E.A.P.Co.

Crude Oil Storage Tanks Farm

Eilat Site (Shore Farm)

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

Document No.

14434-11-CAL-003

Submitted by:

Y.W. Galil Engineering Ltd

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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 7 storage tanks located at the Eilat site.

Eilat tank farm was built in between 1958 and 1965. The first edition of API 650 was published in 1961 and no seismic calculation requirements have been specified there.

The Israeli standard 413 for earthquake resistance of liquid containing tanks was published in 1974, 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 Eilat site includes the following tanks:

- 3 tanks of 48.8 m nominal diameter containing 30,000 m^3 crude oil. Tanks Tag No.: 15, 16, 20. Each tank is equipped with an external floating roof.
- 4 Tanks 50.26 m nominal diameter containing 30,000 m^3 crude oil. Tanks Tag 17, 21, 22, 23. 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. The drawing of Tanks No. 17, 21, 22 and 23 is a low quality scan of the original drawing. We made our best efforts to extract the necessary information for the calculations.

The drawings contain the following technical information:

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

See Table 1 – Reference Drawing List.

Table No. 1 Reference drawings List

No.	Tank Tag No	Drawing				
		Designer	Name	No	Rev.	Date
1.	15, 16	TAHAL	Shell details		-	15.10.58
2.	20	HAMALCHIM	Shell details		-	27.04.65
3.	17,21, 22, 23	WRIGHT ANDERSON	TANK SHELL			1964

In addition, E.A.P.C has provided geotechnical report, recently prepared for the site by "Hazzan-foundation Engineering LTD", for the design of retaining structures and foundations in Eilat site. These reports include valuable information about the sub- soil properties and allowable bearing pressure.

3. SITE VISUAL INSPECTION

3.1. Site Description

The E.A.P.Co site in Eilat (shore) is located south to Eilat, about 200 m away from the Red Sea. It is located at the beginning of Eilat Mountains in altitude of approximately 10-20 m above the sea level.

The site is divided into soil containments (dikes). Each containment surrounds a single tank, and its height is app. 6 m.

All tanks are raised about 1.2 m above the bottom of the soil containment.

3.2. Soil Conditions

According to the site observations and information appears in the geotechnical investigation, the upper layers of soil is a composition of sand and silt mixed with hard stones and a low content of fine materials (clay).
The expected SPT values, according to the report, are high (no specific tests results have been listed) .
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, can be taken as 30 t/m^2.

3.3. Maintenance of the Tanks

The tank shall have no signs of corrosion. On some vessels the tanks annular ring is locally corroded. The annular ring and the bottom plates were replaced in Tanks No. 15 and 17. The concrete around tanks No.20, 22 and 23 has recently been revamped. The tanks are properly painted. E.A.P.Co started to repaint the tanks in White in order to reduce the content temperature.

3.4. Foundations system

All tanks are raised about 1.2 m above the bottom of the soil containment. Around the tanks there is a sloped soil dykes paved with asphalt or concrete, usually in good condition.
The tanks are founded directly on the soil - probably on soil replacement to unknown depth. In few places, where maintenance operations have been handles during the site inspection, it could be observed that the outer steel ring under the Tanks wall is placed on asphalt paving. It is possible that an asphalt paving have been done under the entire floor, but it is not clear.
Some tanks have concrete rings, 30 cm outside the tank shell acting as “separation/ retaining wall” between the raised area and the bottom of the containment. The ring is not completely continuous due to pipe penetration and therefore it cannot be considered as an annular concrete tension ring. The steel reinforcement of the ring was cut out at pipe penetrations and pits. In some rings the steel reinforcement is totally without concrete cover and in very corroded condition.
Soil settlements have been observed in one tank only. The settlements are 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.

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, tank No. T-23 was examined. The tank measured in 156 nodes. 151 measurements results were above the nominal wall thickness or within the allowable under tolerance for plates (0.25 mm). 5 measurements indicated a reduction in the wall thickness of 0.26-0.75 mm. this may be considered as minor and local "pitting" and is within the allowable of API 653.
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. Measurements have been made by Mabat Company.

6.1.3. Content weight:

This weight was calculated as the tank volume for operating height multiplied by the product specific gravity.

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 = 0.2331g for Eilat area

6.2.2. Site classification C (stiff soil) 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= 0.2915 g (calculated) API 650 – E.4..6. 1-1

6.2.7. Convective Spectral Acceleration parameter

Ac= 0.02982 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 7 storage tanks located at the 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 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.

8. CONCLUSIONS

8.1 All tanks in 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 calculations, the tanks in Eilat site , comply with the requirements of API 650 edition 3 (2007) addendum 3(2011), App. E "Seismic design of storage tanks"

8.4 The designed foundations system, even though sometimes involves with expected local soil settelments, is sufficient and foundation's failure due to seismic loads is not expected.

8.5 The tanks maintanance is sufficient and no deterioration due to poor maintanance of the tank itself (tank shell) is expected. Local corrosion was observed in the outsude part of the annular ring.

8.6 The concrete separation/ retaining walls are in poor condition and handling of a proper rehabilitation program is essential.

Appendix 1
Seismic calculations of tanks 15, 16, 20

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

E.A.P.Co.

CRUDE OIL STORAGE TANK
EILAT SITE

SEISMIC CALCULATIONS
FOR

30,000 m³ STORAGE TANKS

TANKS No: 15, 16, 20

0	17/02/13	APPROVED	E.S.	O.A.	
P0	25/12/12	FOR COMMENTS	G.W.	O.A	
REV.	DATE	DESCRIPTION	BY	CKD.	APP’D.

30,000 m^3 STORAGE TANK
EILAT SITE
TANKS No.15,16,20

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	48.768	2.441	33	96880
2	48.768	2.441	28	82202
3	48.768	2.441	23	67523
4	48.768	2.441	19	55780
5	48.768	2.441	14	41101
6	48.768	2.441	9	26422
7	48.768	2.441	8	23486
8	48.768	0.076	9.5	868
TOTAL		17.163		394262

Add 10% for appourtenances

Total weight of tank shell and appurtenances: Ws = 433688 kg = 4.25.E+06 N

Total weight of tank floating roof (Assumed) Wr = 119360 kg = 1170922 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 = 48.768 m (nominal tank diameter)
H = 16 m (maximum design product level)
Hs 17.163 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 = 3.048 >1.333

Wi=[tanh(0.866D/H)]/(0.866D/H)*Wp **9750773 kg = 9.57.E+07 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 **0.87**

Wp=1000PI*D^2*H*gama/4= **26001536 kg = 2.55E+08 N**

Calculation of the Effective Convective Weight of the Liquid

Wc=0.230*D/H*tanh(3.67*H/D)*Wp **15218496 kg = 1.49E+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 = 3.048 >1.333

Xi=0.375*H= **6 m** (E6.1.2.1-1)

Xc=(1-(cosh(3.67*H/D)-1)/(3.67*H/D*sinh(3.67*H/D))*H= **8.844 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) **7.947 sec** (E.4.5.2-a)

Ks - sloshing period coefficient

Ks= 0.578/((tanh(3.68*H/D))^0.5)= **0.632** (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) **0.2915 g** (E.4.6.1-1)

However, **Ai**= 0.2915 ≥ 0.007 (E.4.6.1-2)

for seismic site Class E

Ai = 0.2915 ≥ 0.625 Sp (I / Rwi) = 0.0624 **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, 0.2331 g

According to Israeli STD 413,for 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	0.5828 g	(E.4.3-1)
S1 =	1.25 Sp	0.2914 g	(E.4.3.-2)
Fa (interpolated)=		1.167	(E.4.4 table E-1)
Fv (interpolated)=		1.5	(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 0.2331 g (E.4.6.1)

Convective Spectral Acceleration Parameter, Ac (E.4.6.1)

Tc = 7.947 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 0.03114 (E.4.6.1.-5)

Ai= 0.2915

Ac= min(Ac1,Ai) **0.03114 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) **0.64 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 **1.88E+08 Nm** (E.6.1.5-1)
19157 Tm

where

Ai =	0.2915	g		
Wi =	9.57E+07	N		
Xi =	6.000	m		
Ws =	4.E+06	N		
Xs =	Hs/2 =	8.5815	m	(height from the tank shell bottom to the shell's center of gravity)
Wr =	1170922	N		
Xr =	H	16	m	(height from the tank shell bottom to the floating roof center of gravity)
Ac =	0.0311	g		
Wc =	1.49E+08	N		
Xc =	8.844	m		

Calculation of the Anchorage Ratio

J =Mrw / [(D^2)*(wt(1-0.4Av)+wa)] **0.958** (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	**27769**	**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 =	8.5	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)		**0.816**		(E.2.2)
G- specific gravity of the fluid		**0.87**		
Av=	Vertical seimic acceleration coefficient=0.67*Z	**0.156**	**g**	(I.S.413 2.2 Para5.9)
wa1=99*ta*(Fy*H*Ge)^0.5		56465	N/m	
wa2=201.1*H*D*Ge		127989	N/m	
Use wa =	MIN[wa1,wa2]	**56465**	**N/m**	

The anchorage ratio criterion is:

J = **0.958** ≤ **1.54**

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

if $J \le 0.785$

σc = { wt*(1+0.4Av) + [1.273 Mrw / (D^2)] }*[1 / (1000 ts)]	4.1	MPa	(E.6.2.2.1-1a)

if $0.785 < J \le 1.54$

σc = { (wt*(1+0.4Av) + wa) / (0.607-0.18667*J^2.3) - wa }*[1 / (1000 ts)]	4.4	MPa	(E.6.2.2.1-2a)
Used σc =	**4.4**	MPa	
ts - thickness of bottom shell course less corrosion allowance	32	mm	

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

When G*H*(D^2) /(t^2) = 32.33 <44

t - thickness of the shell ring under consideration, mm

t = Corroded thickness of Course No.1 32 mm

Seismic allowable stress :

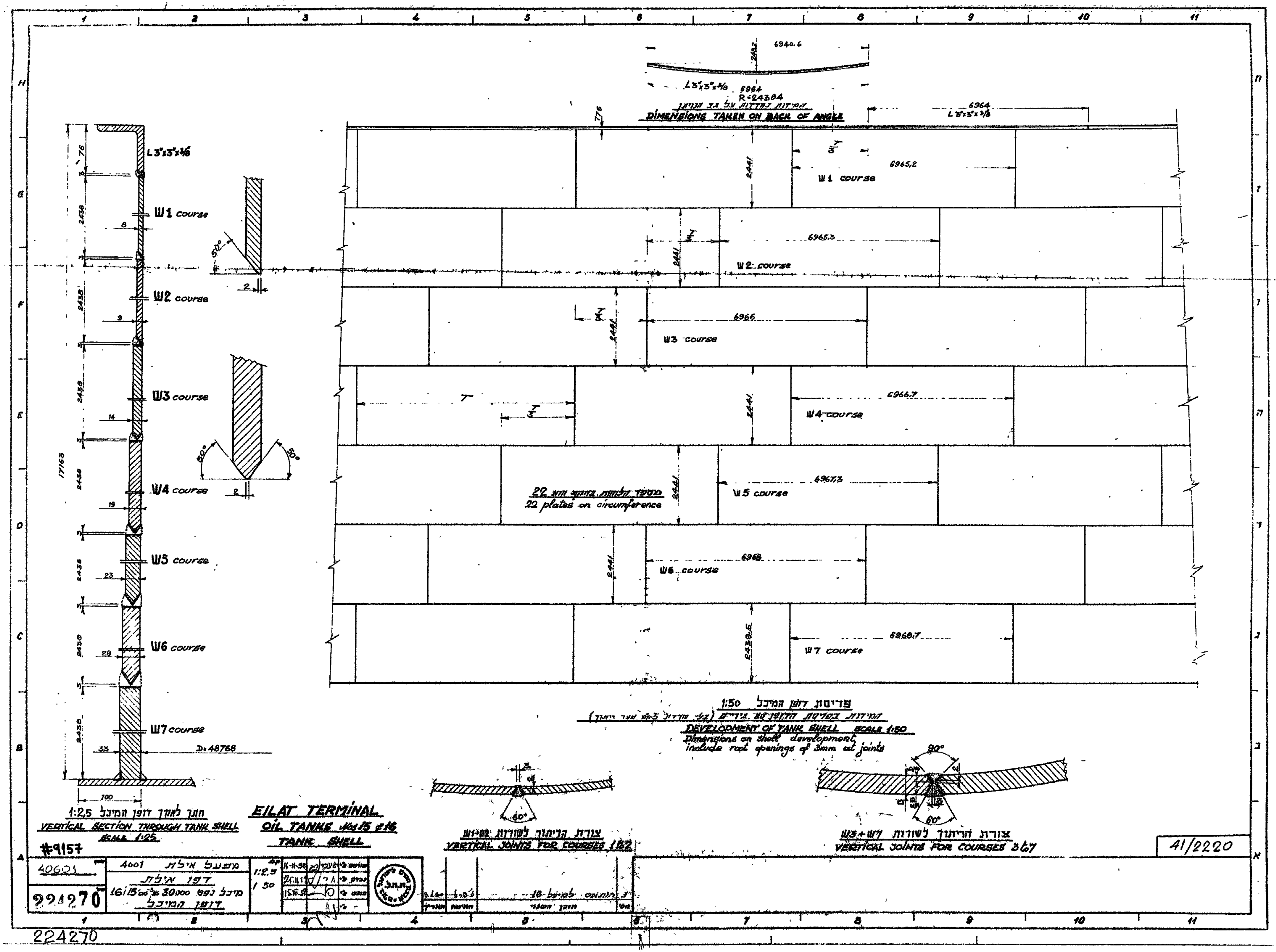
Fc =83 ts / (2.5 D) + 7.5 (G*H)^1/2 =	**50**	Mpa	(E.6.2.2.3-2a)

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

σc = 4.4 **<** **Fc =** 50 Mpa **O.K.**

A1

[redacted]



EILAT TERMINAL
OIL TANKS Nos 15 & 16
TANK SHELL
VERTICAL SECTION THROUGH TANK SHELL
SCALE 1:25
#9157
DEVELOPMENT OF TANK SHELL SCALE 1:50
Dimensions on shell development include root openings of 3mm at joints
22 plates on circumference
DIMENSIONS TAKEN ON BACK OF ANGLE
VERTICAL JOINTS FOR COURSES 1&2
VERTICAL JOINTS FOR COURSES 3&7
W1 course
W2 course
W3 course
W4 course
W5 course
W6 course
W7 course
L3"x3"x3/8
D=48768
17163
R=24384
6964
6940.6
6965.2
6965.3
6966
6966.7
6967.3
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6968.7
2441
2439.5
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76
100
41/2220
40601
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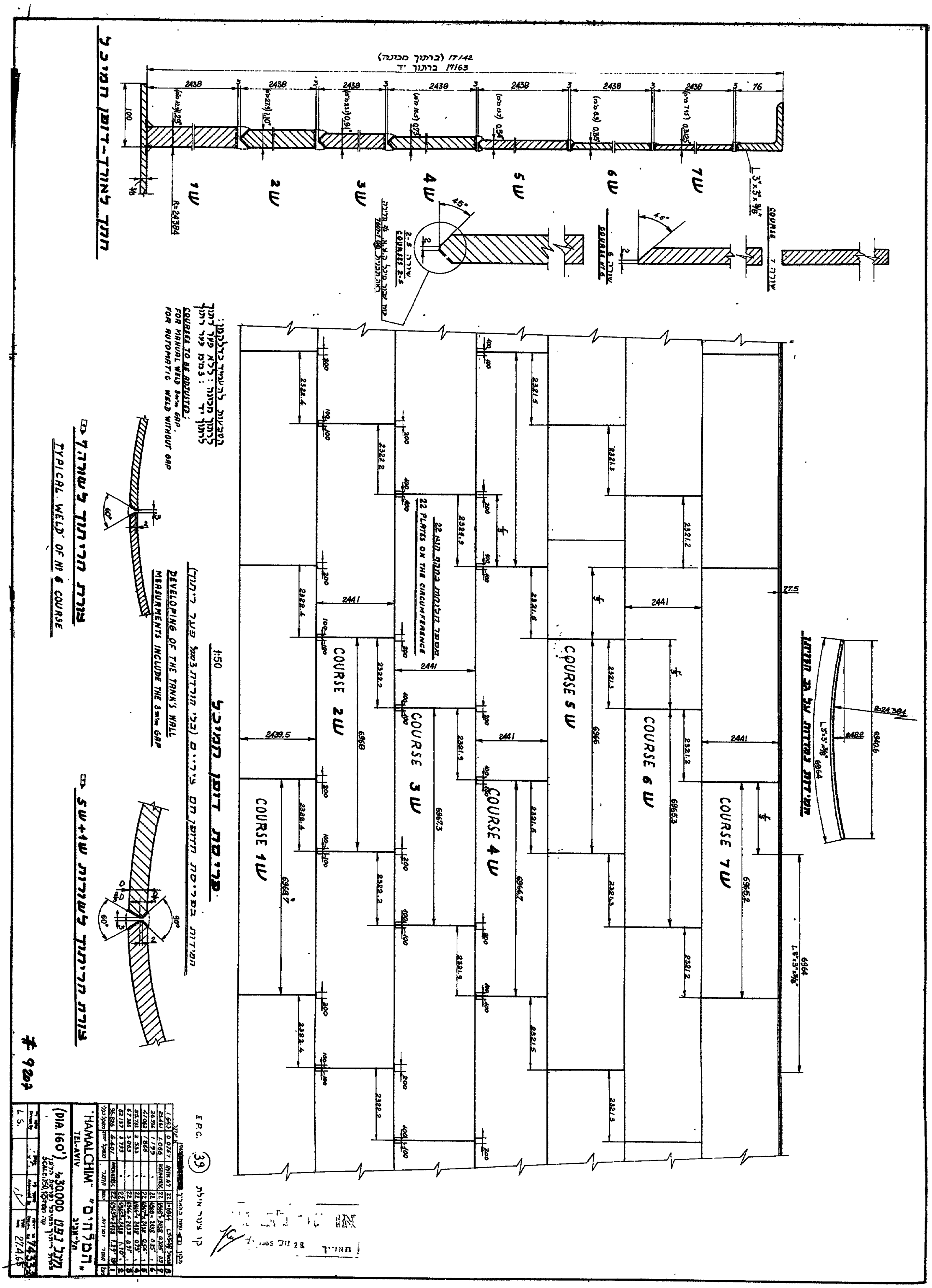
A1


COURSE 1W
COURSE 2W
COURSE 3W
COURSE 4W
COURSE 5W
COURSE 6W
COURSE 7W
22 PLATES ON THE CIRCUMFERENCE
DEVELOPING OF THE TANK'S WALL
MEASUREMENTS INCLUDE THE 3 m/m GAP
1:50
COURSES TO BE BEVELED:
FOR MANUAL WELD 3 m/m GAP.
FOR AUTOMATIC WELD WITHOUT GAP
TYPICAL WELD OF № 6 COURSE
"HAMALCHIM"
TEL-AVIV
(DIA. 160')

Appendix 2
Seismic calculations of tanks 17, 21, 22, 23

Y.W. Galil Engineering Ltd. INDUSTRIAL PLANNING — י.ו. גליל הנדסה בע"מ תכנון מפעלי תעשיה

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

E.A.P.Co.

CRUDE OIL STORAGE TANK
EILAT SITE

SEISMIC CALCULATIONS
FOR

30,000 m³ STORAGE TANKS

TANKS No: 17,21,22,23

0	17/02/13	APPROVED	E.S.	O.A.	
P0	25/12/12	FOR COMMENTS	G.W.	O.A	
REV.	DATE	DESCRIPTION	BY	CKD.	APP'D.

30,000 m³ STORAGE TANK
EILAT SITE

TANKS No.17,21,22,23

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	50.26	2.413	33.6	100494
2	50.26	2.413	28.6	85539
3	50.26	2.413	23.8	71183
4	50.26	2.413	19.05	56976
5	50.26	2.413	14.3	42770
6	50.26	2.413	9.5	28413
7	50.26	2.413	8	23927
8	50.26	0.075	8	744
TOTAL		16.966		410046

Add 10% for appourtenances

Total weight of tank shell and appurtenances: Ws = 451051 kg = 4.42.E+06 N

Total weight of tank floating roof (Assumed) Wr = 115000 kg = 1128150 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 = 50.26 m (nominal tank diameter)
H = 16 m (maximum design product level)
Hs 16.966 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 = 3.141 >1.333

Wi=[tanh(0.866D/H)]/(0.866D/H)*Wp **10064376 kg = 9.87.E+07 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 **0.87**

Wp=1000PI*D^2*H*gama/4= **27616846 kg = 2.71E+08 N**

Calculation of the Effective Convective Weight of the Liquid

Wc=0.230*D/H*tanh(3.67*H/D)*Wp **16435829 kg = 1.61E+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 = 3.141 >1.333

Xi=0.375*H= **6 m** (E6.1.2.1-1)

Xc=(1-(cosh(3.67*H/D)-1)/(3.67*H/D*sinh(3.67*H/D))*H= **8.801 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) **8.122 sec** (E.4.5.2-a)

Ks - sloshing period coefficient

Ks= 0.578/((tanh(3.68*H/D))^0.5)= **0.636** (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) **0.2915 g** (E.4.6.1-1)

However, **Ai**= 0.2915 ≥ 0.007 (E.4.6.1-2)

for seismic site Class E

Ai = 0.2915 ≥ 0.625 Sp (I / Rwi) = 0.0624 **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, 0.2331 g

According to Israeli STD 413,for 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	0.5828 g	(E.4.3-1)
S1 =	1.25 Sp	0.2914 g	(E.4.3.-2)
Fa (interpolated)=		1.167	(E.4.4 table E-1)
Fv (interpolated)=		1.5	(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 0.2331 g (E.4.6.1)

Convective Spectral Acceleration Parameter, Ac (E.4.6.1)

Tc = 8.122 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 0.02982 (E.4.6.1.-5)

Ai= 0.2915

Ac= min(Ac1,Ai) **0.02982 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) **0.64 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 **1.94E+08 Nm** (E.6.1.5-1)

19729 Tm

where

Ai =	0.2915	g			
Wi =	9.87E+07	N			
Xi =	6.000	m			
Ws =	4.E+06	N			
Xs =	Hs/2 =	8.483	m		(height from the tank shell bottom to the shell's center of gravity)
Wr =	1128150	N			
Xr =	H	16	m		(height from the tank shell bottom to the floating roof center of gravity)
Ac =	0.0298	g			
Wc =	1.61E+08	N			
Xc =	8.801	m			

Calculation of the Anchorage Ratio

J =Mrw / [(D^2)*(wt(1-0.4Av)+wa)] **0.926** (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	**28023**	**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 = 8.5 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)	**0.816**		(E.2.2)
G- specific gravity of the fluid	**0.87**		
Av= Vertical seimic acceleration coefficient=0.67*Z	**0.156**	**g**	(I.S.413 2.2 Para5.9)
wa1=99*ta*(Fy*H*Ge)^0.5	56465	N/m	
wa2=201.1*H*D*Ge	131904	N/m	
Use wa = MIN[wa1,wa2]	**56465**	**N/m**	

The anchorage ratio criterion is:

J = **0.926** ≤ **1.54**

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

if $J \le 0.785$			
σc = { wt*(1+0.4Av) + [1.273 Mrw / (D^2)] }*[1 / (1000 ts)]	3.9	MPa	(E.6.2.2.1-1a)
if $0.785 < J \le 1.54$			
σc = { (wt*(1+0.4Av) + wa) / (0.607-0.18667*J^2.3) - wa }*[1 / (1000 ts)]	4.1	MPa	(E.6.2.2.1-2a)
Used σc =	**4.1**	MPa	
ts - thickness of bottom shell course less corrosion allowance	32.6	mm	

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

When G*H*(D^2) /(t^2) = 33.09 <44

t - thickness of the shell ring under consideration, mm			
t = Corroded thickness of Course No.1	32.6	mm	

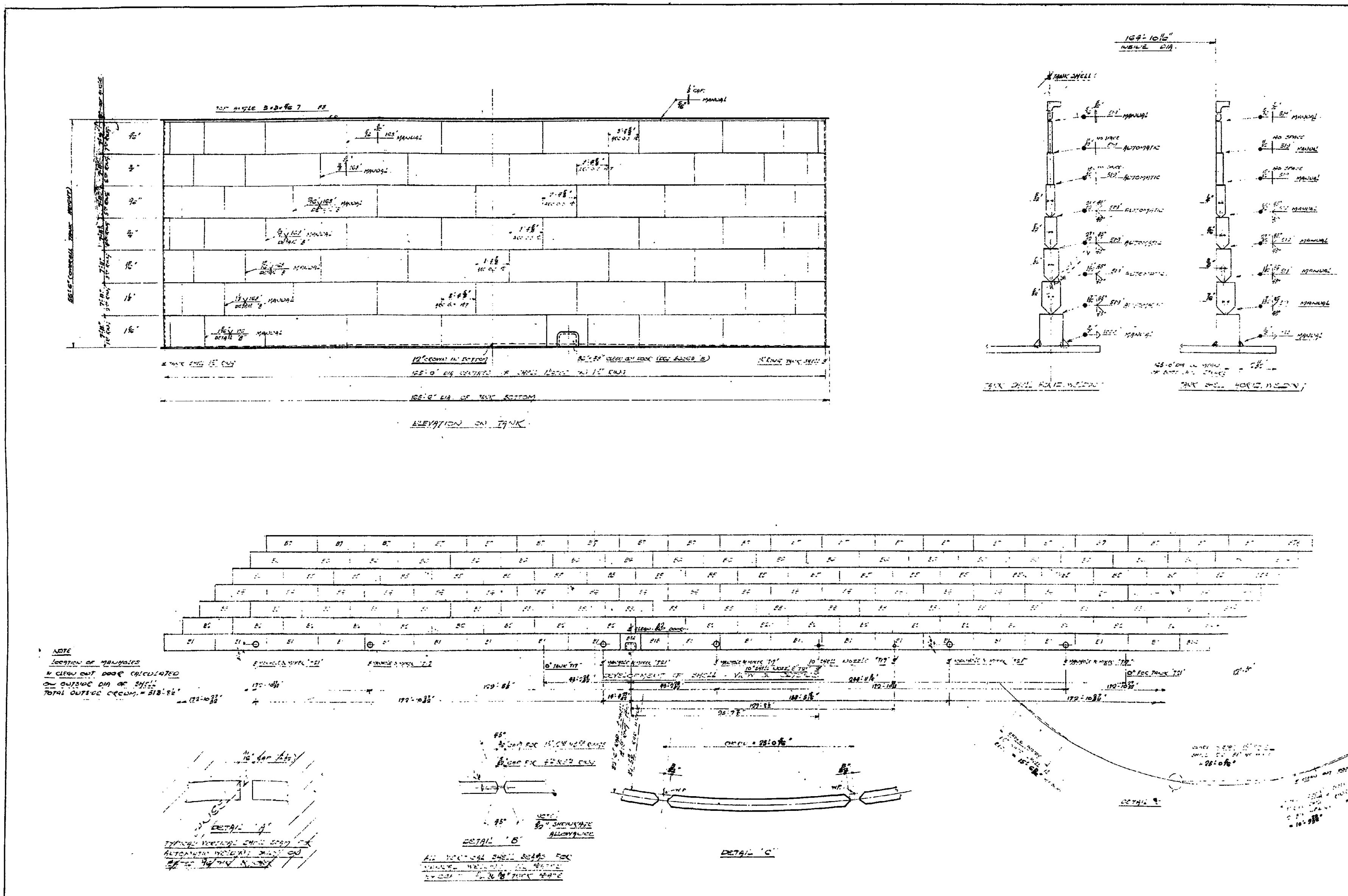
Seismic allowable stress :

Fc =83 ts / (2.5 D) + 7.5 (G*H)^1/2 =	**50**	Mpa	(E.6.2.2.3-2a)

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

σc = 4.1 **<** **Fc =** 50 Mpa **O.K.**

A0



MARK	QUAN.	DESCRIPTION.
B1	19	RECT. PL'S. 7'-11" × 1⅝" × 25'-1 19/32" LONG.
B1A	1	WITH CLEAN-OUT DOOR [illegible]
B1B	1	RECT. PL. 7'-11" × 1⅝" × 14'-3½" LONG.
B1C	1	RECT. PL. 7'-11" × 1⅝" × 15'-6 19/32" LONG
B2	20	RECT. PL'S. 7'-11" × 1⅛" × 25'-1 19/32" LONG.
B2A	1	RECT. PL. 7'-11" × 1⅛" × 15'-5 19/32" LONG
B3	20	RECT. PL'S 7'-11" × 15/16" × 25'-1 19/32" LONG.
B3A	1	RECT. PL. 7'-11" × 15/16" × 15'-5 19/32" LONG.
B4	20	RECT. PL'S 7'-11" × ¾" × 25'-1 19/32" LONG.
B4A	1	RECT. PL. 7'-11" × ¾" × 15'-5 7/16" LONG
B5	20	RECT. PL'S 7'-11" × 9/16" × 25'-1 19/32" LONG
B5A	1	RECT. PL. 7'-11" × 9/16" × 15'-4 13/16" LONG
[illegible]	20	RECT. PL'S 7'-11" × ⅜" × 25'-1 19/32" LONG
[illegible]	1	RECT. PL. 7'-11" × ⅜" × 15'-4 3/16" LONG
[illegible]	20	RECT. PL'S 7'-9" × 5/16" × 25'-1 19/32" LONG
[illegible]	[illegible]	RECT. PL. 7'-9" × 5/16" × 15'-3 13/16" LONG
F1	20	TOP ANGLE 3 × 3 × 5/16 × 27'-0" LONG (NET ON HEEL AFTER ROLLING TO 165'-[illegible] = 25'-10 ⅝")

SCHEDULE ABOVE FOR ONE TANK - 2 TANKS REQ[illegible]

GENERAL NOTE.

ROLL ALL 1ST TO 6TH RING PL'S TO 165'-10[illegible]
ROLL ALL 7TH RING PL'S TO 150'-0" DI[illegible]
FULL PENETRATION (FULL FUSION) WELDS ON [illegible]
[illegible]
BY API 650.
ALL MAT'L TO BE ASTM - A283 GRADE [illegible]
[illegible]
THE SHELL AT [illegible]

No 7 SETS OF TANK SHELL PLATES REQ'D AS SHOWN [illegible]
PREFIX MARKS 7/1 FOR ONE TANK & 7/2 FOR ONE TANK

WRIGHT, ANDERSON (South Africa) LTD. STRUCTURAL ENGINEERS BOKSBURG NORTH	Contract: RAFHAELY & SONS. 165'-0" DIA FLOATING ROOF TANK. TANK SHELL	Unless noted: Holes — dia. Bolts-Rivets — dia. Painting: NIL. "X" Mark to face — after erection	Rev.	Date	Description	By.	Drawn by JT. Date [illegible]. Checked by. Date. Material List. Weight. Works Compl. Date: E-O [illegible]. Marks: SEE SCHEDULE	Works Or. EGO. Drg. G 2. Rev. X
			A.	[illegible]	SHELL PLS SHOWN WITH A CONSTANT I/DIA. VERTICAL SEAMS SHOWN MANUALLY WELDED	J.T.		
			B.	[illegible]	DRG. CHECKED & REVISED.			
			C.	[illegible]	M/HOLE & NOZZLE POSITIONED [illegible]	J.T.		

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Appendix 3
Synoptic table for E.A.P. Co. Tanks – Eilat Site

SYNOPTIC TABLE for E.A.P. Co TANKS
CRUDE OIL STORAGE TANKS FARM, EILAT SITE (SHORE FARM)

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		
15, 16, 20	EILAT	C	III	0.2331 g	48.768	17.163	433,688	119,360	26,001,536	26,554,584	19,157	0.958
17, 21, 22, 23					50.260	16.966	451,051	115,000	27,616,846	28,182,897	19,729	0.926