	1,765	SH
* R/T, T-Cross Points	214	EA	* Welding Rod	715	Kg

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Please contact E-mail ***pes21@pes21.com***