E.A.P.Co.

Crude Oil Storage Tanks Farm

Ramat Yotam Eilat Site

Computational Evaluation of Earthquake Resistance for Compliance Verification to API 650 Edition 2007, Addendum 3, 2011

Document No.

14434-11-CAL-002

Submitted by:

Y.W. Galil Engineering Ltd

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			Y.W. Galil Eng.		Customer		

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FORWARD

Galil Engineering was requested by E.A.P.Co. to perform seismic calculation according to the latest edition of API 650 Appendix E, in order to check the seismic stability of 16 storage tanks located at the Ramat Yotam Eilat site.

Ramat Yotam Eilat tank farm was built 40-50 years ago. At this time no seismic calculation requirements have been specified by API 650.

The Israeli standard 413 for earthquake resistance of liquid containing tanks was published after the tank has been built.

This report includes seismic calculations for the tanks according to API 650, 11th edition (2007) addendum 3 (2011) which is mandatory from February 1, 2012.

This report is based on calculations as described below, based on the below listed documentations and findings during a site visit, performed in December 2012.

1. GENERAL DESCRIPTION

The crude oil storage tank farm of Ramat Yotam Eilat site includes the following tanks:

- 3 tanks of 80 m nominal diameter containing 96,000 m^3 (crude oil) Tanks Tag No 41,43,44. Each tank is equipped with external floating roof with peripheral and central pontoons.
- 4 tanks of 80 m nominal diameter containing 96,000 m^3 (crude oil) Tanks Tag No.: 45, 46, 47, 48 Each tank is equipped with an external floating roof with peripheral pontoons.
- 9 tanks of 60 m nominal diameter containing 57,000 m^3 (crude oil). Tanks Tag No.: 31÷39. Each tank is equipped with an external floating roof.

2. DOCUMENTATION

In order to perform the seismic stability evaluation of the tanks, we received from E.A.P.Co. drawings of the tanks shell. See Table 1 – Reference Drawing List.

The drawings contain the following technical information:

- Thickness and width of each shell course
- Dimensions of top angle
- Bottom thickness
- Material of construction.

Table No. 1 Reference drawings List

No.	Tank Tag No	Drawing				
		Designer	Name	No	Rev.	Date
1.	41,43,44	SWARTTOUW's	Shell plate	38457	B	6.01.71
2.	45,46,47,48	TAHAL Consulting Engineers Ltd.	Shell Details	DG 030/3305	-	1973
3.	31÷39	TAHAL Consulting Engineers Ltd	Shell & Shell Extension	DG 030/3051/C	C	1968 (as made 1970)

In addition, E.A.P.C has provided geotechnical report prepared for the site by "KLAR ISRAEL- Foundations Engineering and Geotechnical Consulting" in the year 2011 for foundation works of crude oil storage tanks. This report includes valuable information about the sub- soil properties.

3. Site Visual inspection

3.1. Site Description

The site is located at the west side of the city of Eilat, at altitude of 200-220 m above sea level. The site contains 16 storage Tanks as described above, erected in separated soil containments, excavated on the side slopes of the mountain on an artificially leveled area. Each containment is divided into shallow "sub containment" by soil dykes, according to fire fighting demands. Around each tank there is an asphalt paved strip, app. 1.5 m wide. Outside of the strip, the surface is made of the local soil.

3.2. Soil conditions

According to the site observations and information appears in the past geotechnical investigation, the upper layers of soil is a composition of Sand, silt and debris of Hard Rock..
SPT tests performed in the different soil layers showed results of 30-75.
According to the described soil components and properties, the local soil may be classified as type "C" according to the soil classification of ASCE7 or IS413.
The allowable bearing pressure of the local soil, based on information appears in the geotechnical report and the common practice, may be taken as 30 t/m^2.

3.3. Maintenance of the Tanks

The tanks and surrounding strip is in generally good conditions. There are no signs for damages or repair actions in the tanks, or in the circumferential asphalt paving. Most of the tanks are painted in the original paint system. Due to the dry weather in this area the painting is in good condition. Recently, E.A.P.Co. has decided to paint all tanks in white color in order to reduce the oil temperature.
The sealant between the base ring of the tank and the asphalt paving is in good condition, generally smooth and straight.

3.4. Foundations system

The tanks are founded directly on the soil- probably on soil replacement to unknown depth.. It is possible that an asphalt paving have been done under the entire floor, but it is not clear. In none of the inspected Tanks there is a concrete foundation. Minor soil settlements have been recognized in some locations, by cracking of the asphalt paving and distortion in the sealant between the base ring and the paving. The settlements are usually identified by downward settlement of the entire tank and "rising" of the soil around the tank. This is normal response of the ground under the heavy imposed loads and the load variation due to filling/ emptying cycles of the tank's content, but it is resulted by surface deformations and cracks around the Tank. In certain cases, on soils with low resistance, it may be resulted in high deformations and possibility of damage to the floor/ wall connection. In Ramat Yotam site this phenomenon is minor and can be considered as negligible - assumably due to high strength properties of the ground and good quality of the earthworks under the Tanks.

3.5. Tank's wall thickness

The calculations were based on the nominal wall thickness as indicated on the tanks drawings. In order to verify the actual condition of the shell, tanks T-32 and T-43 were examined. T-32 was measured in 154 nodes and T-43 was measured in 168 nodes. In T-32 146 measurements results were above the nominal wall thickness or within the allowable under tolerance for plates (0.25 mm). 8 measurements indicated a reduction in the wall thickness of 0.26-0.6 mm. this may be considered as minor local "pitting" and is within the allowable of API 653. In T-43 all measurements are above the nominal required plate thickness.
These measurements provide the required verification that the actual wall thickness is within the required thickness according to API 650 and 653 standards. E.P.Co. will perform measurements to more tanks during 2013.

4. DESIGN REQUIRMENTS

Check the compliance of the existing tanks with current API 650 seismic requirements.

5. Bearing Capacity

The static contact pressure between the tank and the bedding is app 20 t/m^2- significantly less than the allowed bearing pressure for the local soil.
Under seismic action, assuming that the tank is full and that the entire bearing surface respond in elastic response, the bearing pressure may varies.
Under the site specific conditions as described in this document, the maximum bearing pressure may increase to 22 t/m^2- less than the allowable

6. LOADS

6.1. Weights

6.1.1. Weight of shell, top ring, platforms, stairs, manholes, nozzles and other appurtenances.

All appurtenances weights were approximated as 10% of shell weight.

6.1.2. Weight of the floating roof:

These weights have been provided by E.A.P.Co.

6.1.3. Content weight:

This weight was calculated as the tank volume for operating height multiplied by the product specific gravity. Product specific gravity provided by E.A.P.Co.

Note: Bottom tank weight is not included in seismic calculation.

6.2. Seismic loads (calculated as per API 650)

6.2.1. Ground acceleration parameter for 475 year recurrence interval, according to I.S. 413, para. 2.2.

Sp = 0.23 g for Ramat Yotam Eilat area

6.2.2. Site classification C — API 650 – E.4.4

6.2.3. Seismic Use Group III — API 650 – E.3.1.1

6.2.4. Importance factor for Seismic — API 650 – E.5.1.2, Table E5

Use Group III, I =1.5

6.2.5. Response modification factor — API 650 – E.5.1.1, Table E4

R_{WI} (impulsive) = 3.5

R_{WC} (convective) = 2

6.2.6. Impulsive Spectral Acceleration parameter

Ai= 0.2883 g (calculated) — API 650 – E.4..6. 1-1

6.2.7. Convective Spectral Acceleration parameter

Ac= 0.0614 g (calculated) — API 650 – E.4..6. 1-5

See in Appendices detailed calculations for each group of tanks.

7. CALCULATION PROGRAM DESCRIPTION

The target for this work was to perform seismic calculaiton for 16 storage tanks located at the Ramat Yotam Eilat site.

The calculation was requested to follow the requirements of “Welded tanks for oil storage“ API 650 latest edition Appendix “E“.

In order to calculate the tank stability and shell and bottom stress, for seismic loads, we have developed a computerized Program that complies with the calculation method from above mentioned Standard for sites not addressed by ASCE methods.

Our program deals with the following problems:

7.1 Calculation of weight shell and appurtenances based on tanks drawings provided by E.A.P.Co.

7.2 Calculation of content operating weight.

7.3 Selection of seismic Use Group

7.4 Selection of site class.

7.5 Calculation of tank convective period.

7.6 Selection of ground acceleration parameter.according to I.S. 413 for Ramat Yotam Eilat area.

7.7 Calculation of impulsive and convective spectral acceleration parameters.

7.8 Calculation of effective impulsive and convective weight of the liquid.

7.9 Calculation of center of action of impulsive and convective masses.

7.10 Calculation of tank overturning moment.

7.11 Calculation of factor “**J** “ – Anchorage Ratio in order to determine whether the tank is stable or must be anchored.

7.12 Calculation of maximum shell membrane compression stress.

7.13 Calculation of seismic allowable stress and its comparison to the calculated stress.

For the materials: OX-522C, HSB-40 and FB-50 indicated on the old drawings, API 650 provides no allowable stress. For the seismic calculation purpose we assumed that the wall thickness was calculated according to the API 650 formula for hydrostatic pressure. Knowing the wall thickness, we calculate the allowable stress.

See attached calculation, Appendix 5.

8. CONCLUSIONS

8.1 All tanks in Ramat Yotam Eilat site of E.A.P.Co. checked for seismic loads are stable and do not require anchorage.

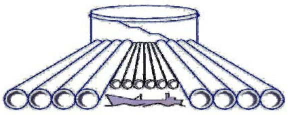
8.2 According to our calculation for all above mentioned tanks, the shell course and bottom thickness are sufficient to match the allowble compression stress due to seismic loads.

8.3 According to our calculation, the tanks in Ramat Yotam Eilat, comply with the requirements of API 650 edition 3 (2007) addendum 3(2011), App. E "Seismic design of storage tanks"

8.4 The foundations system is sufficient and foundation's failure due to seismic loads is not expected.

8.5 The Tanks maintanance is good and no deterioration due to poor maintanance and corrosion is expected.

Appendix 1
Seismic calculations of tanks 41, 43, 44

	Project	14434				
	Document no.					
	Item		Rev.	0		
Y.W. Galil Engineering Ltd. INDUSTRIAL PLANNING	Filename					
	DOCUMENT TITLE: SEISMIC CALCULATIONS					

E.A.P.Co.

CRUDE OIL STORAGE TANK RAMAT YOTAM EILAT SITE

SEISMIC CALCULATIONS FOR

96,000 m³ STORAGE TANKS

TANKS No: 41, 43 ,44

0	17/02/13	APPROVED	E.S.	O.A.	
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REV.	DATE	DESCRIPTION	BY	CKD.	APP'D.

96,000 m³ STORAGE TANK
RAMAT YOTAM -EILAT SITE

TANKS No.41, 43, 44

API Std 650 - Welded Steel Tanks for Oil Storage
Eleventh Edition, June 2007 ADDENDUM 3 : 2011
Appendix E: Seismic Design of Storage Tank

Calculations of the Shell and Appurtenances Weight

Table 1 Shell Course Weight

Course Weight =PI ()*Dm*(h course)*7.85

Carbon steel density 7850 kg/cu m

Shell Course No.	Nominal dia. D m	Course Height m	Course thickness mm	Course Weight kg
1	79.248	2.445	38.1	182059
2	79.248	2.445	31	148132
3	79.248	2.445	26.5	126629
4	79.248	2.44	22	104911
5	79.248	2.44	17.5	83452
6	79.248	2.44	13	61993
7	79.248	1.667	9.5	30950
8	79.248	2.095	9.5	38897
9	79.248	1.853	9.5	34404
10	79.248	0.075	7	1026
TOTAL		20.345		812452

Add 10% for appourtenances

Total weight of tank shell and appurtenance: Ws = 893697 kg = 8.77.E+06 N

Total weight of tank floating roof with Central Pontoon Wr = 350996 kg = 3443271 N

Impulsive Natural Period
For information only-Not used in further calculation
Ti = **0.128 sec** (E.4.5.1)

Calculation of the Convective(Sloshing) Period

Tc= 1.8*Ks*(D^0.5) **11.011 sec** (E.4.5.2-a)

Ks - sloshing period coefficient

Ks= 0.578/((tanh(3.68*H/D))^0.5)= **0.687** (E.4.5.2-c)

Seismic Use Group
Crude oil storage tank is assigned in acc. with
API Std 650, Appendix E, para E.3.1.1, to
Seismic Use Group III
Site Class C

Impulsive Spectral Acceleration Parameter, Ai (E.4.6.1)

Impulsive Spectral Acceleration Parameter:

Ai=2.5*Q*Fa*So*(I/Rwi) **0.2883 g** (E.4.6.1-1)

However, **Ai**= 0.2883 ≥ 0.007 (E.4.6.1-2)

for seismic site Class E

Ai = 0.2883 ≥ 0.625 Sp (I / Rwi) = 0.0616 **NA** (E.4.6.1-3)

where

S1 - mapped maximum considered earthquake,
5%-damped, spectral response acceleration
parameter at a period of one second, %g

Sp (Z) - design level peak ground acceleration parameter
for sites not addressed by ASCE methods, **0.23** g
According to Israeli STD 413,for RAMAT YOTAM- EILAT area (for 475 year recurence interval)

Rwi (impulsive) =	**3.5**		(E.5.1.1 table E-4)
Rwc (convective) =	**2**		(E.5.1.1 table E-4)
Ss = 2.5 Sp	0.5750	g	(E.4.3-1)
S1 = 1.25 Sp	0.2875	g	(E.4.3.-2)
Fa (interpolated)=	1.17		(E.4.4 table E-1)
Fv (interpolated)=	1.5125		(E.4.4 table E-2)
I - importance factor set by Seismic Use Group III is:	1.5		(E.5.1.2 table E-5)

Q - scaling factor from the MCE to the design level
spectral acceleration

Q = 1.000 (E.2.2)

Acc. with API Std 650, Appendix E, para E.4.6.1, for "sites where only the peak ground acceleration is defined" we can "substitute Sp for So."

So= Sp 0.23 g (E.4.6.1)

Convective Spectral Acceleration Parameter, Ac (E.4.6.1)

Tc = 11.011 sec. > TL = 4 sec

where

TL - regional-dependent transition period for longer period ground motion, seconds. (TL is taken as 4 seconds acc. with API Std 650, Appendix E, para E.4.6.1, in regions outside the USA, with regulatory requirements for seismic design differing from the ASCE 7 methods.)

Convective spectral acceleration parameter:
FOR Tc<TL

Ac = 2.5 K*Q*Fa*So (Ts/Tc)* (I / Rwc) ≤ Ai **NA** (E.4.6.1.-4)

FOR Tc>TL

Ac1 = 2.5 K*Q*Fa*So (TsTL/Tc^2)* (I / Rwc) ≤ Ai 0.01614

Ai= 0.2883

Ac= min(Ac1,Ai) **0.01614**

where
K - coefficient to adjust the spectral acceleration from 5% to 0.5% damping **1.5** (E.2.2)

Ts = (Fv * S1) / (Fa * Ss) **0.65** (E.2.2)

<u>Calculation of the Effective Impulsive Weight of the Liquid</u>
Nominal diameter is the centerline diameter of the bottom shell course plates [5.6.1.1 note 1]

D	=	79.248	m	(nominal tank diameter)
H	=	19	m	(maximum design product level)
Hs		20.345	m	(shell height)

acc. with API Std 650, Appendix E, para E.6.1.1 we get:

for D/H = <1.333 (E6.1.1)

Wi = (1-0.218*D/H)*Wp= **NA** (E6.1.1-1)

for D/H = 4.171 >1.333

Wi=[tanh(0.866D/H)]/(0.866D/H)*Wp **24871712 kg = 2.44.E+08 N** (E6.1.1-2)

Wp - total weight of the tank contents, based on the design specific gravity of the product, kg
gama- Specific gravity of fluid **0.96**

Wp=1000PI*D^2*H*gama/4= **89968678 kg = 8.83E+08 N**

<u>Calculation of the Effective Convective Weight of the Liquid</u>

Wc=0.230*D/H*tanh(3.67*H/D)*Wp **60965540 kg = 5.98E+08 N** (E.6.1.1-3)

<u>Center of Action for Ringwall Overturning Moment</u> (E6.1.2.1)

for D/H = <1.333

Xi=(0.5-0.094*D/H)*H= **NA m** (E6.1.2.1-2)

for D/H = 4.171 >1.333

Xi=0.375*H= **7.125** **m** (E6.1.2.1-1)

Xc=(1-(cosh(3.67*H/D)-1)/(3.67*H/D*sinh(3.67*H/D))*H= **10.069** **m** (E.6.1.2.1-3)

where
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, m
Xc - 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 ringwall moment, m

Calculation of the Ringwall Overturning Moment

Mrw = { [Ai(Wi*Xi+Ws*Xs+Wr*Xr)]^2 + [Ac(Wc*Xc)]^2 }^0.5 **5.544E+08 Nm** (E.6.1.5-1)
56513.025 Tm

where

Ai =	0.2883	g			
Wi =	2.44E+08	N			
Xi =	7.125	m			
Ws =	8.77.E+06	N			
Xs =	Hs/2 =	10.1725	m	(height from the tank shell bottom to the shell's center of gravity)	
Wr =	3443271	N			
Xr =	H	19	m	(height from the tank shell bottom to the floating roof center of gravity)	
Ac =	0.0161	g			
Wc =	5.98E+08	N			
Xc =	10.069	m			

Calculation of the Anchorage Ratio

J =Mrw / [(D^2)*(wt(1-0.4Av)+wa)] **0.600** (E.6.2.1.1.1-1)

wt - tank and roof weight acting at base of shell, 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

wt = Ws/(π*D)+wrs **35214** **N/m** (E.6.2.1.1.1-2)

wrs - roof load acting on the shell, N/m **No external roof**

wrs=Wr/(π*D) **0** **N/m**

wa1= 99 ta (Fy*H*Ge)^0.5 ≤ 201.1 (H*D*Ge) (E.6.2.1.1-1a)

ta = 15 mm (thickness of the bottom plate under the shell, less corrosion allowance)

Fy= 345 MPa (minimum specified yield strength of bottom annulus for CS)

Ge - effective specific gravity including vertical seismic effects

Ge= G(1-0.4Av) **0.901** (E.2.2)

G- specific gravity of the fluid	**0.96**		
Av= Vertical seimic acceleration coefficient=0.67*Z	**0.154**	**g**	(I.S.413 2.2 Para5.9)
wa1=99*ta*(Fy*H*Ge)^0.5	114112	N/m	
wa2=201.1*H*D*Ge	272769	N/m	
Use wa = MIN[wa1,wa2]	**114112**	**N/m**	

The anchorage ratio criterion is:

J = **0.600** **<** **0.785**

Acc. with API Std 650, Appendix E, Table E-6, the **TANK is self anchored**

Calculation of the Maximum Longitudinal
Shell Membrane Compression Stress

The maximum longitudinal shell compression stress at the bottom of the shell for Self-anchored tanks

σc = { wt*(1+0.4Av) + [1.273 Mrw / (D^2)] }*[1 / (1000 ts)]	**4.0**	MPa	(E.6.2.2.1-1a)
ts - thickness of bottom shell course less corrosion allowance	37.1	mm	

Allowable Longitudinal Shell-Membrane Compression Stress inTank Shell (E.6.2.2.3)

When G*H*(D^2) /(t^2) 83.22 >44

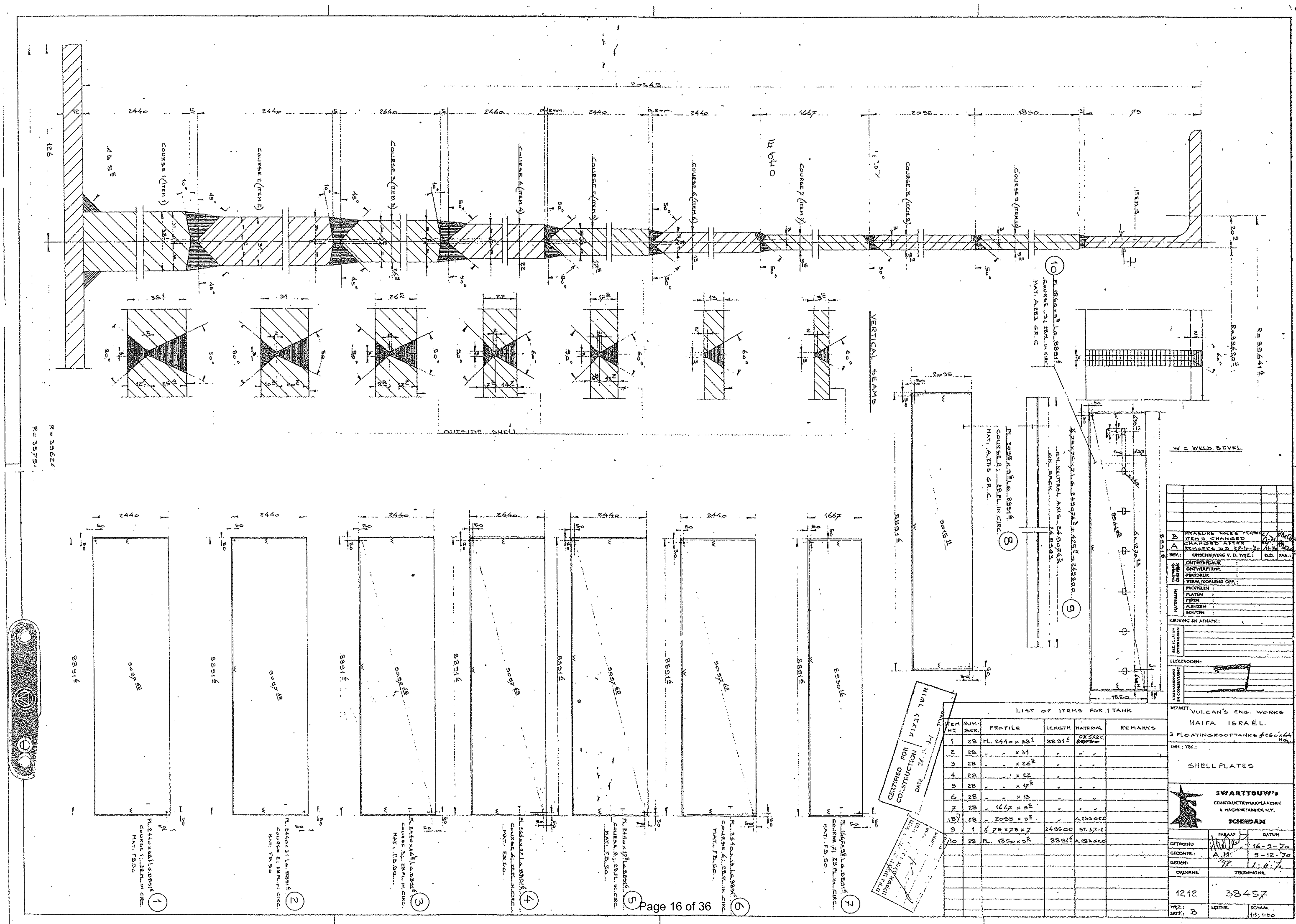
t - thickness of the shell ring under consideration, mm
t = Corroded thickness of Course No.1 37.1 mm

Seismic allowable stress :

Fc =83 ts / D = **39** Mpa (E.6.2.2.3-1a)

Fc value includes the 33% increase for allowable stress design (ADS) for the seismic design.

σc = 4.0 **<** **Fc =** 39 Mpa **O.K.**



LIST OF ITEMS FOR 1 TANK					
ITEM Nº	NUMBER	PROFILE	LENGTH	MATERIAL	REMARKS
1	28	PL. 2440 x 33	8891	OX 322 C	
2	28	" " x 31	"	" "	
3	28	" " x 26	"	" "	
4	28	" " x 22	"	" "	
5	28	" " x 17	"	" "	
6	28	" " x 13	"	" "	
7	28	" 1667 x 9	"	" "	
(8)	28	" 2095 x 9	"	A.283 GR.C	
9	1	∠ 75 x 75 x 7	249500	ST. 37-2	
10	28	PL. 1850 x 9	8891	A.283 GR.C	

BETREFT: VULCAN'S ENG. WORKS
HAIFA ISRAËL
3 FLOATINGROOFTANKS ø 260' x 64'

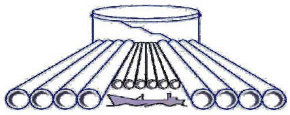
INH.: TEK.:
SHELL PLATES

SWARTTOUW'S
CONSTRUCTIEWERKPLAATSEN & MACHINEFABRIEK N.V.
SCHIEDAM

	PARAAF	DATUM
GETEKEND		16-9-70
GECONTR.:	A.H.	9-12-70
GEZIEN:		2-6-71

ORDERNR.	TEKENINGNR.	
1212	38457	
WIJZ.: LETT.: B	LIJSTNR.	SCHAAL 1:1; 1:50

Appendix 2
Seismic calculations of tanks 45, 46, 47, 48



Project	**14434**				
Document no.					
Item		Rev.	**0**		
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DOCUMENT TITLE: SEISMIC CALCULATIONS					

E.A.P.Co.

CRUDE OIL STORAGE TANK
RAMAT YOTAM EILAT SITE

SEISMIC CALCULATIONS
FOR

96,000 m^3 STORAGE TANKS

TANKS No: 45, 46 ,47, 48

0	17/02/13	APPROVED	E.S.	O.A.	
P0	09/12/12	FOR COMMENTS	G.W.	O.A	
REV.	DATE	DESCRIPTION	BY	CKD.	APP’D.

96,000 m^3 STORAGE TANK
RAMAT YOTAM -EILAT SITE

TANKS No.45, 46, 47, 48

API Std 650 - Welded Steel Tanks for Oil Storage
Eleventh Edition, June 2007 ADDENDUM 3 : 2011
Appendix E: Seismic Design of Storage Tank

Calculations of the Shell and Appurtenances Weight

Table 1 Shell Course Weight

Course Weight =PI ()*Dm*(h course)*7.85

Carbon steel density 7850 kg/cu m

Shell Course No.	Nominal dia. D m	Course Height m	Course thickness mm	Course Weight kg
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2	79.248	2.443	31	148011
3	79.248	2.443	26.5	126525
4	79.248	2.438	22	104825
5	79.248	2.438	17.5	83383
6	79.248	2.438	13	61942
7	79.248	2.438	9.5	45265
8	79.248	2.438	9.5	45265
9	79.248	0.81	9.5	15039
TOTAL		20.329		812165

Add 10% for appourtenances

Total weight of tank shell and appurtenance Ws = 893382 kg = 8.76.E+06 N

Total weight of tank floating roof Wr = 373493 kg = 3663966 N

Impulsive Natural Period
For information only-Not used in further calculation
Ti = **0.128 sec** (E.4.5.1)

Calculation of the Convective(Sloshing) Period

Tc= 1.8*Ks*(D^0.5) **11.011 sec** (E.4.5.2-a)

Ks - sloshing period coefficient

Ks= 0.578/((tanh(3.68*H/D))^0.5)= **0.687** (E.4.5.2-c)

Seismic Use Group
Crude oil storage tank is assigned in acc. with
API Std 650, Appendix E, para E.3.1.1, to
Seismic Use Group III
Site Class C

Impulsive Spectral Acceleration Parameter, Ai (E.4.6.1)

Impulsive Spectral Acceleration Parameter:

Ai=2.5*Q*Fa*So*(I/Rwi) **0.2883 g** (E.4.6.1-1)

However, **Ai**= 0.2883 ≥ 0.007 (E.4.6.1-2)

for seismic site Class E

Ai = 0.2883 ≥ 0.625 Sp (I / Rwi) = 0.0616 **NA** (E.4.6.1-3)

where

S1 - mapped maximum considered earthquake, 5%-damped, spectral response acceleration parameter at a period of one second, %g

Sp (Z) - design level peak ground acceleration parameter for sites not addressed by ASCE methods, 0.23 g
According to Israeli STD 413,for RAMAT YOTAM- EILAT area (for 475 year recurence interval)

Rwi (impulsive) =	**3.5**		(E.5.1.1 table E-4)
Rwc (convective) =	**2**		(E.5.1.1 table E-4)
Ss = 2.5 Sp	0.5750	g	(E.4.3-1)
S1 = 1.25 Sp	0.2875	g	(E.4.3.-2)
Fa (interpolated)=	1.17		(E.4.4 table E-1)
Fv (interpolated)=	1.5125		(E.4.4 table E-2)
I - importance factor set by Seismic Use Group III is:	1.5		(E.5.1.2 table E-5)

Q - scaling factor from the MCE to the design level spectral acceleration

Q = 1.000 (E.2.2)

Acc. with API Std 650, Appendix E, para E.4.6.1, for "sites where only the peak ground acceleration is defined" we can "substitute Sp for So."

So= Sp 0.23 g (E.4.6.1)

<u>Convective Spectral Acceleration Parameter, Ac</u> (E.4.6.1)

Tc = 11.011 sec. > TL = 4 sec

where

TL - regional-dependent transition period for longer period ground motion, seconds. (TL is taken as 4 seconds acc. with API Std 650, Appendix E, para E.4.6.1, in regions outside the USA, with regulatory requirements for seismic design differing from the ASCE 7 methods.)

Convective spectral acceleration parameter:
FOR Tc<TL

Ac = 2.5 K*Q*Fa*So (Ts/Tc)* (I / Rwc) ≤ Ai **NA** (E.4.6.1.-4)

FOR Tc>TL

Ac1 = 2.5 K*Q*Fa*So (TsTL/Tc^2)* (I / Rwc) ≤ Ai 0.01614

Ai= 0.2883

Ac= min(Ac1,Ai) **0.01614**

where
K - coefficient to adjust the spectral acceleration from 5% to 0.5% damping **1.5** (E.2.2)

Ts = (Fv * S1) / (Fa * Ss) **0.65** (E.2.2)

Calculation of the Effective Impulsive Weight of the Liquid

Nominal diameter is the centerline diameter of the bottom shell course plates [5.6.1.1 note 1]

D	=	79.248	m	(nominal tank diameter)
H	=	19	m	(maximum design product level)
Hs		20.329	m	(shell height)

acc. with API Std 650, Appendix E, para E.6.1.1 we get:

for D/H = <1.333 (E6.1.1)

Wi = (1-0.218*D/H)*Wp= **NA** (E6.1.1-1)

for D/H = 4.171 >1.333

Wi=[tanh(0.866D/H)]/(0.866D/H)*Wp **24871712 kg = 2.44.E+08 N** (E6.1.1-2)

Wp - total weight of the tank contents, based on the design specific gravity of the product, kg
gama- Specific gravity of fluid **0.96**

Wp=1000PI*D^2*H*gama/4= **89968678 kg = 8.83E+08 N**

Calculation of the Effective Convective Weight of the Liquid

Wc=0.230*D/H*tanh(3.67*H/D)*Wp **60965540 kg = 5.98E+08 N** (E.6.1.1-3)

Center of Action for Ringwall Overturning Moment (E6.1.2.1)

for D/H = <1.333

Xi=(0.5-0.094*D/H)*H= **NA m** (E6.1.2.1-2)

for D/H = 4.171 >1.333

Xi=0.375*H= **7.125** **m** (E6.1.2.1-1)

Xc=(1-(cosh(3.67*H/D)-1)/(3.67*H/D*sinh(3.67*H/D))*H= **10.069** **m** (E.6.1.2.1-3)

where

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, m

Xc - 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 ringwall moment, m

Calculation of the Ringwall Overturning Moment

Mrw = { [Ai(Wi*Xi+Ws*Xs+Wr*Xr)]^2 + [Ac(Wc*Xc)]^2 }^0.5 **5.556E+08 Nm** (E.6.1.5-1)
56631.421 Tm

where

Ai =	0.2883	g
Wi =	2.44E+08	N
Xi =	7.125	m

Ws =	9.E+06	N			
Xs =	Hs/2 =	10.1645	m		(height from the tank shell bottom to the shell's center of gravity)
Wr =	3663966	N			
Xr =	H	19	m		(height from the tank shell bottom to the floating roof center of gravity)

Ac =	0.0161	g
Wc =	5.98E+08	N
Xc =	10.069	m

Calculation of the Anchorage Ratio

J =Mrw / [(D^2)*(wt(1-0.4Av)+wa)] **0.601** (E.6.2.1.1.1-1)

wt - tank and roof weight acting at base of shell, 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

wt = Ws/(π*D)+wrs **35202** **N/m** (E.6.2.1.1.1-2)

wrs - roof load acting on the shell, N/m **No external roof**

wrs=Wr/(π*D) **0** **N/m**

wa1= 99 ta (Fy*H*Ge)^0.5 ≤ 201.1 (H*D*Ge) (E.6.2.1.1-1a)

ta = 15 mm (thickness of the bottom plate under the shell, less corrosion allowance)

Fy= 345 MPa (minimum specified yield strength of bottom annulus for CS)

Ge - effective specific gravity including vertical seismic effects

Ge= G(1-0.4Av) **0.901** (E.2.2)

G- specific gravity of the fluid	**0.96**		
Av= Vertical seimic acceleration coefficient=0.67*Z	**0.154**	**g**	(I.S.413 2.2 Para5.9)
wa1=99*ta*(Fy*H*Ge)^0.5	114112	N/m	
wa2=201.1*H*D*Ge	272769	N/m	
Use wa = MIN[wa1,wa2]	**114112**	**N/m**	

The anchorage ratio criterion is:

J = **0.601** **<** **0.785**

Acc. with API Std 650, Appendix E, Table E-6, the **<u>TANK is self anchored</u>**

<u>Calculation of the Maximum Longitudinal</u>
<u>Shell Membrane Compression Stress</u>

The maximum longitudinal shell compression stress at the bottom of the shell for Self-anchored tanks

σc = { wt*(1+0.4Av) + [1.273 Mrw / (D^2)] }*[1 / (1000 ts)]	**4.0**	MPa	(E.6.2.2.1-1a)
ts - thickness of bottom shell course less corrosion allowance	37.1	mm	

Allowable Longitudinal Shell-Membrane Compression Stress inTank Shell (E.6.2.2.3)

When G*H*(D^2) /(t^2) 83.22 >44

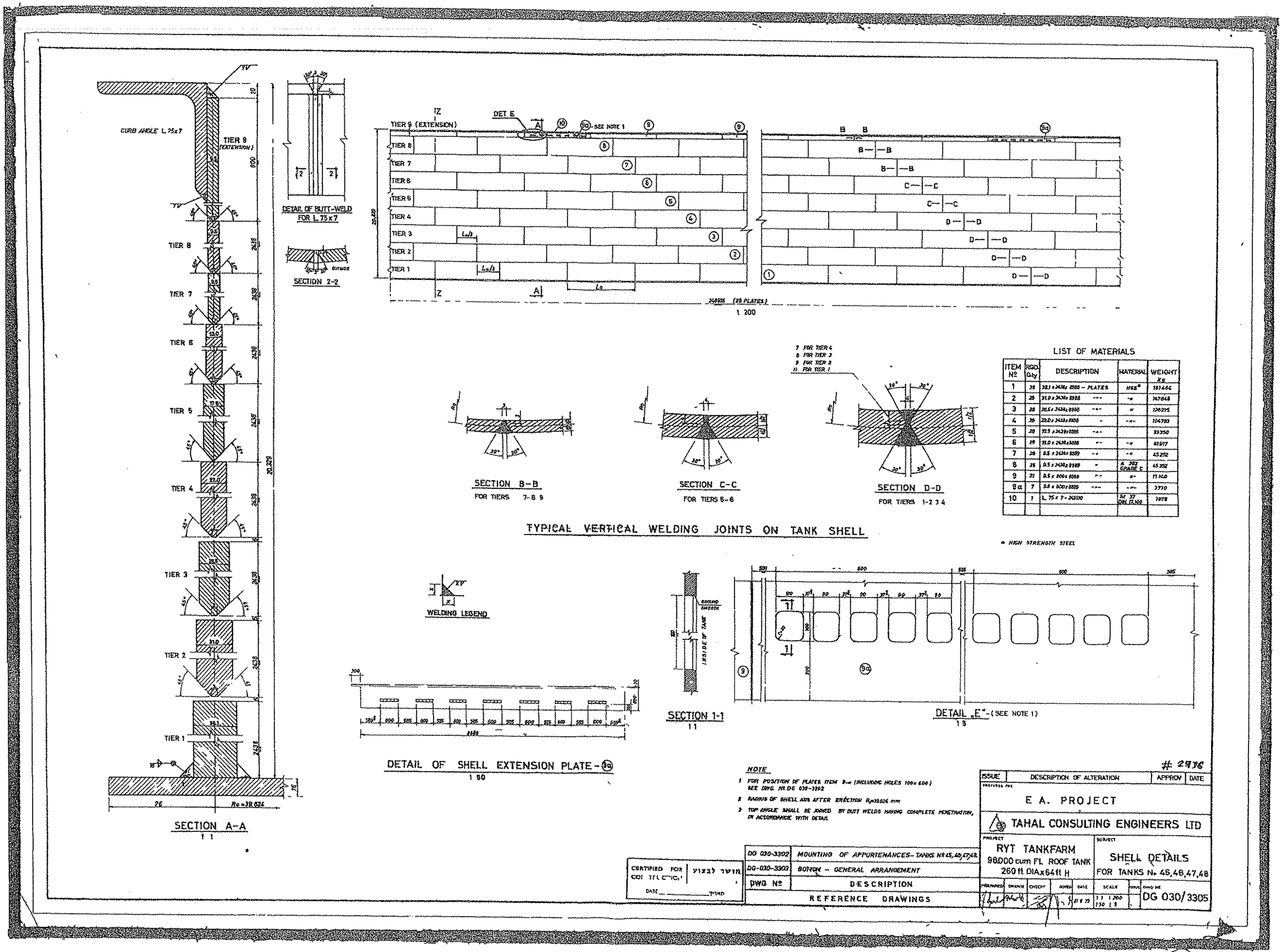
t - thickness of the shell ring under consideration, mm
t = Corroded thickness of Course No.1 37.1 mm

Seismic allowable stress :

Fc =83 ts / D = **39** Mpa (E.6.2.2.3-1a)

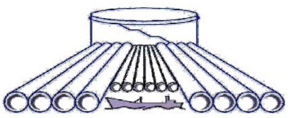
Fc value includes the 33% increase for allowable stress design (ADS) for the seismic design.

σc = 4.0 **<** **Fc =** 39 Mpa **O.K.**



CURB ANGLE L 75x7
TIER 9 (EXTENSION)
TIER 8
TIER 7
TIER 6
TIER 5
TIER 4
TIER 3
TIER 2
TIER 1
SECTION A-A
DETAIL OF BUTT-WELD FOR L 75x7
SECTION 2-2
DET E
TYPICAL VERTICAL WELDING JOINTS ON TANK SHELL
SECTION B-B
FOR TIERS 7-8 9
SECTION C-C
FOR TIERS 5-6
SECTION D-D
FOR TIERS 1-2 3 4
LIST OF MATERIALS
ITEM Nº
RQD. Qty
DESCRIPTION
MATERIAL
WEIGHT Kg
* HIGH STRENGTH STEEL
WELDING LEGEND
DETAIL OF SHELL EXTENSION PLATE - 9a
SECTION 1-1
INSIDE OF TANK
DETAIL „E" - (SEE NOTE 1)
NOTE
1 FOR POSITION OF PLATES ITEM 9-a (INCLUDING HOLES 100x 600) SEE DWG. Nº DG 030-3302
2 RADIUS OF SHELL AXIS AFTER ERECTION
3 TOP ANGLE SHALL BE JOINED BY BUTT WELDS HAVING COMPLETE PENETRATION, IN ACCORDANCE WITH DETAIL
2976
ISSUE
DESCRIPTION OF ALTERATION
APPROV
DATE
E A. PROJECT
TAHAL CONSULTING ENGINEERS LTD
PROJECT
RYT TANKFARM
98000 cum FL ROOF TANK
260 ft DIAx64ft H
SUBJECT
SHELL DETAILS
FOR TANKS N. 45,46,47,48
DG 030-3302
MOUNTING OF APPURTENANCES - TANKS Nº 45,46,47,48
DG-030-3303
BOTTOM - GENERAL ARRANGEMENT
DWG Nº
DESCRIPTION
REFERENCE DRAWINGS
CERTIFIED FOR
מאושר לבצוע
DATE
תאריך
PREPARED
DRAWN
CHECKED
DATE
SCALE
DWG Nº
DG 030/3305
50

Appendix 3
Seismic calculations of tanks 31÷39



Project	**14434**					
Document no.						
Item		Rev.	**0**			
Filename						
DOCUMENT TITLE: SEISMIC CALCULATIONS						

E.A.P.Co.

CRUDE OIL STORAGE TANK
RAMAT YOTAM EILAT SITE

SEISMIC CALCULATIONS
FOR

57,000 m^3 STORAGE TANKS

TANKS No: 31, 32, 33, 34, 35, 36, 37, 38, 39

0	17/02/13	APPROVED	E.S.	O.A.	
P0	09/12/12	FOR COMMENTS	G.W.	O.A	
REV.	DATE	DESCRIPTION	BY	CKD.	APP'D.

30,000 m³ STORAGE TANK
EILAT SITE

TANKS No.31~39

API Std 650 - Welded Steel Tanks for Oil Storage
Eleventh Edition, June 2007 ADDENDUM 3 : 2011
Appendix E: Seismic Design of Storage Tank

Calculations of the Shell and Appurtenances Weight

Table 1 Shell Course Weight

Course Weight =PI ()*Dm*(h course)*7.85

Carbon steel density 7850 kg/cu m

Shell Course No.	Nominal dia. D m	Course Height m	Course thickness mm	Course Weight kg
1	60.96	2.42	31.5	114602
2	60.96	2.422	27.6	100496
3	60.96	2.427	23.7	86473
4	60.96	2.43	19.7	71968
5	60.96	2.434	15.8	57815
6	60.96	2.438	11.9	43616
7	60.96	2.442	8	29370
8	60.96	2.442	8	29370
9	60.96	0.075	8	902
10	60.96	0.8	6.35	7637
TOTAL		20.33		542248

Add 10% for appourtenances

Total weight of tank shell and appurtenances: Ws = 596473 kg = 5.85.E+06 N

Total weight of tank floating roof (Assumed) Wr = 218000 kg = 2138580 N

Calculation of the Effective Impulsive Weight of the Liquid
Nominal diameter is the centerline diameter of the bottom shell course plates [5.6.1.1 note 1]

D = 60.96 m (nominal tank diameter)
H = 19 m (maximum design product level)
Hs 20.33 m (shell height)
According to API Std 650, Appendix E, para E.6.1.1 we get:

for D/H = <1.333 (E6.1.1)

Wi = (1-0.218*D/H)*Wp= **NA** (E6.1.1-1)

for D/H = 3.208 >1.333

Wi=[tanh(0.866D/H)]/(0.866D/H)*Wp **19210681 kg = 1.88.E+08 N** (E6.1.1-2)

Wp - total weight of the tank contents, based on the design specific gravity of the product, kg
gama- Specific gravity of fluid **0.97**

Wp=1000PI*D^2*H*gama/4= **53790445 kg = 5.28E+08 N**

Calculation of the Effective Convective Weight of the Liquid

Wc=0.230*D/H*tanh(3.67*H/D)*Wp **32378808 kg = 3.18E+08 N** (E.6.1.1-3)

Center of Action for Ringwall Overturning Moment (E6.1.2.1)

for D/H = <1.333

Xi=(0.5-0.094*D/H)*H= **NA m** (E6.1.2.1-2)

for D/H = 3.208 >1.333

Xi=0.375*H= **7.125 m** (E6.1.2.1-1)

Xc=(1-(cosh(3.67*H/D)-1)/(3.67*H/D*sinh(3.67*H/D))*H= **10.416 m** (E.6.1.2.1-3)

where

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, m

Xc - 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 ringwall moment, m

Impulsive Natural Period

For information only-Not used in further calculation

Ti = **0.128 sec** (E.4.5.1)

Calculation of the Convective(Sloshing) Period

Tc= 1.8*Ks*(D^0.5) **8.988 sec** (E.4.5.2-a)

Ks - sloshing period coefficient

Ks= 0.578/((tanh(3.68*H/D))^0.5)= **0.640** (E.4.5.2-c)

Seismic Use Group

Crude oil storage tank is assigned in acc. with
API Std 650, Appendix E, para E.3.1.1, to
Seismic Use Group III

Site Class C

Impulsive Spectral Acceleration Parameter, Ai (E.4.6.1)

Impulsive Spectral Acceleration Parameter:

Ai=2.5*Q*Fa*So*(I/Rwi) **0.2883 g** (E.4.6.1-1)

However, **Ai**= 0.2883 ≥ 0.007 (E.4.6.1-2)

for seismic site Class E

Ai = 0.2883 ≥ 0.625 Sp (I / Rwi) = 0.0616 **NA** (E.4.6.1-3)

where

S1 - mapped maximum considered earthquake, 5%-damped, spectral response acceleration parameter at a period of one second, %g

Sp (Z) - design level peak ground acceleration parameter for sites not addressed by ASCE methods, According to Israeli STD 413,for EILAT area (for 475 year recurence interval) 0.23 g

Rwi (impulsive) =	**3.5**		(E.5.1.1 table E-4)
Rwc (convective) =	**2**		(E.5.1.1 table E-4)
Ss = 2.5 Sp	0.5750	g	(E.4.3-1)
S1 = 1.25 Sp	0.2875	g	(E.4.3.-2)
Fa (interpolated)=	1.17		(E.4.4 table E-1)
Fv (interpolated)=	1.5125		(E.4.4 table E-2)
I - importance factor set by Seismic Use Group III is:	1.5		(E.5.1.2 table E-5)

Q - scaling factor from the MCE to the design level spectral acceleration

Q = 1.000 (E.2.2)

Acc. with API Std 650, Appendix E, para E.4.6.1, for "sites where only the peak ground acceleration is defined" we can "substitute Sp for So."

So= Sp 0.23 g (E.4.6.1)

Convective Spectral Acceleration Parameter, Ac (E.4.6.1)

Tc = 8.988 sec. > TL = 4 sec

where

TL - regional-dependent transition period for longer period ground motion, seconds. (TL is taken as 4 seconds acc. with API Std 650, Appendix E, para E.4.6.1, in regions outside the USA, with regulatory requirements for seismic design differing from the ASCE 7 methods.)

Convective spectral acceleration parameter:

FOR Tc<TL

Ac = 2.5 K*Q*Fa*So (Ts/Tc)* (I / Rwc) ≤ Ai **NA** (E.4.6.1.-4)

FOR Tc>TL

Ac1 = 2.5 K*Q*Fa*So (TsTL/Tc^2)* (I / Rwc) ≤ Ai 0.02422 (E.4.6.1.-5)

Ai= 0.2883

Ac= min(Ac1,Ai) **0.02422 g**

where

K - coefficient to adjust the spectral acceleration from 5% to 0.5% damping **1.5** (E.2.2)

Ts = (Fv * S1) / (Fa * Ss) **0.65** **sec** (E.2.2)

Calculation of the Ringwall Overturning Moment

Mrw = { [Ai(Wi*Xi+Ws*Xs+Wr*Xr)]^2 + [Ac(Wc*Xc)]^2 }^0.5 **4.24E+08 Nm** (E.6.1.5-1)
43186 Tm

where

Ai =	0.2883	g
Wi =	1.88E+08	N
Xi =	7.125	m

Ws =	6.E+06	N			
Xs =	Hs/2	=	10.165	m	(height from the tank shell bottom to the shell's center of gravity)
Wr =	2138580	N			
Xr =	H		19	m	(height from the tank shell bottom to the floating roof center of gravity)

Ac =	0.0242	g
Wc =	3.18E+08	N
Xc =	10.416	m

<u>Calculation of the Anchorage Ratio</u>

J =Mrw / [(D^2)*(wt(1-0.4Av)+wa)] **1.011** (E.6.2.1.1.1-1)

wt - tank and roof weight acting at base of shell, 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

wt =	Ws/(π*D)+wrs	**30554**	**N/m**	(E.6.2.1.1.1-2)
wrs - roof load acting on the shell, N/m		**No external roof**		
wrs=Wr/(π*D)		**0**	**N/m**	
wa1=	99 ta (Fy*H*Ge)^0.5 ≤ 201.1 (H*D*Ge)			(E.6.2.1.1-1a)
ta =	11	mm (thickness of the bottom plate under the shell, less corrosion allowance)		
Fy=	345	MPa (minimum specified yield strength of bottom annulus for CS)		
Ge - effective specific gravity including vertical seismic effects				
Ge= G(1-0.4Av)		**0.910**		(E.2.2)
G- specific gravity of the fluid		**0.97**		
Av= Vertical seimic acceleration coefficient=0.67*Z		**0.154**	**g**	(I.S.413 2.2 Para5.9)
wa1=99*ta*(Fy*H*Ge)^0.5		84117	N/m	
wa2=201.1*H*D*Ge		212008	N/m	
Use wa =	MIN[wa1,wa2]	**84117**	**N/m**	

The anchorage ratio criterion is:

J = **1.011** **≤** **1.54**

Acc. with API Std 650, Appendix E, Table E-6, the **<u>TANK is self anchored</u>**

Calculation of the Maximum Longitudinal
Shell Membrane Compression Stress

The maximum longitudinal shell compression stress at the bottom of the shell
for Self-anchored tanks

if J≤0.785

σc = { wt*(1+0.4Av) + [1.273 Mrw / (D^2)] }*[1 / (1000 ts)]	5.8	MPa	(E.6.2.2.1-1a)

if 0.785<J≤1.54

σc = { (wt*(1+0.4Av) + wa) / (0.607-0.18667*J^2.3) - wa }*[1 / (1000 ts)]	6.4	MPa	(E.6.2.2.1-2a)
Used σc =	**6.4**	MPa	
ts - thickness of bottom shell course less corrosion allowance	30.5	mm	

Allowable Longitudinal Shell-Membrane Compression Stress inTank Shell (E.6.2.2.3)

When G*H*(D^2) /(t^2) = 73.62 >44

t - thickness of the shell ring under consideration, mm

t = Corroded thickness of Course No.1	30.5	mm	

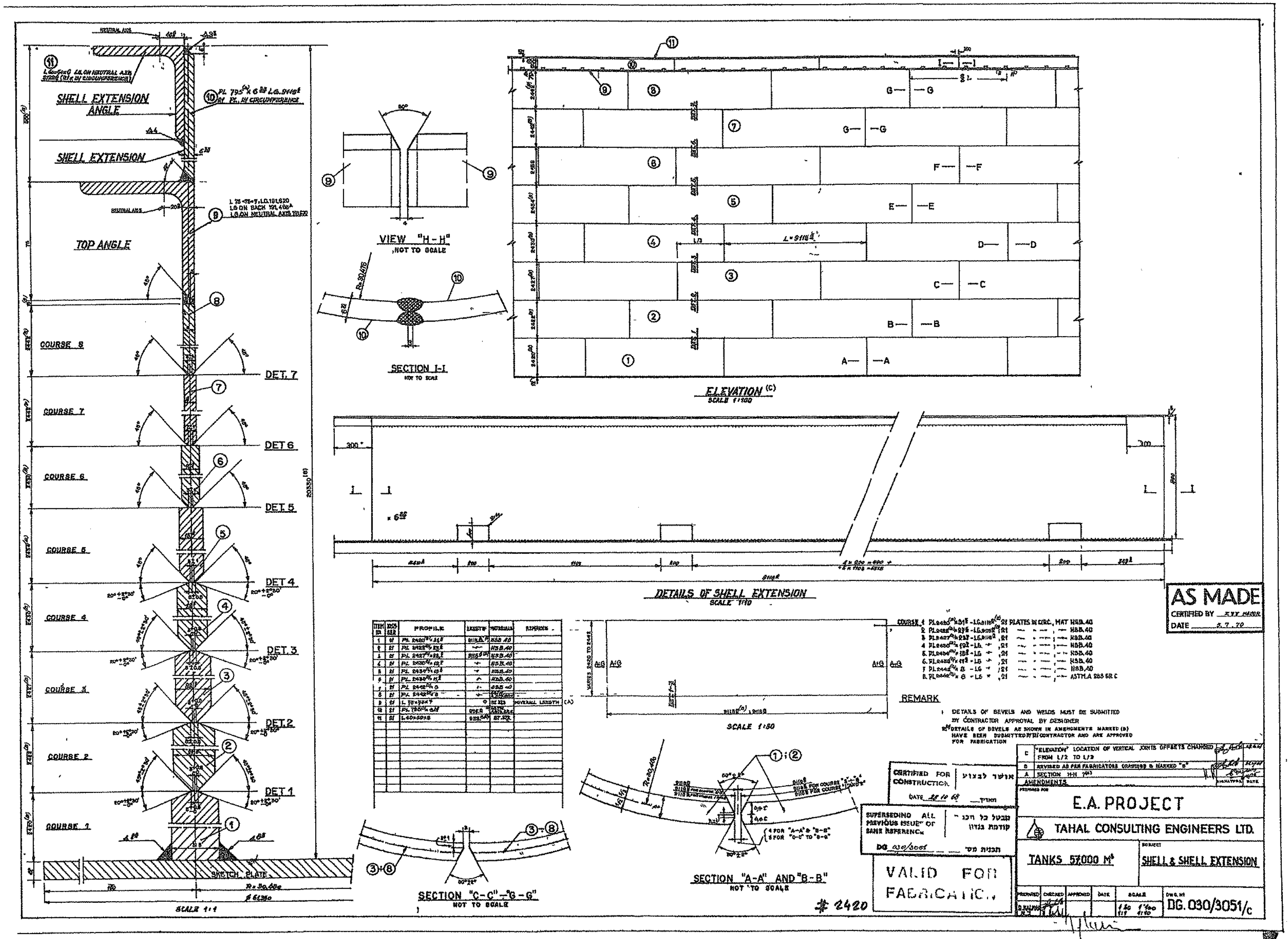
Seismic allowable stress :

Fc =83 ts / D =	**42**	Mpa	(E.6.2.2.3-1a)

Fc value includes the 33% increase for allowable stress design (ADS) for the seismic design.

σc = 6.4 **<** **Fc =** 42 Mpa **O.K.**

A1


SHELL EXTENSION ANGLE
SHELL EXTENSION
TOP ANGLE
COURSE 8
COURSE 7
COURSE 6
COURSE 5
COURSE 4
COURSE 3
COURSE 2
COURSE 1
DET. 7
DET 6
DET 5
DET 4
DET 3
DET 2
DET 1
SKETCH PLATE
SCALE 1:1
VIEW "H-H"
NOT TO SCALE
SECTION I-I
ELEVATION (C)
SCALE 1:100
DETAILS OF SHELL EXTENSION
SCALE 1:10
SCALE 1:50
SECTION "C-C" – "G-G"
NOT TO SCALE
SECTION "A-A" AND "B-B"
NOT TO SCALE
REMARK
1 DETAILS OF BEVELS AND WELDS MUST BE SUBMITTED BY CONTRACTOR APPROVAL BY DESIGNER
DETAILS OF BEVELS AS SHOWN IN AMENDMENTS MARKED (B) HAVE BEEN SUBMITTED BY CONTRACTOR AND ARE APPROVED FOR FABRICATION
AS MADE
CERTIFIED BY
DATE
C "ELEVATION" LOCATION OF VERTICAL JOINTS OFFSETS CHANGED FROM L/2 TO L/3
B REVISED AS PER FABRICATORS DRAWINGS & MARKED "B"
A SECTION H-H
AMENDMENTS
CERTIFIED FOR CONSTRUCTION
אושר לבצוע
DATE 22 10 68
SUPERSEDING ALL PREVIOUS ISSUE OF SAME REFERENCE
מבטל כל תכנ' קודמת בגדו
DG 030/3001
תכנית מס'
VALID FOR FABRICATION
2420
E.A. PROJECT
TAHAL CONSULTING ENGINEERS LTD.
TANKS 57,000 M³
SHELL & SHELL EXTENSION
PREPARED
CHECKED
APPROVED
DATE
SCALE
DWG. NO.
DG. 030/3051/c

Appendix 4
Synoptic table for E.A.P. Co. Tanks – Ramat Yotam Eilat Site

SYNOPTIC TABLE for E.A.P. Co TANKS
CRUDE OIL STORAGE TANKS FARM, RAMAT YOTAM EILAT SITE

By: E.S.
Rev.: 0
Date: 17/02/2013

Tag No.	Site	Site Class	Seismic Group	Ground Acceleration (SI 413)	Diameter, m	Height, m	Weight, kg				Overturning Moment, ton-m	Factor "J" (API-650)
							Shell	Floating Roof	Liquid	Total		
45-48	RAMAT YOTAM EILAT	C	III	0.23 g	79.248	20.329	893,382	373,493	89,968,678	91,235,553	56,631	0.601
41, 43, 44					79.248	20.345	893,697	350,996	89,968,678	91,213,371	56,513	0.600
31-39					60.960	20.330	596,473	218,000	53,790,445	54,604,918	43,186	1.011

Appendix 5
Allowable stress values for materials not identified in accordance with API 650

ALLOWABLE STRESS VALUES FOR MATERIALS NOT IDENTIFIED IN ACCORDANCE WITH API 650

CALCULATION OF ACTUAL STRESS IN COURSE No.1
API 650 Ed.2007 Add.3 (2011)

td=4.9D(H-0.300)G/Sd+Ca (5.6.3.2)

Sd=4.9D(H-0.300)G/td-Ca

D=Nominal tank diameter (m)

H=Design liquid level (m)

td=Design shell thickness (mm)

Ca= Corrosion allowance (mm)

G=Design liquid specific gravity

Sd=Design allowable stress (Mpa)

Tank No.	D m	H m	G	td mm	Ca mm	Calculated Sd Mpa	Material of construction	Equiv.mat. API 650	Sd for the equiv.mat. Mpa
31	60.96	19	0.97	31.5	1	178	HSB.40	**A 516 Gr.70**	173
41	79.248	19	0.93	38.1	1	182	FB 50	**A 537 Gr/1**	194
41	79.248	19	0.93	38.1	1	182	OX 522 C	**A 537 Gr.1**	194